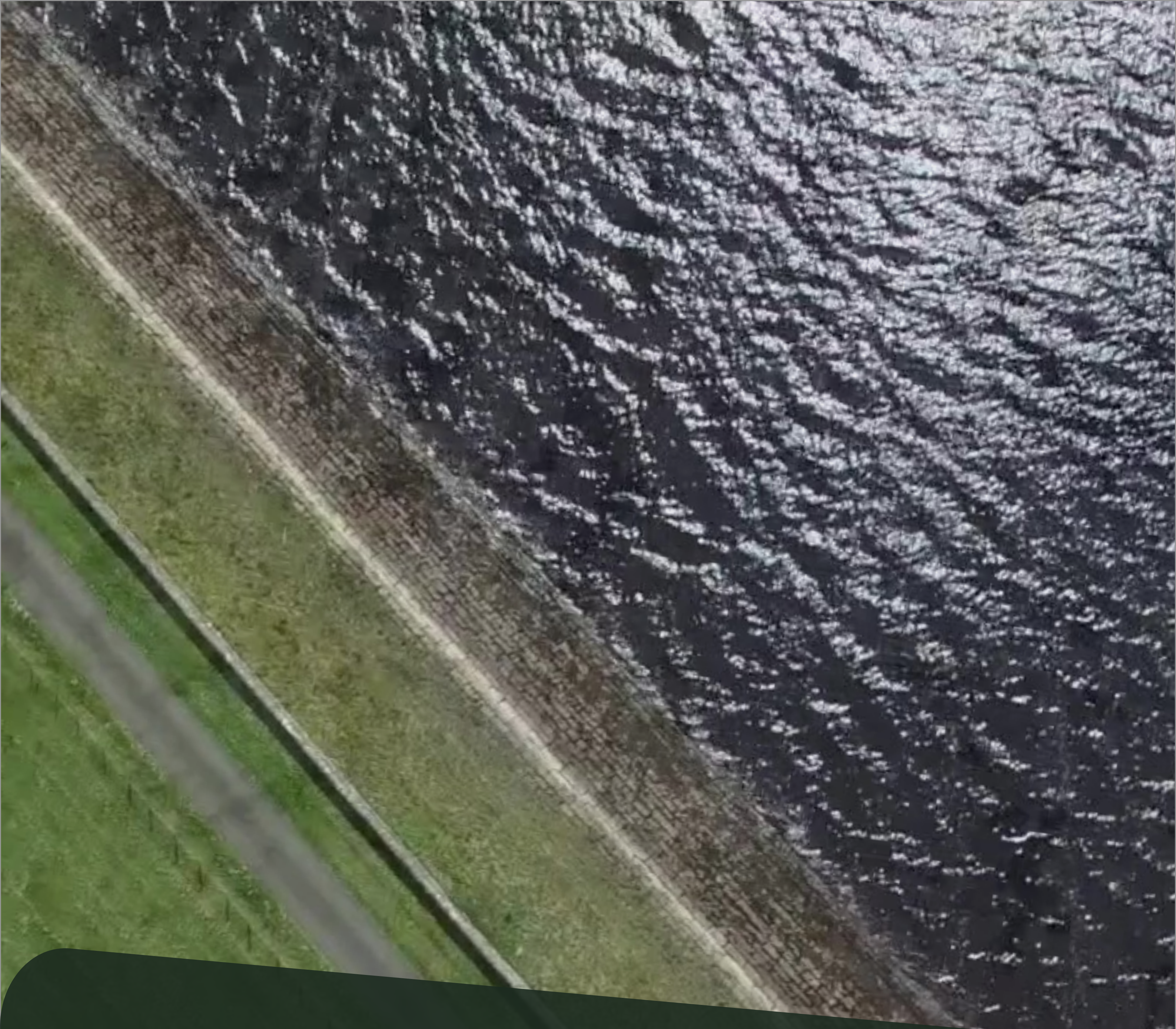

Identifying Environmental Priorities and Analytical Requisites for Environmental Standards Scotland

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ENVIRONMENTAL Standards Scotland
Ìrean Àrainneachdail na h-Alba

SEFARI

The James Hutton Institute

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Summary

Environmental Standards Scotland (ESS) is being established as a new non-ministerial office to monitor Scottish public authorities' compliance with, and the effectiveness of, environmental law following the UK's departure from the EU. It will be independent of the Scottish Government and will be responsible for ensuring that public authorities in Scotland comply with environmental law.

The environment is a system where changes in one part have knock-on impacts on other areas. Environmental legislation, and the duty-holders who are held accountable to the legislation, are however sectoral. This presents specific challenges for compliance assurance where systems understanding is required to ensure holistic success, but where analyses and support need to be sector specific and focussed.

Existing environmental governance is divided into several sectors (soils, waters, biodiversity, climate, etc.). Given logistical, operational, and financial constraints, it is important to understand the level and types of support required to achieve compliance with environmental legislation within each sector. Similarly, it is important to prioritise where initial efforts should be focussed, and the skill sets needed to support compliance assurance.

Part 1 (Environmental Priorities – An Initial Exploration) presents an in-depth analysis of how environmental priorities could be set. It reviews recent published approaches to establishing priorities, and maps published priority lists onto current Scottish environmental strategy, identifying commonalities and gaps. Environmental prioritisation is a multifactorial exercise, and it's important to recognise that the biggest problems might not be the first priorities depending on how intractable those problems might be. The indicators used to evaluate these priorities are reviewed, the levels of compliance against legislature, as well as the maturity of the policies that support these evaluations. The final prioritisation is presented both by overall rank (Figure 2.16) and by the sorts of activities that ESS will need to perform to support compliance, the 'compliance pipeline' (Figure 2.17).

The analysis presented places greater weighting on environmental priorities that have less-developed monitoring/evaluation processes, less-developed supporting policy, and where compliance is less consistent. On this basis, higher prioritisation was given to soils, biodiversity, and greenhouse gases/carbon. Looking at the same environmental priorities through the lens of compliance assurance indicates which stage in the compliance pipeline the different environmental priorities are currently at. On this basis, priorities such as soils and biodiversity were primarily at the compliance promotion stage, while others such as air pollution and marine quality were primarily at the follow up and enforcement stage.

Part 2 (Analytical Requisites) details the skills, roles and governance required to implement the analytical functions of ESS. Specifically, these were developed given the requirement of ESS to embed specific sectoral analyses/advice within a wider systems approach. Thus, the proposed structure combined two main complementary teams. Firstly, a team of domain specialists who bring the systems and research knowledge and can interpret/contextualise results of more specific analyses. This team can evolve with changing priorities. Secondly, a more permanent team of domain-agnostic analysts whose role it is to undertake sector-specific data assurance and analyses. It is also recommended that the technical support side, in terms of infrastructure, data management, and software engineering are well catered for to minimise risks associated with errors, data breaches, inconsistent advice, poor compliance with information governance legislation, etc. that would undermine ESS' authority.

1. Introduction

Environmental Standards Scotland (ESS) is being established as a new non-ministerial office to monitor Scottish public authorities' compliance with, and the effectiveness of, environmental law following the UK's departure from the EU. It will be independent of the Scottish Government and will be responsible for ensuring that public authorities in Scotland comply with environmental law – including bodies and agencies such as the Scottish Environmental Protection Agency (SEPA), NatureScot and Marine Scotland – who are responsible for collating and publishing much of the data on which ESS is likely to rely on to fulfil its remit.

A small transition team was appointed to work with the Chair and Board to help establish ESS ready to take on the statutory functions and powers provided for it in the UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021 (the Continuity Act) on 1st October 2021.

This Fellowship was commissioned to work alongside the transition team and the Board to develop advice on the options for:

a) How ESS can best access and analyse the data and other evidence (e.g., specialist scientific knowledge and expert opinion) it will require to carry out its role; and
b) What capacity and resources ESS will require to have available to it in the longer term to support the analytical work necessary to carry out its functions effectively

During the first steering group meeting (29th July 2021), an additional step prior to those described above was also identified; namely, identifying and defining the potential environmental priorities for ESS. It was recognised, given the timeframe and scope of the ESS remit, that a pragmatic approach to identifying possible priorities was required.

2. Environmental Priorities – An Initial Exploration

This section sets out the approach and thinking undertaken to arrive at an initial shortlist of potential environmental priorities for Environmental Standards Scotland:

Section 2.1 provides a rapid review of recent (within ~5 years) international research into setting environmental priorities and provides a summary short-list of priorities arising from this research.

Section 2.2 summarises the outcomes and indicators included in the Environment Strategy for Scotland. Due to the approaches taken, there is a miss-match between research undertaken on environmental priorities, and the outcomes-driven approach of the Environment Strategy. As such, the Environment Strategy does not set out explicitly the relative importance of the environmental priorities, or which outcomes should be tackled first.

Section 2.3 attempts to map recent research on environmental priorities to the elements of the Environment Strategy Scotland.

Sections 2.4 and 2.5 looks in more depth at the indicators proposed, the associated data sources, and performance/compliance against legislature.

2.1. Recent approaches to setting environmental priorities

A rapid review of recent literature (within past 5 years) was undertaken to examine recent approaches to determining environmental priorities.

Many studies on environmental priorities have focussed on single or restricted outcomes. Most commonly the outcome studied has been biodiversity (e.g., IPES 2019; Knapp et al., 2017), but the narrow focus tends to result in disproportionate importance given to priorities that either already have heavy investment or are simply intractable.

Recently, Allen et al. (2019) prioritised environmental sustainable development targets using three criteria, namely urgency, policy gap, and systemic impact. However, this study was geographically restricted to the Middle East and did not target specific environmental factors of concern.

Scherer et al. (2020) applied a cause prioritisation framework (a concept from budgeting that in formal terms, identifies priorities as the causes with the highest marginal utility per unit spend, see Formalizing the cause prioritization framework - EA Forum (effectivealtruism.org)) to prioritise among 16 prominent environmental challenges. The framework incorporated three criteria: (i) importance, (ii) neglect, and (iii) tractability. (i) If a problem is not important, there is no need to invest resources in its solution. (ii) If resources are already heavily invested in a problem, additional contributions are less likely to make an appreciable difference. (iii) If a problem is intractable, investing resources is likely to be futile. Thus, these three criteria are in many respects like those used by Allen et al. (2019).

Scherer et al. (2020) distinguish two areas of protection: (a) food availability as the primary prerequisite for food security (Ingram 2011; Barrett 2010) which links environmental integrity through agricultural production to human well-being, and (b) biodiversity as a prerequisite for ecosystem (freshwater, marine, terrestrial) functioning (Oliver et al., 2015; Tilman et al., 2014). Thus Scherer et al. (2020) covers both anthropogenic and eco-centric environmental attitudes.

The cause prioritisation framework was applied via questionnaire to 140 international experts, who answered each of the three criteria separately which were then combined to determine a final ranking of environmental priorities across four different sectors (Table 2.1).

Rank	Freshwater Ecosystems	Marine Ecosystems	Terrestrial Ecosystems	Food Security
	Land use	Acidification	Land use	Loss of pollinators
	Climate change	Sea use	Climate change	Soil compaction
	Habitat degradation	Climate change	Habitat degradation	Nutrient depletion
	Chemical emissions	Habitat degradation	Chemical emissions	Climate change
	Eutrophication	Chemical emissions	Habitat fragmentation	Land degradation
	Acidification	Fishing	Biological invasions	Water scarcity
	Habitat fragmentation	Habitat fragmentation	Eco-toxicants	Erosion
	Biological invasions	Biological invasions	Hunting	Land use
	Eco-toxicants	Eco-toxicants	Erosion	Chemical emissions
	Water scarcity		Water scarcity	Human toxicants
	Salinisation		Salinisation	Eutrophication
				Pests and diseases
				Land scarcity

Table 2.1 – Ranked environmental priorities as reported by Scherer et al. (2020)

The above ranking is interesting when comparing the raw ‘importance’ scores with the final ranking. For example, both climate change and land use have very high ‘importance’ scores, but both have relatively less prominent ‘neglect’ and ‘tractability’ scores (Scherer et al., 2020). The result is that the combined score pushes some of the more ‘obvious’ issues further down the ranking.

The scope of ESS also includes public health, and hence setting environmental priorities for public health. There is a structural disconnect between environmental research and public health research, with the latter defining environmental determinants of health as essentially anything that is non-occupational including zoonoses (a disease that can be transmitted to humans from animals), diet, tobacco smoke, access to green space, social and structural inequalities, etc. which might be out of scope for ESS. No studies were found that ranked overall environmental priorities for public health in a similar/semi-quantitative way. Nonetheless, examining the topics most prominent in public health research will be useful in informing ESS’ prioritisation.

Public health research, and more specifically epidemiology, searches for causal links (Hough, 2007). Thus, more straightforward exposures gain more prominence as it is easier to attribute morbidity and mortality to them. Bearing this is mind, 3 or 4 areas stand out as being most highly attributable to burdens of morbidity and mortality rates: (i) air pollution, (ii) noise, (iii) chemicals, and (iv) antimicrobial resistance. (v) Access to greenspace and nature is also prominent as being protective of health.

(i) Air pollution is often cited as the single greatest environmental threat to health in the UK (PHE 2019), with an estimated 5% of mortality associated with PM2.5 alone.

(ii) Noise causes the second greatest burden of disease in western Europe after air pollution (DoH 2017) and is associated with cardiovascular disease, diabetes and obesity as well as learning and development outcomes in children.

(iii) Chemicals in our food, drinking water and environment result in multiple daily exposures. Relatively little is known about the long-term health effects of many common chemical pollutants that people are exposed to at low levels in the home and the wider environment. There is no strong evidence that daily, low-level exposure to synthetic chemicals is causing health effects, but demonstrating causality (or even simple associations) is very difficult especially as outcomes such as cancer have long latency periods (Hough, 2007). Given the range and regularity of exposures, and high burden of cancer in the population, our limited knowledge of chemicals heightens their level of priority.

(iv) Antimicrobial resistant infections are predicted to be the leading cause of death worldwide by 2050 (O'Neil Commission 2014). Antimicrobial resistant bacteria have spread in the environment and while AMR was originally associated with clinical settings, patients are now acquiring resistant infections from elsewhere (Leonard et al. 2018). Evidence suggests that the environment is a significant source and reservoir of AMR with potential for people to be exposed to drug-resistant organisms within environmental settings (Surette & Wright 2017). Where organisms are pathogenic, this could lead to hard-to-treat clinical outcomes.

(v) Recent evidence suggests that living in or nearer to greener environments reduces mortality rates and improves mental wellbeing (Lovell 2018). A UK based study with over 19,000 participants showed that spending 2 hours or more in or around open greenspaces significantly increased likelihood of good health and wellbeing (White et al., 2019). However, given the significant number of confounding and interacting factors, it is problematic to make strong causal links (Hough, 2014) even with the statistical power that 19,000 participants afford.

Based on reviewing the most recent academic literature, the top five environmental priorities for the various sectors of interest are presented in Table 2.2 below using the terminology most referred to.

Rank	**Freshwater ecosystems**	**Marine ecosystems**	**Terrestrial ecosystems**	**Food security**	**Public health**
1	Land Use	Acidification	Land Use	Loss of Pollinators	Air pollution
2	Climate Change	Sea Use	Climate Change	Soil Compaction	Chemicals
3	Habitat Degradation	Climate Change	Habitat Degradation	Nutrient Depletion	AMR
4	Chemicals	Habitat Degradation	Chemicals	Climate Change	Noise
5	Eutrophication	Chemicals	Habitat Fragmentation	Land Degradation	Access to nature

Table 2.2 – Top five environmental priorities by sector based on review of recent (past 5 years) studies

2.2. Priorities through the lens of the Environment Strategy for Scotland

The Environment Strategy creates an overarching framework for Scotland's environmental strategies and plans, including the Climate Change Plan. In February 2020 the vision and outcomes for the Environment Strategy were published (Scottish Government 2020). The outcomes identified in this document are partially-equivalent to the environmental priorities in the format presented above (Section 2.1) but are more encompassing and higher-level. This publication also identified the next critical steps needed to support the vision and outcomes including the identification of strategic priorities and development of a monitoring framework.

In February 2021, an initial set of indicators for the Environment Strategy Monitoring Framework were also published (Scottish Government 2021) with the anticipation that this is an evolutionary process with the framework and indicators likely to adapt and change over time. The indicators, being domain-specific are possibly more analogous to the environmental priorities as discussed in Section 2.1 than the outcomes.

Indicators relevant to each of the outcomes were scored against seven criteria:

- **Relevance** – describes the relationship between the indicator and the outcome
- **Validity** – describes what precisely the indicator is measuring
- **Distinctiveness** – describes the extent of overlap between indicators
- **Practicality** – describes value for money and feasibility of the indicator
- **Clarity** – described ease of interpretation and communication of the indicator
- **Credibility** – describes impartiality and reliability of data sources for the indicator, and ability of these data to provide appropriate precision
- **Public Interest** – describes relevance to the public of the indicator

The relationship between the final selected indicators and the outcomes of interest is depicted in Figure 2.1.

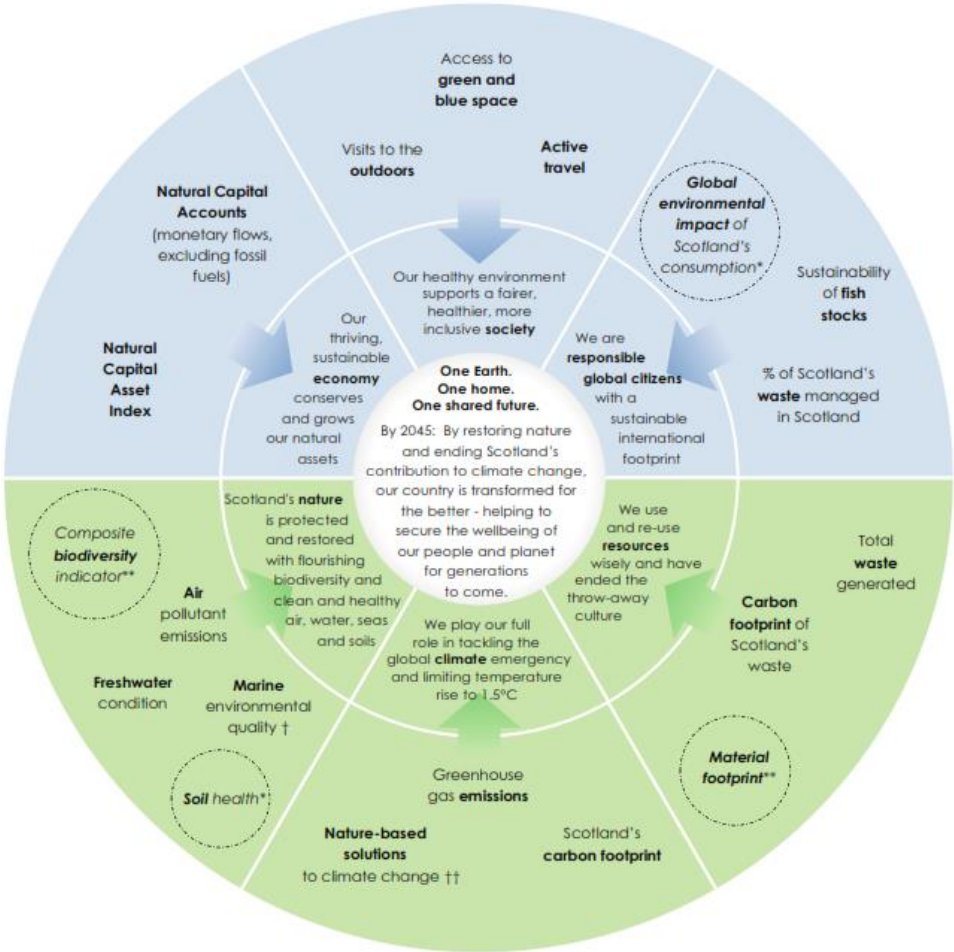

Figure 2.1 – Schematic of the scope of the Environment Strategy Scotland, including outcomes (inner ring) and indicators for monitoring those outcomes (outer ring). Several indicators are yet to be confirmed (*), developed (**), or represent a suite of indicators (†, ††)

2.3. Proposed environmental priorities for Scotland

An initial mapping of recent research priorities from Section 2.1 on to the elements of the Environment Strategy (Figure 2.1) was performed (Table 2.3). The linkage between these two different approaches to setting environmental priorities was essentially via the indicators. Given several indicators in the Environment Strategy are still in development, this mapping was only an approximation based on the most up to date information on the suite of indicators being proposed. The relationship between the reviewed environmental priorities and the indicators from the Environment Strategy can be found in Appendix 1.

Sector	Environmental Priorities (2.1)	Environment Strategy Indicators (2.2)	Environment Strategy Outcomes (2.2)
Freshwater ecosystems	Habitat degradation Chemicals Eutrophication	Freshwater condition	Scotland's nature is protected & restored with flourishing biodiversity & clean & healthy air, water, seas & soils
	All?	Composite biodiversity indicator	
	Climate change Land Use	GHG emissions Scotland's carbon footprint Nature-based solutions	We play our full role in tracking the global climate emergency and limiting temperature rise to 1.5°C
Marine ecosystems	Acidification Habitat degradation Chemicals	Marine environmental quality	Scotland's nature is protected & restored with flourishing biodiversity & clean & healthy air, water, seas & soils
	All?	Composite biodiversity indicator	
	Sea use	Sustainability of fish stocks	We are responsible global citizens with a sustainable international footprint
	Climate change	GHG emissions Scotland's carbon footprint Nature-based solutions	We play our full role in tracking the global climate emergency and limiting temperature rise to 1.5°C
Terrestrial ecosystems	Land use Chemicals	Soil health	Scotland's nature is protected & restored with flourishing biodiversity & clean & healthy air, water, seas & soils
	Habitat degradation Habitat fragmentation	Composite biodiversity indicator	
	Climate change Land use	GHG emissions Scotland's carbon footprint Nature-based solutions	We play our full role in tracking the global climate emergency and limiting temperature rise to 1.5°C

Sector	Environmental Priorities (2.1)	Environment Strategy Indicators (2.2)	Environment Strategy Outcomes (2.2)
Food security	Loss of pollinators	Composite biodiversity indicator	Scotland's nature is protected & restored with flourishing biodiversity & clean & healthy air, water, seas & soils
	Soil compaction Nutrient depletion Land degradation	Soil health	
	Climate change	GHG emissions Scotland's carbon footprint Nature-based solutions	We play our full role in tracking the global climate emergency and limiting temperature rise to 1.5°C
Public Health	Air pollution	Air pollutant emissions	Scotland's nature is protected & restored with flourishing biodiversity & clean & healthy air, water, seas & soils
	Access to nature	Access to green space and blue space Visits to the outdoors Active travel	Out healthy environment supports a fairer, healthier, more inclusive society

Table 2.3 – Mapping of the environmental priorities identified from the rapid literature review (Section 2.1) to those in the Environment Strategy Scotland (Section 2.2)

The environmental priorities identified in Section 2.1 only map to roughly half of the outcomes identified in the Environment Strategy (Section 2.2). Outcomes associated with circular economy, natural assets, and global footprint are not adequately represented by the environmental priorities. This makes sense, as all the indicators associated with these outcomes are essentially management practices/economic/behaviours and are not *sensu stricto* environmental indicators.

It is also evident that environmental indicators of public health are only partially covered by the Environment Strategy, the latter being restricted to access to nature and air pollution. The Environment Strategy therefore does not consider chemicals in other exposure media (food, drinking water, etc.), AMR and noise; all of which are widely considered to have greater public health impact than the protective properties of access to nature.

2.4. Legislation, indicators, and data sources for proposed environmental priorities

2.4.1. Freshwater condition

A list of all legislation relating to the water environment in Scotland can be found at https://www.gov.scot/publications/water-environment-legislation/. Of particular relevance to the freshwater condition indicator are The Water Environment (Water Framework Directive) (Solway Tweed River Basin District) Regulations 2004 (https://www.legislation.gov.uk/uksi/2004/99/contents) and The Water Environment (Water

Framework Directive) (Northumbria River Basin District) Regulations 2003 (https://www.legislation.gov.uk/uksi/2003/3245/contents); as well as various amendments to these regulations.

Freshwater condition is assessed by SEPA and subject to statutory targets set via the River Basin Management Plans (RBMP, Scottish Government 2015a; Scottish Government & Environment Agency 2015). The RBMPs are a key component of the implementation of the EU Water Framework Directive and are developed for each river basin district and reviewed every six years. The RBMPs must include, amongst other details, a programme of measures arising from considering the results of the pressures and impact analysis to achieve the objectives of the directive.

All defined surface waters (rivers with a catchment greater than 10 km^2 or still waters greater than 0.5 m^2) are evaluated using a composite indicator of ecological status that combines measures of water quality, physical condition, access for fish migration, flows and levels of water, and freedom from invasive and non-native species into a categorical variable (High, Good, Moderate, Poor, Bad). Targets are typically set based on the proportion of surface waters achieving Good or better ecological status.

Detailed information on the monitoring and measurements performed can be found in the appendices (primarily Appendix 2) to the River Basin Management Plans (The current plans | Scottish Environment Protection Agency (SEPA)), while the Water Environment Hub (Water Environment Hub (sepa.org.uk)) provides visualisations of the available data as well as some downloadable data sets.

2.4.2. Composite biodiversity indicator

Biodiversity legislation in Scotland is underpinned by the Scottish Biodiversity Strategy (Scottish Government 2004) and the 2020 Challenge for Scotland's Biodiversity (Scottish Government 2013). The 2020 Challenge was billed as Scotland's response to the Aichi Targets and the EU's (then) Biodiversity Strategy for 2020. It rightly noted that there was a need for a "step change" in efforts to halt the loss of biodiversity. In 2015, the two-part strategy was then further complemented with publication of Scotland's biodiversity: a route map to 2020 (Scottish Government 2015b). This set out the priority work needed to meet the international Aichi Targets for biodiversity and improve the state of nature in Scotland. It did this by identifying six 'Big Steps for Nature'. Overall, the Scottish Biodiversity Strategy is often taken as these three strategies combined as summarised in Table 2.4.

The 5 objectives of *Scotland's biodiversity – it's in your hands,* the 2004 Scottish Biodiversity Strategy.	The 3 aims and 7 outcomes of the *2020 Challenge for Scotland's Biodiversity* (2013).	The 6 'Big Steps for Nature' from *Scotland's biodiversity: a route map to 2020* (2015).
Species and Habitats: To halt the loss of biodiversity and continue to reverse previous losses through targeted action for species and habitats. **People:** To increase awareness, understanding and enjoyment of biodiversity, and engage many more people in conservation and enhancement. **Landscapes and Ecosystems:** To restore and enhance biodiversity in all our urban, rural, and marine environments through better planning, design and practice. **Integration and Co-ordination:** To develop an effective management framework that ensures biodiversity is considered in all decision making. **Knowledge:** To ensure that the best new and existing knowledge on biodiversity is available to all policy makers and practitioners.	Aims to: - 1. protect and restore biodiversity on land and in our seas, and to support healthier ecosystems. 2. connect people with the natural world, for their health and wellbeing and to involve them more in decisions about their environment. 3. maximise the benefits for Scotland of a diverse natural environment and the services it provides, contributing to sustainable economic growth. Seven outcomes: - 1. Scotland's ecosystems are restored to good ecological health so that they provide robust ecosystem services and build our natural capital. 2. Natural resources contribute to stronger sustainable economic growth in Scotland, and we increase our natural capital to pass on to the next generation. 3. Improved health and quality of life for the people of Scotland, through investment in the care of green space, nature and landscapes. 4. The special value and international importance of Scotland's nature and geodiversity is assured, wildlife is faring well, and we have a highly effective network of protected places. 5. Nature is faring well, and ecosystems are resilient as a result of sustainable land and water management. 6. Scotland's marine and coastal environments are clean, healthy, safe, productive, and biologically diverse, meeting the long-term needs of people and nature. 7. A framework of indicators that we can use to track progress.	**Ecosystem restoration**– to reverse historical losses of habitats and ecosystems, to meet the Aichi target of restoring 15% of degraded ecosystems. **Investment in natural capital**– to ensure the benefits which nature provides are better understood and appreciated, leading to better management of our renewable and non- renewable natural assets. **Quality greenspace for health and education benefits**– to ensure that most people derive increased benefits from contact with nature where they live and work. **Conserving wildlife in Scotland**– to secure the future of priority habitats and species. **Sustainable management of land and freshwater**– to ensure that environmental, social, and economic elements are well balanced; and **Sustainable management of marine and coastal ecosystems**– to secure a healthy balance between environmental, social, and economic elements.

Table 2.4 - Combined summary of the Scottish Biodiversity Strategy (Scottish Government 2004), the 2020 Challenge for Scotland's Biodiversity (Scottish Government 2013), and Scotland's biodiversity: a route map to 2020 (Scottish Government 2015b). Together, these three strategies are often referred to as the "Scottish Biodiversity Strategy"

There are many human activities that have a biodiversity component so there are many legislations that include aspects of biodiversity. The Nature Conservation (Scotland) Act 2004 (Nature Conservation (Scotland) Act 2004 (legislation.gov.uk)) gave every public body a duty "to further the conservation of biodiversity" and committed Scottish Ministers to prepare a Scottish Biodiversity

Strategy and to report regularly to the Scottish Parliament on its implementation. Public bodies in Scotland have a *Biodiversity Duty* to further the conservation of biodiversity. This duty relates to all biodiversity in any setting and is therefore not restricted to specific species, habitats or locations. Under The Wildlife and Natural Environment (Scotland) Act 2011 (known as the WANE Act; https://www.legislation.gov.uk/asp/2011/6/contents/enacted) every public body in Scotland is required to produce a publicly available report, on compliance with the Biodiversity Duty. This must be completed once every three years.

Other relevant legislation includes that relating to planning and environmental impact assessments (Environmental assessment: Environmental Impact Assessment (EIA) - gov.scot (www.gov.scot)), and marine legislation with a biodiversity component (Marine (Scotland) Act 2010 (Marine (Scotland) Act 2010 (legislation.gov.uk)), Marine and Coastal Access Act 2009 (Marine and Coastal Access Act 2009 (legislation.gov.uk)), The Conservation of Offshore Marine Habitats and Species Regulations 2017 (The Conservation of Offshore Marine Habitats and Species Regulations 2017 (legislation.gov.uk)).

Research underpinning a composite biodiversity indicator was published in March 2021 (Eaton et al. 2021). This indicator will combine trends in both abundance and occupancy of a range of target species without correcting for perceived or real bias, i.e., no weightings or similar corrective measures will be employed.

The recommendations for a headline indicator are based on combining existing monitoring efforts of specific species, rather than taking advantage of technological advances (e.g., e-DNA techniques that have the power to screen for a wide range of species from a single environmental sample with reduced time and personnel). The reasoning for this is the fact that current monitoring efforts can be traced back to at least 1994 thus provide a historical baseline.

Combining tends in abundance with occupancy into the same metric is not used as a biodiversity indicator elsewhere in UK monitoring or compliance. However, the same approach, also without the use of weighting to correct for bias, was used in the 2016 State of Nature report (Burns et al., 2018; Hayhow et al., 2016) and in the Dutch *Living Planet Index* (Van Strein et al., 2016).

As trends in abundance and occupancy will vary in different ways even within the same species (Van Strein et al., 2016) and even show trends in opposing directions (Dennis et al., 2019), the combined biodiversity indicator should only be described in abstract terms and cannot be related back to either abundance or occupancy.

The indicator will be based on trends in abundance from a range of established monitoring schemes and trends in occupancy from analyses of biological records held by the Biological Records Centre. Rules (either associated with the monitoring schemes themselves or created for the purposes of the composite indicator) will filter species trends for inclusion with the aim of only including those trends which are robust. Except for marine fish trends, which are produced specifically for the composite indicator, these species trends arise from existing work programmes.

2.4.3. Greenhouse gas emissions and carbon footprint

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, which amends the Climate Change (Scotland) Act 2009, sets targets to reduce Scotland's emissions of all greenhouse gases to net-zero by 2045 at the latest, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040.

The National Performance Framework reports Scotland's greenhouse gas emissions (GHGs) as a percentage change against a baseline established in 1990. This figure is inclusive of international aviation and shipping where these fall within the definition of territorial emissions, i.e., emissions form aircraft within UK airspace or from shipping within UK waters. This reporting is in line with statutory obligations to the Paris Agreement. The methodology for estimating emissions is described in detail in Tsagatakis et al., 2021.

The National Performance Framework reports Scotland's carbon footprint as the sum of all greenhouse gases emitted because of the goods and services consumed in Scotland. Scotland's carbon footprint includes both the emissions associated with consumption of imported goods as well as territorial emissions, with all emissions calculated across the entire supply chain. The carbon footprint therefore compliments the GHG inventory described in Section 2.5.3.

2.4.4. Marine environmental quality

The Marine (Scotland) Act 2010 (https://www.legislation.gov.uk/asp/2010/5/contents) provides a framework that aims to balance competing demands on Scotland's seas and coastal areas and until recently reported via the UK to the EU Marine Strategy Framework Directive that aims to achieve good environmental status of European seas and coastal waters.

The Marine (Scotland) Act sets out a duty for public bodies in Scotland to protect and enhance the marine environment including measures to help attract economic investment in areas such as marine renewable energy. The main measures include a statutory marine planning system based around the principles of sustainability, reduced marine bureaucracy, powers to protect and manage areas of importance for marine wildlife as well as historic monuments, enhanced seal protection measures, and more rigorous enforcement of the above.

In addition, legislation pertaining to surface waters (see Section 2.4.1) is of indirect relevance to coastal and marine environmental quality. Legislation targeted at fisheries and aquaculture (https://www.legislation.gov.uk/asp/2007/12/contents; https://www.legislation.gov.uk/asp/2003/15/contents), and legislation to do with conservation of species relevant to coastal and marine habitats such as the EU Birds Directive and the EU Habitats Directive and the Nature Conservation (Scotland) Act 2004 (https://www.legislation.gov.uk/asp/2004/6/pdfs/asp_20040006_en.pdf), are also of relevance to how Scotland manages marine environmental quality.

Marine environmental quality summarises four different marine indicators; namely marine chemical pollution (Clean Seas indicator), beach litter, plastic ingested by seabirds, physical damage to sea floor habitats; but does not combine them into a single index as the data types are incompatible for this. Marine biodiversity is incorporated separately into the Composite Biodiversity Indicator (Section 2.4.2). The four marine indicators selected aim to provide a high-level understanding of marine environmental quality that is broadly equivalent to the indicators used to assess the terrestrial environment.

The Clean Seas indicator looks at the extent to which levels of metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are sufficiently low that they are unlikely to cause adverse effects in marine organisms in Scottish waters.

Contaminant data are collected as part of the UK Clean Seas Environmental Monitoring Programme to:

- Cover five contaminant groups – cadmium, mercury, lead, PAHs, PCBs
- Measure levels of the above in fish, shellfish and sediments
- Measure levels in waters in the four biogeographic regions around Scotland – Northern North Sea, Scottish Continental Shelf, Minches and Western Scotland, and Irish Sea

The data are submitted to the UK Marine Environmental Monitoring and Assessment National database (MERMAN) managed by the British Oceanographic Data Centre (BODC).

The density and type of litter found on beaches has been recorded by the Marine Conservation Society (MCS) since 1993. The Great British Beach Clean survey takes place annually (third weekend in September) and relies on volunteers to select and survey a beach. In addition, OSPAR (The Convention for the Protection of the Maritime Environment of the North-East Atlantic; OSPAR is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic) reference beaches (Cramond and Kinghorn Harbour (Forth), Lunderston Bay (Clyde) and Mill Bay (Orkney)) are surveyed 4 times per year by MCS volunteers and staff.

All litter surveys use a standard method, agreed with OSPAR, to count the visible pieces of plastic and non-plastic litter on a beach, with these being put into one of 118 different categories. These 118 categorises were grouped to give the Scottish Beach Litter Performance Indicators (SBLPI) and both the OSPAR reference beach data and MCS data (2008-2017) are assessed by coastal sub-regions. Summary data and visualisations are available at Beach litter | Scotland's Marine Assessment 2020.

The quantity of plastic litter ingested by seabirds is estimated using the OSPAR Plastic Particles in Fulmar Stomachs assessment. The area assessed is currently the Northern North Sea and the Scottish Continental Shelf. This reflects exposure to and ingestion of floating plastic particles. However, no attempt to relate this exposure to harmful outcomes is made. More details can be found at Plastic Particles in Fulmar Stomachs in the North Sea (ospar.org)

Physical damage to sensitive habitats on the sea floor is evaluated using a series of four analytical steps that combine the distribution and intensity of physical pressures (component 3) with the distribution and range of habitats (component 1) and their sensitivities (component 2). Data generated by the first three components above are combined using a step-wise approach to calculate the fourth component, which enables the total area of different levels of predicted disturbance and a combination of those, across the sub-region, per habitat type to be estimated. The results are also used to calculate the levels of variability of fishing intensity and identify trends in disturbance per year across a five-year period. More information can be found at Predicted extent of physical disturbance to seafloor | Scotland's Marine Assessment 2020.

2.4.5. Fish stocks

The status of most commercial fish stocks of greatest commercial value to Scotland (pelagic mackerel and herring being the two most valuable species, with demersal being haddock, monkfish, cod, hake, whiting and saithe) is evaluated each year by the International Council for the Exploration of the Sea (ICES). This evaluation uses fishery and survey data from appropriate countries to estimate three key metrics:

- Fishing mortality – this is a measure of the mortality pressure exerted by fishing on the stock. It relates to the proportion of a population removed by fishing each year according to a non-linear relationship
- Spawning stock biomass – is an estimate of weight (in tonnes) of sexually mature fish in the population, and is used as a proxy for both abundance and reproductive potential
- Recruitment – provides an estimate of the number of young fish entering the fishable population each year

Assessment of the state of the stock typically consist of estimating time series of these three measures, and in doing so judging whether the fishery is suitable and the stock healthy by comparing them to pre-defined management reference points. Stock status advice is provided by ICES based on discrete stocks that may be biologically distinct or simply considered as part of an existing geographically defined management area. The stocks are not in general congruent with the defined Scottish Marine Regions or the Offshore Marine Regions and therefore not possible to assign stock status indicators to these different regional breakdowns.

2.4.6. Soil health

Soil legislature is very complex because soil is a component of a wide number of sectors and processes including primary production, planning, waste management, etc. The Scotland's Soil website lists 69 different policies and legislation that protects some aspects of soils and influences how our soils are managed (https://soils.environment.gov.scot/soils-in-scotland/soil-protection/).

It should be noted that of these, 15 are either European Directives or EU policy/guidance that may become less relevant given we are no longer an EU Member State. It should also be noted that a number of these policies have already been mentioned under Freshwater Condition (Section 2.4.1) and Composite Biodiversity Indicator (Section 2.4.2). In addition, some areas of the various policies and legislation are contradictory, with context being incredibly important when making decisions around soil protection.

The above sums up the challenge – soil health is the most cross cutting of all the proposed indicators. What makes a soil healthy for e.g., agricultural production is not necessarily what makes it healthy for renewable energy development or carbon sequestration. There has not been a concerted effort to unify soils' policy since the publication of the Scottish Soils Framework (Scottish Government 2009). This complex policy and legislative landscape present challenges for anyone trying to identify where legislative breaches have occurred.

To date, no single or composite indicators of soil health have been identified. However, Nielson et al. 2020 provide one of the more recent assessment of an overview of different soil indicators for climate change. While there is no doubting the inherent complexity of soils, we should not allow this complexity to get in the way of their protection. I would like to think there would be scope to develop a composite indicator like that used for freshwater condition (5.1), with possibly some adjustment or weighting to consider desired/achievable land use and other functions such as carbon sequestration.

2.4.7. Air pollutant emissions

Activities relating to the monitoring and management of air quality in Scotland have been primarily driven by European legislation. The Ambient Air Quality Directive 2008 (2008/50/EC) sets legally binding limits for concentrations in ambient air of most major air pollutants that are known to have a significant impact on human health (including PM_{10}, $PM_{2.5}$ and NO_x). This Directive was made law in Scotland through the Air Quality Standards (Scotland) Regulations 2010 which also incorporates the 4th Air Quality Daughter Directive (2004/107/EC) that sets targets in ambient air for specified heavy metals and PAHs.

Legislation is also in place to control emissions of air pollutants, with the main legislature under the auspices of the United Nations Economic Commission for Europe (UNECE) Gothenburg Protocol which in 2010 initiated emission ceilings for sulphur, NO_x, VOCs and NH_4 and since incorporated into EU National Emission Ceilings Regulations (2001/81/EC). This was made into UK law (including Scotland) as the National Emissions Ceilings Regulations 2002. This protocol was since amended in 2012 to include national emission reduction commitments to be achieved by 2020 and beyond (see https://unece.org/environment-policyair/protocol-abate-acidification-eutrophication-and-ground-level-ozone).

In December 2013, the European Commission adopted a Clean Air Policy Package that includes a new Clean Air Programme for Europe with new air quality objectives for the period up to 2030. This has not been fully adopted into UK or Scottish legislation yet and might not be.

The UK Government leads on the UKs input to international/EU legislation with input from Scotland and the other devolved administrations. Linking to the requirements of the EU Directives above, the latest Air Quality Strategy (2007) established a framework for air quality improvements across the UK which stipulates various air quality standards and objectives. However, air quality is a devolved matter with the development of the Air Quality (Scotland) Regulations 2000 (with amendments in 2002 and 2016). Air quality targets are in line with UK and EU limit and target values, but with some Scotland-specific limits values (see http://www.scottishairquality.scot/air-quality/standards).

Air pollutants (ammonia, carbon monoxide, nitrogen oxides, non-methane volatile organic compounds, PM_{10}, $PM_{2.5}$, sulphur dioxide, lead) are reported annually in the Air Pollution Inventories for England, Scotland, Wales and Northern Ireland published by the National Atmospheric Emissions Inventory. An analysis of trends in these data (1990-2018) can be found in Smith et al. 2020.

According to http://www.scottishairquality.scot/air-quality/standards, Scottish local authorities currently do not assess O_3 and PAHs in the context of human health. It is not clear if this is an infrastructural/capacity limitation or if these indicators were of less relevance to Scotland. Scottish local authorities also do not currently assess NO_x, SO_x and O_3 in the context of environmental (vegetation and ecosystems) protection.

2.4.8. Access to green/blue space, active travel and outdoor visits

Access to green/blue space, active travel and outdoor visits are not legislated for. Instead, the rights of citizens to access land and use open spaces for specific purposes is. Part 1 of the Land Reform (Scotland) Act 2003 (https://www.legislation.gov.uk/asp/2003/2/contents) establishes a right of responsible non-motorised access to land throughout Scotland with few exceptions, for recreational, educational and some commercial purposes. Part 9 of the Land Reform (Scotland) Act 2016 made minor amendments on review of core paths plans and service of court applications. The National Parks (Scotland) Act 2000 (https://www.legislation.gov.uk/asp/2000/10/contents) provides for the designation and administration of National Parks in Scotland. Loch Lomond and the Trossachs National Park was established in 2002 and Cairngorms National Park was established in 2003. In addition, Section 50 of the Planning etc. (Scotland) Act 2006 (https://www.legislation.gov.uk/asp/2006/17/contents) inserted section 263A of the Town and Country Planning (Scotland) Act 1997 provides designation of a current suite of 40 National Scenic Areas.

The Scottish Household Survey SHS Data hExplorer provides aggregated individual-level data on activity budgets of people and households, including access and use of open space, active travel and outdoor visits by socio-economic measures (e.g., level of education or deprivation index of area), gender, and other factors. These data are derived from a voluntary face to face survey and so will contain some selection bias. However, the survey has been running since 1999, attracts ~10,000 respondents annually, and covers all 32 Local Authorities in Scotland. It should be noted that each participant only answers a sub-set of the questions to reduce the individual burden. And some questions are only asked every second year. A weighting methodology has been used to derive estimates of each indicator of interest.

2.4.9. Antimicrobial resistance, Noise

Antimicrobials and antimicrobial resistance

Antimicrobials and antimicrobial resistance are currently not legislated against in Scotland or in the EU. In 2019, the European Commission adopted a Strategic Approach to address the issue of pharmaceuticals in the environment. Whilst this communication highlighted that this problem could no longer be ignored, it largely failed to propose concrete measures to mitigate the devastating impact of pharmaceutical pollution on human, animal, and environmental health.

In November 2020 the European Commission released its Pharmaceutical Strategy for Europe with a whole section on high-quality, safe and environmentally sustainable medicines. It acknowledges the need to strengthen oversight of the global manufacturing chain and ensure more transparency across the pharmaceutical supply chain.

It notably paves to the way to a welcomed revision of the pharmaceutical legislation to strengthen the environmental risk assessment requirements and a review of the framework on good manufacturing practice that should assess the extent to which antimicrobial resistance can be addressed. The scope and ambition of these initiatives remain however to be evaluated.

Noise

Noise pollution is governed by the European Parliament and Council Directive for Assessment and Management of Environmental Noise 2002/49/EC, more commonly known as the Environmental Noise Directive (END). This Directive deals with noise from road, rail, air traffic, and from industry. It focuses on the impacts of such noise on individuals, thus complementing existing EU legislation that sets standards for noise emissions from specific sources. This legislation stipulates that noise is monitored and mapped for specified areas including agglomerations (large urban centres above a specified population) and transport corridors.

In 2006, this directive was transposed into Scots law via the Environmental Noise (Scotland) regulations 2006. Under the auspices of this Directive, six geographically specific action plans for controlling and reducing noise have been developed and implemented. Four of these cover the main large urban centres of Glasgow, Edinburgh, Dundee and Aberdeen (Scottish Government, 2014a, b, c, d), one specifically centred on Dundee Airport (Scottish Government, 2014e) and another focussed on transportation more generally (Scottish Government, 2014f). Implementation of these action plans is a joint responsibility between Scottish Government, Transport Scotland, Local Authorities, SEPA and others.

Noise data are available at Scotland's noise (environment.gov.scot), including noise exposure estimates as submitted to the European Commission.

2.5. Performance against current legislature

2.5.1. Freshwater condition/Water Framework Directive

Within the Water Framework Directive, Scotland has two river basin districts (RBDs), one that falls entirely within the Scottish territory (Scotland RBD) and one which is shared with England (Solway Tweed).

In the first cycle of Water Framework implementation (2009–2015) the two Scottish RBDs expected an increase of 6.5 percentage points (pp) and 4.4 pp (against a UK average of 2.5pp) in the number of water bodies with good global (ecological and chemical) status from 63.5% and 32.5% respectively. The better performance of the Scotland RBD has continued throughout the second cycle and now SEPA expects a further increase of 6 pp and 16 pp by 2021 and 2027 respectively (Scottish Government 2015a). While it is important to recognise the differences in physical environment, population density, etc. between England and Scotland, De Vito et al. (2020) cites the implementation of the WFD in Scotland as being very cooperative with extensive and iterative engagement with interest groups from early in the implementation process as partly responsible for this relative success.

The European Environment Agency assesses performance of all member states against the Water Framework Directive. While Scotland’s data are aggregated under the UK in available databases (e.g., WISE Water Framework Directive Database), derived mapped information available in reports enables a Scotland-specific view. The most recent report was in 2018 (EEA 2018), the following figures have been re-used directly from this report hence the lack of quality of the reproduction.

Scotland has a relatively high ecological status compared to most member states (Figure 2.2). The EEA note: “*…northern countries, particularly the northern Scandinavian region and Scotland, as well as Estonia, Romania, Slovakia and several RBDs in the Mediterranean region have a high proportion of water bodies in high or good ecological status or potential*.” This contrasts with the rest of the UK and with many central European RDBs that are not in good ecological status or potential.

Scotland’s surface and ground waters also have a good chemical status, i.e., chemical emissions are low (Figure 2.3, Figure 2.4). Groundwater chemical status contrasts to the rest of the UK which is relatively poorer than Scotland.

Noteworthy is the scale of reporting done under the EU WFD compared with local-level monitoring undertaken by SEPA (Figure 2.5). Under the WFD, Scotland has two River Basin Districts. The main one covers the majority of Scotland and in effect the more pristine waters of the north-west balance widespread non-compliance in the East and Central Belt. Thus, reporting at RBD level enhances Scotland’s apparent water quality at this level of aggregation.

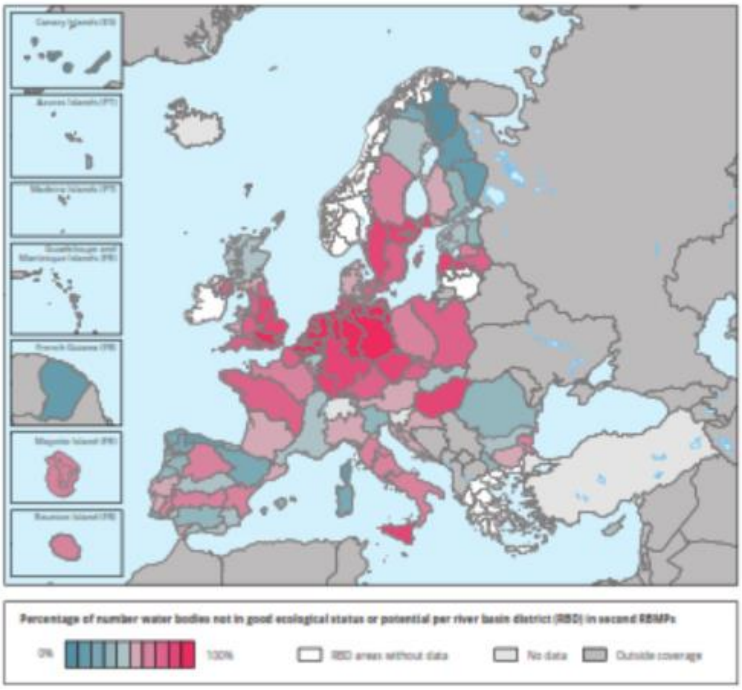

Figure 2.2 - Percentage of water bodies in Europe's RBDs that are not in good ecological status or potential.

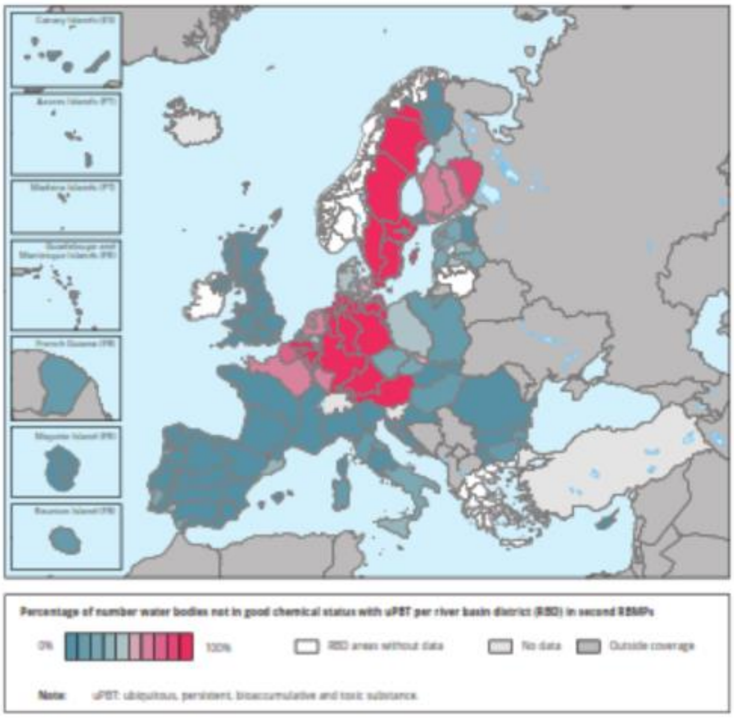

Figure 2.3 - Chemical status per River Basin District using full suite of priority substances including so-called ubiquitous, persistent, bioaccumulative and toxic compounds (uPBTs) which include mercury, brominated diphenyl ethers (pBDE), tributyltin and certain polyaromatic hydrocarbons (PAHs).

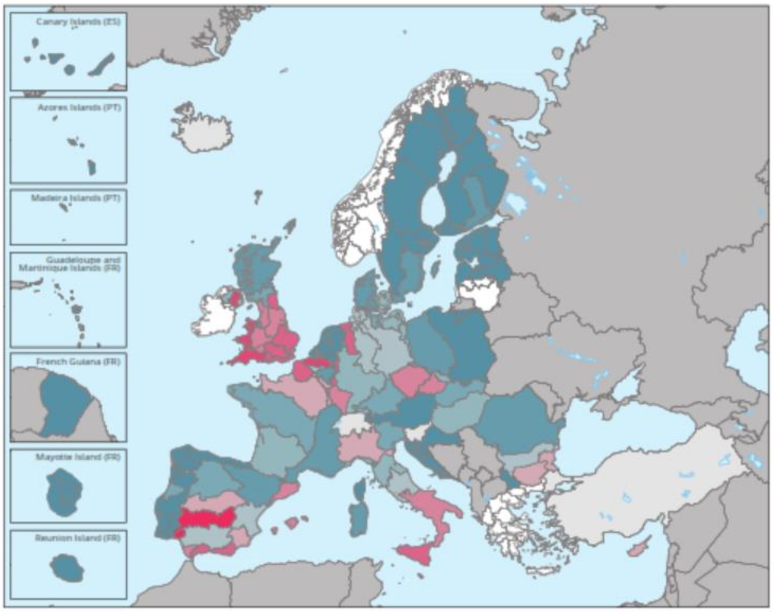

Figure 2.4 – Groundwater Chemical Status per River Basin District using full suite of priority substances including so-called ubiquitous, persistent, bioaccumulative and toxic compounds (uPBTs) which include mercury, brominated diphenyl ethers (pBDE), tributyltin and certain polyaromatic hydrocarbons (PAHs).

Figure 2.5 - Ecological status (left), chemical status (middle), and ground water status (right) at Scotland-level. These data are fed into the EU WFD reporting by SEPA and underlay Figure 2.2, Figure 2.3 and Figure 2.4.

2.5.2. Biodiversity and habitat protection

While the focus on indicators has explored the development of a composite biodiversity indicator (under development), reporting of both terrestrial and marine ecology has been under the framework of the EU Habitats Directive which covers a wider remit than biodiversity alone. Data from the Habitats Directive reporting can be used to place Scotland in the wider context of other EU member states. It should be noted, however that all figures published (where Scotland can be identified separately to UK, i.e., mapped products) under the Habitats Directive are based on levels of reporting and so partially reflect effort as well as environmental quality. It should also be noted tat the term 'biodiversity' is relatively new in legislature, with many other analogous terms being used historically. This makes the assessment of progress against biodiversity over time problematic as it is rarely a straightforward mapping of one indicator into another. Overall, this assessment and interpretation should therefore be read with some level of caution.

Figure 2.6 shows diversity of the habitats and species listed under the EU Habitats Directive. Scotland, and more widely the UK, have a low diversity of both habitats and species. This is based on levels of reporting so might reflect the relative efforts put into reporting efforts in different Member States or sub-regions within Member States. It also potentially reflects population density and the interests of the population, e.g., I would expect more reports of sightings from higher economic classes who tend to have access to reporting mechanisms, have higher levels of education and are more likely to live in greener environments where wildlife resides.

The low diversity of habitats propagates into subsequent analyses. For example, Figure 2.7 provides an estimate of conservation status for the habitats listed in the EU Habitats Directive. Scotland and the UK are notable in having almost ubiquitous 'bad' conservation status for all habitats. Under the Habitats Directive, Scotland is dominated by two habitat types: grasslands and meadows; bogs, mires and fens with over 70% of these considered to have bad conservation status. In contrast, the conservation status of individual species (Figure 2.8) indicates >60% of reports being of 'good' status.

Trend analysis indicates that habitat conservation status in Scotland is fairly stable but on the cusp of degradation (Figure 2.9) while trends in species conservation status show stronger levels of stability (Figure 2.10). Marine species conservation shows a strongly improving trend based on reporting.

Biodiversity recording at Scotland-level is split into several different initiatives, often species specific (see https://www.nature.scot/scotlands-biodiversity/biodiversity-where-find-data) and is therefore difficult to get a good national picture. Most of these data sets are based on number of records which is dependent on interested members of the public, studies, planning applications, etc. This reliance on voluntary reporting, and measuring 'good' status as high numbers of reports, introduces significant bias into baseline data.

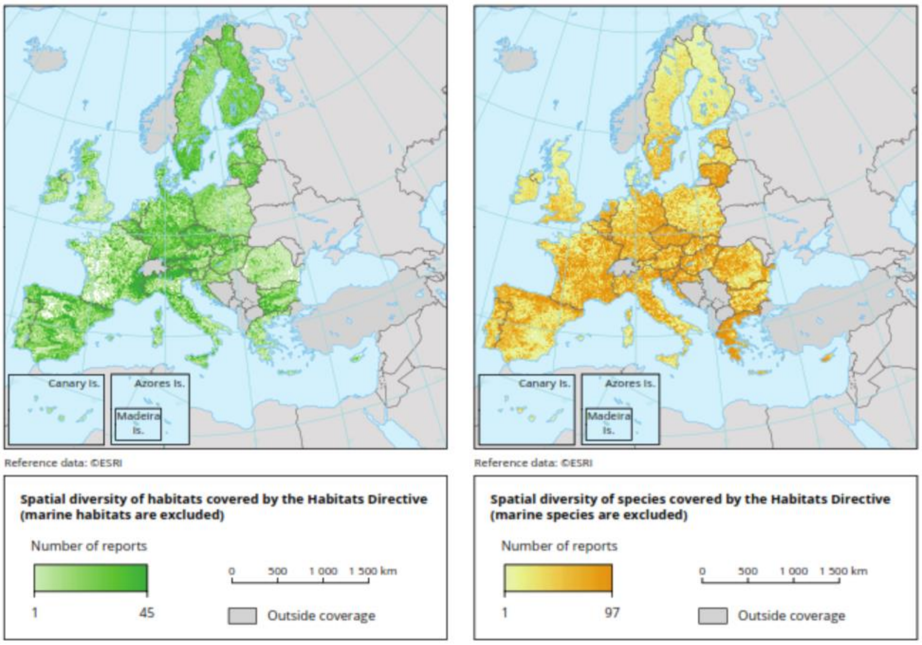

Figure 2.6 - Spatial diversity of habitats and species covered by the EU Habitats Directive

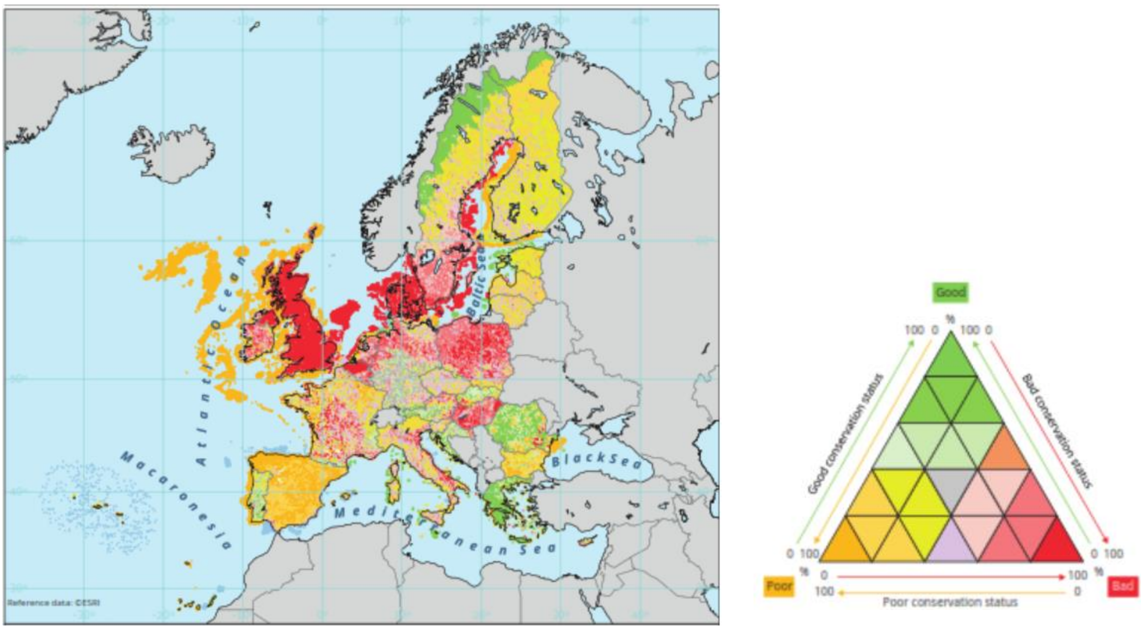

Figure 2.7 - Spatial distribution of habitats' conservation status at Member State level represented on a 10 x 10 km grid

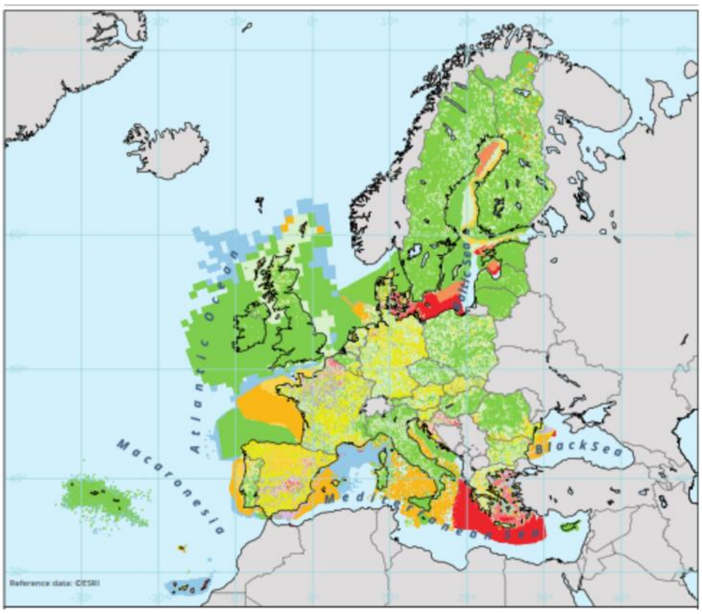

Figure 2.8 - Spatial distribution of conservation status of species listed in the EU Habitats Directive presented on a 10 x 10 km grid

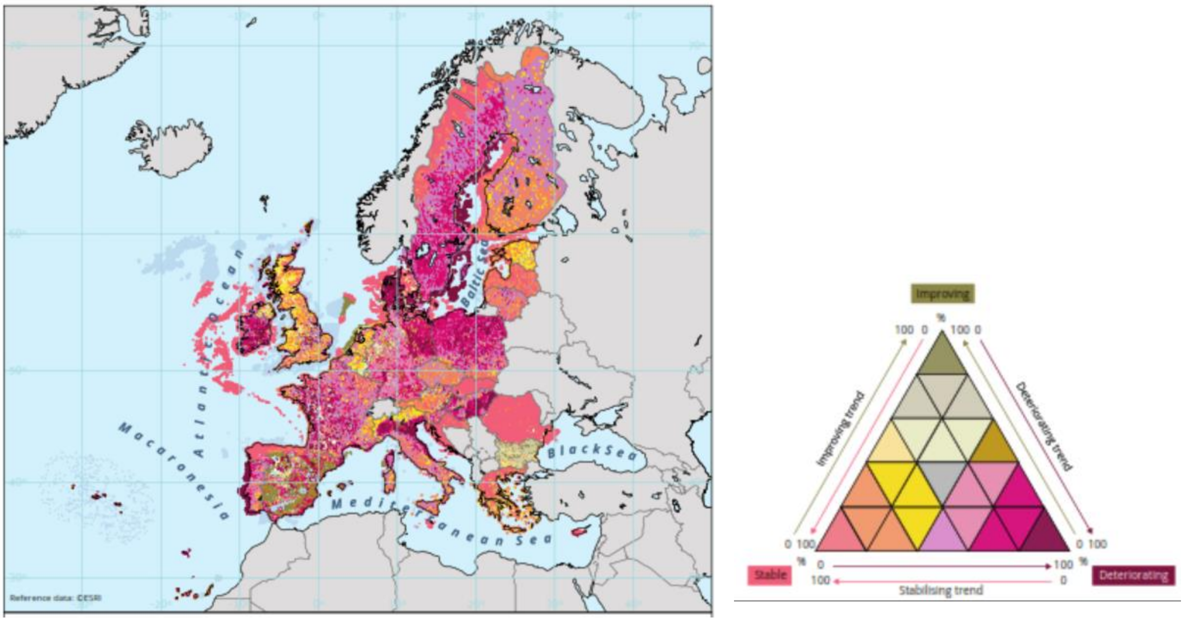

Figure 2.9 - Spatial distribution of habitat conservation status trends across EU Member States on a 10 x 10 km grid

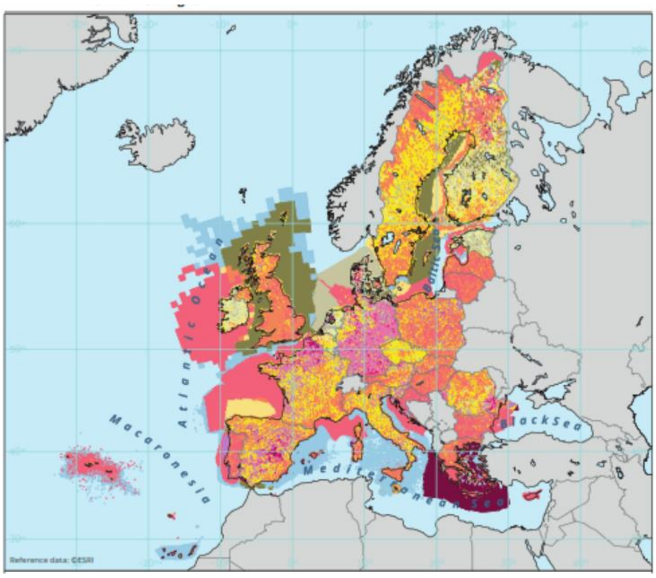

Figure 2.10 - Spatial distribution of species conservation status trends across EU Member States on a 10 x 10 km grid.

2.5.3. Greenhouse gases and carbon footprint

While EU-level data are available under the EU Climate Monitoring Mechanism, no mapped visualisations are available so it's difficult to place Scotland (as opposed to the UK as a whole) in the context of Europe. There are however several independent visualisations derived from the same data. Figure 2.11 provides an example of total emissions per capita in 2017. From this the UK is towards the lower end with 8 t CO_{2eq} per capita. Obviously, in this analysis the UK benefits from our relatively high population density. As with other aggregated reporting (see Figure 2.2 vs. Figure 2.5 for another example), these country-level analyses will smooth over the extremes of the analysis so are not a tool for identifying non-compliance.

The UK has reported GHGs under the EU Climate Monitoring Mechanism and maps are available from various sources including Tsagatakis et al. (2021; Figure 2.12). Clearly Scotland if taken as a unit, benefits from large areas of relatively wild land with minimal emissions. The populated areas of the Central Belt and the Eastern seaboard are clearly visible as higher emitters. Also noticeable, are the extensive peatland areas of Caithness and the Flow Country that emit 10 – 32 t CO_2 km^{-2} presumably due to degradation of the peat.

Scottish emissions have decreased steadily from a well-established baseline, driven primarily by the decarbonisation of energy production (Figure 2.13). Biggest potential for further reductions in emissions come from transport, agriculture and business with agriculture (or at least soil management) being probably the most readily achievable with less reliance on development of new technology.

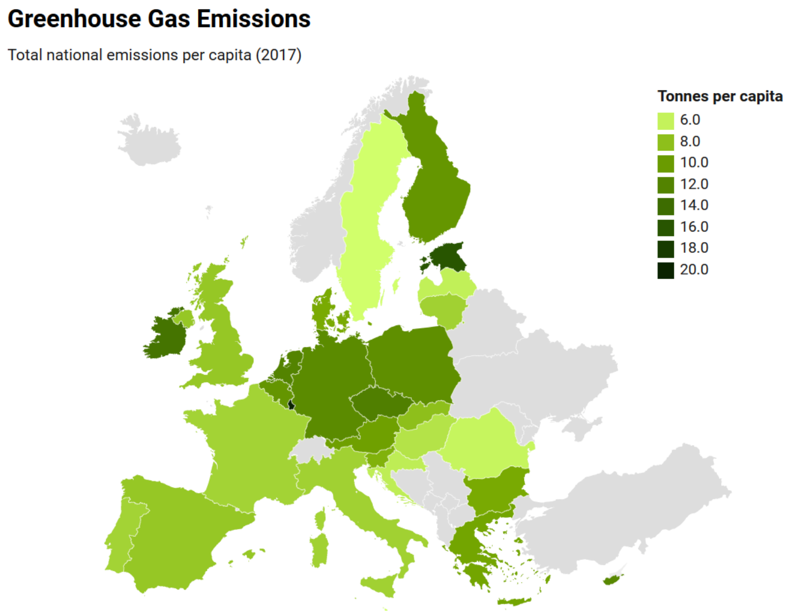

Figure 2.11 - Total national greenhouse gas emissions (t CO_{2eq} capita^{-1}) in 2017

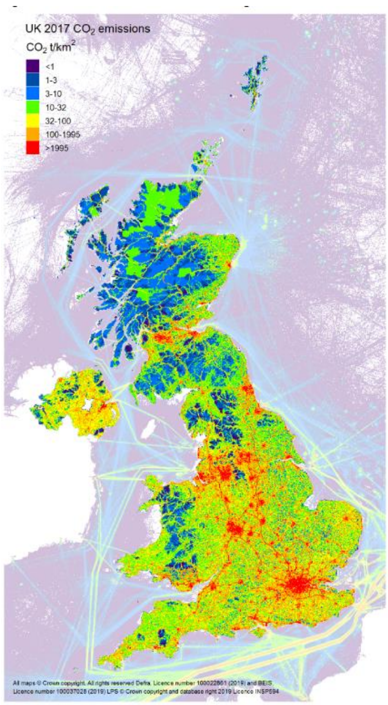

Figure 2.12 - Emissions of CO_2 km^{-2} (from Tsagatakis et al., 2021).

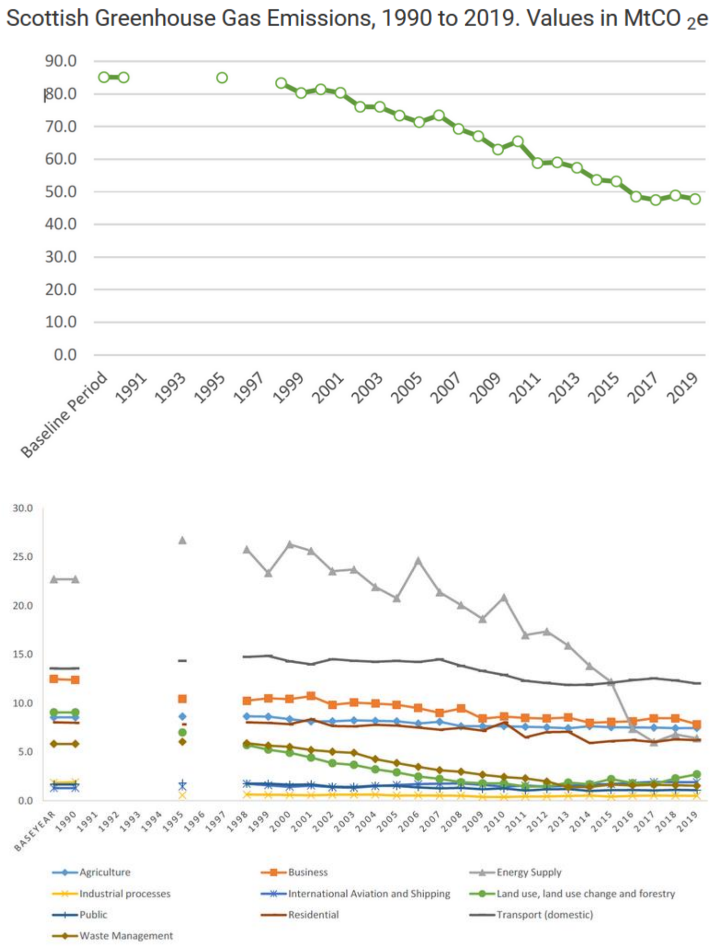

Figure 2.13 - Scottish greenhouse gas emissions (Mt CO_2eq) relative to 1989, in total and split by sector.

2.5.4. Marine environmental quality

An overall quality status analysis is produced by OSPAR roughly every 10 years. The last one was in 2010, with an analysis currently underway and due to be published in 2023.

The reporting structure divides the seas into specific bioclimatic regions so reporting at Scotland level can only be ascertained from raw data. Figure 2.14 summarises the trends in key aspects of the Clean Seas Act with risks to threatened species and marine noise pollution both increasing in Scotland's waters. However, data on chemical pollution, marine litter, radiation and invasive species are generally unsuitable for undertaking trend-based analyses due to their incomplete and inconsistent nature.

Marine environmental quality seems both poor and poorly understood in terms of spatial extent/differences.

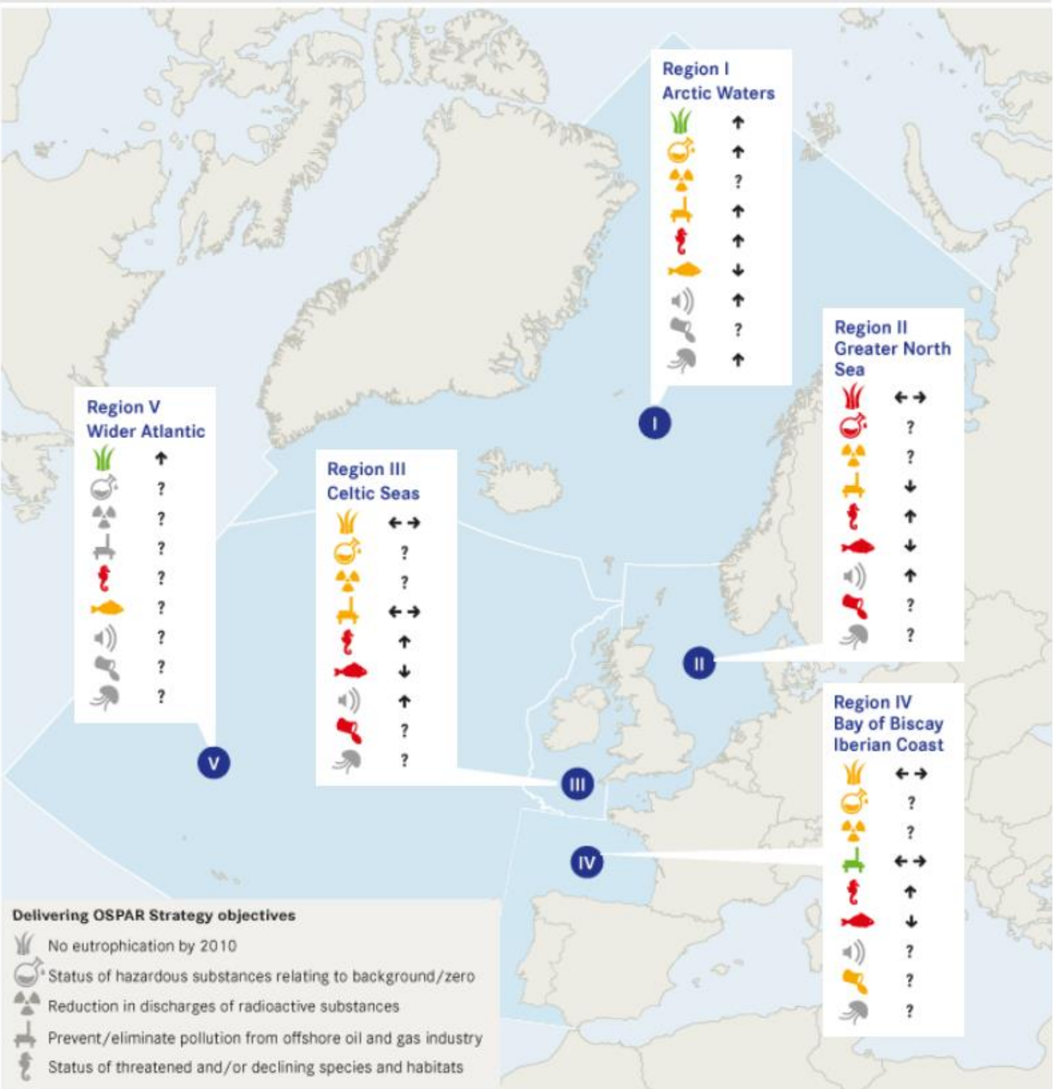

Figure 2.14 - trends in key aspects of the Clean Seas Act taken from the 2010 OSPAR Quality Status Report

2.5.5. Fish stocks

Graphical summaries of fish stock data are available at ICES Standard Graphs. The single Scottish Sustainable Fishing Indicator, which summarises trends in fishing mortality across key stocks and how these compare with the fishing mortality rate consistent with maximum sustainable yield (F(msy)), has shown regular improvement over the period 2016 to 2018, the percentage of stocks being fished at or below F(msy) has increased from 46% (2016), to 50% (2017) and to 54% (2018). This suggests either effective management action overall, or broadly beneficial environmental conditions, or a combination of both. While positive, the indicator is a very high-level metric, and it remains the case that further improvements are required for some key stocks. Furthermore, the indicator has thus far been estimated for only three years and would have greater utility if calculated over a longer time period. Advise on the operational aspects of this analysis are provided by ICES (ICES 2018), however it is not clear from the reporting whether these increases in F(msy) are in excess of the bounds of uncertainty in the derivation of F(msy). In other words, whether we are seeing a statistically significant improvement.

The key commercial stocks covered in this assessment are some of the most data-rich in the world and are extensively analysed by internationally renowned groups. The Scottish Sustainable Fishing Indicator summarises the recent trends in fishing mortality for these stocks, as compared with the estimated fishing mortality rates that should lead to the maximum sustainable yield. The fishing mortality estimates on which the Scottish Sustainable Fishing Indicator are based are measured with varying degrees of uncertainty, but they remain the best estimates generated by ICES.

The Scottish Sustainable Fishing Indicator shows a steady increase during 2016 to 2018, from 46% to 54%. However, the indicator is a broad summary metric that conceals stock-specific information. As the stocks are biologically distinct, and subject to different management measures, it is important to note cases for which the trends in fishing mortality are increasing. This is the situation for the important mackerel, monkfish and cod stocks. This outcome again highlights the disbenefits of aggregation - whether that be an aggregated indicator or spatial aggregation – ultimately important details are lost. Thus, any indicator needs to balance costs vs. benefits in the way that it is designed.

2.5.6. Soil health

There is limited legislature dealing with soil health in general, with statutory targets operating primarily in the contaminated land/development sector. Information on general (i.e., less targeted site-specific) soil monitoring efforts in Scotland can be found at Soil monitoring | Scotland's soils (environment.gov.scot). The site describes the initiation and on-going development of a Soil Monitoring Action Plan that aims to improve communication, awareness and understanding between a range of different users. The desired outcome is to develop a soil monitoring programme that supports the collection of soil data and makes soil data and information available that meets the needs of these users. The current focus is on three areas identified as pertinent gaps; namely, soil erosion, peatland and carbon, and soil sealing. Currently soils data are available from a diversity of sources with 10 different data bases highlighted on this page alone. There is also information available on ecosystem health indicators which can be a proxy measure for soil health where the desired function of the soil is to support a natural ecosystem.

2.5.7. Air pollution

Air pollution boasts some of the best established and accessible environmental data. One route of access is via Air Quality in Scotland - latest data, forecasts and air quality information (scottishairquality.scot) and a smart phone app is also available to provide daily information on pollution levels. This site provides summaries and analysis as well as access to raw data.

Air quality monitoring is often in response to exceedances of statutory air quality parameters, hence much of the site-specific data are biased towards more polluted locations. As an approach this is different to many of the other indicators described above that attempt to summarise Scotland-wide conditions. Having said this, national-scale data are also available based on remote sensing. Ultimately, air pollution is relatively well monitored compared to all other environmental priorities.

Long-term trend analysis indicates that levels of NO_2, PM_{10} and $PM_{2.5}$ have all tended to decrease over the past ~10 – 15 years and these trends tend to be statistically significant. Despite this, exceedances still occur regularly at many urban sites. Conversely, levels of O_3 have tended to increase slightly over the same period although these increases are only statistically significant at the longest running monitoring sites (~30 years continuous data) where the sheer number of data points provides more statistical power.

2.5.8. Access to green/blue space

Access to green/blue space, active travel and outdoor visits are not legislated for and therefore performance against these indicators is not a question of compliance and would therefore fall outside of the remit of ESS. Having said this, the Scottish Household Survey provides extensive information on levels of activity, active transport, and use/access to green space by age, gender, socioeconomic status, etc. over the past 15 years. The only obvious trends are seen in walking and in amount of time spent outdoors, both of which do seem to be increasing regardless of gender or socioeconomic status (although the trends are most pronounced for the least deprived). However, it is not clear from the analysis presented whether these trends are significant. All raw data are available so an independent analysis could be performed.

2.5.9. Antimicrobial resistance, noise

Antimicrobial resistance

Antimicrobial resistance is not currently legislated for and therefore is not currently a compliance issue. There are no coordinated/official monitoring efforts of environmental AMR with the majority of data residing with independent research organisations in the form smaller geographically-specific studies. This presents challenges for compiling and comparing data due to inconsistencies of approach and analyses (Hassoun-Khier et al., 2021).

Noise

The WHO recommend that daytime noise exposure from traffic and railways do not exceed 53 dB and 54 dB respectively. They also recommend that noise exposure from aircraft and wind turbines should not exceed 45 dB and leisure noise exposure should not exceed 70 dB (WHO 2018). The latter specifically relates to events such as concerts so can be seen as more of an acute exposure limit.

Currently, exceedance of traffic and aircraft noise limits occurs regularly in Scottish Agglomerations. Figure 2.15 shows that noise from major roads and airports is regularly exceeding 60 or even 65 dB.

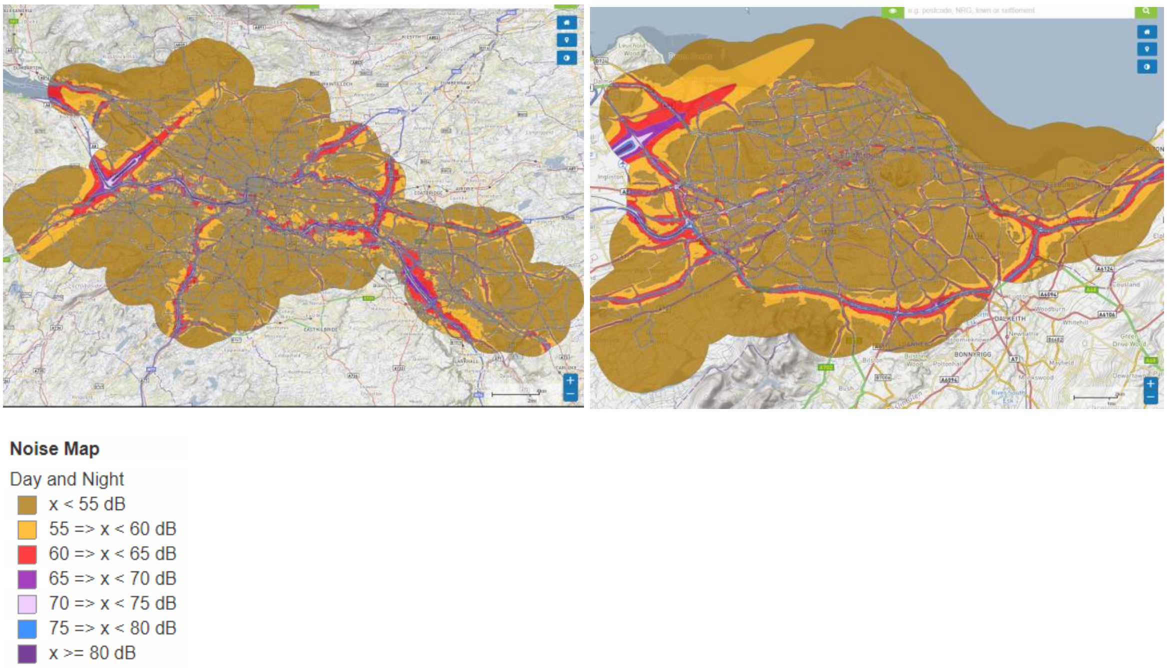

Figure 2.15 – Noise maps (consolidated indicator, daytime and evening) for the Glasgow and Edinburgh agglomerations

2.6. Proposed Priorities for ESS

Based on the analysis described in Section 2, an environmental priority is one that not only has a detrimental impact on the terrestrial/aquatic environment, food security or public health, but is also possible (with the right investment (time, financial, expertise, etc.)) to improve. The below table summarises the environmental priorities that feature in independent analyses and are included in the Scottish Environment Strategy.

These priorities were then ranked (

Figure 2.16; Table 2.5) based on:

- How well-established existing evaluation of compliance is, and how appropriate the existing evaluation is for establishing compliance
- Level and regularity of compliance with current standards
- Level of development and appropriateness of existing policy to support the above

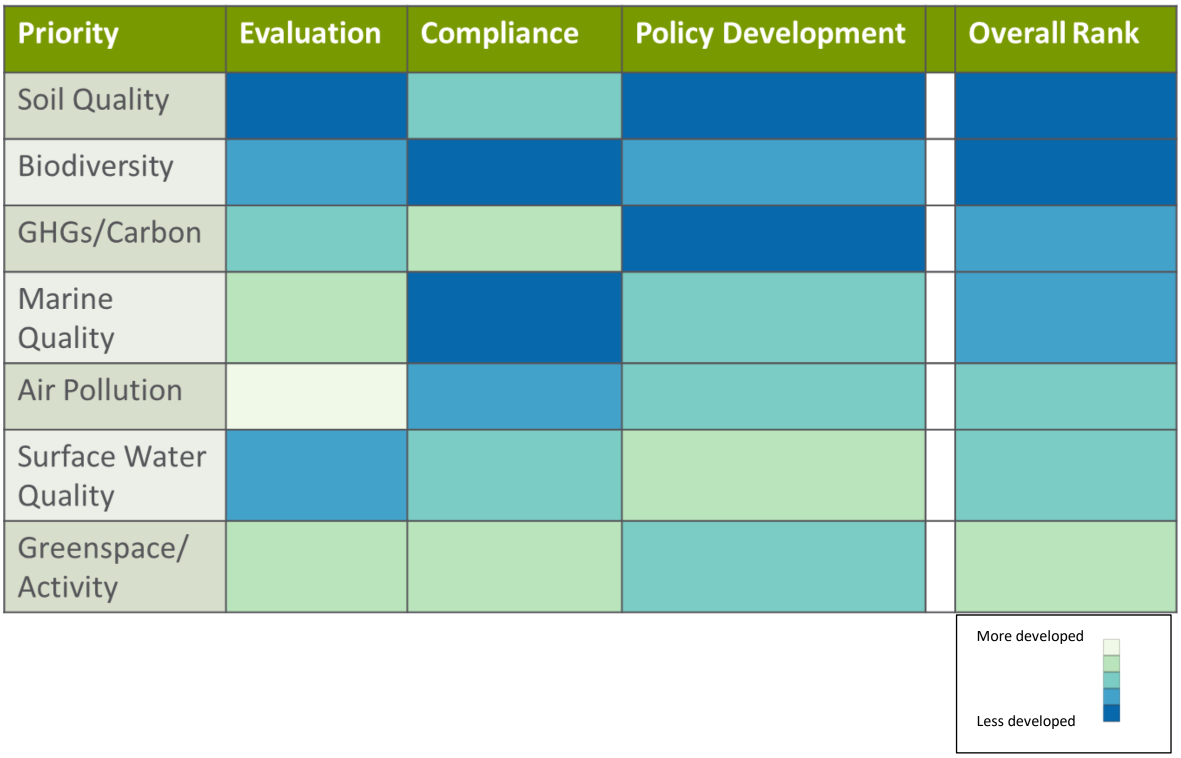

Figure 2.16 – Final ranked list of environmental priorities. The darker blue colours indicate where indicators, systems and processes are less well developed and therefore are of higher priority. The table below (Table 2.5) provides a narrative to each of the evaluations.

Priority	**Narrative**
Soil Quality	Key factor in food security, water quality, GHG emissions and impacts to a lesser extent on health and air quality. No ‘Framework Directive’, no ‘good soil quality’ indicator, no baseline. Compliance relates to contamination, agricultural practices, planning yet agricultural soil is responsible for 10% GHG emissions, peatlands 8% and one of the next targets for decarbonisation after energy production. Potential to achieve wide impacts from investment = high rank
Biodiversity	Previous reporting to meet EU requirements is statistically biased and shows that we have not been meeting the Habitats Directive when it comes to habitat conservation, but species conservation is good. This seems contradictory and there is significant potential to improve reporting mechanisms (although this would need to be weighed up against the downside of essentially setting new baseline measurements) A new consolidated indicator is currently being developed and there is opportunity to re-design monitoring and reporting.

Priority	Narrative
GHGs/Carbon	Climate emergency. Strong investment over time but sometimes to the detriment of other aspects of environmental quality. Improving picture but reliant on decarbonisation of energy supply which is now a low source of GHGs Focus needs to shift to other sectors including agriculture (soil quality above) and transport with any technological advances mindful of soil/water/biodiversity. Agriculture is potentially the most achievable area for decarbonisation as it requires less technological development thus more widely environmentally protective. Transport is incredibly difficult given the high environmental damage of battery production.
Marine Quality	Apart from fish stocks, monitoring and reporting are not representative and would be difficult to achieve this without significant investment. Rising sea temperatures and associated GHG emissions is a significant issue but is intractable for a single nation. Focus on marine health and biodiversity seems sensible as this supports fish stocks and hence food security. Marine litter is a big issue and highly emotive and is impacted by water and soil quality.
Air pollution	Very well-established monitoring and reporting, compliance is variable. While monitoring network could be expanded, main suggestion is to maintain what is already in place and continue using the combination of direct measurements and earth observation techniques.
Surface water quality	Essential. Impacts on marine quality. Previous EU-level reporting by River Basin District has 'masked' non-compliance which is localised but widespread. The success of investment and improvement of surface water habitats is demonstrable.
Greenspace/Active	Established public health benefit. Creating more quality green environments helps carbon sequestration and water quality by slowing urban run-off. Such spaces are more prevalent with new developments, but there are large parts of our urban centres that lack decent facilities or suitable areas. As with any planning decision, there are always multiple points of view. Ranked lower as there are no statutory targets and the biggest underlying challenge is behavioural/societal which is incredibly difficult to achieve tangible progress.

Table 2.5 – Narrative to the ranked environmental priorities

As a generalised ranking of environmental priorities,

Figure 2.16 provides a reasoned basis taking into account that all prioritisations are multi-factorial. However, from the perspective of ESS or similar agencies, it is more a case of knowing how to tackle each priority rather than a simple ranking *per sé*.

Until recently, environmental compliance in Scotland was governed by the European Commission with all Member States duty bound to co-operate in good faith on the achievement of EU objectives. The Court of Justice has derived from this a requirement on Member State authorities to redress the unlawful consequences of a breach of EU law and a requirement that enforcement be effective, proportionate, and dissuasive. Member States must therefore have appropriate mechanisms in place to ensure compliance with EU-derived obligations.

Non-compliance may occur for different reasons, including confusion, poor understanding or lack of acceptance of rules, lack of investment, opportunism and criminality. Its impacts on the environment, human health and the economy will depend on the nature, scale and persistence of breaches.

In practice, mechanisms for securing compliance involve Member States using three broad classes of intervention collectively referred to as 'environmental compliance assurance' (Čavoški, 2019):

- **Compliance promotion** (CP) helps duty-holders to comply through means such as guidance, frequently asked questions and helpdesks
- **Compliance monitoring** (CM) identifies and characterises duty-holder conduct and detects and assesses any non-compliance, using environmental inspections and other checks
- **Follow-up and enforcement** (F&E) draw on administrative, criminal and civil law to stop, deter, sanction and obtain redress for non-compliant conduct and encourage compliance.

Therefore,

Figure 2.16 was adapted to indicate where in the compliance assurance pipeline each environmental priority currently sat (Figure 2.17). While clearly this is a generalisation, and each environmental priority can be further subdivided into sub-priorities, the depicted analysis can give general guidance or steer on where specific focus or resources should be placed.

Priority	Evaluation	Compliance	Policy Development	Compliance Pipeline
Soil Quality				CP/CM
Biodiversity				CP/CM
GHGs/Carbon				CM
Marine Quality				CM/F&E
Air Pollution				CM/F&E
Surface Water Quality				CM
Greenspace/ Activity				CP

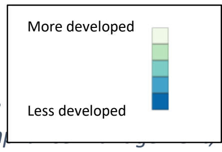

Figure 2.17 – Ranked environmental priorities with indication of where [illegible]rance pipeline they currently sit in general terms; where CP is Compliance Promotion, CM is Com[illegible] and F&E is Follow-up and Enforcement.

3. Analytical Requisites

This section of the report aims to identify what capacity and resources ESS will require to have available to it in the longer term to support the analytical work necessary to carry out its functions effectively. To assess this, specific environmental priorities were selected for consideration that were at different places along the compliance pipeline; namely soil health (primarily compliance promotion), biodiversity (compliance promotion and management) and air pollution (primarily follow-up and enforcement) (see Figure 2.17).

3.1. Analysis of priority areas

Official Data Sources

An initial analysis of official data and statistics in terms of scope and quality was undertaken by Emma Macrae of ESS (and the results of this are available on request). The information provided was evaluated in the context of the preceding analysis. Thus, the official data sources associated with each environmental priority can be summarised as:

1. Soil health
    a. Data were variable in quality, were a mixture of measured point data and modelled spatial map units
    b. (Spatial) Scale and aggregation of both data points and indicators were variable
    c. No continuous monitoring, but national-scale sampling had been undertaken
    d. Relatively good coverage of rural areas, but limited available information on urban soils

e. While not directly highlighted in ESS' analysis, many of the indicators are well-established, but spread across different sectors and scales for different purposes; and regulatory standards are available for some sectors (e.g., planning) but more poorly defined in others (e.g., agriculture)

2. Biodiversity
    a. Large number and diversity of data sources including multiple holdings of: raw individual species-level data; species-level modelled indicators; multiple species modelled indicators; multiple indicator data
    b. There is a diversity of indicators, some better established than others.
    c. Many of these data sources were repositories containing many records from multiple contributors. In all cases, QA/QC was the role of the individual data providers leading to variabilities and inconsistencies in data quality.
    d. As discussed in Section 2, many data are reliant on reporting by the pubic and other groups which results in biases.

3. Air pollution
    a. Data were easily available, of good quality and were a mixture of measured and modelled values
    b. Monitoring systems were well-established, and the uncertainties and errors well understood, analysed and reported on
    c. Well-established indicators and regulatory standards
    d. Compliance was variable, with monitoring efforts biased towards non-compliant locations

Likely analytical tasks

The capacity and capabilities of any analytical team are defined by the tasks that the team are likely to have to undertake. The aim here is to speculate what the analytical team of ESS are likely to do 80% of the time to highlight the main core competencies required. The remaining 20% are likely to be more unusual or specialist analyses that ESS might consider putting out to tender. While focus on systems-based approaches is desirable, and should be the direction of travel, the existing duty-holders are sectoral in nature thus most of the analyses (to have utility) also need to maintain a sectoral focus. This means that analytical tasks will have a lot of domain-specific elements.

In practice, most systems approaches when applied to environmental domains become incredibly specialist. A systems approach will try to take account of all the knock-on and interacting factors associated with a particular action so that mitigations are designed which not only improve compliance in one sector but are at least protective across all other sectors. For example, a policy driver of planting more trees on the face of it would seem to mitigate against GHG emissions. However, once soil types, drainage conditions, tree species, altitude, latitude, etc. are considered it becomes clear that in many situations the planting of trees causes a net release of carbon into the atmosphere (Matthews et al., 2020). Systems approaches are usually the domain of complex large-scale mechanistic and/or spatial models. Therefore, for ESS, it might be more practicable to employ wide-knowledge experts who can provide a contextual narrative to more domain-specific analyses.

Compliance promotion

If part of ESS' role, this will likely entail performing analyses that support decision-making, i.e., identify actions that duty-holders can undertake to improve their compliance performance. These analyses might primarily be undertaking literature-based reviews but could also involve more complex statistical or modelling approaches to understand more complex systems, or the use of higher-level systems-based frameworks such as DPSIR (drivers, pressures, state, impact and response model of intervention) to help identify interventions or actions that should have positive outcomes. In the areas of soils and biodiversity there is significant need for these types of analyses to underpin sector-tailored best practice advice. An analytical function might also be involved in e.g., automating a help desk that links queries to specific guidance.

Compliance monitoring

Compliance monitoring is probably the main area of activity for the analytical function.

It is likely ESS will need to perform analyses that check or confirm the levels of compliance of duty-holders. While in many cases, individual organisations report on environmental compliance, it is suggested that wherever possible ESS perform their own independent analyses from scratch from the raw data. It would be politic for ESS to establish themselves as the 'gold standard' organisation for compliance monitoring. Otherwise, duty-holders will be able to undermine ESS evaluations and not see ESS as having the expertise to support improved compliance. Maintaining independence of analysis also negates the conflicts of interest that arise when auditing duty-holders using data and analysis provided by those same duty-holders. Part of this work would involve assurance of data quality of the data submitted to ESS. Such analyses should also explicitly handle the uncertainties in the data arising from aggregation of data either spatially or to form indicators.

It will also be necessary to perform analyses to understand the trend in compliance over time to alert duty-holders to situations where improvement is/is not happening. Again, it is recommended that in most cases ESS perform these from scratch from the raw data. Such analyses need to fully and explicitly include the uncertainties in the data to inform the statistical significance of any trends seen.

To undertake the above analyses, interpolation of data is often a key step given spatial resolution of monitoring data. Therefore, to undertake compliance monitoring from scratch, understanding of statistical modelling would be an advantage.

Compliance monitoring is of key relevance to all the environmental priorities but is harder to perform for e.g., soils due to the lack of legislative standards. Air pollution is one area where existing compliance monitoring and trend analysis are undertaken to a high standard and for this environmental priority it is enough to simply audit their reporting and results. Longer term, the aim might be for ESS to encourage or even support duty-holders to reach similar high standards of reporting and analysis.

Follow-up and enforcement

One key aspect of follow-up is trying to identify why non-compliance is happening so that advice given is sensible, and enforcement itself results in real improvement and not simply sanctions. In 2018 the European Commission abandoned a sanction-based approach to compliance to the more structured and supportive one we see today (Čavoški, 2019). The main reason for this change was the sheer scale of persistent non-compliance with environmental legislation being experienced despite the sanctions (Čavoški, 2019). More recently we see a very similar situation with water companies persistently discharging untreated wastewater despite heavy fines. The experience of the

European Commission highlights that effective enforcement is actually providing duty-holders with something palpable that they can implement to agreed timescales, rather than handing out penalties.

The causes of non-compliance might not always be obvious, especially in priority areas that use aggregated indicators such as biodiversity where the specific causes of non-compliance will be masked. Thus, the activities of follow-up require analysts to dive deep into raw data and elucidate causal links in these data. This can require fairly specialist statistical and modelling skills, depending on the priority area. For example, air pollution is far less static (the atmosphere is always moving) compared to soils where change tends to be slow; in nearly all cases there are both spatial and temporal components that are interacting. Ultimately the analyst needs to convert the numerical analysis into advice to improve compliance.

This type of follow-up analysis is most likely in areas where monitoring and legislation is well-developed such as air pollution. The next stage is the follow-up. For example, most priority air pollutants are reducing even in regularly non-compliant areas apart from ozone which is increasing. A follow-up analysis of the ozone is pertinent to understand why it is increasing and therefore what can be done to curb levels.

3.2. Skills and roles

This section identifies the types of skills and roles necessary to perform the types of task identified above. While six specific roles have been identified and are described here, this does not mean that the team required would have six full time equivalents. Indeed, some roles would be duplicated to support work in different domains, while other roles could be amalgamated.

- Strategic lead. This person could act as the team lead, and is the link between the strategic priorities of ESS and the data analytics:
    - This individual would have a strong analytical background in environmental science, public health, or related with experience of managing an analytical team.
    - Would provide strategy and horizon scanning
    - Would manage the work/projects occurring in the team
    - This post could be hired first and then involved in designing the team & hiring the remaining posts

- Domain experts, i.e., senior analysts or researchers with both technical and domain-specific experience.
    - The specific domain experts hired are likely to change over time with changing priorities, e.g., if the strategic plan was to tackle soils in the coming two years one of these domain experts might have soil science background
    - Would provide domain knowledge to support the team in interpretation of data
    - Undertake desk-based research of specific topic areas
    - Help identify more specialist projects that need to be commissioned

- Contextual analysts. These roles essentially read, understand and interpret data.
    - Interpreting data and identifying areas of non-compliance
    - These individuals would have proficient coding abilities, e.g. python, R, but not necessarily domain knowledge
    - Key competencies in data wrangling/munging, coding, statistics, visualisation

    - ‘Trendy’ competencies like ML/AI less relevant unless desire to develop in-house progressive approaches to compliance monitoring (e.g., analysis of satellite images to assess compliance)
    - 3 key roles:
        - For many environmental data, a spatial/GIS analyst is a key part of this team
        - A statistician with appreciation of statistical modelling approaches would be necessary for QA/QC and understanding data limitations
        - Environmental Risk analyst or economist with experience of assessing compliance & liabilities – this role is important to the horizon scanning and investigation aspects of ESS remit

- Data vizualisation. This role has design skills and able to convert data and findings into compelling graphics.
    - Vital for communicating important messages arising from the analysis, both within and outwith ESS
    - This may or may not be the same person as the contextual analyst, my experience is that it is rare to find a good analyst with good design skills, but this role does need understanding of data.
    - GIS skills would be an important component of this role
    - These skills might be available elsewhere in the organisation, e.g., Communications

- Software Engineer
    - Vital for any contemporary data analytics team
    - Play important role in automation, developing pipelines, and enabling efficient data analytics and reporting
    - Developing front-ends for data submission from duty-holders, and platforms for hosting and working with the data in a secure manner
    - Have utility across the organisation, not just in analytics
    - This role could be 0.5 FTE, could be the same person as the Data Manager, or be a contractor (experience says the latter is not ideal unless they are embedded into the hiring organisation)

- Data Manager/Sys Admin
    - This role is custodian of the data and ensure best practice
    - Responsible for development of ESS Data Management policies, archiving of (derived) data and records for appropriate timescales
    - They would design and manage appropriate IT architecture, maintain software, updates, etc.
    - Responsible to adhering to standards and protocols, cybersecurity, DSAs, etc.
    - Not a standard IT support role or something I would recommend leaving to an IT Helpdesk or out-sourced IT function.
    - Of wider organisational relevance

3.2.1. Structure and governance

The diagram below (Figure 3.1) indicates the relative seniority and permanence of the roles described above. The below is also indicative of hierarchy and reporting structures but would depend on the overall governance structure of ESS.

The Strategic Lead oversees the analytics function, sets the strategic priorities, develops and manages the performance of the team. If data (it's acquisition, management, analysis, etc.) has important strategic aspects within ESS, and if the longer-term plan is to grow the data analytics function, then one consideration would be to appoint the Senior Analyst at CDO-level or equivalent. One strategy would be to appoint the Strategic Lead first with their first responsibility to refine and recruit the remaining team members. The individual occupying this role should have domain knowledge and experience, whether that's environmental or compliance aspects. Wide/general domain knowledge would be preferable to specialist. They should have had a technical background and experience of working with/managing technical specialists.

The Data Manager is an incredibly responsible role and one that needs some thought to ensure attracting the right kind of individual. The occupant of this role is likely to have a post-graduate qualification and several years' experience. To ensure independence, it might not be desirable to rely entirely on existing Government IT systems/support. Setting up semi-independent IT architecture and data management systems allows for better control and being a small system should be easy to manage with less time delays and reduced risk of mistakes/breaches. It also enables the Data Manager/Sys Admin to work closely with the analyst team which has many advantages for efficiency and maintaining good practice. This role would be responsible for data acquisition, management, storage, archive, etc. and the development of the policies and protocols that support these.

The Domain Experts act as the link between the Strategic Lead and the Analyst Team. They would be responsible for managing the Analysts, maintaining performance and interpreting their results and communicating this to the Strategic Lead. They would likely undertake more holistic analyses that incorporate specific actions such as placing the results of individual analyses into systems frameworks such as DPSIR (drivers, pressures, state, impact and response model of intervention). The Domain Experts would also be researching literature on specific topics and provide briefs on these topics to the Strategic Lead as appropriate. These individuals are likely to have PhD-level training in specific areas of science plus experience of working in public sector roles.

The Analyst Team are the engine room of the operation. Here, three types of skill-sets are identified, but would expect this team to expand/contract with workflow demands. Ideally, these individuals have domain experience be that in air pollution or soil health or other relevant domains. However, many applicants for these types of roles will have domain agnostic training. These roles are likely to be graduate level but would benefit from experience working in a research or industrial setting. A larger team would operate best with a range of experience/qualifications with more senior and junior staff working together.

Independence is an enabler to quicker progress and increased efficiency. A Software Engineer enables you to develop bespoke solutions to automation and data visualisation rather than be constrained by expensive off the shelf products, licensing, support packages etc. A Software Engineer can create a front-end for data submission to enable duty-holders to report to ESS efficiently. From experience, you cannot have enough Software Engineers, but as a minimum bringing someone in for the first 3 years to develop your systems alongside your team is a sensible strategy. A good software engineer can get you to the point where routine analyses can be a fully automated pipeline. The Software Engineer might not be a full-time role, and it might be possible to combine this with the data visualisation role. You might have to appoint this role at a more senior level to get the sort of person you need given market forces. The individual is likely to be a graduate in computer science with demonstrable track record of successful software development.

The Data Visualisation role is one that could be undertaken by other roles. The individual would be data literate with e.g., a degree in graphic design. You might find someone with these skills in e.g., a Communications function. The Data Visualisation role is very important where data are used to convey complex ideas or to non-specialist or even reluctant audiences, and it is certainly advantageous to have someone with a flair for data visualisation working within the Analyst Team.

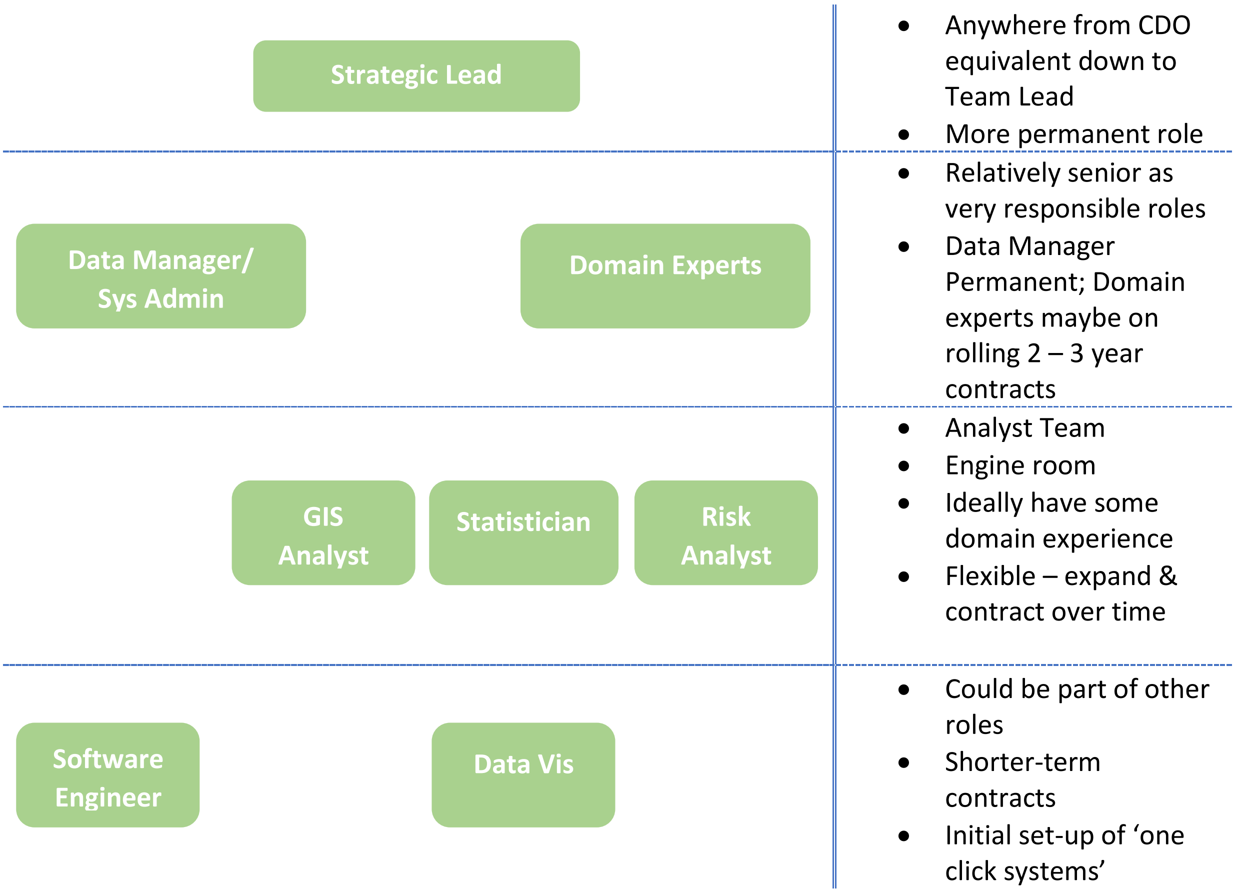

Figure 3.1 – Seniority, permanence and relative responsibilities of the roles identified for the analytical function

4. Conclusions

History tells us that sanctions are an ineffective tool for facilitating compliance. Learning from the experiences of the European Commission, for compliance assurance to be successful the approach taken needs to be supportive of, and deliver solutions to, duty-holders.

While policy and science often look to systems-based approaches, duty-holders are usually sectoral. This means that delivery by ESS will often need to be sector-focussed and this is reflected in the setting of priorities and the skills required by members of the ESS analytical team. Systems analyses will inform sectoral analyses and vice versa.

The setting of environmental priorities is multifactorial, and it is important to identify priority areas where progress can be made within budgetary and organisational constraints. The analysis presented in this report places greater weighting on environmental priorities that have less-developed monitoring/evaluation processes, less-developed supporting policy, and where compliance is less consistent. On this basis, higher prioritisation was given to soils, biodiversity, and GHG's/carbon.

Looking at the same environmental priorities through the lens of compliance assurance is possibly a more helpful approach. This indicates which stage in the compliance pipeline the different environmental priorities are currently at. On this basis, priorities such as soils and biodiversity were primarily at the compliance promotion stage, while others such as air pollution and marine quality were primarily at the follow up and enforcement stage.

Given ESS will be evaluating compliance of duty-holders who are usually the sources of the data that support compliance evaluation, there is risk of various conflicts of interest arising. Given this, it would be desirable for ESS to undertake analyses from scratch from the raw data rather than work from reports or analyses submitted by duty-holders. Obviously, such ambitious would be resource dependent.

The analytical team would require a Strategic Lead who essentially provides the link between the senior management and the analytical function. Below them would be domain experts to help support the sectoral nature of the support provision to duty-holders. Complementing this would be an analyst team made up of domain-agnostic individuals. The analyst team would perform domain-specific analyses, while the domain experts would place these results into wider systems thinking to understand the wider implications of changes in on domain on impacts in other domains.

It is recommended that these activities are supported by specific technical roles including a data/infrastructure manager responsible for the development, implementation and operationalisation of data acquisition, management, and archiving. A software engineer would help support development of e.g., data submission portal to enable duty-holders to submit the desired data directly to ESS, and other aspects of automation. Finally, data visualisation skills would be invaluable and could sit anywhere in the team described but should not be overlooked.

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Appendices

Appendix 1 - relationship between the reviewed environmental priorities and the indicators from the Environment Strategy

Priority	Freshwater Ecosystems	Marine Ecosystems	Terrestrial Ecosystems	Food Security	Public Health
Freshwater condition	✓			(✓)	
Composite biodiversity indicator	✓	✓	✓	✓	
GHGs & Carbon footprint	✓	✓	✓	✓	
Marine environmental quality		✓		(✓)	
Fish stocks		✓		(✓)	
Soil health	(✓)		✓		
Air pollutant emissions	(✓)	(✓)	(✓)		✓
Access to green/blue space					✓
Active travel					✓
Visits to outdoors					✓
Not included in Environment Strategy but considered important priorities (Chemicals and AMR could be part of the general quality indicators above):					
Chemicals	✓	✓	✓	✓	✓
AMR	(✓)	(✓)	(✓)	(✓)	✓
Noise					✓