Riverine Natural Capital Condition and Ecosystem Service Mapping Project: Project Summary

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Introduction

The Riverine Natural Capital Condition and Ecosystem Service Mapping Project created the Ecosystem Service Map Explorer (ESME). ESME uses evidence on the condition of the water environment (initially rivers) to model and map ecosystem service capacity (i.e. the potential to provide key ecosystem services). Ten ecosystem services are currently included:

- Provisioning services (Water Supply),
- Regulating services (Water Quality Regulation; Water Flow Regulation; Habitat and Species Population Maintenance),
- Cultural services (Aesthetic and Amenity Experience; Recreation; Physical / Mental Health and Wellbeing; Education and Investigation; Spiritual, Cultural and Religious Experiences; and Intrinsic Value of Nature).

The data can be explored at 3 spatial scales: management catchment (broad scale), river water body (medium scale) and river reach (fine scale). **ESME is currently being released as a Beta version innovation product, and we welcome all feedback**.

The **ecosystem service capacity** is the potential of a natural asset to provide a specific service under current conditions, regardless of whether that service is being used by beneficiaries.

ESME was developed over multiple phases. It began with a quick scoping review to understand the links between natural asset condition and the provision of ecosystem services in rivers. This was accompanied by the development of conceptual frameworks and the identification of evidence gaps. Next began the development of prototype mapping methods and the testing of mapping options, followed by a process of refinement and review, and the development of a draft national mapping tool. This was completed by a period of further refinement and testing and preparation for publication.

An important component of the project in all phases was that it was designed to be collaborative with Environment Agency staff, who were fully involved in shaping the project through workshops and surveys, and by active participation in the review team. The project was commissioned by the Environment Agency's Natural Capital Team and delivered by Natural Capital Solutions Ltd, in conjunction with the River Restoration Centre. It was funded by the Defra-wide Natural Capital and Ecosystem Assessment (NCEA) Programme.

This document provides a summary of each of the key aspects of the project. There are a number of documents that explore different aspects of the project and the ESME mapping tool, which are outlined here:

- **Project Report** - describes the background to the project, an assessment of existing ecosystem service mapping tools, the process followed to create the indicators and the tool, the key decisions made, and how to use and interpret the outputs. It also provides information on level of confidence in the outputs, and provides a series of recommendations.
- **Methodology Report** – presents the methodology used to develop evidence presented in the ESME tool. It outlines the approach to indicator development, provides technical details on how the reaches, indicators and decision trees were developed, and for each ecosystem service presents the indicators and the logic behind each decision tree. It also describes how the ESME tool was created.
- **Applications and Limitations Report** – short report detailing uses and applications of ESME, relationship with the Water Framework Directive (WFD), information on how to use the outputs, and it draws together all the limitations and caveats.
- **User Guide** – annotated guide on how to use each part of the ESME tool.
- **Case Studies** – brief description of some examples of where ESME has been used. The case studies document will be expanded over time, once ESME has been published and starts to be used more widely.
- **ESME Dataset and Indicators Library** – an Excel spreadsheet providing comprehensive information on, and a full assessment of each dataset and indicator used in ESME, as well as datasets not taken forward.

ESME can be accessed from this link.

To provide feedback please contact NaturalCapital@environment-agency.gov.uk.

Ecosystem service mapping tools

A wide range of ecosystem service assessment tools exist, each designed with slightly different purposes and strengths. To set the context and establish the need for ESME, we briefly outlined some of the most relevant ecosystem service tools and assessed six of the most promising in more depth: InVest, the Environmental Benefits of Nature (EBN) tool, England Green Infrastructure Mapping Database, NEVO, EcoServR and Co$ting Nature. The comparison highlighted that although these tools collectively provide strong spatial and analytical foundations, there is a clear gap in capabilities. There is a need for a tool that focusses on rivers and one that integrates both habitat and river condition to more accurately capture variability in ecosystem service capacity. A further need is for a tool that provides ready to use and user-friendly mapped outputs, rather than requiring the user to carry out modelling, and one that does so at a fine spatial scale. The Ecosystem Service Map Explorer (ESME) has been designed to meet these needs.

Validation process and key points

The project was designed to be collaborative with Environment Agency staff throughout, who were fully involved in shaping the project through workshops and surveys and by active participation in the review team. Wider partner feedback was also sought and considered. The key decisions taken, based on extensive feedback, are summarised below:

- Mapped riverine ecosystem service capacity with national coverage, at three different scales: river reach, WFD waterbody and WFD management catchment to suit a variety of user needs.
- There was a clear preference for the tool to be fully open, so it can be made publicly accessible and shared with partners once complete.
- Due to the lack of data, and therefore confidence in the outputs, it was decided that the mapping of artificial watercourses (such as canals) could not be completed and these watercourses would not be included in the current version of the mapping tool.
- A brand new tool (ESME) has been developed with an improved look and much greater functionality compared to an earlier prototype.
- Ten different ecosystem services have been mapped: Aesthetic and Amenity Experiences; Water Quality Regulation; Habitat and Species Population Maintenance; Water Supply; Recreation; Physical / Mental Health and Wellbeing; Intrinsic Value of Nature; Spiritual, Cultural and Religious Experiences; Education and Investigation; and Water Flow Regulation.

Reaches

An earlier phase of the project delineated river reaches (stretches) based on digitised segments of polylines in the Open Rivers Network (ORN). As such, the reach lengths and groupings of river segments were arbitrary and did not represent environmental or hydrological properties that would affect ecosystem service provision. We now offer a more scientifically rigorous approach to river segmentation with the aim of maximising similarity in hydromorphological conditions within reaches and the differences between adjacent reaches. It also divides rivers by key administrative boundaries in the WFD, including water body ID, and includes criteria that match the needs of users. To reach consensus on reach delineation, an expert workshop was designed to determine what

represents a good reach, what it should be used for and by whom, and the delineation criteria and method. The need and approach for reach delineation are described in Section 5 of the Project Report. The method chosen was a modified version of the method designed and validated by the River Restoration Centre (RRC) for the CatchmentLife project, which uses a hierarchy of segmentation break causes based on WFD waterbody ID, Strahler stream order, changes in Principal Component Analysis score, and land-use, with a shorter minimum reach length of 1km. Very small reaches (less than 0.5 km) were removed and reaches over 7.2 km were further divided. As a final step, all reaches were reshaped to exclude areas that overlapped with existing lakes or had culverted sections.

Indicator method, approach and principles

ESME was underpinned by an extensive literature review and the development of conceptual frameworks (flow diagrams) for each ecosystem service that explored the link between condition and capacity, and the components that influence each ecosystem service in turn. A series of indicators was then developed based on this knowledge and using best available data. ESME brings together a range of different types of indicators, including capacity, demand, flow, ecological pressure, and vulnerability indicators, and we use a mixture of metrics, proxies and indicators. Assessing cultural services adds complexity as we need to consider public access and built infrastructure for some ecosystem services, and use a mixture of indicators that assess different aspects of ecosystem assets, environmental spaces, and cultural practices. All of these types of indicator are defined and described. Despite this range of indicator types, and the use of proxies, the indicators are all being used to achieve the same overall aim of mapping the river's ecosystem service capacity in a location.

Scaling and combining indicators

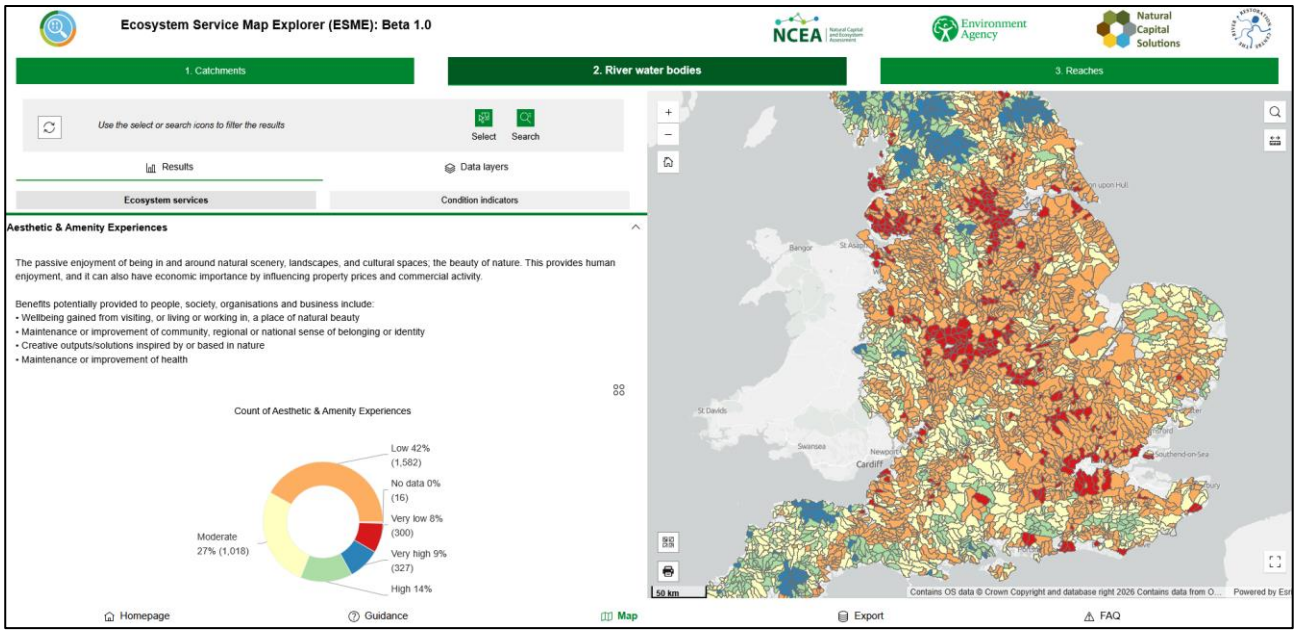
A challenging aspect of this project concerned how to scale the indicators appropriately and how to combine indicators into an overall predicted ecosystem service score. An expert workshop was held during which it was decided that we would use the quintile approach for scaling indicators where existing break points were not already provided in the input data. When combining indicators, the overwhelming consensus was to use decision trees (flow charts showing how different factors are related), so this approach was taken forward and developed for each ecosystem service. Decision trees were chosen as they enable indicators to be combined together in a more scientifically robust and nuanced way, based on expert opinion and evidence, while also being fully transparent. To scale up results from reach to waterbody to catchment scale we decided to use the weighted average approach (for most indicators – there were some cases where this was not appropriate and alternatives were identified, and these are identified in the Methodology report). To address the preference for a proportional breakdown when presenting results at broader scales, especially at the management catchment scale, we have added graphics into ESME that show the breakdown of results within each catchment.

Developing the Ecosystem Service Map Explorer (ESME)

The ESME tool was created using the ArcGIS Experience Builder application available on ArcGIS Online. It has the following key features:

- A landing page which includes information on what the tool is and how to use it.
- An integrated guidance page including step-by-step guide and animated screenshares.
- A series of maps for each scale that interact with one another.
- Charts that show a summary of the ecosystem service results.
- Select and search widgets that allow the user to filter the results.
- A large list of reference datasets that users can add to the maps.
- The ability for users to import their own datasets.
- The ability for users to export the results to file for their own analysis.
- Options to print the map view and the current screen view of the tool.
- An FAQ (frequently asked questions) page that provides users with further guidance on using the tool.

A user workshop was held in February 2025 attended by approximately 70 people. First impressions were positive for ease of navigation, usability, and sufficiency of the guidance, with user testing after the workshop confirming these findings. More detailed comments were also collected and actions were addressed. In autumn 2025 the Beta version of ESME was finalised, completing the mapping of all ecosystem services and making a number of small enhancements. The Beta version of ESME was subject to User Acceptance Testing (UAT) by approximately 20 Environment Agency staff, as well as more general testing by the project team. Changes were made to ESME post UAT to address issues raised.



Screenshot showing the look of the Ecosystem Service Map Explorer (ESME) Beta version.

Using and interpreting the mapped outputs in ESME

Information is provided on what each of the indicator and ecosystem service maps show and how to interpret them.

There is interest from users in understanding the *sensitivity of the ecosystem service scores to change*. In particular, which indicators are driving scores, which should be targeted first to enable the score to improve, and how much change would be required to shift a score into a better category. The most important indicator for each ecosystem service (which is the one(s) that will have the greatest effect on the overall score) has been identified for all ecosystem services, and this gives a good indication of the most effective interventions that could be made to enhance scores.

The indicator and ecosystem service maps are presented at three different scales in ESME – reaches, waterbodies and management catchments. *Each scale has advantages, disadvantages and caveats*, which are described. We have also listed the importance of spatial considerations for each ecosystem service, the spatial resolution of the indicators and data currently used, and the potential to make improvements to the spatial aspects of the indicators.

- Reach scale provides the most detailed results and is best for assessing many of the cultural services, especially Aesthetic and amenity experiences, Recreation, and Physical / mental health and wellbeing. But not all data sets and indicators could be assessed at that level of detail so there may be a false sense of accuracy, or missing data in some cases.
- Waterbody scale provides a good compromise between providing enough detail to make the results useful and not giving a false sense of accuracy. It is a particularly good scale for assessing the results of the regulating services and some of the cultural services such as Intrinsic value of nature, and Education and investigation. It also matches the scale used in other reporting published by the Environment Agency, such as for WFD.
- Management catchment scale is considered much less useful operationally as most results are broad averages, removing much of the variation and nuance in the outputs. But user feedback indicates it may be useful for strategic reporting, comparing broad patterns across regions, and it provides some additional useful information for Water supply.

Conclusions and recommendations

A RAG rating was used to show the **overall confidence in and limitations of the predicted ecosystem services.** All ecosystem services are assessed to be green or yellow, indicating that we have at least moderate confidence in all of the ecosystem service outputs, with none now showing as amber or red. In later phases of the project we have materially increased confidence in all the ecosystem services, due to the use of more appropriate reaches and a more scientifically accurate way of combining indicators into the final ecosystem service score. There are, however, a number of limitations and caveats and these are listed in the report and in the Applications and limitations document.

RAG rating showing overall confidence in the outputs for each ecosystem service mapped in ESME, the scale considered best for examining the outputs, and notes on limitations and caveats. The confidence of ecosystem service scores varies according to availability and/or certainty of the data covering aspects of condition. This is derived using expert judgement. Ecosystem service descriptions are provided in Appendix A of the Project Report.

Red = no confidence; Amber = low confidence; Yellow = moderate confidence; Green = high confidence.

Best scale: R = reach, W = WFD waterbody, C = WFD management catchment, () = suitable scale but may not be optimum.

Overall confidence	Best scale	Limitations and caveats
Aesthetic and amenity Experiences	R, W	Does not pick up very fine scale changes in tranquillity and this dataset is old (2007). Does not consider impact on house prices.
Education and investigation	W	No comprehensive data available on school / educational visits to watersides.
Intrinsic value of nature	(R), W	High confidence in decision tree and key factors, but data on iconic species and INNS is severely limited due to licencing restrictions on relevant data.
Habitat and species population maintenance	R, (W)	Decision tree constructed in a different way. Unlike other ecosystem services, final map is closer to an absolute score, rather than a relative score of ecosystem service capacity.
Physical / mental health and wellbeing	R, (W)	Data on local swimming spots and continuous discharges could be further improved. Does not pick up very fine scale changes in tranquillity and this dataset is old (2007).
Recreation	R, (W)	Considered to work well. Data on local swimming spots and continuous discharges could be further improved. **This map does not necessarily indicate that the river is suitable for immersive watersports.**
Spiritual, cultural and religious experiences	R, W	Some identified heritage features are not directly relevant to the river. Sense of place / history is very broad and may have nothing to do with the river. Difficult to capture all aspects of this ecosystem service.
Water flow regulation	W	Considers how natural processes of rivers regulate both peak flows (flood) and low flows (drought) so difficult to map the ecosystem service. This map is not suitable for assessing flood or drought risk.

		Data/proxies for baseflow contribution (groundwater input) could be further improved. **This ecosystem service should not be conflated with regulation of flows and levels by man-made structures.**
Water quality regulation	W	Concerned with the regulation of water quality, not water quality itself. Difficult to map as data on the former is lacking and we have to rely on proxy indicators. **This ecosystem service should not be conflated with regulation of water quality by permitting**.
Water supply (drinking/ agriculture/ industry)	W, C	Does not consider groundwater abstraction. Abstraction in one waterbody likely to be influenced by upstream abstractions and water level management. **This map is not suitable to support water abstraction permit applications.**

Potential uses, applications and user needs are presented in a separate document *ESME Applications and limitations.*

Limitations and caveats. The tool is released as a Beta version innovation product, so we would welcome all feedback. Feedback can be sent to NaturalCapital@environment-agency.gov.uk. It has been through a considerable period of development and review, but there are still limitations to be aware of. General limitations and caveats are listed here. A more comprehensive list of limitations is provided in the document *ESME Applications and limitations*.

- This is a desk-based mapping tool based partially on national scale datasets, so spatial accuracy is not always high or coverage comprehensive for all indicators. While ESME can inform decision making across a range of uses*, decisions ultimately need to be considered alongside data and evidence collected on the ground and local knowledge*.
- In several indicators, quintiles have been used to determine the range of condition scores, meaning that a proportion of sites will always score well or badly. The tool uses a mix of scoring approaches, although overall it should be seen as providing *relative* ecosystem service scores, e.g., a place with a value of 'high' ecosystem service capacity is showing relatively higher capacity than a place with a value of 'low'.
- The indicators are not all strictly "condition" or "capacity" indicators, with some indicators of demand, flow, ecological pressure, and vulnerability, but *in all cases used as a proxy of condition and ecosystem service capacity*.
- The indicators used within ESME were developed at the finest spatial scale, which was nearly always either reach or waterbody scale. These were then extrapolated or averaged (typically a weighted average) to other scales. This means that in some cases reach scale values are the same across a waterbody. It also means that

management catchment scale results are almost always simply an average of results at finer scales.

- ESME reports a 2025 baseline assessment of condition and ecosystem service capacity based on data from 2013 to 2025 (tranquillity dates from 2007), which was the most suitable national evidence available in 2025. The WFD data used in ESME dates from the period 2013-2019 (forming the statutory basis of Cycle 3 River Basin Management Plans), so it is important to bear in mind that there may have been changes since that time. More recent comprehensive classification data for the Cycle 4 River Basin Management Plans, expected in 2027, is not yet available. A number of data sets used are more recent, so there may be a slight temporal mismatch. The Environment Agency will assess the impact of updated classification data on ESME once the new classification data is available and plan when best to incorporate it into updated ESME outputs.
- There is some overlap between the assessment of condition of natural capital assets, with built assets, especially around public access. It is not possible or desirable to disentangle these different types of asset.
- The mapping of ecosystem services and indicators cannot be linked directly to monetary value as most of the indicators used could not be valued directly.
- Artificial waterbodies (e.g. canals) are not currently included in the tool.
- Most species data is not available openly, so indicators that rely on this are limited.
- Although Defra colleagues were consulted as part of the project's expert panel their opinions do not represent Defra official stance.

Frequency of updating of ESME is a balance between funding, user desires, data updates, and access to new and improved data sources. WFD classifications are being re-run across 2025 to 2026 to use in the Cycle 4 River Basin Management Plans (due to be published in 2027) and it would make sense to update ESME once these have been published. This update would also enable us to address any issues discovered following public release so that ESME could be published as a final stable release Alpha version. After this initial update a full update would be most relevant over a 3-6 year cycle, with an interim update every 3 years and a full update to fit with the WFD reporting cycle occurring every 6 years.

Recommendations to improve and update ESME include:

- scoping, designing and implementing a reporting function within ESME to support user interpretation;
- obtaining licencing to include more species data to improve confidence in ecosystem service outputs that use species data;
- mapping the reasons for low scores to inform environmental planning (identifying indicators that are low scoring, but with the capacity to be changed through interventions);
- expanding the series of case studies to illustrate potential uses of ESME;
- and adding other potential features and functions suggested by users.

A range of possible extensions are presented, including national reporting, adding more ecosystem services, and rolling out the approach to other assets. Recommendations are also made around enhancing specific indicators, such as tranquillity, property price uplift, longitudinal connectivity, lateral connectivity, and vertical connectivity, and further work around river reaches and River Habitat Surveys are also presented.

ESME can be accessed from this link.