Report on progress with developing the Defra 25 Year Environment Plan indicator B6 – natural functions of water and wetland habitats

Final draft for B6 steering group 23/09/22

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Summary

Defra's Operational Indicator Framework consists of a family of indicators intended to track progress with action taken under the 25-year Environment Plan. This report documents collaborative work on the B6 indicator undertaken to date, including work on freshwater habitats (rivers, streams, lakes and ponds), freshwater wetlands, and estuaries/coasts (termed transitional and coastal waters in previous B6 reports). Recent work under the B6 indicator builds on previous collaboration between Natural England and CEH, assisted by the Environment Agency, to develop a new framework for assessing the natural function/naturalness of the freshwater habitat resource for the purposes of reporting against strategic biodiversity targets. The objective of B6 work is two-fold: 1) to service the needs of Defra's indicator framework; 2) to provide a data framework for strategic biodiversity reporting processes.

A targeted consultation of Defra family staff and external partners was undertaken on the last progress report, released in July 2021.This provided valuable feedback on a range of issues, including the coverage of river and stream attributes, the design of individual attributes, the links to strategic restoration plans, and the portrayal of outputs. Development work in 2021/22 has taken account of this feedback as far as possible.

- ***Freshwater habitats*** – Wheel diagrams have now been generated for lakes and ponds, populated with illustrative data as far as possible. New data on the naturalness of groundwater and surface water flows have been secured from the Environment Agency and hydrological attributes have been populated. A method has been designed to process non-native species records from the GB NNS Information Portal into attributes for all freshwater habitats. Further development work has been undertaken on river/stream attributes relating to flooding regime and in-channel structures. Work has progressed with securing regular data transfers for some attributes, working towards operationalising this component of the indicator.
- ***Estuaries/coasts*** – A feasibility study has been undertaken to identify what datasets are available and what naturalness indicators might be defined, using existing work on freshwater habitats as a guide. This work is acting as a technical specification for the next phase of development, involving securing available datasets and processing them into attributes.
- **Freshwater wetlands** – A draft attributes table has been developed to help encourage integration between the B6 indicator and the broad habitats indicator D1 (extent, quality and connectivity of habitats). This seeks to make use of data being assembled under one or other indicator to evaluate both water-driven and terrestrially driven aspects of naturalness (modification).

Wheel diagrams are valuable in providing a compact and information-rich assessment of the state of the habitat resource across naturalness attributes and components at any one point in time, and are considered to be critical for strategic biodiversity reporting purposes. For reporting change through time, a dashboard structure has also been developed which portrays information at the level of key naturalness components (physical, hydrological, chemical, biological) across the main habitat types. This dashboard structure is intended to be the principal reporting format for Defra's indicator framework, with wheel diagrams providing a secondary layer of detail that also feeds into strategic biodiversity reporting processes.

Integration of B6 work with development of the headline biodiversity indicator D1 (extent, quality and connectivity of habitats) is on-going. The intention is that B6 data outputs provide the freshwater habitat component of D1, whilst data for some freshwater wetland attributes in B6 are supplied by D1. Some B6 attributes are also intended to contribute to D1 in a more general way, in relation to the naturalness of hydrological and chemical function of terrestrial habitats.

Successful operationalisation of the B6 indicator is dependent on the development and implementation of new strategic surveillance programmes currently under development within the Defra Family, as well other Environment Agency data sources (such as groundwater and river flow modelling) and citizen science programmes. Progress has been made in embedding B6 data requirements in these surveillance and data supply programmes but further work is needed to agree data collection and data handling procedures across all attributes to service the B6 data framework.

Development work will continue in 2022/23 to bring the B6 data framework close to operationalisation. This will include populating the data framework for estuaries and coasts, firming up the data framework for wetlands in collaboration with the D1 development team, and finishing off attribute development and data protocols for freshwater habitats. The B6 indicator is on course to be fully operational in 2024 (the target for the indicator framework as a whole), but this will depend on suitable data becoming available from planned surveillance programmes.

Acknowledgements

Thanks are due to those who have helped with the sourcing and use of data in recent B6 development work:

- Mark Whiteman, Matthew Ramscar, Judith Bennett and Fiona Lobley at the Environment Agency and Dave Ottewell at Natural England for assistance with sourcing and using hydrological data;
- Lucy Butler and Josh Jones of the Rivers Trusts and CaBA Initiative in relation to in-channel structures and general liaison with CaBA work;
- Helen Roy, Colin Harrower and Stephanie Rourke at CEH, Gavin Measures in Natural England and Alice Hiley in the Environment Agency in relation to non-native species data.

Thanks are also due to Sian Davies and Mike Dunbar in relation to discussions over Environment Agency surveillance programmes, and Vicky Beaumont-Brown in relation to communications with the Environment Agency and links with water indicators within Defra's indicator framework.

The work has also benefited from datasets and analyses gathered under previous work documented in Natural England Research Report JP016, which contains further acknowledgements of assistance (including Environment Agency hydrology and Water Resources staff).

We are grateful to Callum Fry and Mark Jacob at Defra who have supported the work and helped with securing continuing funding.

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1. Introduction

Indicator B6 sits within the operational indicator framework (OIF) for Defra's 25 Year Environment Plan (25YEP). It is a progression of technical proposals for monitoring and assessing freshwater habitats in relation to priority habitat objectives, as laid out in Natural England Report JP016 (Mainstone *et al.* 2018). The indicator is based on evaluating levels of naturalness (or natural ecosystem function), which provides not only a sound ecological framework for restoring water and wetland habitats but also a common language for maximising synergies between biodiversity and water decision-making and restoring natural capital (including for climate change adaptation and mitigation, natural flood management, and resilience and quality of water resources). This language is equally applicable to open freshwater habitats (rivers, streams, lakes and ponds), wetland habitats, estuaries and coastal waters.

The biodiversity rationale for using naturalness/natural function as the basis for conserving freshwater and wetland habitats is explained in the 'freshwater and wetland habitats narrative' (NE Report NERR064 - Mainstone *et al.* 2016), and summarised in a series of biodiversity fact sheets generated to inform delivery under the Water Framework Directive (WFD) Catchment-Based Approach (CaBA) initiative. Increased recognition of the importance of protecting and restoring natural ecosystem function to all habitats and species (terrestrial, wetland, aquatic), to different degrees in different places depending on circumstance, is driving an ecological shift in biodiversity decision-making (Report NERR071 - Natural England 2018). This has been reinforced by the development of a new 'habitats and ecosystems narrative' (Natural England 2020), which outlines the shift in mindset needed and the measures required to embed it in operational decision-making processes for biodiversity.

Indicator B6 is positioned to contribute to this strategic shift and help build an ecological bridge between biodiversity and water decision-making, contributing to and influencing the content and structuring of 25 YEP headline biodiversity indicator D1 (extent, quality and connectivity of habitats). Developed in the right way, these indicators can provide the framework and supporting datasets needed to develop future biodiversity targets that have ambitions for restoring more natural ecosystem function embedded within them. This provides the basis for building ecosystem restoration more squarely into biodiversity planning and associated operational processes, as envisaged by on-going international discussions on the post-2020 global biodiversity framework under the Convention on Biological Diversity.

Naturalness is a broad concept with many different facets. It can be thought of as the consideration of all of the ecosystem structures and functions that are involved in making natural ecosystems what they are, with functions shaping structures in complex, interactive and dynamic ways. It is generally simpler to evaluate the level of artificial modification to ecosystems than to characterise what a natural ecosystem looks (or should look) like in any given place and evaluate deviations from that. This is because indicators of modification often have an in-built (or at least more easily quantified) reference condition of ‘no modification’, which equates to ‘natural’ in the context of that indicator. This is important in the selection of attributes and monitoring regimes and highlights the strong relationships between pragmatic assessment of naturalness/natural function and the assessment of human pressures.

Many different attributes can provide different windows in on naturalness but do not provide an overall assessment in themselves. Any broader indicator of naturalness therefore has to be compound in nature, covering hydrological, physical, chemical and biological components and drawing on a range of evidence strands to provide a complete picture. This makes its development more complicated than many indicators, and its interpretation more involved.

2. Scope, rationale and context

The B6 data framework is intended to cover open freshwater and wetland habitats, and estuarine/coastal habitats (termed transitional and coastal, or TRAC, waters in previous B6 reports). The spatial rationale for the assessment is to evaluate the entire habitat resource (in England), in a structured way to allow evaluation of different habitats/ecosystems (types and sub-types). There are some conceptual issues around what constitutes the 'habitat resource'.

- Given that the B6 indicator is seeking to characterise natural function, a focus on naturally occurring habitats might reasonably be expected. The habitat types used in the B6 data framework are based on naturally occurring ecosystems and there are no inherently artificial habitat types included. However, the B6 data framework seeks to encompass existing sites, including artificially generated habitat (such as ponds, wetlands, gravel pits), as long as they relate to the naturally occurring habitat types used in the B6 data framework. The assessment of naturalness allows differentiation of functional artificiality in existing sites, as reflected in observed levels of human modification. The main exclusions from the B6 framework are canals, ditches and drains, since these do not relate to natural habitat types. In addition, ditches and drains constitute a major impact on the naturalness of habitat types included in the B6 framework (particularly wetlands and streams) so they would not be appropriate to include as separate habitat types. This is not to say that these artificial habitats are unimportant to biodiversity – many of them provide vital refuge for species displaced by widespread wetland drainage and destruction.
- Since the B6 data framework focuses on the existing habitat resource, there is an issue around how to deal with locations where a habitat type (ecosystem) would naturally occur but has been eliminated (for instance, wetlands by drainage). This is a particular issue for ponds and wetlands, where there have been very large losses of habitat extent over time and there is a need to re-establish substantial amounts of habitat. This cannot be dealt with directly by characterising naturalness in the existing habitat resource - strategic targets for habitat extent are the primary mechanism for ensuring that action is taken to re-establish lost habitat. The B6 indicator can however provide the driver for re-establishing lost habitat extent based on natural function principles. The habitat resource as a whole can be moved towards higher levels of natural function either by naturalising existing sites or by re-establishing habitat in places in the landscape according to natural processes. This is in line with Natural England's conceptual thinking on integrated biodiversity objectives (Natural England 2018).

The B6 data framework provides a hierarchical assessment of naturalness (Figure 2.1) drawing together different attributes into the assessment of key naturalness components (physical, hydrological, chemical and biological) for different habitat types.

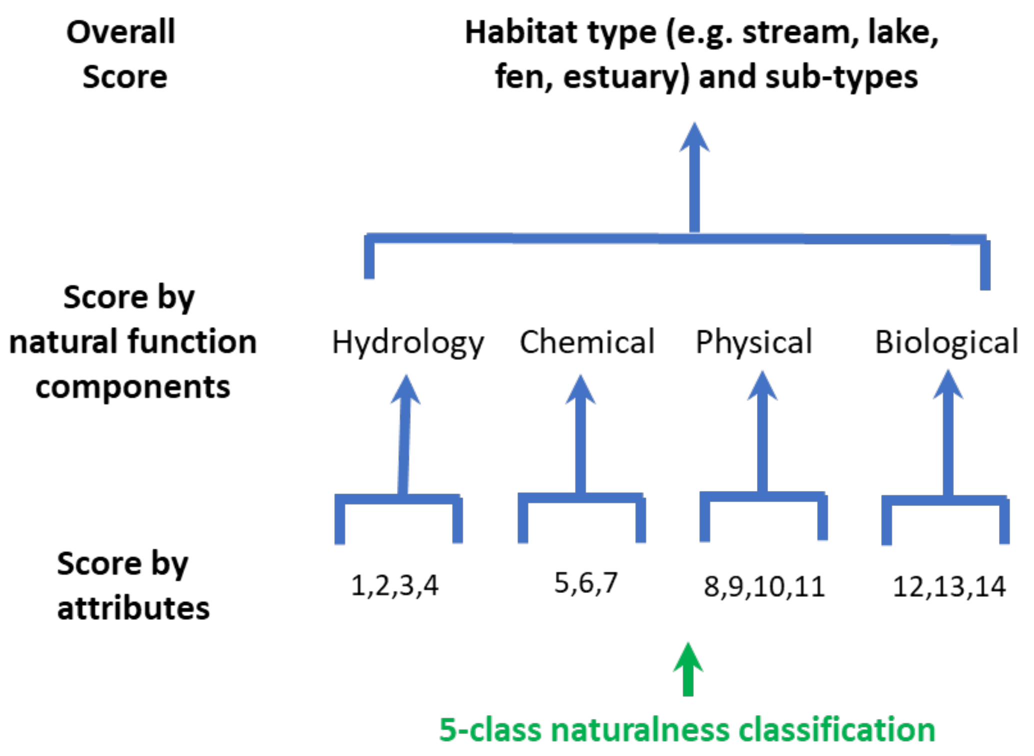


Figure 2.1 Conceptual outline of the B6 data framework.

The naturalness assessment framework needs to be of sufficient spatial resolution to provide a reasonable estimate of the statistical distribution of the habitat resource (including its component sub-types) across the naturalness spectrum, from very high to very low naturalness. This involves the use of a 5-class classification, providing sufficient discrimination of the higher end of the naturalness spectrum to support strategic habitat restoration ambitions whilst allowing adequate detection of change/progress at the lower end of the spectrum.

The data framework used for B6 employs a mixture of data sources, including whole-inventory datasets and representative sampling depending on what data are currently available and what monitoring/data generation is being planned. This mixed data model has implications for how data are analysed and brought together in coherent data outputs.

The ability to detect changes through space and time is central to any indicator. Sensitivity to change depends on issues such as the spatial intensity of representative sampling, the spatial resolution of any modelling undertaken, and the timescales over which updated data are/can be generated. These issues were considered in detail in Report JP016 (Mainstone et al. 2018) and thinking is being progressively refined through the development of the B6 indicator. The intention for B6 is that all attributes must be updateable at least every 5 years but preferably more frequently. Datasets, with suitable filtering, should be capable of providing resolution of key habitat sub-types (e.g. chalk rivers, oligotrophic lakes).

Being a compound indicator employing data relating to a range of pressures, B6 has links to a range of other indicators in Defra’s indicator framework. The use of complex compound indicators like B6 makes the Defra OIF a much more interconnected framework, using the same or similar data for different perspectives on the natural environment. In some cases, data relevant to other indicators are best re-processed in different ways (such as non-native species in the H2 indicator). In other cases pre-processed data from another attribute might best be used directly (such as for wetlands in the D1 indicator or potentially chemicals in the H4 indicator).

The relationship with the D1 indicator (extent, quality and connectivity of habitats) is particularly important. The D1 indicator aims to evaluate the entire national resource of all land-based (non-marine) habitats, including open freshwater and wetland habitats. It has previously been agreed that B6 should provide the freshwater habitat component of D1, whilst development of the wetland habitat component of B6 should be led by D1 development. It was further agreed that there needed to be strong collaboration between the development of D1 and B6 to ensure a complementary framework is developed for the two indicators, explicitly incorporating characterisation of natural function and making best use of available water-related datasets.

The B6 indicator provides a valuable accompaniment to other water-related indicators within the Defra OIF. It provides a more holistic and sensitive appraisal of modifications to natural ecosystems than is possible in headline water indicators, which provides an important platform for expressing and highlighting progressive synergies between biodiversity and water objectives, based on protection and restoration of natural ecosystem function (this is explored further in Section 12).

3. Consultation feedback

A progress report on the B6 indicator (Mainstone *et al.* 2021) was produced at the end of July 2021, which comprised a working model of the rivers and streams component, a structural approach to data aggregation (in the form of wheel diagrams) and a plan for the lakes and ponds component. Feedback was sought from a range of individuals, including academics involved in freshwater habitats, and relevant staff in NGOs, Natural England, the Environment Agency and Defra. In addition to inviting any comments, individuals were asked a series of questions relating to attributes and data sources, data analysis, data portrayal and data access.

A detailed account of feedback is provided in Appendix A. A summary of key feedback is given below, together with notes (in italics) on how the feedback has affected B6 development this in 2021/22. Note that feedback inevitably focused on the rivers and streams components of the indicator as these were the only components described in detail in the 2021 progress report.

Attributes and data inputs – A number of useful suggestions for additional river/stream attributes were made, on fine sediment regimes, headwater streamflows, thermal regimes, chemicals and catchment land use. Additional or alternative data sources for existing attributes were suggested in some cases (e.g. Lidar data for flood embankments and tree cover). *Whilst it has not been possible to address all of these suggestions in this latest round of development, we have been able to act on some suggestions.*

Analysis methods -Some responses indicated a need to better articulate the basis for positioning naturalness class boundaries, with suggestions to revisit some of the boundaries used for some existing river/stream attributes so that a consistent rationale can be discerned. Some responses indicated a need to look at alternative ways of generating and expressing certain attributes (such as artificial in-channel structures) and explore whether a more mixed analytical approach to the expression of attributes is possible within the spatial data structure currently used. *This progress report seeks to provide greater clarity on the conceptual basis for class boundaries. A key consideration concerns providing sufficient discrimination of the upper end of the naturalness spectrum to drive restoration of highly naturally functioning habitat mosaics. It is important to avoid thinking about naturalness class boundaries as environmental standards – rather, they provide a framework for thinking about existing and potential future levels of naturalness within the habitat resource, which can inform how we plan nature recovery in landscapes as well as how we manage water specifically – Section 12 provides more strategic explanation. Good progress has been made on alternative expression of certain attributes, as well as on building more flexibility into the form of expression of attributes in wheel diagrams.*

Data presentation – Some respondents had difficulty in interpreting wheel diagrams. *Further refinements to the portrayal of wheel diagrams have been made to* *address feedback. We have also developed other forms of data presentation to better reflect the needs of Defra's Operational Indicator Framework.*

Data outputs – Some respondents were interested in access to underlying datasets. *The datasets for B6 come from a variety of sources and there is no one approach to ensuring they are available. Part of operationalising B6 relates to providing clarity on data sources and making sure they are available wherever possible. In some cases this will be signposting to datasets owned and held by others, whilst in other cases it will be appropriate for Natural England to store datasets and make them available directly. For processed data (i.e. the data underlying wheel diagrams and other outputs) the aim is to host these on Natural England on-line data repositories. This forms part of the work planned for 2022/23 in bringing the B6 indicator to operational status.*

Data sourcing and handling – A feature of some consultation responses was highlighting the scale of work involved in organising and resourcing the regular pre-processing, transfer and analysis of different data sets within the B6 data framework, not only in relation to rivers/streams but also lakes and ponds, wetlands (including from indicator D1) and estuaries/coasts. Allied to this are uncertainties in the shape of future statutory agency monitoring programmes to service the B6 data framework. *These operational issues must not be under-estimated and need to be properly planned in. B6 development work continues to highlight the issue and seek strategic agreement with relevant parties on how the indicator will be operationalised. The next phase of development will involve clarifying and specifying data sourcing and handling processes.*

Links to target-setting - Some of the feedback related to uncertainties in how the data will eventually be used, not only in relation to the Defra indicator framework but also in relation to the framing of strategic biodiversity targets aiming to shift the habitat resource towards higher levels of naturalness, in different parts of the resource and to different degrees based on local benefits, opportunities and constraints. How the data are used has a major bearing on how this work is perceived – its relevance, usefulness etc.. *Allied to work on the B6 data framework, considerable progress has been made in framing strategic biodiversity targets for freshwater habitats through the development of thinking on definitions of Favourable Conservation Status (FCS). This work is explained in Section 12 of this report.*

4. Data visualisation formats

4.1 Preamble

B6 is a complex compound indicator. Aggregating data from different attributes and components of natural function into an informative and readily understandable visual output is challenging, particularly considering the dual role of the B6 indicator framework (as part of Defra's OIF and also broader strategic biodiversity reporting processes). Wheel diagrams have been developed to provide a holistic visual output, since they are capable of presenting complex data at varying levels of aggregation in one schematic. However, the OIF also requires a simple summary format indicating key trends over time. A hierarchical framework of data aggregation and visual display is needed to allow the data to be understood at different levels of summary. The framework needs to encompass:

1. key habitat/ecosystem types (rivers, streams, lakes, ponds, key wetland types, estuaries and coastal waters);
2. habitat sub-types involved in biodiversity reporting processes;
3. small and large waterbodies, since small waterbodies have been consistently neglected in monitoring, assessment, reporting and hence habitat conservation planning and delivery;
4. key components of naturalness;
5. individual naturalness attributes.

4.2 Data aggregation issues

4.2.1 Attribute data aggregation

In traditional reporting of habitat condition (UK Common Standards Monitoring of protected sites, WFD reporting of ecological status), data aggregation across attributes is undertaken by adopting the status of the worst-performing attribute. Whilst this approach is important for ensuring that action to achieve objectives addresses all components of impact, it is of less value for detecting changes in status because no change is evident until there is a significant positive change across all attributes. Aggregation by averaging provides a vehicle for any improvements in any attribute to be reflected in the aggregated indicator, thereby improving sensitivity to change.

Statistically speaking, the method of averaging we have adopted for the B6 indicator is somewhat 'clunky', in that it averages the integer naturalness class values of spatial units within the habitat resource (generating a weighted mean), firstly for each attribute across the habitat resource and then across attributes (within each naturalness component, and then across all naturalness components). To achieve an adequate level of resolution for indicating change, these mean class values are calculated to one decimal place. Although clunky, classifying data prior to averaging does allow standardisation of different types of data, even though this is at the expense of losing the continuous nature of the underlying data on each attribute.

There are more statistically elegant ways of aggregating the data whilst preserving the continuous nature of the underlying data, but this can only be achieved at the expense of losing consistency/clarity of interpretation in terms of portraying levels of naturalness at the attribute level.

Again, unlike traditional assessment of habitat condition, aggregation of data on individual attributes is not performed at the level of individual spatial units (e.g. waterbodies) within the habitat resource, but rather at the habitat resource level. A weighted mean naturalness value for each attribute across the habitat resource is generated, and a mean value of these values is then generated at the level of each key naturalness component. A mean value of naturalness components is generated as a single naturalness score for the habitat resource. This approach is dictated by the mixed data model used in B6 (which is itself dictated by the datasets available) and has implications for precisely what can be said about the naturalness of individual spatial units within the habitat resource. At the habitat resource level, changes in one attribute may be happening in different places to changes in another; for instance, parts of the habitat resource with highly naturally functioning hydrology may be different parts of the habitat resource to those with highly naturally functioning chemistry or physical habitat.

Whilst this approach does improve our ability to detect change, it is less useful in the context of highlighting areas where naturalness is at a high level across all attributes or where action is being taken to improve naturalness across all attributes. Since restoring highly naturally functioning habitat mosaics is a key strategic ambition, some other cross-checks are needed to ensure delivery is planned in a holistic way. The way in which the B6 data framework is intended to be used to set strategic biodiversity targets is key to this (see Section 12), helping to guide related delivery processes for nature recovery and water planning.

4.2.2 Habitat aggregation

The most summarised level reporting of habitat types intended in B6 is rivers, streams, lakes, ponds (these four together comprising freshwater habitats), bogs, fens (these two together comprising freshwater wetlands), estuaries and coasts. However, there is a critical level of typological detail below this that needs to be considered in the B6 data framework and related biodiversity assessment and reporting processes.

There is some complexity to deciding which habitat sub-types to include in the data framework, but key considerations are habitat types included in the UK list of priority habitats (incorporated into English law in Section 41 of the 2006 NERC Act) and Annex I of the European Habitats Directive, as well as habitat typologies used in conservation assessment and reporting.

The B6 data framework needs to be amenable to spatial filtering in various way to provide naturalness and trend assessments of detailed types of river/stream, lake, wetland and estuarine/coastal habitats. This typological detail is vital to ensure that key parts of the habitat resource are not neglected in strategic plans to protect and restore the habitat resource as a whole.

4.3 Wheel diagrams

Wheel diagrams allow us to provide a detailed portrayal of the naturalness of the habitat resource within a set time window, drilling down into the detail of key components of naturalness and individual attributes contributing to those components. This is critical for providing an assessment of the state of the resource, feeding into strategic biodiversity assessment and reporting processes including the setting and assessment of strategic restoration targets (see Section 12). They also provide detailed context that can sit behind the B6 indicator.

An example wheel diagram from the July 2021 B6 progress report is shown in Figure 4.1. The inner circles of the wheel characterise the proportions of the national habitat resource in different naturalness classes according to individual attributes – the darker the grey shades towards the centre of the wheel, the more natural the habitat resource. The outer coloured 'assessment' rings provide mean class values across the habitat resource, at attribute level (innermost ring - weighted mean based on the distribution of the habitat resource) and at the level of key naturalness components (outermost ring – arithmetic mean of relevant attribute values in the innermost ring). An overall (arithmetic) mean naturalness value (shown in the centre circle or bull's eye).is generated from the mean scores for the main naturalness components.

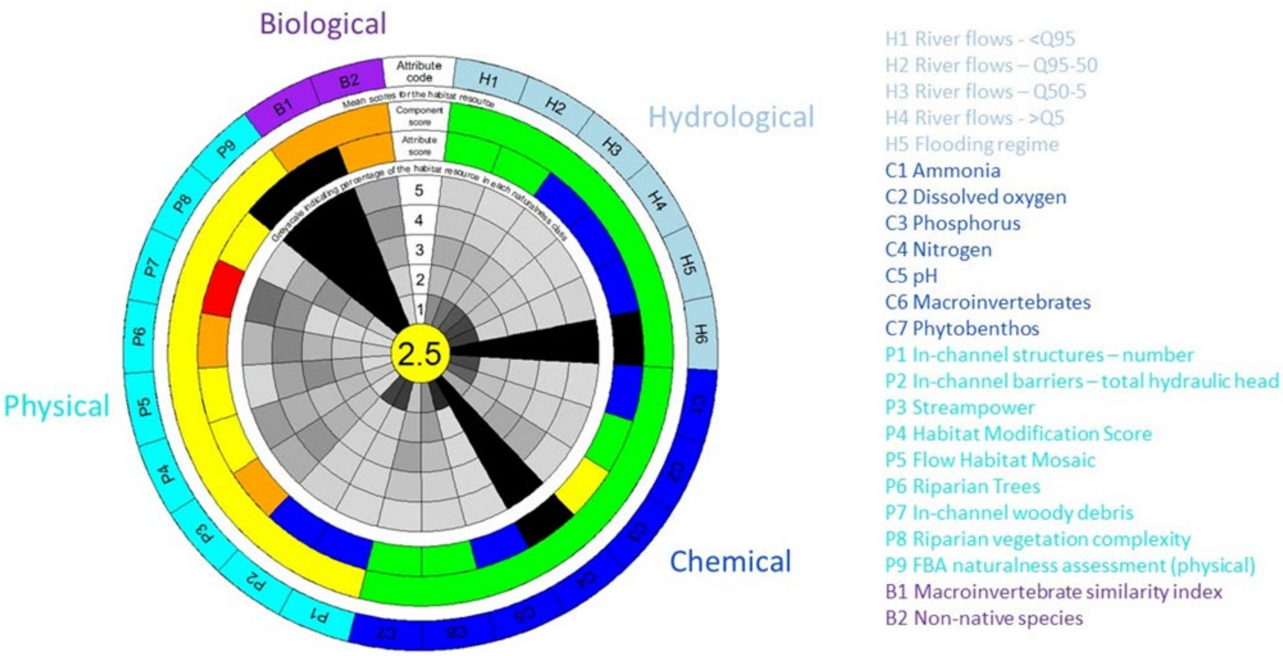


Figure 4.1 Last year's form of wheel diagram (for larger rivers) used in the July 2021 progress report (Mainstone *et al.* 2021).

The 2021 consultation exercise provided some useful feedback on the understandability of wheel diagrams. Practical suggestions included inverting the grey-scale of the inner rings and simplifying the colour-coding of naturalness classes. After consideration it was decided to leave the grey-scale as it is – it is signifying the relative proportion of the habitat resource in a given class, and therefore an intensifying grey-scale with increasing proportion of the habitat resource seems appropriate. We have simplified the colour scheme of naturalness classes, to move through red, orange, yellow, green and dark green with increasing naturalness. We have also altered the portrayal of attribute coding to avoid confusion with the outer assessment rings. A further innovation is to include a fifth naturalness component termed ‘Cross-cutting’, to provide a home for any attributes that cannot reasonably be allocated to any one of the four existing components (hydrological, chemical, physical and biological). An updated example wheel diagram is shown in Figure 4.2.

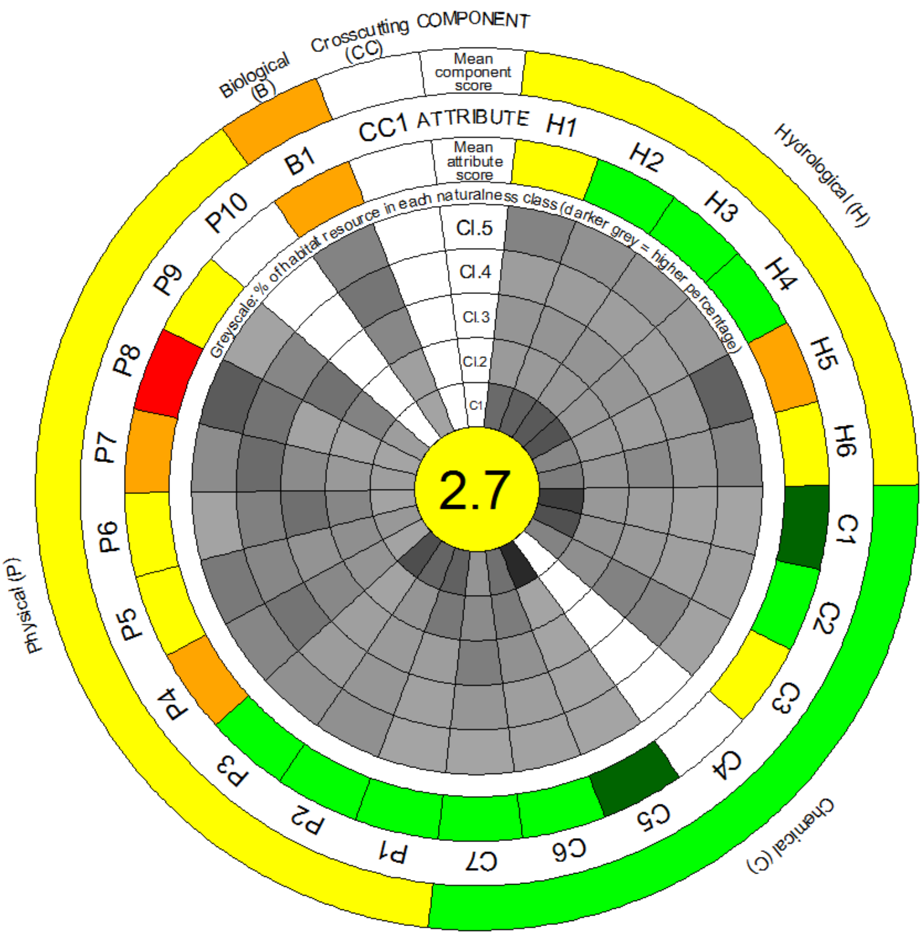
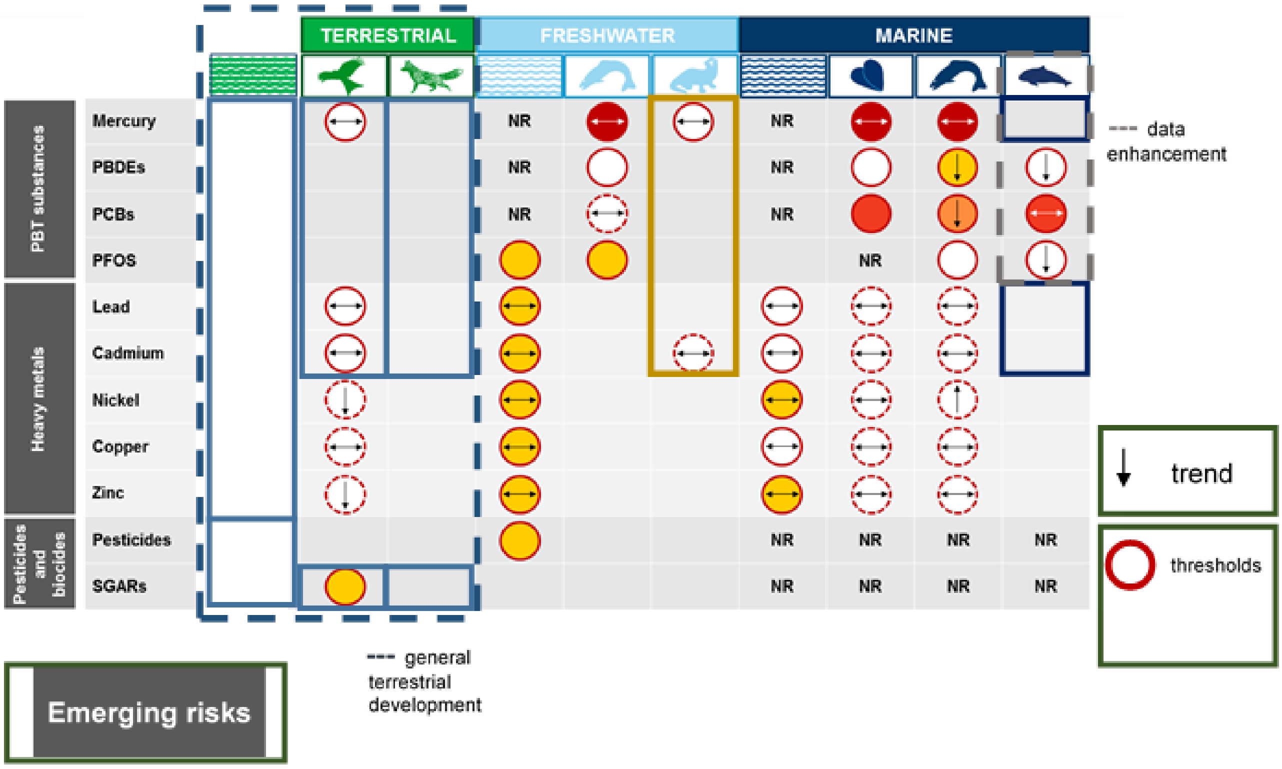


Figure 4.2 Updated wheel diagram format used in this report. Inner grey-scale rings indicate the proportion of the habitat resource in each naturalness class – darker grey = more of the habitat resource. Colouring of naturalness classes: dark green = Class 1 (highly natural); light green = Class 2; yellow = Class 3; orange = Class 4; red = Class 5 (highly un-natural). White cells indicate no assessment yet made.

Wheel diagrams are not suited to portraying trends over time since there is no simple way of adding a time dimension and there are too many parts to track in any case (particularly the inner grey-scale rings). We therefore need another visual format for headline reporting under the Defra OIF.

4.4 Dashboards

A dashboard approach is a typical format for reporting aspects of both status and trends. There is no standard approach to the structure and symbology for dashboards within the OIF but the H4 indicator on toxic and persistent chemicals (Figure 4.3) provides a useful case study. A matrix of attributes/components versus environment/habitat types is a useful basic framework, and the trend symbology used in H4 is broadly transferable. Other aspects of H4 symbology are more specific to toxic chemicals, particularly the concept of toxicological thresholds as a standardising reference condition. The use of ‘proportions of samples’ conforming to threshold value is in some ways analogous to the inner greyscale rings of the B6 wheel diagrams, but the wheel diagrams do not attempt to indicate a desired or target status of naturalness across the habitat resource in the way that toxic threshold values might imply. Still, the concept of coloured circles as an indication of the state of the habitat resource at a given point in time is useful and can be employed in B6.



Key

Data sources Sparrowhawk / red kite; Red fox; Freshwater; Roach / chub / brown trout; Otter; Estuarine / coastal waters; Blue mussels; Dab; Harbour porpoise

Acronyms PBT: persistent, bioaccumulative and toxic; PBDEs: polybrominated diphenyl ethers; PCBs: polychlorinated biphenyls; PFOS: perfluorooctanesulfonic acid; SGARs: second-generation anticoagulant rodenticides; NR: not relevant – unlikely to be an exposure route for that substance

Trend ↑ Increasing concentrations; ↔ No observed change in concentrations; ↓ Decreasing concentrations

Only statistically significant trends in environmental concentrations are shown for upward and downward arrows; no arrow indicates minimum requirements for trend assessment are not met. Available year ranges for assessing trends vary and trends are only assessed for data sources with at least 5 full years of change (6 independent sampling years).

Risk More than 75% sites/samples above threshold; 50 to 74% sites/samples above threshold; 25 to 49% sites/samples above threshold; 1 to 24% sites/samples above threshold

All sites/individuals or population average below threshold; No threshold available; not currently able to assess risk

Assessment is based on comparison of concentration data for the most-recent year, 2 years for dab and 3 years for PFOS and heavy metals in water.

Notes

1. Blank spaces indicate there are currently insufficient or no comparable data available to allow trend or risk reporting.
2. Data cover up to and including 2019 where available; exceptions are mercury (2013) and heavy metals (2014) in sparrowhawk, mercury and cadmium in otter (2016), and PBT substances in harbour porpoise (2018).

Figure 4.3 Illustrative dashboard format developed for Defra OIF Indicator H4 (toxic and persistent chemicals).

4.5 Developing a dashboard structure for B6

4.5.1 Level of aggregation of attribute data

The B6 wheel diagrams provide a number of levels of data aggregation to consider in dashboard format. The best compromise between too much detail and over-summarising would be the key components of naturalness – hydrological, physical, chemical, biological and cross-cutting (i.e. the outermost assessment ring of wheel diagrams). The colour coding from the wheel diagram can be transferred directly to high-level reporting dashboards covering all habitat elements. It would be possible to generate a more detailed portrayal at the level of individual attributes, but there is variation in the precise nature of attributes between habitat types, such that a simple unifying dashboard matrix would not be possible. More detailed attribute-level dashboards could be generated for each habitat type, sitting behind the high-level dashboards and using the colour coding of the attribute assessment ring. The overall naturalness value, which is the mean value of the key naturalness components (located at the centre of the wheel diagrams), could be added to the high-level dashboards as long as it is not separated from the naturalness component values anywhere in the OIF. Figure 4.4 summarises the suggestions made above.

There is an issue around harmonisation with the D1 indicator, in that there are five key pillars of natural function used in cross-habitat assessment in D1 (in essence, the four main naturalness components used for B6 and an additional component on the naturalness of vegetation controls). Further explanation of the five pillars can be found in Natural England 2018. It is possible (for the most-part) to tease out attributes relating to vegetation controls from the physical naturalness component of the B6 data framework so that the B6 dashboard can be portrayed in terms of the five pillars of natural function. Alternatively, B6 could continue to be expressed as the four key naturalness components (plus the cross-cutting component) and converted into the five pillars of natural function when B6 data are built into the D1 reporting framework. A decision can be made over the course of the next year.

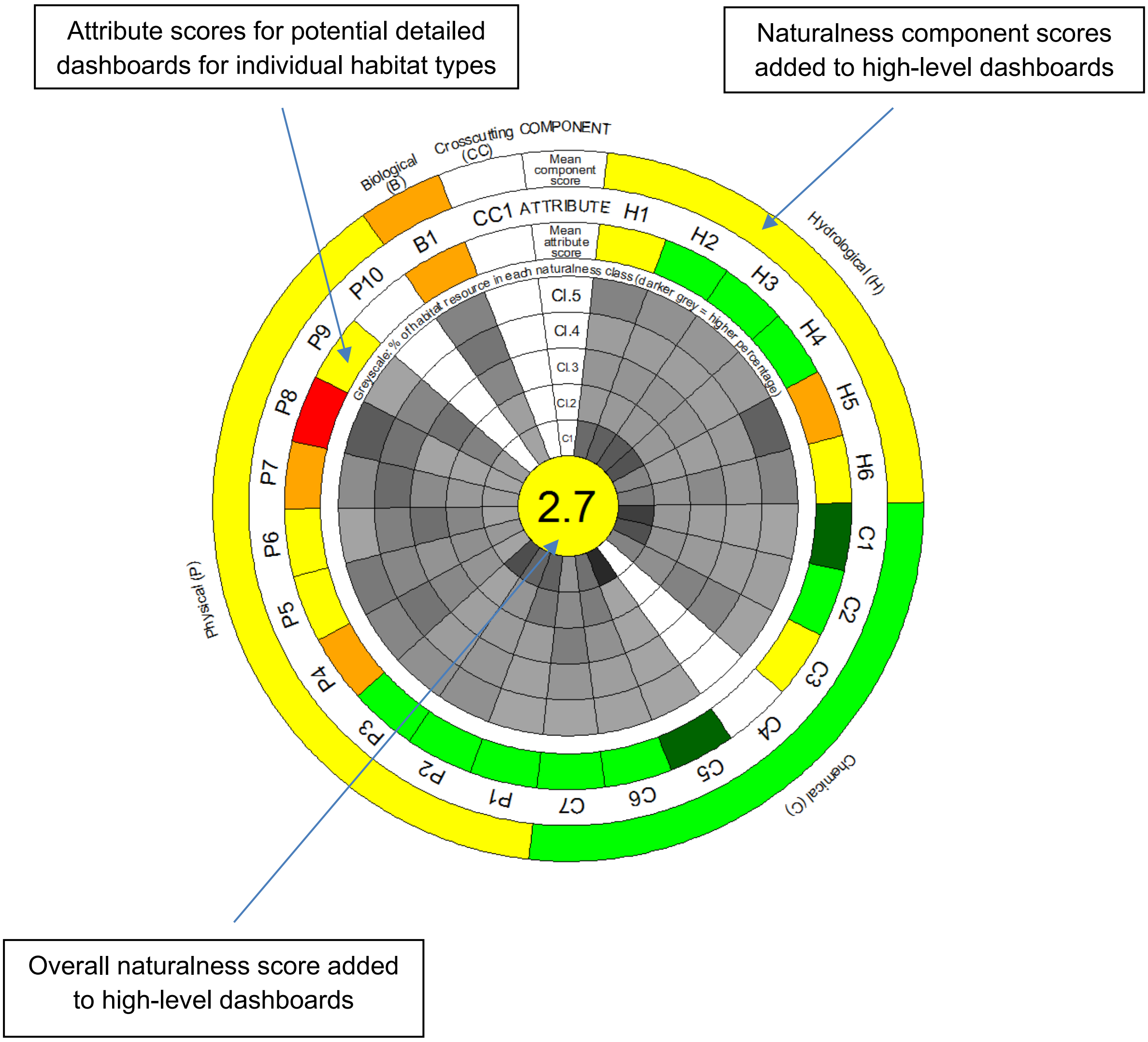


Figure 4.4 Relationship between wheel diagrams and dashboards in B6.

4.5.2 Level of habitat aggregation

For the headline dashboard, a high-level division of water and wetland habitat types is the minimum required: rivers, headwater streams, lakes, ponds, wetlands (subdivided into bogs and fens), estuaries and coastal waters. The large number of more detailed sub-types make them more amenable to handling in supplementary detail.

4.5.3 Indicating change

The mean naturalness scores used to colour the outermost assessment ring of wheel diagrams are calculated to one decimal place, so they provide more sensitivity to change than the colour coding of integer class values shown in the wheel diagrams. These more precise values can be used to portray change over time on the dashboard – a change of 0.1 is a reasonable basis for registering a change on the dashboard, since this is equivalent to a significant shift in naturalness levels in the habitat resource as a whole. It may be useful to indicate different scales of change on the dashboard, separating out small (e.g. change in score of 0.1), moderate (e.g. change in score of 0.2) and large changes (e.g. >0.2).

4.6 Developing B6 dashboards

A mock-up of a headline B6 dashboard is provided in Table 4.1, loosely based on the H4 matrix structure. Note that mean class values relating to the extreme highest and lowest classes (1 and 5 respectively) are not shown, because it is highly unlikely that any key naturalness component for any habitat type would be so natural or modified across the habitat resource to register mean values in those classes. Wheel diagrams for each principal habitat type in the dashboard can sit behind this to provide a detailed picture of the current level of naturalness of the habitat resource.

Table 4.1 Mock-up of a B6 headline dashboard. NB colours and arrow directions are for illustrative purposes only and are not intended to indicate the current status of the habitat resource. Green = Mean naturalness score within Class 2; Yellow = Mean naturalness score within Class 3; Orange = Mean naturalness score within Class 4.

	Running waters		Standing waters		Wetlands		Estuaries/coasts	
Naturalness component	**Rivers**	**Streams**	**Lakes**	**Ponds**	**Bogs**	**Fens**	**Estuaries**	**Coastal**
Hydrological	Green ↑	Orange ↓	Green ↓	Green ↑	Orange ↓	Green ↓	Orange ↓	Green ↓
Physical	Yellow ↔	Yellow ↔	Orange ↔	Yellow ↔	Yellow ↔	Orange ↔	Yellow ↔	Orange ↔
Chemical	Green ↑	Orange ↓	Yellow ↔	Green ↑	Orange ↓	Yellow ↔	Orange ↓	Yellow ↔
Biological	Orange ↓	Green ↓	Yellow ↔	Orange ↓	Green ↓	Yellow ↔	Green ↓	Yellow ↔
Cross-cutting	Orange ↓	Green ↓	Yellow ↔	Orange ↓	Green ↓	Yellow ↔	Green ↓	Yellow ↔
Overall	Green ↑	Orange ↓	Yellow ↔	Green ↑	Orange ↓	Yellow ↔	Orange ↓	Yellow ↔

Colour coding: Green – Mean naturalness score for habitat resource is within Class 2; Yellow - Mean naturalness score for habitat resource is within Class 3; Orange - Mean naturalness score for habitat resource is within Class 4.

A more detailed mock-up dashboard including greater resolution of habitat sub-types is shown in Table 4.2. This would help to increase the visibility of detailed habitat types of conservation interest such as chalkstreams and mesotrophic lakes. It would be too detailed to act as a headline dashboard, but could sit behind and allow people to drill down into greater habitat detail.

Table 4.2 Mock-up of a more detailed supplementary dashboard. NB Habitat types needing to be represented in the B6 data framework are still being clarified. Colours and arrow directions are for illustrative purposes only and are not intended to indicate reality. Green = Mean naturalness score within Class 2; Yellow = Mean naturalness score within Class 3; Orange = Mean naturalness score within Class 4. HD = Habitats Directive Annex I habitat type.

Habitats	Habitat types	Naturalness components					Combined
		Hydrological	Physical	Chemical	Biological	X-cutting	
Running waters*	Rivers	Green ↑	Yellow ↔	Green ↑	Orange ↓	Orange ↓	Green ↑
	Headwater streams	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Green ↓	Orange ↓
	Ranunculus rivers (HD H3260)	Green ↑	Yellow ↔	Green ↑	Orange ↓	Orange ↓	Green ↑
	Chalk river/streams	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Green ↓	Orange ↓
	Active shingle rivers/stream	Green ↑	Yellow ↔	Green ↑	Orange ↓	Green ↑	Green ↑
Standing waters	Lakes	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Yellow ↔	Yellow ↔
	Ponds	Green ↑	Yellow ↔	Green ↑	Orange ↓	Green ↑	Green ↑
	Naturally dystrophic	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Orange ↓	Orange ↓
	Naturally oligotrophic	Green ↑	Yellow ↔	Green ↑	Orange ↓	Green ↑	Green ↑
	Naturally mesotrophic	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Green ↓	Orange ↓
	Naturally eutrophic	Green ↑	Yellow ↔	Green ↑	Orange ↓	Orange ↓	Green ↑
	Marl	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Yellow ↔	Yellow ↔
Wetlands	Blanket bog	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Yellow ↔	Orange ↓
	Raised bog	Green ↑	Yellow ↔	Green ↑	Orange ↓	Yellow ↔	Green ↑
	Base-rich fens	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Orange ↔	Yellow ↔
	Acidic/base-poor fens	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Yellow ↔	Orange ↓

Habitats	Habitat types	Naturalness components					Combined
		Hydrological	Physical	Chemical	Biological	X-cutting	
Estuaries and coasts	**Estuaries (HD 1130)**	Green ↑	Yellow ↔	Green ↑	Orange ↓	Green ↑	Green ↑
	Large shallow inlets and bays (HD1160)	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Yellow ↔	Yellow ↔
	Permanently submerged sandbanks (HD1110)	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Yellow ↔	Yellow ↔
	Inter-tidal sandflats and mudflats (HD1140)	Orange ↓	Yellow ↔	Orange ↓	Green ↓	Orange ↓	Orange ↓
	Reefs (HD1170)	Green ↑	Yellow ↔	Green ↑	Orange ↓	Green ↑	Green ↑
	Atlantic salt meadows (1330)	Green ↓	Orange ↔	Yellow ↔	Yellow ↔	Yellow ↔	Yellow ↔

* Types from the European Red List of habitats are also relevant – see Section 5

4.7 Developing a hierarchy of visual outputs

More detailed dashboards dealing with individual habitat types and sub-types and their naturalness attributes can be produced to provide another layer of assessment detail, supported by corresponding wheel diagrams. This would generate a 3-tier hierarchy of detail in visual outputs, within which dashboards focus on change over time and wheel diagrams on spatial variation within the habitat resource. An indication of what this might eventually look like is given in Figure 4.5.

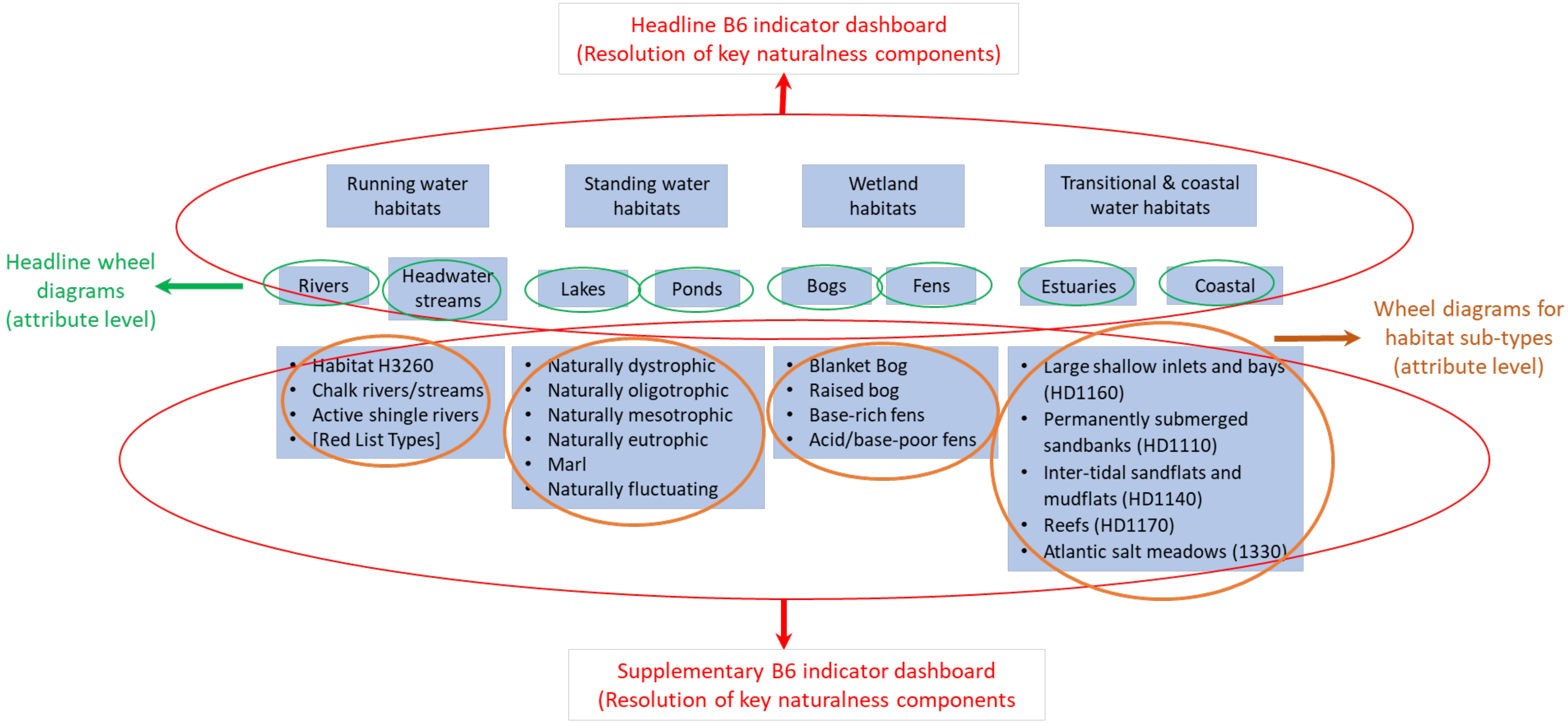


Figure 4.5 Indicative hierarchical framework for outputs, feeding into the B6 indicator and strategic biodiversity reporting processes.

5. Rivers and streams

5.1 Preamble

Work on rivers and streams in 2021/22 focused on existing attributes where further definition and dataset sourcing and handling were required. An account of work on these attributes is given in the sub-sections below. In looking at these attributes we have included notes on how decisions have been made about suitable class boundaries to help clarify conceptual thinking.

A summary of the status of all attributes is provided in Table 5.1, and updated wheel diagrams for headwater streams and larger rivers are provided in Figures 5.1 and 5.2. The classification rules for allocating data to naturalness classes for each attribute are summarised in Table 5.2.

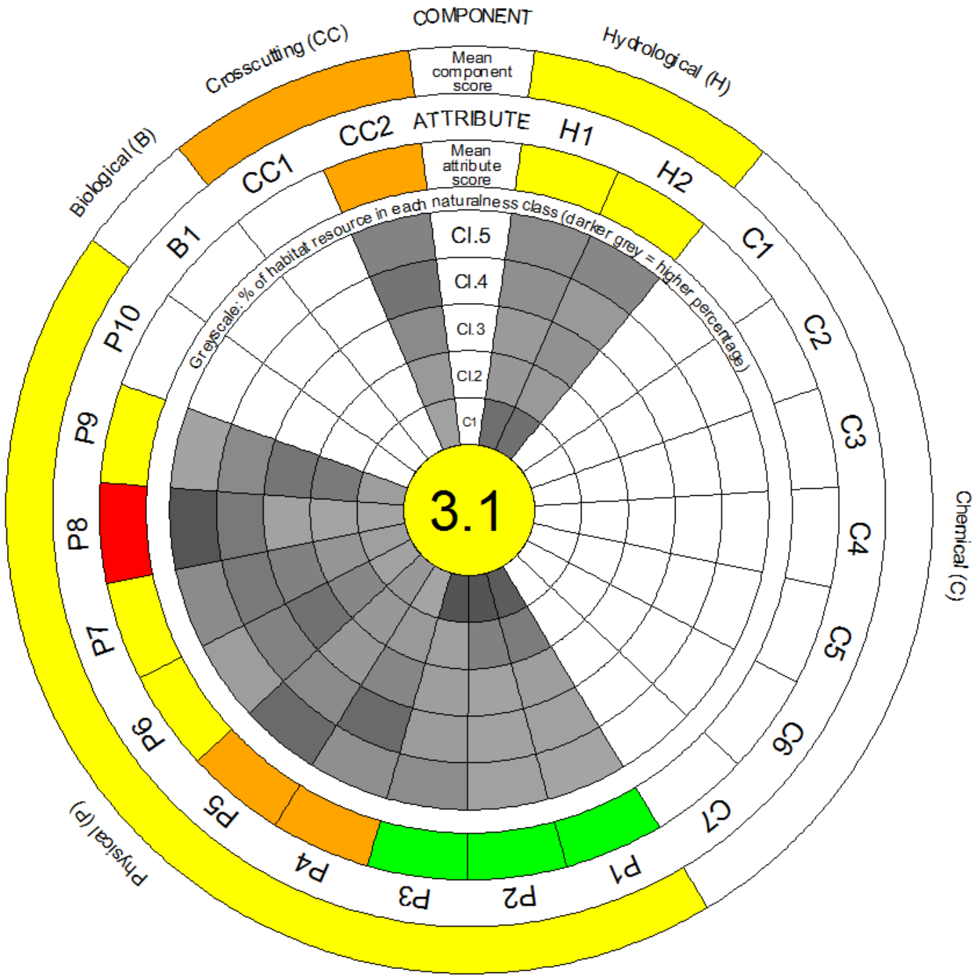
Although data aggregation within the wheel diagram still makes extensive use of the WFD waterbody framework (with each waterbody catchment divided into a headwater stream zone and a larger river zone based on a threshold catchment area of $10km^2$), the approach to individual attributes has been flexed to allow other spatial aggregation approaches where relevant, all within the general framework of providing an estimate of the proportion of the habitat resource within each naturalness class.

Data portrayal for headwater streams will be limited until data are available from the Environment Agency's new stream surveillance programme (part of the Natural Capital and Ecosystem Assessment, NCEA, programme).

Table 5.1 Summary of the status of river and stream attributes. Green – ready; Amber – nearly ready; Red – requires significant further work.

<table>
<tr><th>Naturalness component</th><th>Attribute</th><th>Headwater streams, rivers or both</th><th>Data Source</th><th>Data model</th><th>Current status</th><th>Current status of process for data updates</th></tr>
<tr><td rowspan="3">Hydrological</td><td>Flow regime – % deviations from naturalised flows.
Sub-attributes:
1.Qn95; 2.Qn70; 3.Qn50 4.Qn30</td><td>Rivers only</td><td>EA Water Resource Management System</td><td>Whole inventory, modelled</td><td>Complete using most recent data</td><td>Process for data updates agreed</td></tr>
<tr><td>Groundwater inputs to flows - % deviation from contribution to natural low flow (Qn90)</td><td>Both</td><td>EA hydroecology tool</td><td>Whole inventory, modelled (with some gaps in complex geologies and largely unexploited aquifers)</td><td>Complete using most recent data</td><td>Process for data updates agreed</td></tr>
<tr><td>Floodplain function - % channel length embanked</td><td>Both</td><td>EA national LIDAR dataset</td><td>Whole inventory (with some gaps)</td><td>Proof of concept complete using EA AIMS dataset</td><td>Requires change log process</td></tr>
<tr><td rowspan="7">Physical</td><td>In-channel structures:
Sub-attributes:
1. Fragmentation
2. Impoundment
3. Strategic connectivity</td><td>Both</td><td>CaBA River Obstacles dataset</td><td>Whole inventory (with some gaps, particular for headwater streams)</td><td>Complete although some attribute refinement needed</td><td>Via new app (in development – Rivers Trusts leading)</td></tr>
<tr><td>Stream power</td><td>Both</td><td>NE/CEH observed and reference data layers</td><td>Whole inventory, modelled</td><td>Complete using recent modelled data</td><td>Requires change log process</td></tr>
<tr><td>Habitat Modification Score</td><td>Both</td><td rowspan="5">River Habitat Survey from:
1.EA river surveiilance programme
2.Proposed NCEA headwater surveillance programme</td><td rowspan="5">Representative survey</td><td rowspan="5">Complete although currently using old RHS baseline survey data</td><td rowspan="5">Data transfer protocol required</td></tr>
<tr><td>Flow habitat mosaic</td><td>Both</td></tr>
<tr><td>Riparian trees</td><td>Both</td></tr>
<tr><td>In-channel woody material</td><td>Both</td></tr>
<tr><td>Riparian vegetation complexity</td><td>Both</td></tr>
</table>

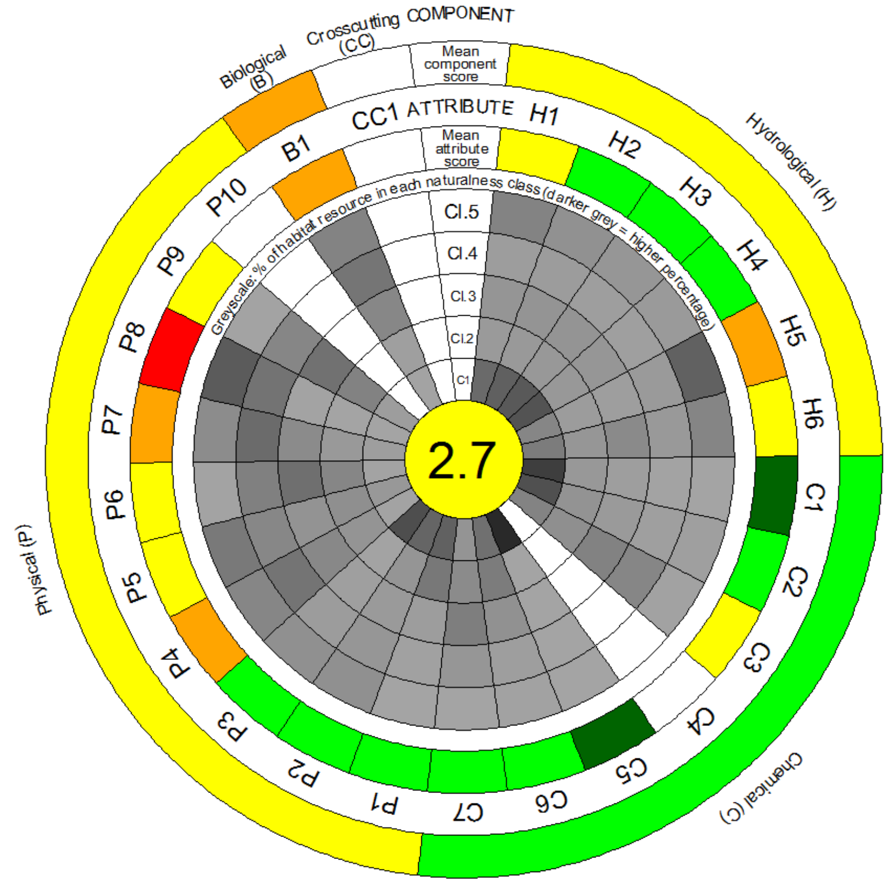
Naturalness component	Attribute	Headwater streams, rivers or both	Data Source	Data model	Current status	Current status of process for data updates
	FBA physical naturalness assessment	Both	Discovering priority habitats website	Dataset would need to be filtered to be representative	Insufficient data available as yet	Data transfer process to be established under partnership project between NE and FBA
Chemical (water quality)	Ammonia	Both	1.EA river surveillance programme 2.Proposed NCEA headwater surveillance programme	Representative sampling	Rivers – complete using EA WFD reporting database (2019 version). Headwater streams – Awaiting data from the NCEA surveillance programme	New data transfer protocol required
	Dissolved oxygen	Both				
	Phosphorus	Both				
	Nitrogen	Both				
	pH	Both				
	Macroinvertebrates	Both				
	Phytobenthos (macrophytes and diatoms)	Both				
Biological	Native species assemblage - similarity index comparing observed and reference invertebrate assemblages	Both	1.EA river surveillance programme 2.Proposed NCEA headwater surveillance programme		Attribute needs further development – under discussion with the EA	Data transfer protocol required
	Non-native species	Both	GB Non-native species information portal and associated data sources	Whole inventory but patchy – predictive modelling used to gap-fill	Analytical approach agreed	Data transfer protocol being agreed
General	Naturalness of catchment land cover	Headwater streams only	Living England GIS dataset	Whole inventory	Complete	As Living England is updated



Attribute codes

H1 Flooding regime
H2 Groundwater inputs
C1 Ammonia
C2 Dissolved oxygen
C3 Phosphorus
C4 Nitrogen
C5 pH
C6 Macroinvertebrates
C7 Macrophytes and diatoms
P1 Fragmentation – number of In-channel structures
P2 Impoundment - % length impounded
P3 Strategic connectivity - & length free-flowing to estuary
P4 Streampower
P5 Habitat Modification Score
P6 Flow Habitat Mosaic
P7 Riparian Trees
P8 In-channel woody debris
P9 Riparian vegetation complexity
P10 FBA naturalness assessment (physical)
B1Non-native species
CC1 Macroinvertebrate similarity index
CC2 Catchment land cover

Figure 5.1. Updated wheel diagram for headwater streams. Inner grey-scale rings indicate the proportion of the habitat resource in each naturalness class – darker grey = more of the habitat resource. Colouring of naturalness classes – dark green – Class 1 (highly natural); light green = Class 2; yellow = Class 3; orange = Class 4; red = Class 5 (highly un-natural). White cells indicate no assessment yet made.



Attribute codes

H1 River flows at Q95
H2 River flows at Q70
H3 River flows at Q50
H4 River flows at Q30
H5 Flooding regime
H6 Groundwater inputs
C1 Ammonia
C2 Dissolved oxygen
C3 Phosphorus
C4 Nitrogen
C5 pH
C6 Macroinvertebrates
C7 Macrophytes and diatoms
P1 Fragmentation – number of In-channel structures
P2 Impoundment - % length impounded
P3 Strategic connectivity - & length free-flowing to estuary
P4 Streampower
P5 Habitat Modification Score
P6 Flow Habitat Mosaic
P7 Riparian Trees
P8 In-channel woody debris
P9 Riparian vegetation complexity
P10 FBA naturalness assessment (physical)
B1Non-native species
CC1 Macroinvertebrate similarity index

Figure 5.2 Updated wheel diagram for rivers (i.e. streams excluded). Inner grey-scale rings indicate the proportion of the habitat resource in each naturalness class – darker grey = more of the habitat resource. Colouring of naturalness classes – dark green – Class 1 (highly natural); light green = Class 2; yellow = Class 3; orange = Class 4; red = Class 5 (highly un-natural). White cells indicate no assessment yet made.

Table 5.2 – Updated rules used for assigning naturalness classes to rivers and streams (refined from Mainstone *et al*. 2014b, 2018, 2021). The rules for spatially aggregating data vary between attributes but many use a Water Framework Directive waterbody (catchment) framework, divided into headwater stream and larger river components. Attributes are applied separately to headwater streams and rivers, although some attributes are only applied to one or other (see table detail).

Naturalness component and attribute	Naturalness class				
	1	2	3	4	5
Hydrological					
Flow regime - % deviation from naturalised flows (Qn) (**Rivers only**)					
a) Qn95	<5	5-10	10-25	25-40	>40
b) Qn70	<5	5-10	10-25	25-40	>40
c) Qn50	<5	5-10	10-25	25-40	>40
d) Qn30	<5	5-10	10-25	25-40	>40
Groundwater inputs – % deviation from natural GW inputs to stream flows at Qn90	<5	5-10	10-25	25-40	>40
Flooding regime - % of channel with flood embankments	0	0-5	5-10	10-30	>30
Physical					
In-channel structures					
a) Fragmentation – number of structures in waterbody	0	1-5	6-10	11-30	>30
b) Impoundment - % of channel length impounded	0	>0-5	>5-10	>10-30	>30
c) Strategic connectivity - % of channel length free flowing from sea	100	90-100	50-90	10-50	<10
Stream power – % deviation of modelled existing from modelled reference	<10	10-25	25-40	40-75	>75
Habitat Modification Score –aggregated to Habitat Modification Class	<17	17-199	200-499	500-1399	>1400
Flow habitat mosaic	12-14	9-11	6-8	3-5	0-2
Riparian trees - prevalence of RHS riparian tree elements	3 or 4 'extensive'	2 'extensive'	1 'extensive'	>= 1 'present'	All 'absent'
In-channel woody material – prevalence of RHS woody material elements	3 'extensive'	2 'extensive'	1 'extensive'	>= 1 'present'	All 'absent'
Riparian vegetation complexity	48-60	36-48	24-36	12-24	0-12
FBA physical naturalness assessment – Mean naturalness class	1	2	3	4	5
Chemical (water quality)*					
Total ammonia	HES	GES	MES	PES	BES
Dissolved oxygen	HES	GES	MES	PES	BES
Phosphorus	HES	GES	MES	PES	BES
Nitrogen	HES	GES	MES	PES	BES
pH	HES	GES	MES	PES	BES
Macroinvertebrates	HES	GES	MES	PES	BES
Macrophytes and diatoms (collectively termed phytobenthos)	HES	GES	MES	PES	BES

Naturalness component and attribute	Naturalness class				
	1	2	3	4	5
Biological					
Non-native species (aggregate weighted score of species)	N/A	N/A	N/A	N/A	N/A
Cross-cutting					
Native species assemblage – similarity index	-	-	-	-	-
Naturalness of catchment land cover (headwaters only) – 2 sub-attributes 1. % natural/semi-natural vegetation 2. % urban	100 0	80-100 0-5	50-80 5-10	25-50 10-25	<25 >25

* H/G/M/P/BES = class boundary for WFD high/good/moderate/poor/bad ecological status.

5.2 Groundwater to surface water flows (rivers and headwater streams)

Extensive collaboration with Environment Agency contacts has led to a way forward for extending the pilot B6 analysis in 200/21 (which used data from East Anglian groundwater models). The data specification for the B6 attribute has been built in association with the development of the Environment Agency's new Hydroecology Tool, which draws on data from available groundwater models across England. This now gives the B6 attribute a much more representative spatial coverage (Figure 5.3). There are some notable gaps in model coverage relating to complex geologies since they are extremely difficult to model, but (with suitable funding) it is anticipated that model coverage will improve further in the future.

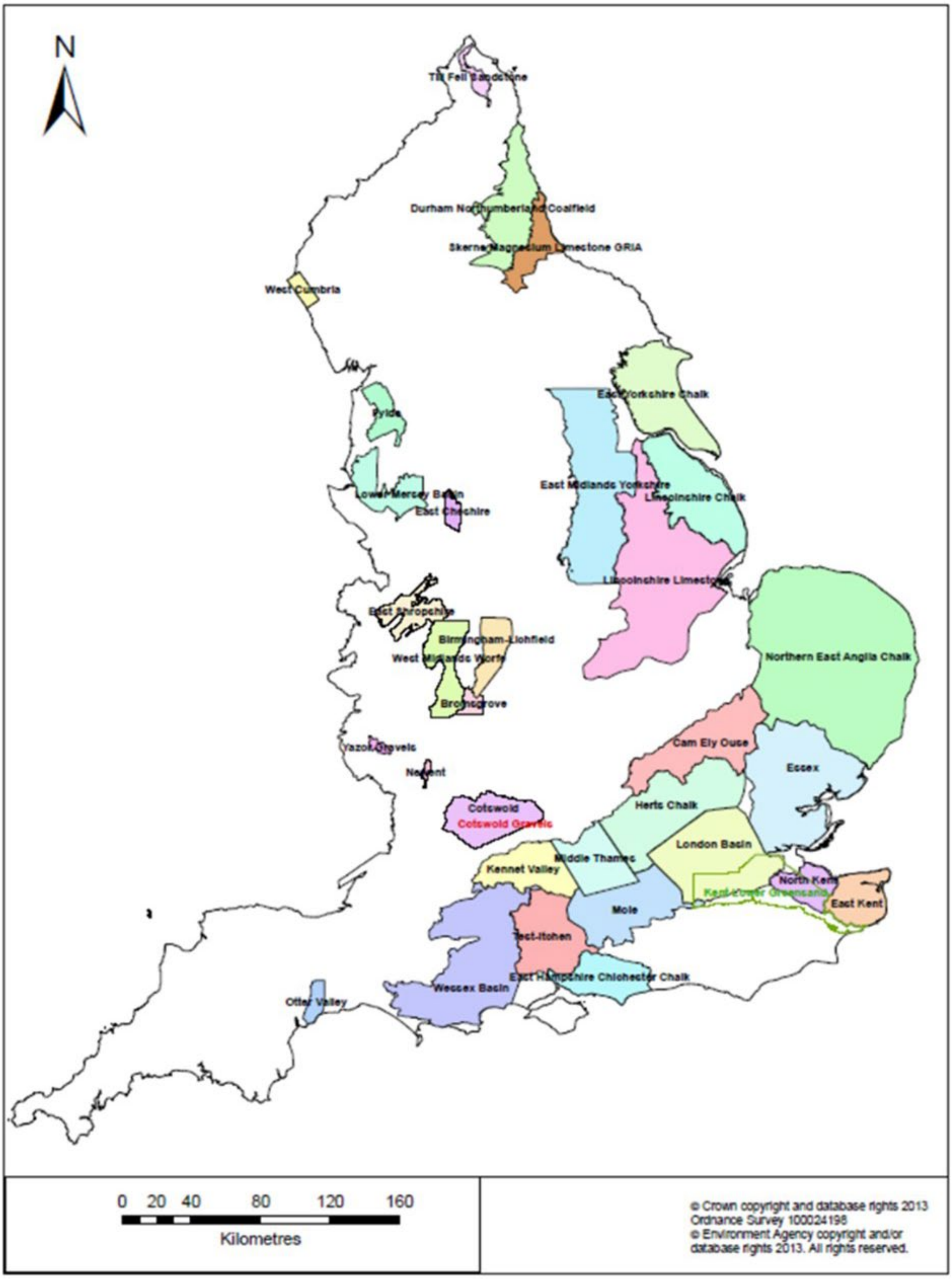


Figure 5.3. Spatial coverage of groundwater models included in the new Environment Agency hydroecology tool.

The original data processing for the attribute (see Box 5.1) has now been re-run with data from the EA hydroecology tool, generating attributes for both headwater streams and larger rivers.

Box 5.1 Calculating attributes of groundwater-to-surface water flows for headwater streams and larger rivers.

1. Extract recent actual (abstraction scenario) GW-to-SW flows and naturalised GW-to-SW flows for low flows (Qn90%ile): i.e. L90GSRA and L90GSN fields.

2. For all model cells in a waterbody catchment (separately for headwaters zone and larger river zone):

Sum GSRA values
Sum GSN values

3. Calculate ratio of Sum(GSRA) / Sum(GSN) in the waterbody catchment (separately for headwaters zone and larger river zone).

4. Transform ratio as absolute % deviation from unity (e.g. if ratio is 0.8 or 1.2, % deviation is 20%).

5. Classify deviations as follows: Class 1 <5%, Class 2 = 5-10%, Class 3 = 10-25%, Class 4 = 25-40%, Class 5 >40%.

The class boundaries used for last year's pilot were checked against this larger dataset and were considered to provide the right balance between discrimination at the higher end of the naturalness range and ability to detect change. Figure 5.4 shows the distribution of waterbody values across naturalness classes.

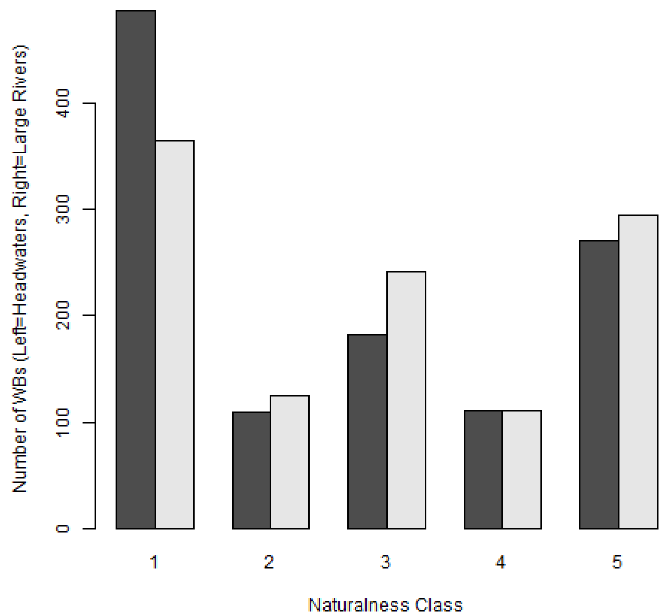


Figure 5.4 Frequency distribution of naturalness class values for the attribute on groundwater flows. Headwater streams (dark grey) and rivers (light grey).

5.3 River flow regime (rivers only)

The thinking on this attribute derives from collaboration with Environment Agency contacts during the development of Natural England Report JP016. The data specification from that time was formulated into a request for data extraction from the EA's Water Resource Management System (WRMS). This system contains data relating to observed and naturalised flows across England, modelled to generate outputs for each Water Framework Directive waterbody. There is no headwater stream attribute because the spatial focus of monitoring/assessment points in the WRMS is on the downstream ends of WFD waterbodies.

The required data were packaged up by the Environment Agency as follows:

Attribute	Description
EA_WB_ID	Water body ID number.
WB_NAME	Waterbody name.
Type_IWB	Type of waterbody.
CATCHMENT	Name of catchment.
ScenRA%QN30	Recent actual scenario as a percentage of natural flows at Q30.
ScenRA%QN50	Recent actual scenario as a percentage of natural flows at Q50.
ScenRA%QN70	Recent actual scenario as a percentage of natural flows at Q70.
ScenRA%QN95	Recent actual scenario as a percentage of natural flows at Q95.

The data were converted to absolute deviations from naturalised flows to indicate both artificial reductions and elevations in flows. The precise percentiles of the flow regime used in the attribute are somewhat different to those used in the 2021 B6 progress report, to fit in with the standard outputs from the WRMS. This does provide less discrimination at the high end of the flow regime but is a pragmatic approach, particularly given the need for regular data updates from the WRMS. The values of percentage deviation from naturalised flows used to allocate waterbodies to naturalness classes remain unchanged.

Frequency histograms of the data are provided in Figure 5.5 These continue to show a somewhat surprisingly high allocation of waterbodies to the highest naturalness class. This is due to a combination of: 1) the inclusion of effluent and other artificial 'returns' and diversions of water to rivers within observed flows; and 2) the spatial focus of monitoring/assessment points in the WRMS being on the downstream ends of WFD waterbodies.

It is difficult to exclude returns and diversions from the assessment and if this were done the picture would look very different. At the same time, not excluding them risks the B6 assessment indicating an improving trend in naturalness because of artificial movements of water aimed at compensating for lost natural flow – this is at odds with the general ecosystem restoration ambition of resolving problems with natural function at source. In terms of within-waterbody variation, there can be considerable deviation from naturalised flows within a river water body even though the downstream end of the waterbody exhibits a flow regime close to naturalised. There is potential for a more refined spatial assessment to be undertaken to provide some discrimination of modifications to flow regime within each waterbody. This can be considered in the future to provide a more refined assessment of the proportions of the habitat resource in each naturalness class.

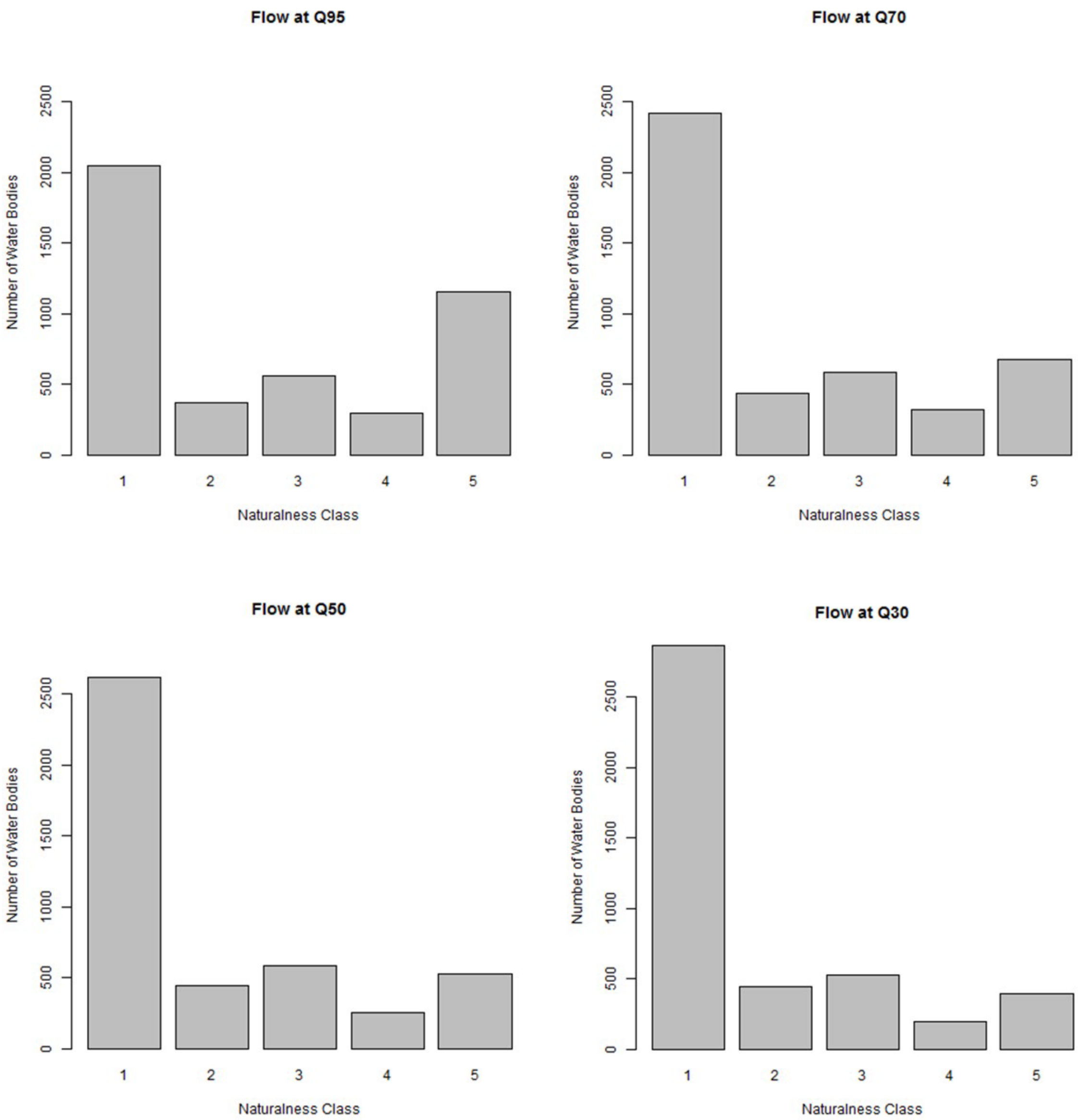


Figure 5.5 Naturalness of larger rivers according to different components of the flow regime (Naturalness class 1 = very high, Class 5 = very low). Classes are based on levels of deviation (positive or negative) from naturalised flows.

5.4 Flooding regime

The original data processing for this attribute involved the use of EA flood risk zone data to generate a ratio of observed to putative natural area of functional floodplain in each WFD waterbody. The problem with this approach was that it only addressed the modifications generated by major flood defence assets, providing no reflection of the many other flood embankments around the country. This is particularly important considering that these other flood defences are the ones that are most likely to be amenable to removal to restore more natural flooding regimes, since they often defend agricultural land rather than housing and related built infrastructure.

The Environment Agency has generated a spatial layer of flood embankments using interpretation of LIDAR data. It was originally thought that this provided a much more comprehensive picture of flood embankments than our existing approach to the flooding regime attribute. However, at present it only provides a LIDAR-generated dataset of EA flood defence assets, so essentially covers the same set of physical modifications as the attribute as it stands. It was decided that the EA's existing layer (called AIMS) should be used as proof of concept with respect to using LIDAR data for this attribute. The feasibility of generating a comprehensive layer of flood embankments from LIDAR data will be explored in the next phase of B6 work.

The main drawback to the use of LIDAR data is that the effect of embankments on natural inundation of the floodplain is not modelled, such that any attribute has to be based on the spatial extent of embankments (as a percentage of banklength modified). In a way this might perhaps be more accurately included as an attribute under the physical component of naturalness but, since it relates so strongly to flooding regime and an assessment of flooding regime is required, we have retained the attribute under the hydrological component of naturalness. Modifications to the naturalness of flooding regime are also created by channel over-sizing (deepening and widening) and straightening, but these are more difficult to relate specifically to flooding regime and remain in the physical component of naturalness.

The AIMS dataset has been used to calculate the total channel length with flood embankment (on either bank) in each waterbody. This figure has then been converted to a percentage of total channel length in the waterbody. Naturalness class boundaries were positioned to ensure sufficient discrimination of high levels of naturalness whilst giving reasonable discrimination of higher levels of modification. The resulting histogram of class values is shown in Figure 5.6.

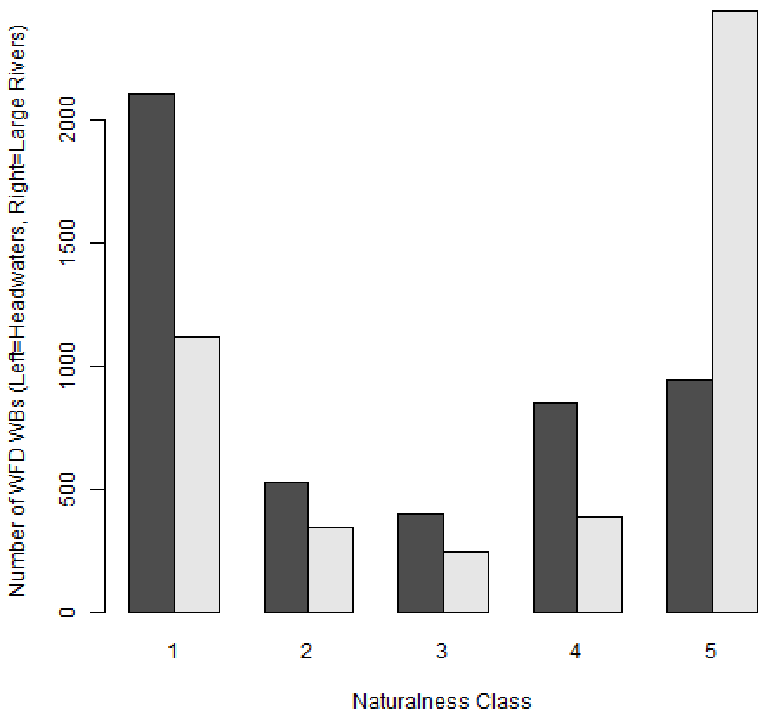


Figure 5.6 Naturalness of flooding regime in headwater streams (dark columns) and larger rivers (light columns) according to the extent of flood embankments in the Environment Agency's AIMS dataset. (Naturalness class 1 = very high, Class 5 = very low)

The other issue with this attribute is how to provide an assessment of change over time, given that LIDAR data are not routinely updated. A process for logging changes in the presence of flood embankments is required that can feed back data into the B6 attribute. At its simplest level it could be a grid reference location with length of flood bank removed or added. Data would need to be resolved into the digital spatial framework of waterbody catchments used for rivers and streams in B6, and attributes values recalculated. This will most likely need to be a joint endeavour between citizen science, the Environment Agency and Natural England. It could be located on the data portal provided by the CaBA initiative.

5.5 In-channel structures

5.5.1 Data and general approach

Data on in-channel structures comes from the 'River Obstacles' dataset held by the CaBA initiative, which has been formed from an original dataset generated by the Environment Agency and supplementary data from the AMBER project. Discussions have been held with the CaBA initiative and the Environment Agency to ensure that the structures dataset will be subject to regular updating so that the B6 attributes will be able to detect change. An app is being generated to record information on in-channel structures and this will provide the functionality to log removals and additions of structures that is needed.

The original attributes on in-channel structures have been reviewed on the basis of feedback from the 2021 consultation. After reflecting on the aspects of naturalness that the attributes need to characterise (including consideration of literature on the assessment of free-flowing rivers and discussions with key contacts) a revised set of attributes was settled on:

- Fragmentation
- Impoundment
- Strategic connectivity

Some limitations of the River Obstacles dataset have become apparent during recent analysis and discussions with CaBA. Firstly, there are widely recognised issues with the patchiness of records of structures – many existing structures are not currently included, including some major dams. This should be progressively resolved as the app is used and structures are added, but in analytical terms these additions to the database over time may spuriously manifest as a loss of naturalness unless some form of correction is included in the B6 data analysis. New records of structures will need to be flagged as historical or new to allow relevant structures to be retrospectively added to the baseline scoring of attributes rather than to subsequent updates to attribute scores. Secondly, the 'drop' or 'head' in water levels generated by each structure is both patchily recorded and of relatively low confidence. This is not so much of an issue in habitat resource-level analyses such as B6, where site-based uncertainties are drowned out by large-scale data aggregation, but still has implications for data processing and interpretation.

5.5.2 Fragmentation

This relates generally to fragmentation of natural processes, particularly the movement of sediments and biota. We tried approaches involving aggregation of data to catchment/river basin level (but still divided into headwater and larger river zones) and expressing the attribute as mean inter-structure distance to emphasise the real-world impact on the free-flowing of rivers/streams. Whilst there are benefits to these approaches in terms of being system-orientated, there are disadvantages associated with loss of the spatial discrimination afforded by the WFD waterbody framework already used for rivers and streams in B6. This loss of discrimination would be particularly difficult when data are filtered to provide assessments of individual river/stream types (such as active shingle rivers), which typically comprise only a part of a wider catchment.

It was therefore decided to use a refined version of the existing B6 attribute on the number of structures per WFD waterbody, modifying naturalness class boundaries to allow Class 1 to equate to no structures (as suggested by consultation feedback). WFD waterbodies are designed to be of relatively standard size so there is no particular need to standardise structure density by channel length in the attribute, which makes the definition of Class 1 easier. The distribution of naturalness class values across waterbodies is shown in Figure 5.7.

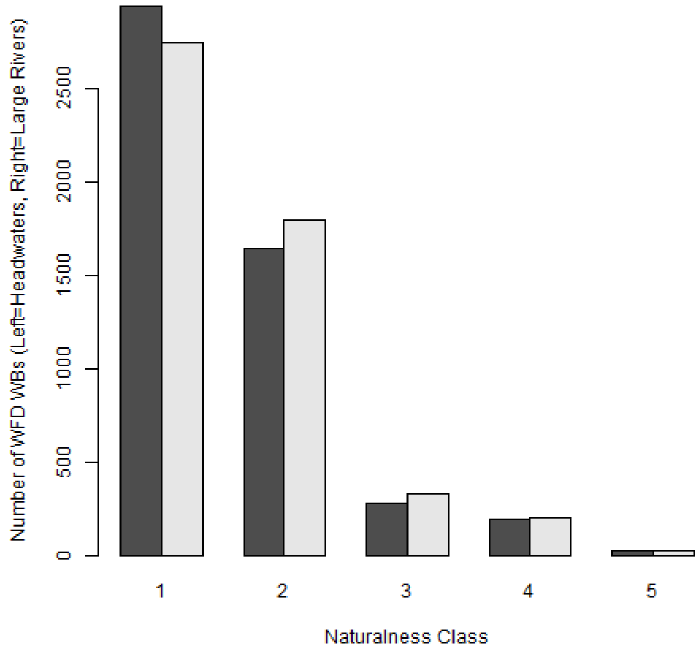


Figure 5.7. Fragmentation of the river and stream network based on the number of in-channel structures per waterbody. Headwater streams (dark grey) and rivers (light grey).

The number of WFD waterbodies without any structures is somewhat surprising. It is unclear to what extent this is due to the patchiness of records of existing structures or a real absence of structures. The relatively small size of WFD waterbodies does increase the likelihood of zero records in any one waterbody.

An alternative approach that would maintain discrimination of the naturalness of individual river types would be to generate whole-catchment assessments for reporting on the river/stream habitat resource as a whole, but to reanalyse the raw data separately for reporting on individual river types. This would require a spatial overlay of the distribution of each river type on the River Obstacles data and filtering on relevant structures to generate a type-specific attribute value. Whilst this would provide a type-specific assessment, it would not really provide a systems perspective, because most catchments are made up of multiple river types occupying different parts of the catchment. The overall effect of in-channel structures on one type is partly dependent on the effect on neighbouring types within a catchment.

5.5.3 Impoundment

This attribute provides an improvement on the existing attribute of total head of structures per waterbody. It relates the head of each structure to channel gradient at that point to generate an estimate of channel length impounded at each structure. The estimated impounded lengths are then summed for each waterbody catchment (divided into headwater streams and larger rivers) and divided by total channel length within the waterbody to provide an estimate of % channel length impounded. Dividing by total channel length feels more appropriate with this attribute than with the fragmentation attribute, to help provide a frame of reference for the level of impact on naturalness.

The distribution of naturalness class values within the habitat resource is shown in Figure 5.8. The high proportion of waterbodies with no impoundment just reflects the high proportion with no recorded in-channel structures as per the fragmentation attribute above. The spread of values across the other classes indicates a reasonable level of discrimination of naturalness in the rest of the habitat resource.

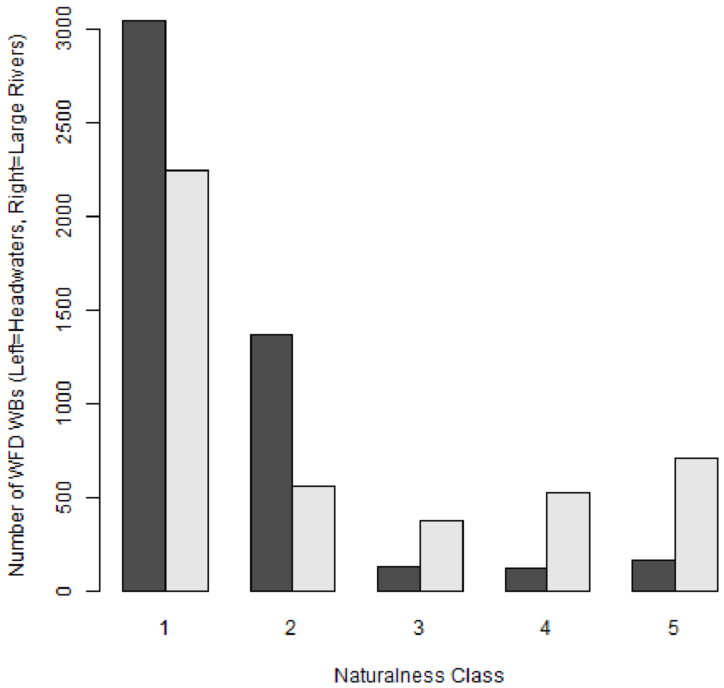


Figure 5.8 Frequency distribution of naturalness class values for the impoundment attribute in headwater streams (dark grey) and rivers (light grey).

5.5.4 Strategic connectivity

This characterises the positioning of structures relative to the estuary/sea, evaluating the length of free-flowing river/stream from the estuary/sea upstream to the first structure. It seeks to focus attention on removing structures to restore natural connectivity in a strategic way, helping to restore naturally tidally influenced rivers and streams and encouraging the longest possible stretches of free-flowing river from the coast upstream.

The construction of this attribute needs to consider multiple routes up river systems into various tributaries, not just the principal route up the main stem. A river basin approach is the only way of making the necessary calculations. The spatial framework of river basins that has been used is shown in Figure 5.9. It is the digital layer of 'Integrated Hydrological Units (IHA) of the United Kingdom' (Kral *et al*., 2015), which is consistent with the UKCEH river network used in the rest of the B6 analysis and very similar to the river basin delineation used for the WFD. Very small basins with no river/stream channels evident at 1:50,000 map scale have been excluded from the analysis, but this still leaves a large bias in the frequency distribution of basin areas towards small coastal basins.

A GIS algorithm was developed to identify the most downstream structures on the river/stream network and calculate, for each basin, the total channel length downstream of those structures (see inset map in Figure 5.9). This channel length was apportioned between headwater stream and larger river and expressed as percentages of total headwater stream and larger river length within each basin. These percentage values were assigned to naturalness classes using the thresholds shown for the attribute in Table 5.2.

It should be noted that for the smallest basins there will be little or no larger river length within the basin and all or most of the channel length is therefore allocated to headwater streams. For large basins, none of the headwater stream length will be free-flowing to the estuary/sea if none of the larger river length is free-flowing.

The distribution of naturalness class values generated is shown in Figure 5.10. It is heavily skewed towards the highest naturalness class, which is surprising given that allocation to Class 1 requires 100% of channel length within a basin to be free-flowing to the estuary/sea. This is likely to be the result of the skewed distribution of basin areas towards small values, giving greater prominence to small basins dominated by headwater streams that are less likely to have tidal structures and more likely to have missing records of in-channel structures in the River Obstacles dataset. Effectively, the River Thames basin generates only one value within the histogram, having no greater weight in the analysis than the smallest coastal basin. Further thought will be given to whether the analytical process needs to be refined to counteract this bias without further complicating the attribute and making it more difficult to understand/interpret.

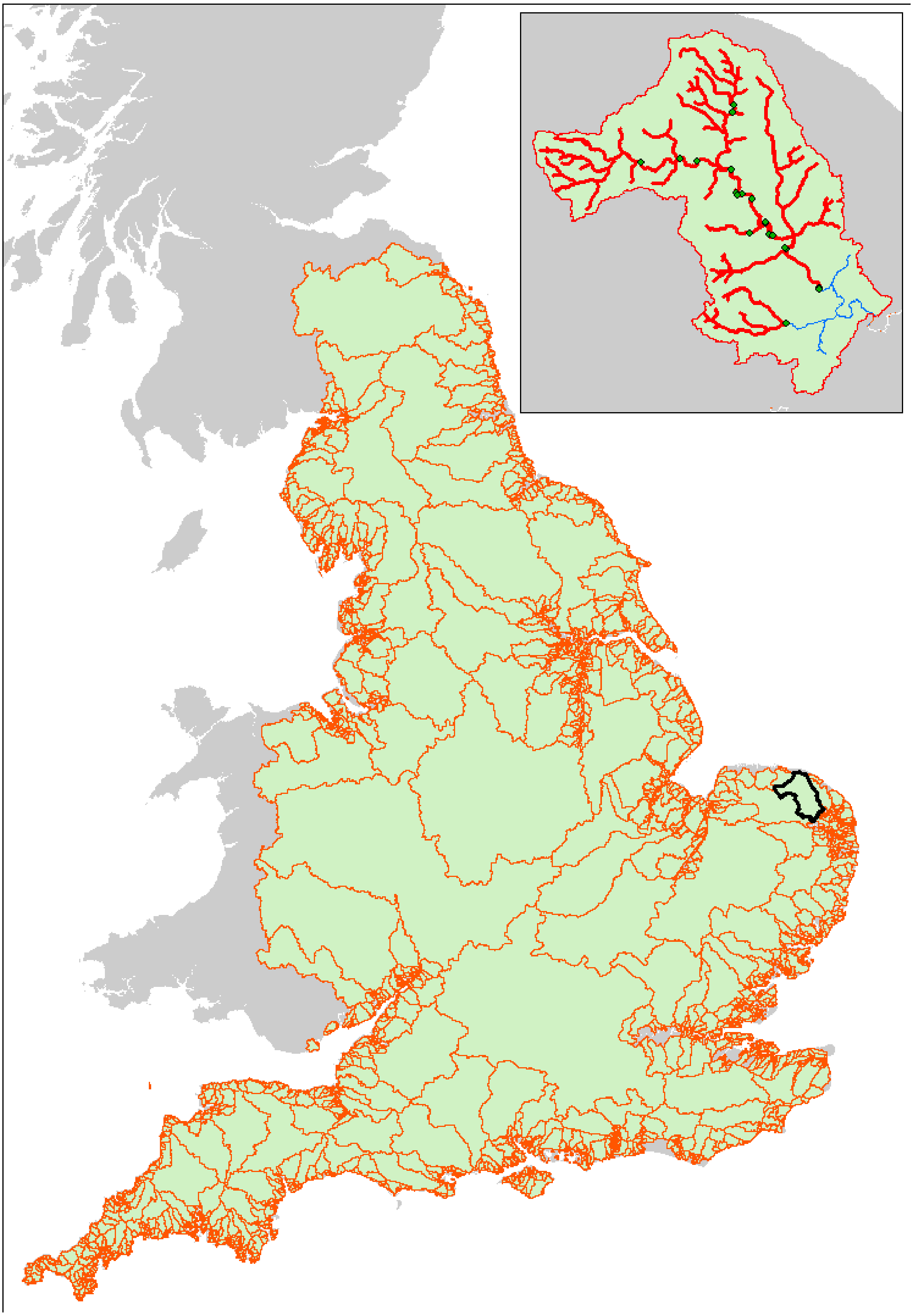


Figure 5.9 Map of river basins used for the strategic connectivity attribute. Inset map shows the allocation of river/stream channel length to upstream or downstream of the most downstream in-channel structure.

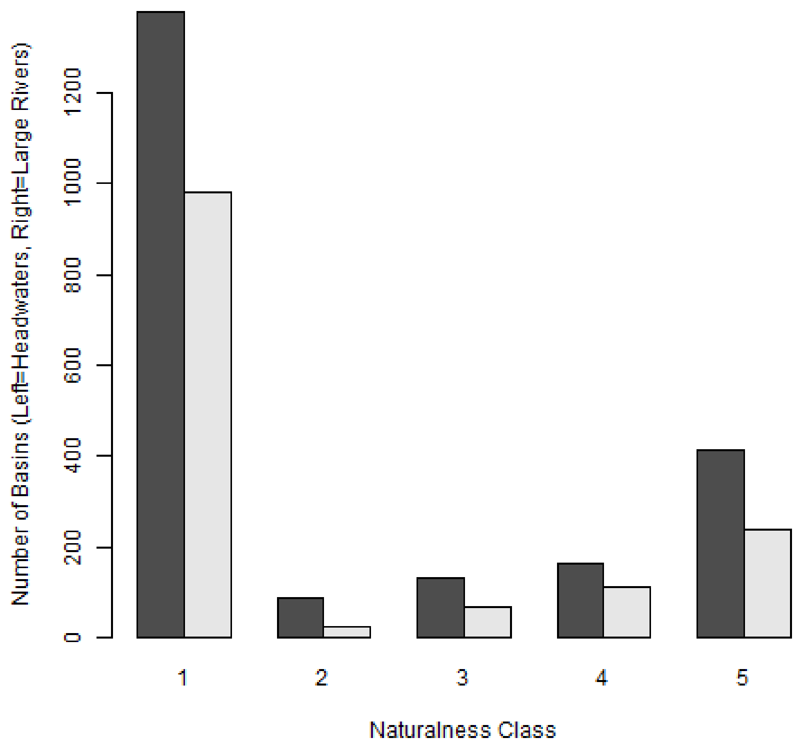


Figure 5.10 Frequency distribution of naturalness class values allocated to basins for the strategic connectivity attribute. Headwater streams (dark grey) and rivers (light grey).

There are other ways at looking at strategic connectivity but this is considered to be a pragmatic approach. An alternative approach would be to focus on structures that, if removed, generate the greatest increase in ‘free-flowing’ river wherever that may be in a catchment context. Whilst this an important approach in terms of local targeting of structures for removal (highlighting where the greatest improvement in the fragmentation and impoundment attributes above might be generated), it is not so amenable to inclusion in the B6 data framework in the context of strategic connectivity.

5.6 Streampower

The existing dataset of % deviation from reference (putative natural) streampower and associated classification rules are considered to be fit for purpose, but an issue remains about the updatability of the dataset. There is no scope for re-running the modelling process with updated data so some sort of pragmatic on-the-ground change-logging process is needed, sitting alongside an agreed protocol for editing values in the dataset based on the changes logged. This would sensibly be established in combination with the change logging process required for flood embankments, but is potentially more complicated because of the multiple factors that affect streampower.

A sufficiently simple approach is required, logging the grid reference location and length of channel where full geomorphological restoration or full channelisation has been undertaken. Again, data would need be resolved into the digital spatial framework of waterbody catchments used for rivers and streams in B6, and attributes values recalculated. The attribution recalculation requires a processing step to convert observed change to the channel to a change in the ratio of observed:reference streampower. For full naturalisation the streampower ratio would be changed to unity, i.e. observed streampower is reference (putative natural) streampower. For full channelisation a nominal ratio value will have to be adopted).

5.7 Non-native species

Detailed discussions have now taken place with UKCEH, NE and EA lead contacts on non-natïve species. It had been hoped that B6 could draw on the wider non-native species datasets being used for the general Defra OIF indicator on non-native species (now called H2), but the data are too coarse to provide a picture of the different habitats involved in Defra indicator B6. In fact the needs of B6 are stretching the limits of available data and some bespoke work from UKCEH non-native species specialists will be needed to package up data in the best way for deriving B6 attributes.

An outline proposal has been developed for pre-processing of species records from the NBN and Biological Records Centre, involving consideration of spatial resolution of records and predictive species distribution modelling to gap-fill datasets. This is now being discussed with UKCEH non-native species specialists with a view to generating and populating attributes for non-native species in the 2022/23 B6 work programme.

5.8 Chemical naturalness data

There has been no new work undertaken on existing attributes relating to chemical naturalness but there are some issues that need to be explained.

Biological metrics for classifying ecological status under the Water Framework Directive are included in the chemical naturalness component because they perform best at indicating water quality. The current intention is that, for both biological and chemical attributes, naturalness is classified according to the class boundaries used for ecological status or supporting ecological status. This is a pragmatic decision to ensure that data processing and transfer are as simple as possible and stakeholder confusion is minimised. Whilst there are issues with the extent to which some class boundaries are able to adequately reflect the upper end of the naturalness spectrum in rivers and streams (for instance phosphorus in high alkalinity conditions, or organic pollution in lowland conditions), any alternative approach would generate a great deal of work.

Through the development phase the chemical attributes have been populated from the Environment Agency's WFD Reporting database, which used to be updated every year. The way in which the Environment Agency generates and reports such data is subject to change and the last available version of the WFD Reporting Database only includes data up to 2019. This is the version from that has been used to generate the data in the current wheel diagram. A new protocol for securing data will need to be agreed with the Environment Agency.

The EA is still developing the surveillance programme for headwater streams and there are methodological issues to address which may mean alterations to the way that B6 attributes are defined. This will have to be dealt with through the course of 2022/23.

5.9 Consideration of new attributes

5.9.1 Naturalness of catchment land cover/use (headwater streams only)

One of the suggestions from the consultation exercise was to use naturalness of land use as a general proxy for a wide range of impacts on naturalness. This is not easy to embed into the B6 data framework since the framework is based on generating a higher level of discrimination of impacts on naturalness (divided into key naturalness components), but it does provide a useful vehicle for highlighting the extent of natural and semi-natural vegetation in headwater catchments where there are strategic ambitions for re-establishing high coverage in targeted parts of the headwater catchment resource.

Naturalness of land cover in headwater catchments formed one of the indicators used in the review of the river SSSI series (Mainstone *et al.* Awaiting Publication) and the mapping of priority river habitat (Mainstone *et al.* 2014, 2015) and the analysis has effectively been repeated for use in the B6 data framework. The Living England map has been used as the source data layer, since this will be a key vehicle reporting change in the countryside in the future and will be updated on suitable timescales to enable this.

The following land cover types within the Living England map have been allocated to an aggregate natural/semi-natural land cover category:

- Acid, Calcareous, Neutral Grassland
- Bare Ground
- Bare Sand
- Bog
- Bracken
- Broadleaved, Mixed and Yew Woodland
- Coastal Saltmarsh
- Coastal Sand Dunes
- Dwarf Shrub Heath

- Fen, Marsh and Swamp
- Scrub
- Water

For the headwater zone of each waterbody, the total area under natural/semi-natural land cover has been calculated and divided by the total area of the headwater zone. The same calculation has been made for urban land cover. Each waterbody has then been allocated to naturalness classes using the class boundaries for the attribute shown in Table 5.2. The overall value for the attribute for each waterbody is taken as the worst class of % natural/semi-natural and % urban.

Note that different class boundaries have been used for this exercise than used in the previous analyses mentioned above, to suit the current purposes of highlighting highly natural headwater catchments and providing adequate discrimination of lower levels of naturalness. The resulting distribution of class values is shown in Figure 5.11.

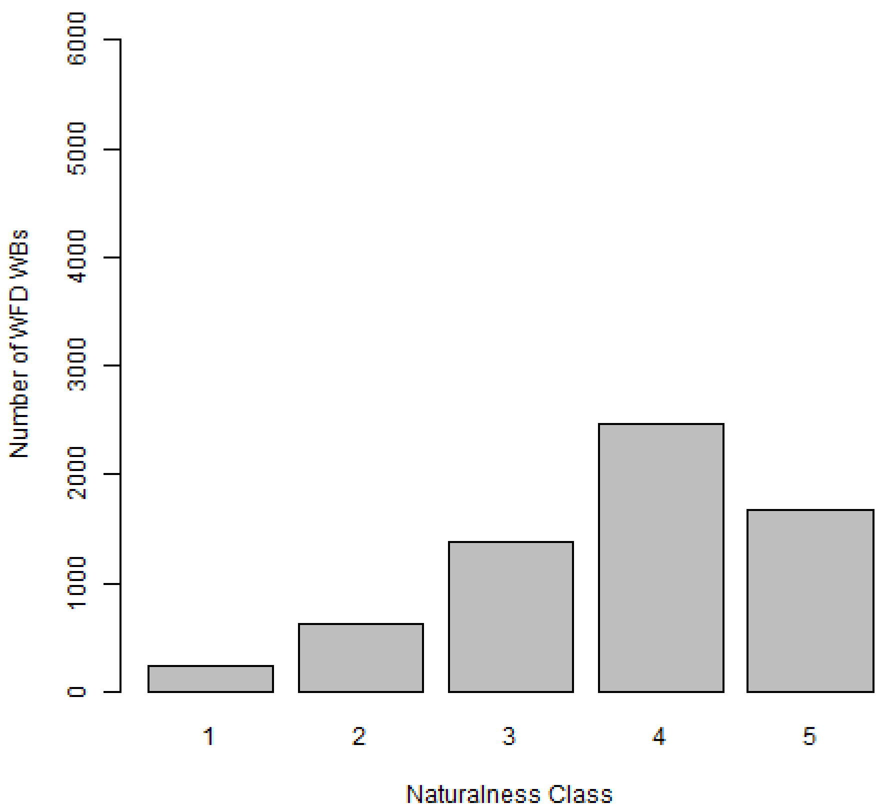


Figure 5.11 Frequency distribution of naturalness class values allocated to the land cover of headwater zones of waterbodies (Naturalness class 1 = very high, Class 5 = very low)

The distribution of naturalness class values highlights the low proportion of natural/semi-natural land cover in the majority of headwater areas of England.

5.9.2 Toxic and persistent chemicals

Consultation feedback included a proposal for including assessment of chemicals from the H4 indicator. Currently the ecotoxicological effects of chemicals are addressed through the biological metrics included in the chemical component of naturalness. More direct portrayal of chemicals in B6 (across all habitat components not just rivers and streams) would provide greater profile to chemical pollution, but the approach needs some thought.

A key issue would be the basis for standards in the H4 indicator. There has been a strategic shift towards setting chemical environmental standards based on human health risks rather than biodiversity risks, which has resulted in a tightening of many standards in ways that might not be as relevant to ecosystem naturalness. This is not necessarily a problem, since the H4 indicator still provides a form of sliding scale of naturalness of chemical status, but it would be important to understand that the relationship with standards is not the same across B6 and H4. An alternative approach would be to re-process the chemicals data for use in B6, to provide a sliding scale of chemical concentrations. This would be less anchored in specific standards and potentially provide more sensitivity to reductions in chemical concentrations towards standards.

A further issue would be the representativeness of the chemicals surveillance programme across the freshwater habitat resource. This would need investigating to understand the extent to which a representative picture could be provided of principle habitat types (rivers, streams as well as lakes, ponds, estuaries and coastal waters).as well as sub-types (e.g. chalk rivers, oligotrophic lakes).

5.9.3 Fine sediment delivery/siltation

Consultation feedback highlighted that there was no specific consideration of artificially enhanced fine sediment delivery. This has always been a problem in freshwater habitat assessment. There is conflation of enhanced fine sediment delivery (from the catchment and from excessive bank erosion) and fine sediment deposition (which may be a result of physical degradation of the channel such as over-sizing and impoundment). There is also an issue which what constitutes natural reference conditions in relation to both delivery and deposition. In UK Common Standards guidance for assessing the condition of SSSI/SAC rivers, observations of surface siltation of the channel from RHS survey are used. Since representative RHS survey sites form a fundamental part of the B6 data framework the same approach could be employed here, generating a 5-class classification based on the severity of surface siltation. Alternatively, the EA has a specific macroinvertebrate index for assessing levels of siltation, which could be included in B6 if macroinvertebrate data from EA river and stream surveillance programmes can be processed to provided values.

5.9.4 Headwater streamflows

Currently the assessment of hydrological naturalness for headwater streams only includes impacts on groundwater flows. Consultation feedback included a suggestion to include an attribute to assess above-ground hydrological modifications to surface flows, such as cross-contour catch-drains which gather up stream flows from a landscape and divert water into reservoirs. The EA's WRMS is focused on providing information on points further down the catchment and there is no other data set that can provide suitable information.

As part of cross-cutting biodiversity work within Natural England, proposals have been made to generate a broad assessment of naturalness of function across both the terrestrial and freshwater environments (Natural England 2021), which include the assessment of modifications to headwater hydrology. This type of approach could be structured according to the spatial framework used for headwater catchments in the B6 data framework. This is something to consider as part of the further development of representative surveillance networks in NE and EA. An alternative approach is to make use of the river/stream naturalness assessment that forms part of the FBA/Natural England citizen science initiative - see this data portal for details of the method and data capture. The physical component of that assessment method is already included in the B6 data framework (see Table 5.1).

5.9.5 Riparian trees

The potential use of LIDAR in evaluating the naturalness of riparian tree cover was raised by the 2021 consultation. This is currently covered by representative RHS survey in the B6 data framework but there is potential to include a 'whole-inventory' attribute using LIDAR. It would only cover part of the function of the current RHS attribute, which includes consideration of the level of interaction between riparian trees and the river/stream channel.

5.9.6 Riparian plant species diversity

The new Natural England ecosystem survey includes representative botanical plots of the riparian zone, which might be brought into B6 as an attribute. Species diversity and richness indicators have a complicated relationship with naturalness and natural function, but for the purposes of B6 it can be broadly assumed that floristic diversity will increase with increased naturalness of the river and stream corridor, as riparian zones are re-wetted and vegetation controls are reduced to levels that mimic natural herbivory. The extent, distribution and nature of data emerging from the survey would have to be reviewed before making a decision.

5.10 Clarifying relevant river and stream types

Further consideration has been given to the detailed river and stream types that the B6 data framework should be aiming to assess and report on. In addition to types listed in the UK definition of priority river habitat, UK-level work on the predictive mapping of river/stream types (Mainstone *et al.* In Draft) has considered the extent to which we should also be looking to report against a holistic typology for international reporting purposes (this work relates to improving definitions of Favourable Conservation Status). The European Red List of habitats and broader IUCN reporting on threatened habitats both employ broad typologies of river and stream habitat, which need to be reflected in the B6 data structure.

Habitat types considered to be relevant are summarised in Table 5.3, which aims to place UK priority habitat types and Red List types in the most parsimonious framework possible. The left-hand column is intended to provide a holistic and non-overlapping typology based on hydraulics and geomorphology, broadly synonymous with the Red List typology. The right-hand column lists types that overlap with each other and the left hand column. The overlap between types is inevitable because many types considered to be a priority were not conceived within a holistic and non-overlapping typology. The existence of overlaps is somewhat confusing but not a technical problem, since any one stretch of river or stream can be assigned to multiple types and contribute to the assessment of each (or any combination).

Predictive modelling has so far produced digital maps of all of the types on the left-hand side of Table 5.3 and some of the types on the right-hand side. Figure 5.12 provides some examples of the map outputs. Further work is planned this year that will fill in the typological gaps. At the end of 2022/23 there will be a digital layer of rivers and streams labelled with relevant types that can be used to design and refine representative surveillance programmes and overlay on whole-inventory datasets in the B6 data framework to filter data and provide type-specific assessments and outputs.

Table 5.3 Relevant river/stream habitat types for biodiversity assessment and reporting purposes. European Red List types in red. Types listed in the UK definition of priority river habitat in green.

<table>
<tr><th>Key hydraulic/geomorphic typology
(holistic, non-overlapping)</th><th>Other types
(Overlapping)</th></tr>
<tr><td>High energy with boulders/cobbles (C2.2a)</td><td rowspan="6">Headwater streams (<2.5km from source, derived from the digital river network):
• Base-poor spring/spring brook (C2.1a)
• Calcareous spring/spring book (C2.1b)
• Other
Temporary streams and rivers (C2.5a) – generally headwater streams but can be small rivers
Habitats Directive H3260 (largely C2.2b)
Chalk rivers (largely a chalk subset of H3260)
Low, moderate and high alkalinity rivers streams (derived from modelled alkalinity data)</td></tr>
<tr><td>Bedrock channel (not in Red List typology)</td></tr>
<tr><td>High-moderate energy, very dynamic gravel substrate (Active shingle type - included in riparian component of Red List typology only)</td></tr>
<tr><td>Moderate energy dominated by largely stable gravels (C2.2b)</td></tr>
<tr><td>Low energy dominated by sand and silt (C2.3)</td></tr>
<tr><td>Tidally influenced river and stream sections (C2.4)</td></tr>
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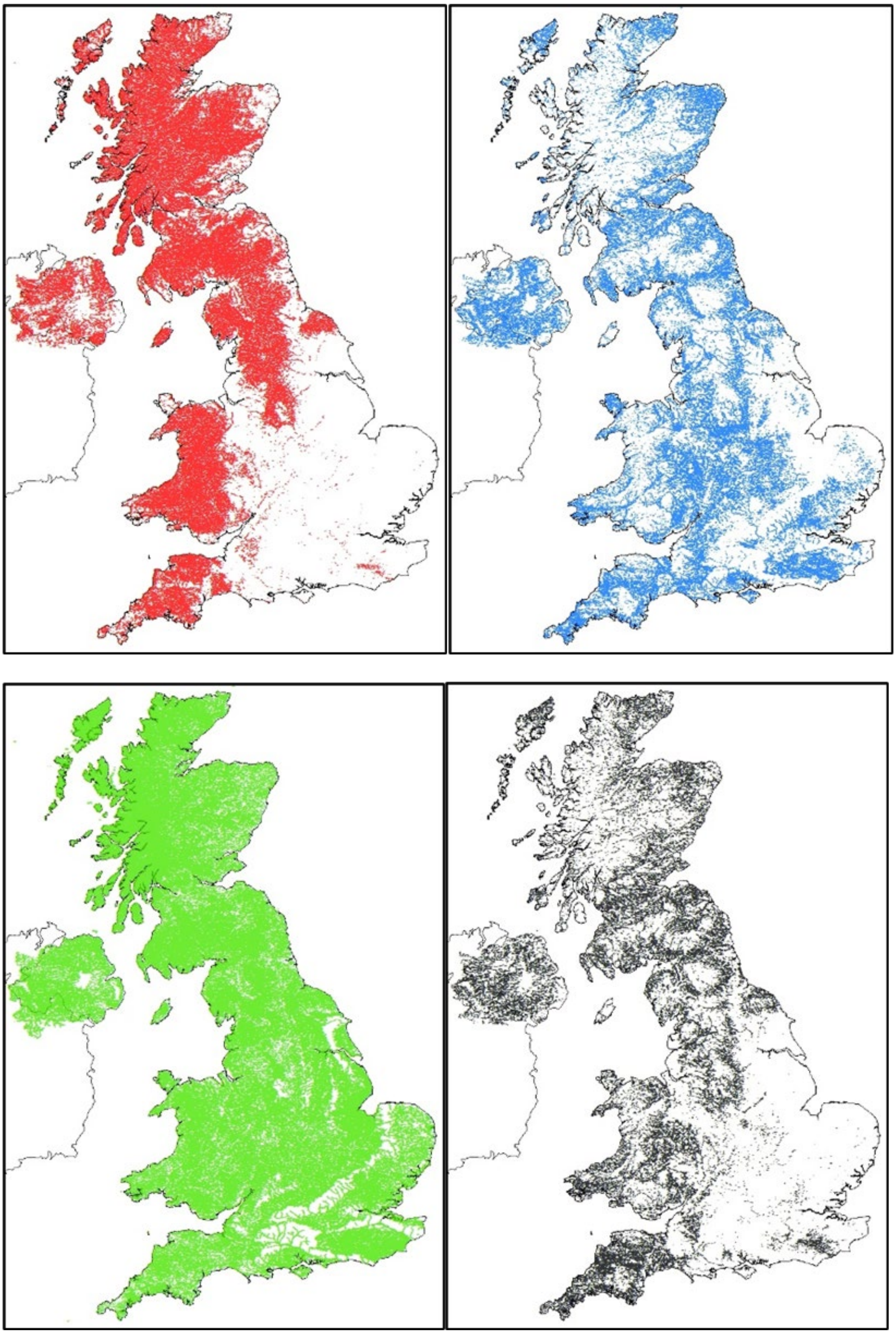


Figure 5.12 Distributions of 'most probable' river/stream type from UK predictive modelling (Mainstone et al. In draft). Top left, red - Red List type C2.2a; top right, blue - C2.2b; bottom left, green - C2.3; bottom right, black) - active shingle habitat.

6. Lakes and ponds

Work on lakes and ponds in 2021/22 focused on using existing data to populate the wheel diagrams. This work has further developed the thinking of how the data can be best used to assess the attributes. The rationale for the attributes used is detailed in Report JP016 (Mainstone *et al*. 2018) and is not repeated here.

6.1 Lakes

A summary of the status of all lake attributes is presented in Table 6.1 whilst the current version of the wheel diagram for lakes is shown in Figure 6.1. Data portrayal will be limited until data are available from the Environment Agency's new lake surveillance programme (part of the NCEA programme).

6.1.1 Lake hydrology component

Development of a suitable attribute assessment of the naturalness of the hydrological regime of lakes has not yet been possible due to a lack of data. There are no plans to increase lake hydrological monitoring through the NCEA. Consequently, the only remaining option is to investigate the possibility of using the data and models used to assess rivers. This will need to be investigated in 2022-23 but will only be possible for on-line lakes.

The height of water control structures on the outflows from lakes is considered under the physical component rather than the hydrological component because it is primarily a physical modification. However, since the effect of the modification largely relates to modifying the hydrological regime within the lake (the naturalness of inundation regime of marginal land, water depth, residence time), there is an argument for including it under the hydrological component. This situation is similar to the handling of flooding regime of rivers and streams.

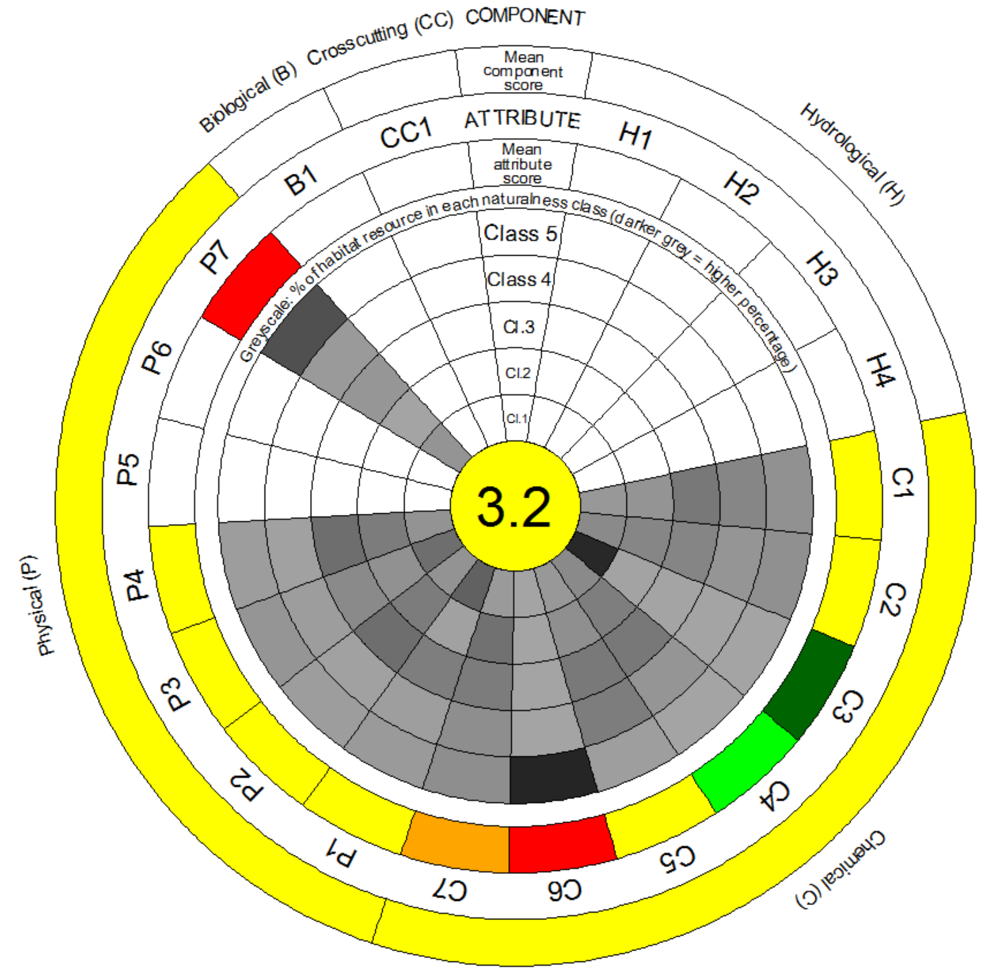
6.1.2 Lake chemical component (water quality)

Data on water quality will be collected via the NCEA in the future but this programme of monitoring is not yet operational. Consequently, the most recent WFD monitoring dataset (2019) has been used to populate the wheel diagram for these attributes. There is a direct read across between the WFD five-class system and the five naturalness classes used in the wheel diagram. The exception to this is for the fish eDNA tool where the bad and poor classes cannot be distinguished from one another, hence there is no distinction between class 4 and 5 in the wheel diagram for this indicator.

Table 6.1 Summary of the status of lake attributes. Green – ready; Amber – nearly ready; Red – requires significant further work. Purple- No assessment is possible until new Environment Agency surveillance data are available.

Naturalness component	Attributes	Data Source	Data model	Current status	Current status of process for data updates
Hydrological	Deviation from naturalised flow on the lake outflow	EA	Likely to be online lakes only	Attribute needs further development.	Data transfer protocol required
Chemical (water quality)	Total Phosphorus	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	Total Nitrogen	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	ANC	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	Chlorophyll	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	Macrophytes and diatoms	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	Chemicals	EA lakes monitoring	Representative sampling	Currently completed using 2019 wfd data new data should become available through NCEA roll out.	New data transfer protocol required
	Fish e-DNA	EA lakes monitoring	Representative sampling	Currently completed using eDNA tool development data new data should become available through NCEA roll out.	New data transfer protocol required
Physical	Hydrological structures	EA	Representative sampling	Currently completed using old LHS data new data should become available through NCEA roll out.	New data transfer protocol required
	Artificial shoreline	EA	Representative sampling	Currently completed using old LHS data new data should become available through NCEA roll out.	New data transfer protocol required

Naturalness component	Attributes	Data Source	Data model	Current status	Current status of process for data updates
	Non-natural sediment fluxes	EA	Representative sampling	Complete using old LHS data. New data should become available through NCEA roll out.	New data transfer protocol required
	Semi-natural riparian habitat	EA	Representative sampling	Complete using old LHS data. New data should become available through NCEA roll out.	New data transfer protocol required
	Riparian trees	EA	Representative sampling	Sufficient data not currently collected or planned to be collected. Continue to investigate if this can be included in NCEA.	If data become available a new data transfer protocol will be required
	FBA naturalness assessment	FBA	Would require representative sub-sampling of database	Insufficient surveys to currently use this data. Using NCEA data would be more robust as long as it can deliver all physical naturalness components	Simple to arrange if needed via partnership project between NE and FBA.
	Presence of a marginal fringe of emergent vegetation	EA	Representative sampling	Nearly completed using old LHS data new data should become available through NCEA roll out. It would be beneficial to influence the precise nature of what is monitored through NCEA	New data transfer protocol required
Biological	Non-native species	GB Non-native species information portal and associated data sources	Whole inventory but patchy – predictive modelling used to gap-fill	Analytical approach agreed.	Data transfer protocol being agreed.
Cross cutting	Landscape connectivity - Number of lakes	Unclear possibly Living England	Whole Inventory	Needs discussion with Living England team	



Attribute codes

H1 Naturalness of flow at lake outflow
C1 Total Phosphorus
C2 Total Nitrogen
C3 ANC
C4 Chloropyll
C5 Macrophytes and diatoms
C6 Chemicals
C7 Fish e-DNA
P1 Hydrological structures
P2 Artificial shoreline
P3 Sediment fluxes
P4 Riparian habitat
P5 Riparian trees
P6 FBA naturalness assessment (physical)
P7 Marginal fringe emergent vegetation
B1Non-native species
CC1 Landscaoe connectivity – number of lakes

Figure 6.1 Wheel diagram for lakes. Inner grey-scale rings indicate the proportion of the habitat resource in each naturalness class – darker grey = more of the habitat resource. Colouring of naturalness classes – dark green – Class 1 (highly natural); light green = Class 2; yellow = Class 3; orange = Class 4; red = Class 5 (highly un-natural). White cells indicate no assessment yet made.

6.1.3 Lake physical component

Preamble

The data for this component come largely from Lake Habitat Surveys (LHS) last undertaken in 2012. Future surveys are planned through the NCEA which will create a more up-to-date picture of the physical component of lake habitat. The LHS does not provide all the data that are required to assess the attributes in this component. Where the LHS method could be modified in a simple fashion to collect appropriate data it is highlighted in the following sections. It is hoped that these modifications can be incorporated into the NCEA lake monitoring programme led by the Environment Agency, although technical discussions have not yet taken place about this.

Hydrological structures

Within LHS the presence of a range of structures are recorded. An estimate of the maximum height from the bed to top of principal retaining structure is also recorded. The attribute is assessed by combining these 2 pieces of information as described in Table 6.2

Table 6.2 Naturalness classification of hydrological structures for lakes.

Class	Structure type/ height
Class 1	No structures
Class 2	Small structure <50cm
Class3	Structure 50cm-1m
Class 4	Structure 1m+
Class 5	Water level control structure (no fish pass) 1m+

For some of the 2012 LHS surveys the height of the structure was recorded but not its presence. Desk-based site-checking found that this was an omission by the surveyors and the heights were used. More problematic was where a structure was recorded but not height. In order to populate the wheel diagram such sites were assigned to class 3, but in the future it is important to ensure these data are collected through the NCEA. There was no obvious reason why this was omitted from some LHS surveys.

Artificial shoreline

LHS records the extent of artificial bank construction across multiple perimeter sections that cover at least seventy-five percent of the shoreline. The extent of artificial bank construction along the shoreline is summed and weighted based on the length of the shoreline section surveyed. Naturalness class values are assigned to percentage values of artificial shoreline as in Table 6.3.

Table 6.3 Naturalness classification of lake shoreline.

Class	% artificial shoreline
1	0%
2	≥0 ≤5 %
3	>5 ≤33.3 %
4	>33.3 ≤ 66.7 %
5	>66.7 ≤ 100 %

Non-natural sediment fluxes

The presence of signs of sedimentation or depositional imbalances are recorded in LHS and are used to assess this attribute using the classification in Table 6.4.

Table 6.4 Classification of naturalness of sediment fluxes for lakes.

Class	Evidence of artificial sediment flux
1	<5 % of shore affected by erosion AND signs of sedimentation or depositional imbalance recorded at < 2 Hab-plots AND sedimentation over natural substrate recorded at < 2 Hab-plots
2	≥ 5% < 20 % of shore affected by erosion OR signs of sedimentation or depositional imbalance recorded at 2 Hab-plots OR sedimentation over natural substrate recorded at 2 Hab-plots
3	≥ 20% < 40 % of shore affected by erosion signs of sedimentation or depositional imbalance recorded at 3-4 Hab-plots OR sedimentation over natural substrate recorded at 3-4 Hab-plots
4	≥ 40% < 60 % of shore affected by erosion OR signs of sedimentation or depositional imbalance recorded at 4-6 Hab-plots OR sedimentation over natural substrate recorded at 4-6 Hab-plots
5	≥ 60 % of shore affected by erosion OR signs of sedimentation or depositional imbalance recorded at >6 Hab-plots OR sedimentation over natural substrate recorded at >6 Hab-plots

Semi-natural riparian habitat

LHS includes data on riparian land cover 15 metres from the lake edge, which is used to assess naturalness based on the class boundaries in Table 6.5.

Table 6.5 Semi-natural riparian habitat classification for lakes. Semi-natural includes wet woodland/carr, bog, fen or marsh, broadleaf mixed woodland, scrub and shrubs, moorland heath, open water, rough grassland, tall herb rank vegetation, rock/scree or dunes.

Class	Riparian land use 15m from lake edge
1	Riparian land is all semi-natural.
2	Riparian land is predominantly semi-natural (90%).
3	Riparian land semi-natural for at least 2/3 of its extent
4	Riparian land semi-natural for at least 1/3 of its extent
5	Riparian land semi-natural for less than 1/3 of its extent

Riparian Trees

LHS collects data on the presence of trees from approximately 10 hab-plots per lake, which are 15m wide so can represent only a small fraction of the shoreline. LHS does record the presence of woodland in the riparian zone but this does not include the occurrence of riparian trees outside woodlands. LiDAR could potentially be used to identify where trees surround lakes, but there is no intention of regularly updating this information. Consequently, there are no data currently available to assess this attribute. An assessment of the percentage of perimeter of the lake with riparian trees could relatively easily be incorporated in LHS, which records other attributes for the lake perimeter.

Marginal fringe of emergent vegetation

The ambition for this metric is to record the extent of emergent vegetation as a percentage of the lake perimeter, but this is not recorded at present as part of LHS. The presence of certain types of emergent vegetation are currently recorded in LHS, particularly reed beds and floating vegetation mats, but this excludes other emergent vegetation particularly those found in more nutrient-poor water bodies (such as *Eleocharis* and *Equisetum)*. Consequently, at present only eutrophic and mesotrophic lakes are assessable using the data available from LHS. Discussions are needed to incorporate measurement of all marginal emergent vegetation types (as a percentage of lake perimeter) within the NCEA lake survey method.

It is not expected that lakes would necessarily have emergent vegetation around their entire perimeter, as this can naturally be limited by factors such as exposure, substrate and lake profile. To take this into account lakes with more than 40% of their perimeter supporting emergent vegetation are assigned to Class 1 (see Table 6.6). Whilst some lakes will support a significantly more expansive emergent fringe than this, the class boundaries ensure lake-wide pressures are not causing significant declines.

To allow this attribute to be included in the wheel diagram for lakes, oligotrophic lakes have been removed from the current LHS data and assessment has been undertaken on mesotrophic and eutrophic lakes only. This creates a known bias in the data but the wheel diagram is only for illustrative purposes at this stage.

Table 6.6 Naturalness classification of marginal fringing emergent vegetation.

Class	% of perimeter supporting emergent marginal fringing vegetation
1	40% +
2	>30<40%
3	>20-<30%
4	>10<20%
5	<10%

6.1.4 Lake biological component

The invasive non-native species attribute has not progressed this year and will be taken forward in 2022-23 in conjunction with parallel attributes on rivers, streams and ponds.

6.1.5 Lake landscape connectivity

Traditionally, it has been suggested that the number of lakes changes very little over time but new work on the GB Lakes database for the NCEA has revealed greater changes than expected. This change in perception is at least partly due to the consideration of changes in the number of artificial lake water bodies. It would appear logical that information on the number of lakes could be gained from earth observation, but this has yet to be discussed with Natural England's Earth Observation Team. The Living England dataset currently only identifies water rather than lakes specifically. This needs to be further investigated in the next phase of B6 development.

6.2 Ponds

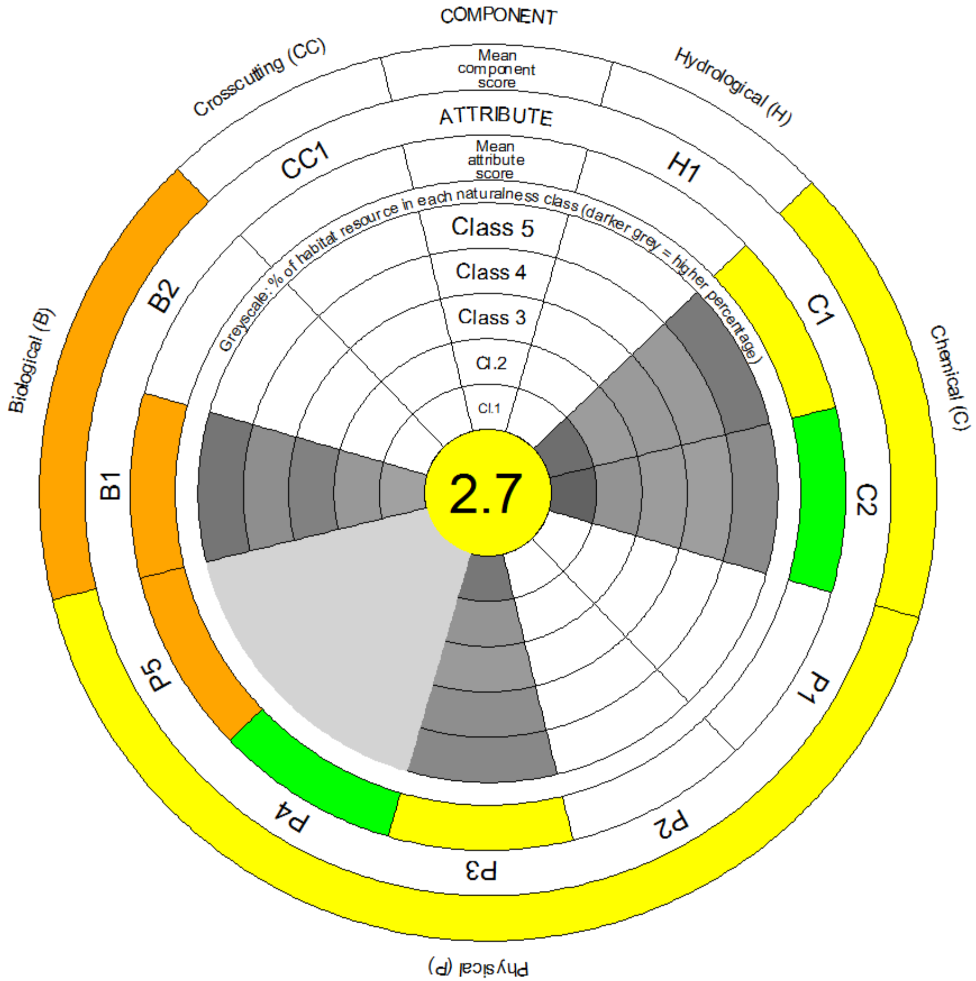
6.2.1 Preamble

Data on ponds will be collected through the NCEA in the future, but in order to illustrate the use of the attributes Countryside Survey data from 2007 has been used to populate the wheel diagrams where possible. A summary of the status of all pond attributes is presented in Table 6.7 whilst the current version of the wheel diagram for ponds is shown in Figure 6.2.

Table 6.7 Summary of the status of pond attributes. Green – ready; Amber – nearly ready; Red – requires significant further work. Purple- No further work until NCEA data are available

Naturalness component	Attributes	Data Source	Data model	Current status	Current status of process for data updates
Hydrological	Presence of artificial inflows and outflows or water control structures (H1)	NE NCEA	Representative sampling	Currently there is no data on this but it should be provided through the NCEA	From NE NCEA programme so no external data transfer required
Chemical (water quality)	Phosphate and nitrate	NE NCEA	Representative sampling	Currently completed using old Countryside Survey data, but the NCEA should provide data in the future.	From NE NCEA programme so no external data transfer required
	Acid Neutralising Capacity	Data will not be available so attribute has been deleted			
Physical	Natural pond base	NE NCEA	Representative sampling	Currently there is no data on this but it should be provided through the NCEA	From NE NCEA programme so no external data transfer required
	Natural shoreline	NE NCEA	Representative sampling	Currently there is no data on this but it should be provided through the NCEA	From NE NCEA programme so no external data transfer required
	Semi-natural land use 5m from pond edge	NE NCEA	Representative sampling	Nearly completed using old Countryside Survey data, but the NCEA should provide data in the future. Need to confirm the exact nature of NCEA data.	From NE NCEA programme so no external data transfer required
	Semi-natural land use 100m from pond edge	NE NCEA	Representative sampling	Not used	N/A
	Percentage of pond margin overhung or percentage of	NE NCEA	Representative sampling	Currently calculated using old Countryside Survey data, but the NCEA should provide data in	From NE NCEA programme so no external data transfer required

Naturalness component	Attributes	Data Source	Data model	Current status	Current status of process for data updates
	perimeter shaded			the future. Contractor needs to finish this work	
	Grazing intensity score	NE NCEA	Representative sampling	Currently completed using old Countryside Survey data, but the NCEA should provide data in the future..	From NE NCEA programme so no external data transfer required
Biological	PSYM score	NE NCEA	Representative sampling	Currently completed using old Countryside Survey data, but the NCEA should provide data in the future.	From NE NCEA programme so no external data transfer required
	Non-native species	GB Non-native species information portal and associated data sources	Whole inventory but patchy – predictive modelling used to gap-fill	Analytical approach agreed. Contractor to analyse processed data secured.	Data transfer protocol being agreed.
Cross-cutting	Landscape connectivity - Number of ponds	Citizen science FHT	Representative sampling	Citizen science programme being trialled this year	If citizen science initiative delivers it will need an agreed data transfer protocol



Attribute codes

H1 Artificial inflows/outflows/control structures
C1 Phosphate
C2 Nitrate
P1 Pond base
P2 Shoreline
P3 Riparian land use
P4 % perimeter overhung/shaded
P5 Grazing intensity
B1 PSYM score
B2 Non-native species
CC1 Landscape connectivity – number of ponds

Figure 6.2 Wheel diagram for ponds. Inner grey-scale rings indicate the proportion of the habitat resource in each naturalness class – darker grey = more of the habitat resource. Colouring of naturalness classes – dark green – Class 1 (highly natural); light green = Class 2; yellow = Class 3; orange = Class 4; red = Class 5 (highly un-natural). White cells indicate no assessment yet made. Solid light grey segments of inner wheels relate to attributes operating solely at the level of the whole habitat resource.

6.2.2 Pond hydrology component

The NCEA should provide these data, but until NCEA data are available no data interpretations are possible.

6.2.3 Pond chemical component

Data from Countryside Survey were used to classify ponds for nitrate and phosphate. Assessment of total phosphorous and total nitrogen would be preferable in standing waters because substantial amounts of nutrients are locked up in biomass (particularly in the growth season). However, Countryside Survey data only include nitrate and phosphate and this is also likely to be the case with the NCEA due to practicality and cost considerations. This said, previous studies have shown that such data can give a reasonable impression of the water quality in ponds, particularly when used in conjunction with biological components that are included below.

6.2.4 Pond physical component

Shoreline and pond base

Shoreline and pond base data should be supplied by the NCEA but no NCEA data are currently unavailable. Until these data are collected this attribute cannot be progressed.

Riparian land use

Countryside Survey recorded riparian land use at 5 and 100 metres of the pond edge. Whilst the 5m data will provide an insight to the immediate surroundings, ponds can also be impacted by land use further away. In contrast land use 100m away will have less impact and is harder for surveyors to accurately assess. An alternative of looking at land use at 15m is suggested and needs to be discussed with the NCEA survey team. In the meantime, for the purpose of illustration the 5m riparian land use data has been used.

Grazing and shading

Grazing intensity and shading have been found to have considerable impacts on ponds and have been highlighted in recent declines. However, there is not a simple relationship where a single level of grazing or shading will lead to good quality ponds. Instead, for biodiversity to thrive a variety of levels of grazing and shading are required across the pond resource.

Ensuring a range of grazing and shading requires a different approach to assessing attributes as it is not individual ponds that are assigned a class but the pond resource as a whole, which is assessed on the distribution of shading and grazing levels across the resource. In order to do this an ideal distribution of shading and grazing levels has been produced based on the literature and expert opinion on ponds in England. The further the current distribution of grazing and shading levels are from this ideal the lower the class score.

As this provides a single class for the whole pond resource for these two attributes they cannot be visualised in the same way as other attributes in the wheel diagram. The inner grey-scale wheels will need to be left blank but values can be generate for the mean attribute score, which will feed into the physical component score and the overall naturalness score.

The production of an ideal distribution of shading and grazing relies on knowledge of the current trends in pond condition in relation to grazing and shading and knowledge of the current distribution of levels of shading and grazing. For example we know that a loss of grazing can lead to a decline in pond quality, but that excessive levels of grazing could also lead to decline. So using the distribution of grazing intensity from Countryside Survey data from 2007 the ideal would be to increase the amount of light to moderately grazed ponds and reduce the number of non-grazed and heavily grazed ponds.

As data will be provided from the NCEA rather than Countryside Survey in the future there is a risk that that these figures will no longer represent the ideal distribution due to differences in the sampling design between the NCEA and Countryside Survey. As the NCEA sampling design becomes clear and the first data are collected the ideal distribution may need to be refined to take account of this.

6.2.5 Pond Biological Component

The PSYM scores created from Countryside Survey data were used for this component as described in Report JP016 (Mainstone *et al.* 2018).

The non-native species attribute will be progressed in 2022-23 as part of development work on non-native species attributes for all freshwater habitat components.

6.2.6 Pond Landscape Connectivity Component

An NCEA pilot citizen science project is currently underway to assess methods of collecting suitable data for this attribute. The results will be considered in the next stage of B6 development.

7. Freshwater wetlands

7.1 Preamble

The development of this component of B6 is strongly linked to the development of the D1 indicator. Owing to the agreed lead role of the D1 indicator on wetlands there has so far been no explicit work undertaken as part of B6. This section discusses wetland habitats from a B6 perspective, drawing on D1 indicator work and providing some strategic thinking to provide a foundation for making progress in 2022/23.

7.2 Scope of habitat resource

In line with Section 2, the general approach to the B6 data framework is to evaluate the existing wetland habitat resource rather than the wider historical extent of natural wetlands that has been lost to drainage and land development. This would include any locations that can be considered examples of recognised wetland types (see Section 7.3) but are artificially supported by water supply or water level management. Wetlands specifically constructed to assimilate nutrient pollution would not be considered within scope because their primary purpose involves artificially enriching the wetland, which has a detrimental effect on wetland ecosystems and limits ecological and biodiversity potential.

7.3 Wetland classification

Current definitions of priority habitats and other wetland habitat typologies (Habitats Directive Annex I, UKHAB) are not ecologically coherent and often overlap. As part of Natural England work to better define Favourable Conservation Status, attempts are currently being made to generate an ecologically coherent wetland habitat classification, upon which existing types can be superimposed to characterise their relationship (Figure 7.1). As with rivers and streams (see Section 5.10), the B6 data framework will need to consider both an ecologically coherent typology and additional wetland types requiring discrete consideration.

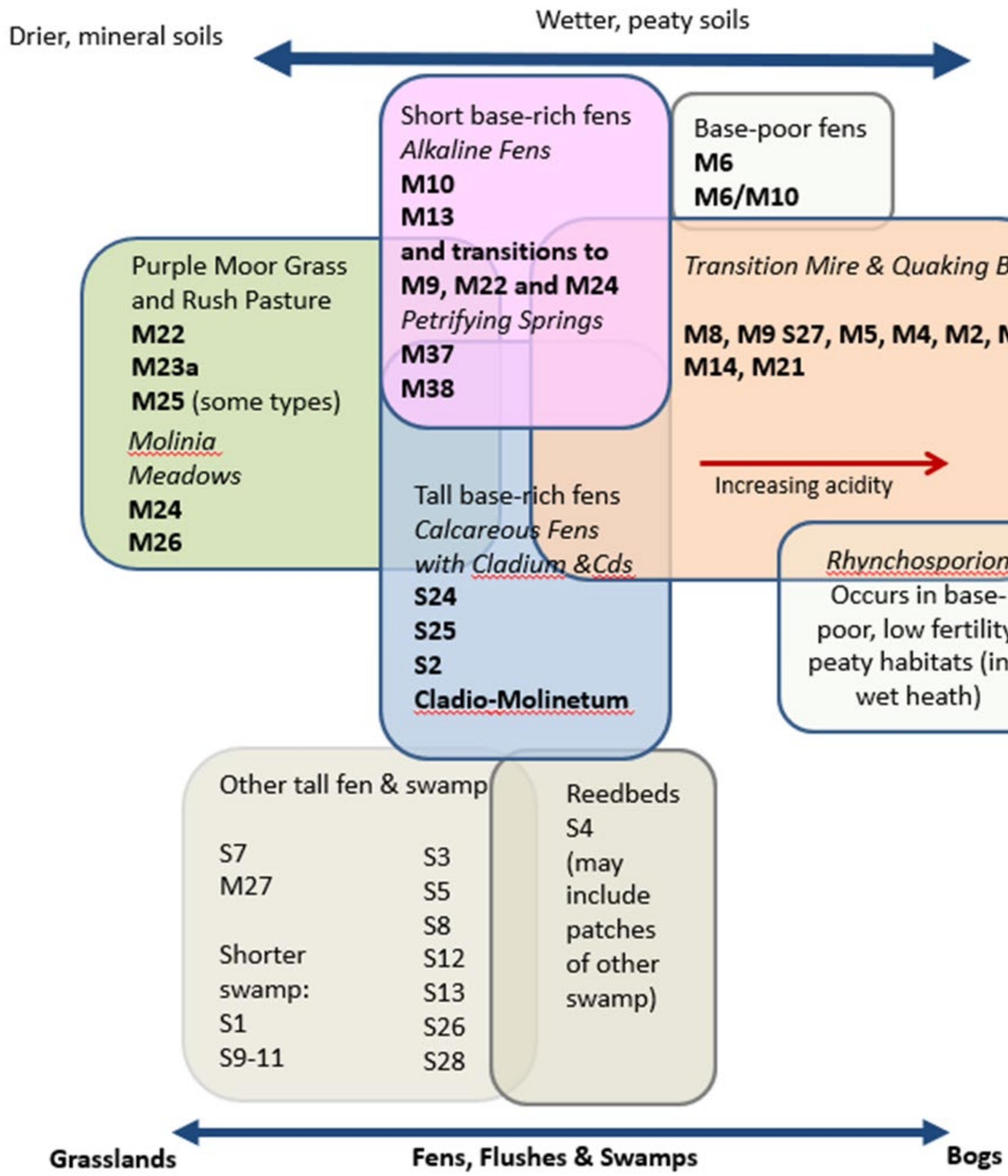


Figure 7.1 Relationships between habitats and NVC communities categorised as minerotrophic wetland habitats of principal importance for the conservation of biodiversity. Annex 1 habitats are shown in italics. Overlaps between habitats illustrate the relationships between habitats and the decision making sequence for allocating patches of vegetation supporting *Cladium mariscus* to Annex 1 habitat categories. See https://jncc.gov.uk/our-work/nvc/ for more information about NVC communities.

7.4 Attributes

The attributes used for wetlands in B6 will be a combination of attributes being developed in D1 indicator work, water-related attributes developed for non-wetland components of B6 that are of relevance, and other sources. It is still unclear where the relationship between D1 and B6 on wetland habitats will end up, but it anticipated that there will be some injection of B6 attributes and thinking back into D1 before the D1 indicator is finalised.

A collated list of potential attributes for wetlands in B6 is provided in Table 7.1, drawing on D1 work and B6 work on other habitat components and identifying potential gaps where needed.

Table 7.1 Provisional attribute table for the wetland component of B6, drawing on current D1 and B6 attributes and other potential sources. Structured by the four B6 key naturalness components but with notes on links to the five pillars of natural function used in D1.

Wetland naturalness component	Attributes	B6/D1 or other description	Comments
Hydrological (NEF Pillar 1)	Surface water delivery	Flow regime – deviations from naturalised flows. Larger rivers only- from EA Water Resources GIS	For all sub-catchments in England. Not strongly related to natural wetland function because of local complexity in natural water delivery mechanisms to wetland habitats..
		Surface water modifications to headwater stream flows	To evaluate upstream catch drains affecting water delivery. Suggested for the stream element of B6 but not included as yet. Included as an attribute in proposals for a cross-habitat method for assessing naturalness of ecosystem function (Natural England IBA project 2020)
	Groundwater inputs	Groundwater inputs to headwater steams – from EA groundwater monitoring and modelling	Coverage of most exploited aquifers in England. Will indicate impacts on water delivery to spring-fed wetlands.
		Floodplain upwelling feeding raised bogs	No known monitoring or assessment to draw on. Perhaps groundwater inputs to headwater streams provide a reasonable indication.
	Floodplain function	River flooding regime - Separate assessments of headwater streams and larger rivers. Based on extent of flood embankments affecting natural flooding of floodplain	Complete LIDAR dataset of floodplain relief showing all flood embankments. No ability to model effect on natural floodplain inundation.Looking at logging change (removal of embankments) to generate time series. Need to consider relationship with Floodplain Wetland Mosaic mapping outputs
	Drainage	There was an intention to address this in D1 –current status needs checking	Whole inventory - Possibly included in the national peat map work? May need bespoke work as part of NE NCEA. Representative surveying - drainage included in EES survey method as per IBA paper on naturalness assessment so should be able to pull in data from there as a minimum. NB if drainage at a surveyed location is efficient the wetland habitat will be lost and the site will be categorised as a dry habitat type.
Chemical (water quality) (NEF Pillar 2)	Groundwaters: Phosphorus Nitrogen	EA water quality surveillance monitoring of WFD groundwater-dependent terrestrial ecosystems (GWDTEs)	Need liaison with EA groundwater monitoring staff. Issues around spatial coverage/relevance to wetland locations, parameters monitored. Water quality monitoring of springs or just aquifers?

Wetland naturalness component	Attributes	B6/D1 or other description	Comments
		Vegetative indicators of enrichment	Unclear how D1 attribute will relate to unimpacted reference conditions, i.e. which species would be present if the wetland were functioning naturally? Irrespective of this vegetative indicators should still provide indications of heavy enrichment even if th natural trophic state of a site is not clear.
	Surface waters: Ammonia Dissolved oxygen Phosphorus Nitrogen pH	Representative sampling from EA surveillance network of surface waters. Separate assessments for rivers, streams and lakes.	Sampling design limits usefulness for wetlands. Really needs bespoke wetland sampling programme to properly tie water quality data to wetland systems.
Physical	Water level control structures (NEF Pillar 3)	In-river/stream structures are assessed separately for headwater streams and rivers, as well as structures affecting lakes. Uses a national structures dataset updated via a CaBA citizen science app	The specific attributes for rivers, streams and lakes will be too coarse for wetlands – a more spatially explicit approach is required. The national structures data set could be explored to see if it could be used to identify where river/stream/lake-related wetlands are propped up by impounded water levels.
		Coverage of water level management plans	There is probably a spatial layer of areas covered by water level management plans which would highlight the major areas affected by water level control structures. Not sure if it would be updated for any withdrawals of areas subject to plans so might not work as an updateable attribute.
	Vegetation management (NEF Pillar 4)	D1 uses a vegetative indicator of management intensity	Should be able to use the data directly in D1 form.
Biological	Non-native species (NEF Pillar 5)	Weighted score based on occurrence of non-native species of different impact categories. Being generated for rivers, streams, lakes and ponds.	Intending to use processed BRC/NBN species records resolved into a 2m grid and modelled to address variations in recorder effort. Based on WFD UK TAG lists of water-related non-native species, which include wetland species. The approach could be extended to wetlands.
General	Missing species	Assessment of wetland species that should be present but are missing due to impacts on one or more component of natural function above (i.e. hydrological, chemical, physical or direct biological modifications)	No tools exist for undertaking this sort of assessment. Comparison of historical and modern records might provide a suitable approach.

7.5 Spatial aggregation of naturalness data

As with other habitats/ecosystems within the B6 data framework, data need to be aggregated into spatial units to provide an assessment of the distribution of the habitat resource across the naturalness spectrum. Wetland habitats are rather more variable than freshwater habitats in terms of the ease with which spatial units can be delineated. Small discrete wetland areas can form their own units and can be assigned to different habitat types and naturalness classes, but larger areas with significant spatial variation in naturalness really need to be sub-divided, particularly where they comprise different wetland habitat types that require bespoke assessment and reporting. This is less of an issue for representative surveillance monitoring programmes where a habitat resource assessment can be achieved by looking at the distribution of monitoring sites across naturalness classes. However, the B6 data framework is a mixed data model, including spatial datasets that provide an assessment of the whole habitat resource.

With lakes and pond, the spatial aggregation unit is generally the lake or the pond and the distribution of the habitat resource across naturalness classes is provided by the proportion of lakes or ponds in each class. With rivers and streams, WFD waterbodies and waterbody catchments provide the principle spatial aggregation units. The digital spatial layers that map rivers, streams, lakes and even ponds are good and comprehensive. The Priority Habitat Inventory (PHI) provides the most coherent spatial representation of the occurrence of different wetland habitat types that we have, although it is known to be very patchy in its coverage of at least certain wetland types.

Ultimately, the approach to spatial aggregation of data on wetland naturalness will vary between attributes, depending on the nature of the dataset. For digital datasets with whole-inventory coverage, the overlay of PHI layers will discretise the habitat inventory by naturalness class and so provides a flexible spatial aggregation framework. Where appropriate, it may be pragmatic to ‘borrow’ the WFD waterbody catchment framework used for rivers and streams (overlaying it on the wetland PHI) to provide an added layer of spatial aggregation, which would have the benefit of providing more linked assessment

8. Estuaries and coasts

8.1 Preamble

Work has focussed on developing a list of indicator attributes that would together form a robust assessment of the level of natural function. The provisional list of attributes is summarised in Table 8.1, comprising attributes that parallel the rivers and streams element as well as other potentially suitable attributes identified through a review of available data products within English estuaries and coasts. Datasets considered include data collected by the Environment Agency as well as attributes and associated datasets developed by Natural England's marine Conservation Advice project.

A summary of current thinking on different attributes is provided in the following sub-sections. Generally, availability of coherent data sets is an issue and the development of the B6 estuaries and coasts element may mean that more comprehensive monitoring is required in future. The datasets likely to emerge from reformulated Environment Agency and related surveillance programmes of estuaries and coasts need to be reviewed to make sure they are built in to B6 development. Further detail on B6 attributes for estuaries and coasts can be found in the separate feasibility study (Bleach 2022).

Table 8.1 Attributes recommended for inclusion in the B6 estuaries and coasts element (from Bleach 2022)

Naturalness component	Attributes	Data availability	Comment
Hydrological	Freshwater flows	Data has not yet currently been sourced; this will be further investigated in the next stage.	Potential this may still be included in the B6 indicator.
Physical	Obstacles	Environment Agency maintains dataset of obstacles to flow. All data obtained.	This is likely to be scored on the basic of No. of obstacles per water body.
	Coastal protection	Environment Agency maintain a number of datasets that will be combined to provide data for this attribute (NCERM and Flood Risk Zone 3). All data obtained.	Scoring is likely to consider the presence of a number of types of coastal defence and the risk of the areas behind defences to flooding.
	Built structures over the foreshore	OS MasterMap Topo layer with GIS calculation of man-made areas. Latest MasterMap layer will be obtained just prior to commencing the next phase of work, as updated every 6 weeks.	Scoring is likely to include a calculation of percentage of foreshore area taken up by man-made structures, within each water body.
	Fishing activity	To use Fishermap as a proof of concept, as no currently available thorough dataset. It is envisaged this will not be suitable for subsequent assessment stages. Fishermap data obtained.	Will likely calculate levels based on most damaging activity (dredging) and then add on a number of subsequent fishing activities, in descending levels of likely disturbance. Will likely include demersal fishing, potting and also aquaculture areas.

Naturalness component	Attributes	Data availability	Comment
		Data also obtained on aquaculture in English waters.	
	Combined licenced/unlicenced activities	Number of datasets that are obtained from both MMO and TCE. All data obtained.	Scoring will be confirmed during the next stages. This could include cables, aggregate extraction and disposal, wind farms etc.
Chemical (water quality)	Synthetic and toxic chemicals	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring likely be a direct derivative from the WFD classification, but may be grouped or scored differently.
	Dissolved Oxygen (DO)	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring likely be a direct derivative from the WFD classification, but may be grouped or scored differently.
	Dissolved Inorganic Nitrogen (DIN)	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring likely be a direct derivative from the WFD classification, but may be grouped or scored differently.
	Opportunistic macroalgae	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring likely be a direct derivative from the WFD classification, but may be grouped or scored differently.
Biological	Infaunal Quality Index (IQI)	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring likely be a direct derivative from the WFD classification, but may be grouped or scored differently.
	INNS	Requires species records collated via the National Biodiversity Network. Data will be obtained in the next stage.	Scoring will be derived from the No. of INNS that are present within a water body.
	Saltmarsh	Data entirely from Environment Agency WFD dataset. All data obtained.	Scoring for the saltmarsh attribute will be a combination of data assessment for WFD by the Environment Agency, looking at historic coverage and the No. of saltmarsh types present.
Other	Anthropogenic light	CPRE dataset has been obtained for this first assessment.	Scoring will be confirmed during the next stages. Will likely calculate levels that fall within each water body as an average of levels throughout the water body.
	Underwater noise	Combination of data from impulse noise (JNCC noise register) continuous shipping noise (Cefas) and consideration of low-level noise from windfarms. All data required has been successfully obtained.	Scoring will be confirmed during the next stages. Will likely calculate contribution from impulse noise first, then add noise generated by shipping and lastly some low-level generated by windfarms.

8.2 Hydrological naturalness component

As with the rivers elements of B6, deviations from what would be considered natural flow, based on a modelled dataset of natural flows, between seasons was highlighted for potential inclusion as an attribute for estuaries and coasts. However, obtaining suitable data to assess this attribute has been difficult for these habitats. In addition, in order to detect deviations, there is the need to obtain data on observed flows to compare with modelled natural flows. Flow data may be downloaded from the National Rivers Flow Archive (NRFA: CEH) or from the Environment Agency's WRMS but this will not provide information on flows into all transitional waterbodies. There would also be difficulties in determining flows from one transitional part of an estuary. Coastal water bodies have very little flow information for direct freshwater input. Therefore, the flow attribute will need further investigation, including spatial filtering of the EA WRMS data secured for the river attribute on flow regime (see Section 5). A judgement will have to be made about whether there is sufficient data to support the inclusion of freshwater flow regime as an attribute for estuaries and coasts, The EA WRMS data is probably the best option available but if used it will be important to highlight the limitations of the approach.

8.3 Physical naturalness component

8.3.1 Obstacles

The presence of any man-made obstacles is an unnatural feature that will, in some way, block movement of material (sediment/water) or animals towards the marine environment, or back from the marine into the freshwater environment. The dataset on in-channel structures in rivers and streams available on the CaBA website is relevant to the estuaries/coasts element of B6. It includes information on both natural and man-made obstacles but only the latter are relevant to B6. Obstacles are associated with most coastal water bodies, but they are generally more prevalent in estuaries. The actual scoring for this attribute will be fully developed in the next stage. It is currently envisaged that the B6 indicator will use a simplified count of obstacles per water body. An example of scoring is provided below:

- 0 obstacles = 1 (most natural);
- 1-5 obstacles = 2;
- 6-10 obstacles = 3;
- 11-15 obstacles = 4;
- More than 15 obstacles = 5 (most unnatural).

8.3.2 Coastal protection

Coastal defence structures can have a major impact on the natural expression of dynamic coastal and estuarine habitat mosaics and can also prevent estuarine and coastal ecosystems from adapting to climate change through natural processes by constraining the natural retreat of habitat zones landward. Coastal protection structures affect the ability of transitional and coastal water bodies to interact with their natural flood zone, but they also affect natural sediment erosion and deposition processes. They are therefore relevant to both hydrological and physical naturalness but for pragmatic reasons have been included under physical naturalness.

A number of datasets have been obtained from the Environment Agency, which will be used in combination to achieve a naturalness score relating to coastal and flood protection.

8.3.3 Built structures over the foreshore

The degree to which structures have encroached onto the shore has been investigated and is considered likely to be suitable as an attribute. It is possible to quantify the area taken up by structural components through direct measurement via area analysis of the Ordnance Survey's MasterMap Topography Layer. A benefit of using this dataset is that it is readily updated (every six weeks) and would allow for suitable change analysis, for example every 5 years that is envisaged for repeating the attribute scoring.

It is likely that the score will be derived from the percentage of built structure versus natural. However as this would not a representative for smaller transitional water bodies when compared to larger coastal sites, it is likely this will be calculated as a percentage of overall foreshore in each water body, as opposed to total water body area. An example scoring is provided below:

- 0-2.5% manmade area of total waterbody foreshore area = 1 (most natural);
- 2.5-5% manmade area of total waterbody foreshore area = 2;
- 5-7.5% manmade area of total waterbody foreshore area = 3;
- 7.5-10% manmade area of total waterbody foreshore area = 4;
- Over 10% manmade area of total waterbody foreshore area = 5 (most unnatural).

8.3.4 Fishing activity

One of the biggest impacts on marine areas is that associated with fishing activity. The type of fishing activity, its duration and frequency in a particular area will produce varying degrees of severity that could impact the naturalness of the area. For example, bottom trawling is generally the most impactful; it damages large areas of the seabed. Less physical impacts are associated with other forms of fishing, such as potting.

There is currently no data set that adequately shows fishing activity across all fishing vessels. The requirement for larger fishing vessels (over 12 m in length) to have a vessel monitoring system (VMS) means that vessels operating predominantly offshore, or at least beyond 1 nm, are monitored. Data have been sourced from the MMO from VMS tracked vessel effort.

The fishing effort in estuarine and coastal ecosystems is also made by many under 12 m vessels. As such the MMO data does not (currently) provide a suitable dataset that can be used for B6 attribute development. There are plans to introduce monitoring systems onto smaller vessels, which in combination with more digital recording of fishing kit usage and fishing times, will provide future datasets that are readily available and potentially suitable for the B6 indicator.

The scoring that will be applied to the fishing data is not yet developed, however is likely to represent a stacked data layer, that includes all fishing pressures that interact with the seabed in some way from the Fishermap dataset. This is likely to include the following three pressure layers:

- Dredging fishing;
- Demersal fishing; and,
- Pots fishing.

These layers are likely to be weighted in the order they are listed in the bullets above, with the dredging pressure layer having a higher weighting than the demersal layer, and the potting layer having the least weighting. This reflects the relative impact these fishing types are likely to have on the naturalness of the seabed.

Another impact associated with fishing activity is the ecological impact from direct removal of target and non-target species from the ecosystem. Again, it is expected that the level of impact would vary by the type of fishing activity with bottom trawling generally resulting in greater impact, particularly to non-target species. It is recommended that the removal of target and non-target species be considered for inclusion as an indicator under the biological naturalness component.

8.3.5 Combined licenced and unlicenced activity attribute

There are a number of activities that are licensable by The Crown Estate (TCE), as well as un-licensable activities, which have the potential to affect the naturalness of a particular area. A scoring system will be determined in the next stage, which will consider all of these licenced and unlicensed activities as one attribute. One of the main drivers for this is the fact that many activities are skewed in their location – for example offshore wind windfarms (a licensable activity) are presently more likely to be located on the east coast.

It is expected that the actual score will differ depending on the activity: all disposal sites areas would likely have a score of 5 (most unnatural), whereas cable routes for offshore renewables may only have an area score of 2 or 3. The relative areas of all of these activities will be summed and compared to the overall size of the water body in question. An overall score will be derived from the percentage of area that is covered with each of the contributing activities.

8.4 Chemical (water) naturalness component

8.4.1 Synthetic and toxic chemicals

An attribute that considers these chemicals is recommended for the estuaries and coasts element of B6. The Environment Agency regularly collect water samples from a number of estuarine and coastal water bodies as part of their monitoring for the purpose of fulfilling obligations under the Water Environment (Water Framework Directive) Regulations.

At present, monitoring is done on a risk basis, where water bodies that are more likely to change status are monitored more frequently. As such this is not currently a fully representative dataset for all estuaries and coasts. Changes in the way the Environment Agency undertakes surveillance monitoring should result in a more representative dataset, as is the case in rivers, streams and lakes.

The final scoring for water quality for the purpose of determining naturalness of estuaries and coasts will be developed in the next stage, however it is expected that this attribute will be scored on the same basis as chemicals reporting by the Environment Agency. Records of a large range of chemicals are grouped into a number of categories: 'Priority hazardous substances' (of which there are 24), 'Priority substances' (again, 24) and 'Other pollutants' (6). Priority Hazardous Substances and Priority Substances both have a pass/fail status, whereas Specific pollutants are either reported as high or moderate. As such an initial indication of scoring for water quality may be to consider the Specific pollutants (non-pass/fail) first, per water body:

- High Specific pollutants status = 1;
- Moderate Specific pollutants status = 2.
- Then to consider the pass/fail Priority Hazardous Substances status:
- Fail Priority Hazardous Substances = Add 2 to the Specific pollutants initial score of 1 or 2;
- Pass Priority Hazardous Substances = Add 0 to the Specific pollutants initial score of 1 or 2.
- Then consider the pass/fail Priority Substances status:
- Fail Priority Substances = Add 2 to the Specific pollutants and Priority Hazardous Substances score;
- Pass Priority Substances = Add 0 to the Specific pollutants and Priority Hazardous Substances score.
- The overall score from the calculation above could (at worst) total 6, however it will be capped to a score of 5.

As with freshwater habitats, there are links with Defra indicator H4 on chemicals that need to be recognised and considered.

8.4.2 Dissolved oxygen (DO)

The Environment Agency collects dissolved oxygen (DO) samples as part of regular monitoring of estuaries and coasts. DO is recorded on a five-point scale which can easily be transferred to a B6 attribute.

- High = 1 (most natural);
- Good = 2;
- Moderate = 3;
- Poor = 4;
- Fail = 5 (least natural).

However, DO is not recorded for all waterbodies and decisions will need to be made in the next stage about how to deal with water bodies that do not have direct monitoring and assessment. Some data gaps may be filled through interpolation between sample data points. Should this prove unsuitable there may be a reasonable argument to support the inclusion of monitoring at sites that are not currently monitored. Strategic monitoring reform is again relevant and may ensure data representativeness.

8.4.3 Dissolved Inorganic Nitrogen (DIN)

Nitrogen is a limiting nutrient factor within estuaries and coastal waters, and the Environment Agency collect dissolved inorganic nitrogen (DIN) samples as part of regular monitoring of estuaries and coasts. Nitrogen is recorded on a five-point scale which can easily be transferred to a B6 attribute.

- High = 1 (most natural);
- Good = 2;
- Moderate = 3;
- Poor = 4;
- Fail = 5 (least natural).

However, DIN is not recorded for all waterbodies and decisions will need to be made in the next stage about how to deal with water bodies that do not have direct monitoring and assessment. Some data gaps may be filled through interpolation between sample data points. Should this prove unsuitable there may be a reasonable argument to support the inclusion of monitoring at sites that are not currently monitored. Strategic monitoring reform is again relevant and may ensure data representativeness.

8.4.4 Opportunistic macroalgae

The presence of opportunistic macroalgae within a water body provides some indication of the levels of nutrients that are present within the system. As such the use of the opportunistic macroalgae classification results from the WFD assessments can be used to show deviations from a natural level of nutrients that a system would usually experience. Opportunistic macroalgae is recorded on a five-point scale which can easily be transferred to a B6 attribute.

- High = 1 (most natural);
- Good = 2;
- Moderate = 3;
- Poor = 4;
- Fail = 5 (least natural).

However, opportunistic macroalgae are not recorded for all waterbodies and decisions will need to be made in the next stage about how to deal with water bodies that do not have direct monitoring and assessment. Some data gaps may be filled through interpolation between sample data points. Should this prove unsuitable there may be a reasonable argument to support the inclusion of monitoring at sites that are not currently monitored. Strategic monitoring reform is again relevant and may ensure data representativeness.

8.5 Biological naturalness component

8.5.1 Infaunal quality index (IQI)

The infaunal quality index was created by the Environment Agency as a means to determine the condition of soft sediment invertebrate communities within coastal waters as part of their reporting requirements under the water framework directive.

The index has been developed over a number of years, with categories that allow for the representation of disturbance to benthic invertebrate communities. IQI data is recorded on a five-point scale and will easily be transferable to a B6 attribute.

- High = 1 (most natural);
- Good = 2;
- Moderate = 3;
- Poor = 4;
- Fail = 5 (least natural).

However, IQI data is not recorded for all waterbodies and decisions will need to be made in the next stage about how to deal with water bodies that do not have a direct monitoring assessment. Some data gaps may be filled through interpolation between sample data points. Should this prove unsuitable there may be a reasonable argument to support the inclusion of monitoring at sites that are not currently monitored.

There is a need to consider where this attribute is best housed in the data framework for this element of the B6 indicator. Generally the biological naturalness component of the data framework was originally intended to cover direct biological modifications to naturalness (such as non-native species and direct species exploitation or persecution), to sit alongside hydrological, chemical and physical components of naturalness. It has subsequently housed some biological attributes that are affected by a range of modifications from all naturalness components. The addition of a cross-cutting naturalness component is intended to help deal with this issue.

8.5.2 Invasive non-native species (INNS)

Invasive non-native species may affect both natural species composition and also directly impact environmental conditions within estuarine and coastal habitats. There are a number of organisations that identify INNS within UK waters and the precise list relevant to B6 will need to be agreed before the next stage commences.

Data for INNS species present within estuaries and coasts will be obtained from a number of different sources and should be collated for the next phase of work. The most readily available source of information on INNS is from the National Biodiversity Network (NBN-Atlas).

Records for each INNS from the agreed list need to be obtained individually for the whole of England to produce a data layer for each INNS. A calculation will be performed within GIS to count the occurrences of INNS over the preceding five years since the last assessment. The envisaged scoring system is based on the number of INNS within each area. An indication of the scoring for INNS is provided below:

- 1-2 INNS = 1 (most natural);
- 3-4 INNS = 2;
- 4-8 = 3;
- 8-10 INNS = 4;
- Over 10 INNS = 5 (least natural).

B6 discussions on NNS attributes in freshwater habitats are relevant and need to be taken into account in finalising the approach.

8.5.3 Saltmarsh

The Environment Agency collects data and information to determine the status of saltmarsh in a number of coastal and estuarine waterbodies. Saltmarsh, extent, and the number and variety of different species and zones within the saltmarsh habitat can indicate of the overall health of a system, including the ability of that system to adapt with effects of changing climate. However, whilst present in most water bodies, saltmarsh is not present in all, which presents a limitation to using saltmarsh as a B6 attribute. Where it is present, there is also an issue around whether it is a product of natural processes or human modification to natural processes. Nonetheless, the extent to which saltmarsh is monitored, and the potential to show alterations to what would be a natural state, mean that is still recommended as a B6 attribute.

The Environment Agency collects data on saltmarsh using the SKIPPER tool (Saltmarsh Key Indicators Processed Precisely and Estimated Robustly. It is a multimetric index composed of six individual components known as metrics, these are:

a. saltmarsh extent as proportion of historic saltmarsh (SMAh);
b. saltmarsh extent as proportion of the intertidal (SMAi);
c. change in saltmarsh extent over two or more time periods (ΔSMA);
d. proportion of saltmarsh zones present (Zn/5);
e. proportion of saltmarsh area covered by the dominant saltmarsh zone (ZnMax);
f. proportion of observed taxa to historical reference value or proportion of observed taxa to 15 taxa (Th or T15).

Of the six metrics recorded above, three (SMAh, SMAi and ZnMax) are proposed for combining to provide a B6 attribute for saltmarsh. SMAh provides a set baseline with which to assess change overtime. In combination with the other two metrics, this should provide a good assessment of the naturalness of saltmarsh habitat within a water body. SMAi provides a good representation of changes overtime and allows comparison between water bodies of significantly different sizes, which vary widely in total area. ZnMax provides a good representation of naturalness of saltmarsh in a particular water body. If there is a larger percentage of one or two dominant saltmarsh zones, this is an indication that either there are high levels of nutrients in the area which make one zone more dominant, or that there is an example of coastal squeeze whereby the full range of zones are not able to exist. It is also a reflection of the presence and dominance of spartina, which lowers diversity of the marsh overall.

The scoring for the saltmarsh attribute will be finalised in the next stages. However, the scoring for WFD reporting for each of the three SKIPPER saltmarsh metrics are on a five-point scale, which could be converted into a naturalness score as follows.

- High = 1 (most natural);
- Good = 2;
- Moderate = 3;
- Poor = 4;
- Bad = 5.

It is envisaged that each of the three suitable SKIPPER metrics will be converted to the 1-5 score, summed and then averaged. As an example, Water body GB520503503800, the Alde & Ore, at transitional water body in the Anglian region, has a SKIPPER status of:

a. saltmarsh extent as proportion of historic saltmarsh = Bad = 5;

b. saltmarsh extent as proportion of the intertidal = High = 1;

e. proportion of saltmarsh area covered by the dominant saltmarsh zone = Moderate = 3.

So the overall saltmarsh B6 indicator score for the Alde & Ore would be (5+1+3)/3 = 3.

8.6 Other naturalness attributes

8.6.1 Anthropogenic light

The introduction of light into the night-time environment be detrimental to a number of marine animals, where natural processes are interrupted. The naturalness level would in this instance be the lack of anthropogenic light during the hours of darkness.

There are various available datasets that look at night-time light levels, including the Campaign for Rural England (CPRE) project supported by Natural England. The project used satellite data collected at 1.30 am throughout the month of September 2015, the most cloud-free month during of the year. A composite map was produced, taking averages per unit area for the whole country, as different parts of the country may have had more, or less cloud influence on certain nights. Data was obtained from CPRE for B6 attribute development. Although this dataset is currently a one-off, there is the potential this could be reassessed in future years. If this is not the case other data sets may need to be found that provide a similar assessment of night time light levels, in and around the coast.

The final scoring for anthropogenic light (recorded as Nano Watts / cm^2 / sr) will be determined during the next stage of work, but an indication of the potential scoring using mapped data (illustrated in Figure 8.1) is as follows:

- Grey (<0.25) = 1 (most natural);
- Dark blue/light blue (0.25-1) = 2;
- Yellow/green (1-4) = 3;
- Pink/orange (4-16) = 4;
- Dark and light red (>16) = 5 (least natural).

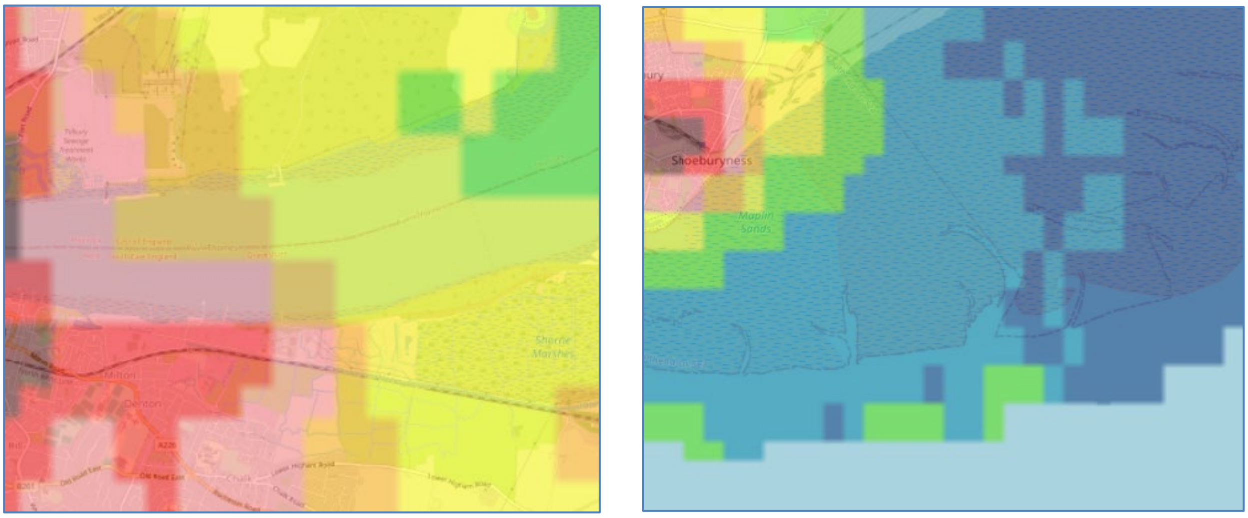


Figure 8.1 Mapped light levels in the Thames Middle waterbody (left) and Essex coast (Maplin Sands, right) (https://nightblight.cpre.org.uk/maps/).

The categories suggested above are skewed to represent larger categories for the higher brightness levels. There are smaller categories in the 1 (most natural) to 3 group, which represent the lower levels of light which are more representative of light that is expected to be at the coast. The actual range of data for light levels at the coast shall be investigated at the next stage, determined by the range that is representative of the full light levels that are found within water bodies. The final score for light levels per waterbody, will be the average light levels that are experienced within the water body as a whole.

8.6.2 Underwater noise

Noise is a naturally occurring component of the marine environment and can be created by many natural sources. However, additional noise, especially noise introduced at levels that are well above that which would be produced naturally, can have negative impacts.

Anthropogenic noise can be separated into continuous noise (e.g., from shipping and operating offshore wind farms) and impact or impulse noise (e.g., seismic surveys, sub-bottom profiling, impact piledriving etc). As underwater noise is only recently becoming a concern, current data sources are not well developed. For continuous noise, a dataset developed by Cefas coupling modelled data with underwater noise monitoring (to ground truth the modelled data) is proposed for the B6 attribute. For impulse noise, JNCC holds a Marine Noise Registry. However, these records were made as a requirement placed on operators and developers as part of the marine licensing process, which is a limiting factor in the data available.

It is envisaged that shipping, windfarm and impact noise will be combined to give an aggregated score for underwater noise. These may be weighted to give more emphasis to the more impulsive noise activities, as these have a higher potential to impacting marine life. It is likely that one of the two data sets will need to be transformed, as they are both represented at different spatial scales. The continuous noise produced by shipping is provided at a much finer resolution, whereas the impulse noise data is presented in a block area which is at a far coarser resolution.

Indicative scoring for underwater noise is provided below, using colour coding from Figure 8.2 which illustrates mapped data from the impact noise registry (portrayed as 'pulse block days', PBD, in the range of 1-100.

- 0 PBD (white) = 1 (most natural);
- 1-25 PBD (dark and light green) = 2;
- 26-50 PBD (yellow and light orange) = 3;
- 51-75 PBD (dark orange and light red) = 4;
- 76-100 PBD (dark red) = 5 (least natural).

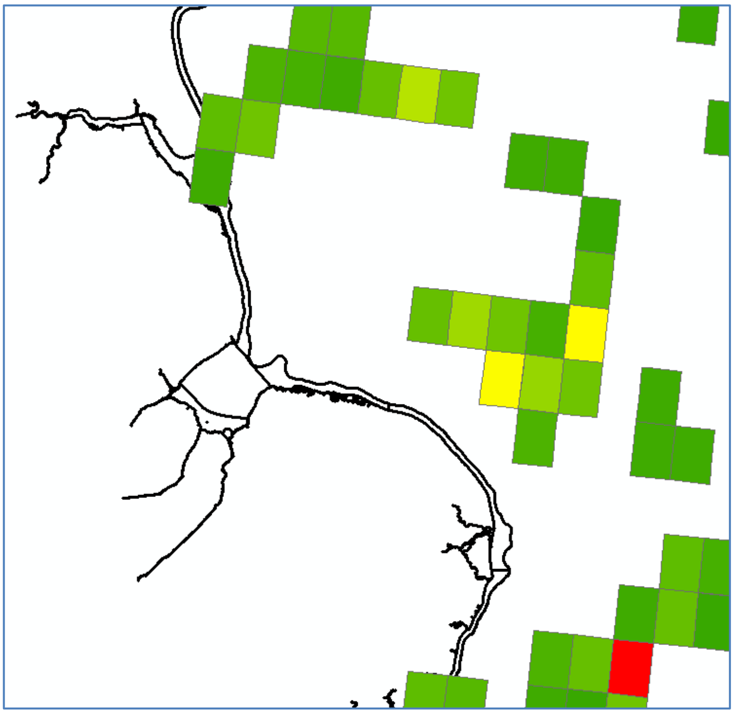


Figure 8.2 Example map of 2020 underwater noise records in the east of England.

Continuous shipping noise level is presented as BBHz_SPL (Broadband Hertz Sound Pressure Level) for a full year as shown in Figure 8.3. Indicative allocation of noise levels to naturalness classes is shown below.

- 95-100 (black and very dark blue) + 0 to the score obtained from impulse noise (most natural);
- 101-110 (dark and light blue) +1 to the score obtained from impulse noise;
- 111-120 (pinks) + 2 to the score obtained from impulse noise;

- Over 121 (orange and yellow) + 3 to the score obtained from impulse noise.

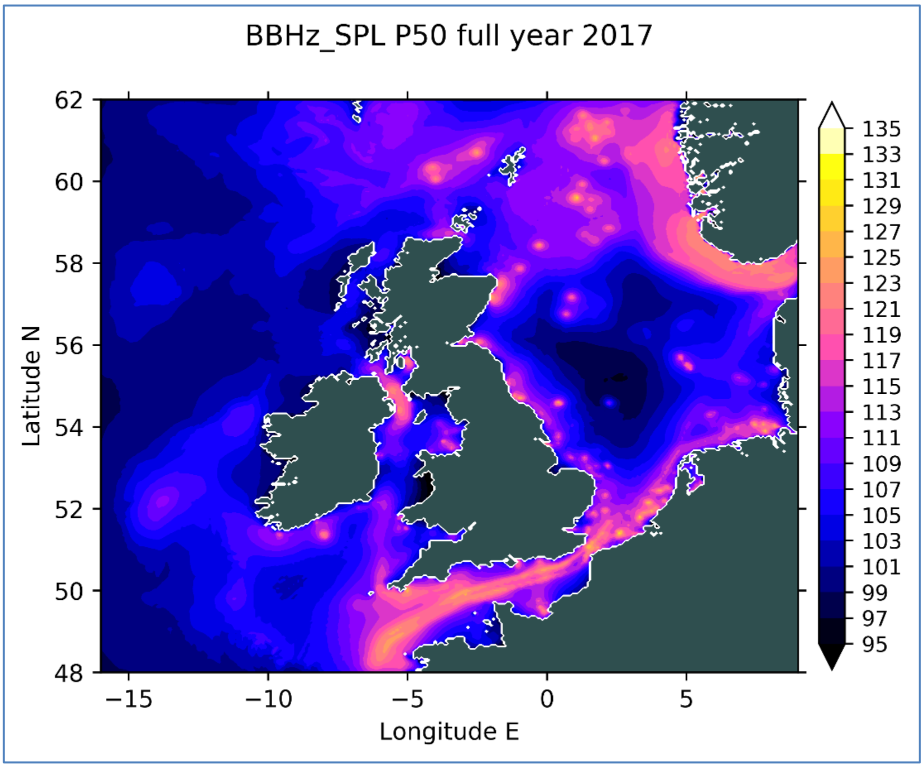


Figure 8.3 Continuous underwater noise produced from shipping (Source: Cefas)

The maximum value that can be achieved by continuous shipping noise alone is a score of 3 on the naturalness level. This is to ensure that continuous noise as a result of shipping cannot achieve an unnatural score of 4 or 5 In the same way that impulse noise can, as it is deemed to be less impactful, and hence less unnatural.

The scoring and transformation process will be considered further during the next stage of work. As regulatory requirements increase in this area, including the need to map noise as part of the reporting requirements under the Marine Strategy Framework Directive, it is expected that assessments in future years will include sophisticated underwater noise data. These could be used to generate updates to the B6 attribute.

9. Development work in 2022/23

Work on the principal habitat components of B6 is at varying stages of development. A summary of further development work planned on each habitat component in 2022/23 is given below.

- **Freshwater habitats** (rivers, streams, lakes and ponds) – Work in the coming year will bring this component of the B6 data framework to a point where it can become operational. It involves finalising the definition of outstanding attributes, securing outstanding datasets, agreeing outstanding data transfer protocols, finalising data aggregation and reporting formats and generating technical information sheets on each attribute that will lay out how to secure and process data and generate outputs. A provisional template for attribute information sheets is provided in Appendix B.
- **Freshwater wetland habitats** – Work this year will involve technical liaison with the D1 indicator team, rationalisation of potential attributes, securing datasets where available and the construction of wheel diagrams ready for populating with new surveillance data.
- **Estuaries and coasts** – Work this year will focus on implementing the recommendations of the 2021/22 feasibility study, securing datasets and processing data into attributes and then developing wheel diagrams as appropriate.

Within the work on freshwater habitats, the establishment of change-logging processes will be key for certain attributes and will require coordination across attributes through liaison with the Environment Agency and the CaBA initiative. Logging facilities are needed that are accessible to EA, NE and the CaBA initiative but are as hardwired into organisational processes as possible, perhaps reinforced by conditions on the financing of activities.

Rationalising the more detailed level of habitat types and associated outputs within the B6 data framework is a common issue across all principal habitat components. Work on freshwater habitats in 2022/23 will aim to provide clarity and test outputs at the detailed habitat type level, using spatial overlay of type distributions on relevant attribute datasets. As a minimum, outputs will be produced on selected river and lake types (e/g/ chalk rivers and mesotrophic lakes) for illustrative purposes. Work on wetlands and estuaries/coasts in 2022/23 will seek to clarify the typological framework required but is unlikely to provide type-specific outputs.

10. Operationalising the B6 data framework

Resources and organisational planning are needed to maintain the B6 data framework and provide timely outputs for the Defra OIF and Natural England strategic biodiversity reporting processes. The best strategy for supporting this work is not yet clear and will depend on broader planning of data services and analysis resource within Natural England. The next B6 progress report is intended to provide a clear and detailed blueprint for the work to be undertaken, wherever it is done. A provisional template for attribute information sheets is provided in Appendix B. A sheet will be generated for each attribute and will provide all of the information needed to secure and process the data.

The work could be built into Data Services work planning in Natural England, or it could be contracted out to UKCEH where the knowledge of the datasets and analytical processes is already located. Whichever route is chosen will require Natural England data services and analysis staff to have a good understanding of the B6 data framework and its role in strategic biodiversity assessment and reporting. In particular, it will require collaboration over the storage and access to the processed data underlying key outputs and any underlying raw datasets that are not owned and maintained by others.

Eventually it is envisaged that all dashboards, wheel diagrams and at least some of the underlying datasets would be stored on Natural England open data platforms, linked with wider strategic biodiversity reporting processes. In the interim a provisional framework of visual outputs can be developed and displayed on Sharepoint. Test pages can be developed and consulted on over the course of the coming year, using freshwater habitats as a pilot.

11. Timescales, risks and dependencies

The overall aim of operationalising the B6 indicator in 2024 is still realistic, but in interim form subject to further refinement. The rivers and streams component will be available for Defra to publish in test/pilot mode in the next OIF update in Spring 2023. Depending on the availability of data from national surveillance networks the other B6 elements should be available to publish in interim form in Spring 2024.

In terms of budgets for finishing development work, funds have been secured for 2022/23 for undertaking the work outlined in Section 9. Further funding will be required in 2023/24 to finalise development work across all B6 elements.

Of the many data dependencies outlined in previous sections, the reliance on Environment Agency surveillance programmes and emerging NCEA monitoring programmes is the most important to highlight. The scale of these programmes is key to providing a robust assessment of the water and wetland habitat resource, particularly in relation to the assessment of habitat sub-types (such as chalk rivers/streams, oligotrophic lakes etc.). The statistical power of these programmes still needs to be tested in relation to the B6 data framework and this needs to be taken into consideration when making decisions about the spatial intensity and distribution of surveillance sites.

12. Strategic biodiversity assessment and reporting processes

The precise form of post-2020 strategic biodiversity assessment and reporting processes is not yet clear. However, the B6 data framework provides a structured and coherent basis for strategic assessment and reporting of relevant habitats, linking across to the D1 data framework.

The B6 data framework is being built into the definition of Favourable Conservation Status (FCS) for freshwater habitats, and will help inform the approach to FCS for other habitats within the ambit of B6. The concept of FCS originates from the EU Habitats Directive but has been extended by Natural England to provide a holistic framework within which our long-term ambitions for all habitat/ecosystems and species can be expressed. This generates strong alignment between the FCS concept and the objectives of the B6 data framework. For the freshwater habitat resource a series of nested FCS targets is proposed (Mainstone and Hall 2022), based on naturalness of ecosystem function and incorporating targets for protected freshwater sites (SSSIs and SACs) as well as ecological status under water legislation. The detailed typology for freshwater habitats to be used for FCS definition will be aligned with the typology to be used for the B6 data framework.

Proposed general FCS targets for the freshwater habitat resource as a whole are shown in Box 1. Those highlighted in green are assessed by data sourced from the B6 data framework. The precise percentages of the habitat resource used in each target may be refined based on best understanding of long-term achievability (bearing in mind that FCS is aspirational in nature), and there is also potential to vary the values for each detailed freshwater habitat type based on more detailed understanding of immovable constraints associated with each type.

Box 1. Proposed general targets for assessing FCS of freshwater habitats.
From Mainstone and Hall 2022.

1. All SACs designated for the habitat in question to be in favourable condition.
2. All SSSIs designated for the habitat to be in favourable condition.
3. All WFD waterbodies containing the habitat currently at HES maintained at HES (broadly equating to Naturalness Class 1).
4. 10% of national habitat extent to be in a highly naturally functioning state (Naturalness Class 1 across all naturalness components) - to be delivered in association with re-establishment of broader naturally functioning wetland and terrestrial habitats.
5. 25% of national habitat extent to exceed good levels of natural function (Naturalness Class 2 across all naturalness components).
6. 75% of national habitat extent to exceed good levels of chemical and hydrological function (Naturalness Class 2) and moderate levels of physical and biological function (Naturalness Class 3) - note that biological class relates specifically to direct biological pressures rather than biological indicators of naturalness.
7. 95% of national habitat extent to exceed good levels of chemical naturalness (Naturalness Class 2).

Setting targets for a desired state at the habitat resource level is a very different process to setting environmental standards that act as a requirement for all parts of the habitat resource to achieve. FCS targets for freshwater (and potentially other) habitats allow flexibility in where we set high levels of ambition for restoring naturally functioning habitat mosaics and where we accept heavy constraints to natural function generated by, for instance, urban development and other fixed infrastructure. It allows us to target restoration action at places in landscapes that are most amenable to restoring high levels of natural ecosystem function, delivering resilient mosaics of freshwater, wetland and drier terrestrial habitats and their associated species in those locations as well as clean and plentiful water to downstream habitats - plus a wealth of natural capital in the process, including carbon sequestration and storage, resilient water resources, natural flood management and clean raw water for drinking (Natural England 2018, 2020).

The nature of FCS targets means that we should avoid attempts to force hard linkages between them and water-related standards - linkages between ambitions for biodiversity and water (outside of protected sites) need to be soft and high-level, aiming for broad compatibility at the habitat resource level and synergies of message/direction (co-support for actions that restore natural ecosystem function).

It is also worth noting that the targets proposed for FCS definitions of freshwater habitats require that the B6 data framework is used in a different way to its use in B6 indicator outputs. A different data portrayal will need to be designed for this purpose. Data need to be processed to generate a picture of the proportion of the habitat resource that fulfils all of the individual requirements of a given FCS target. This is because appropriate levels of habitat quality (natural function) are required across a range of attributes **in the same location** to achieve the desired overall state. Conceptually this is similar to assessing favourable condition of SSSIs and SACs, as well as ecological status under the Water Framework Directive - i.e. ‘one-out-all-out’ at a given location. Data portrayal will need to be designed in a way that is better at showing progress towards targets, to ensure that restoration efforts are properly recognised. As with B6 indicator outputs, this means data portrayal that works at the level of key naturalness components or individual attributes.

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Appendix A - Consultation feedback on the July 2021 progress report

A1. General observations on consultation responses

The concept of naturalness of ecosystem function is complex and multi-faceted, as is its place in strategy and operational decision-making. Through the B6 indicator and associated data framework it is being applied to water-related habitats/ecosystems but it has broader relevance to all habitats and species so B6 indicator development forms part of a broader discussion and accommodation of natural ecosystem function. All this means that there is a wide range of possible queries and issues arising from consultation, of a conceptual, strategic or detailed technical nature.

In order to keep the progress report concise, the larger body of work on natural ecosystem function on which B6 is based (including the links to conservation and water strategy and associated processes) was simply signposted rather than explained fully in the report. This left some respondents short on context to inform their comments. Additional explanation of supporting material is provided in the commentary on consultation feedback below (highlighted in italics), which should help to clarify some issues for respondents.

A2. Summary of feedback on Question 1: attributes and data inputs. Do the attributes cover the most important pressures affecting natural function? If not, what is missing? Considering data inputs, do you have views about how data should be collected, particularly for attributes where citizen science needs to play a role?

A summary of the various comments on individual attributes for rivers and streams listed in the progress report is provided in Table A1. In addition to these attributes a number of other attributes were suggested by respondents.

- **Fine sediment delivery** – One respondent felt that impacts arising from artificially high bankside erosion from heavy livestock densities could be included. *This is an issue that was considered in Report JP016 but for which it is difficult to provide and service an attribute. Bankside erosion is one source of fine sediment delivery alongside wider catchment delivery agriculture, forestry etc..*
- **Thermal regime –** One respondent felt this was a major omission and that its assessment might be made feasible with new modelling work being undertaken by the EA. *Modelling would be the only way to include naturalness of thermal regime because it would require evaluation against a reference (unimpacted) regime. There is an issue around the treatment of climate change effects - the B6 data framework is intended to highlight local (catchment-scale) impacts on naturalness/natural function of water and wetland habitats so that they can be addressed (and through this increase ecological resilience to climate change), but global climate change is a major impact on thermal regimes and would obscure any thermal effects of local activities (for instance from effluents or online reservoirs). The large influence of riparian tree cover is a further issue - the wide range of tree cover values considered by B6 to be consistent with the highest*

naturalness class (i.e. anything >30% cover) generates considerable natural variation in thermal regimes that would need to be factored out of the assessment along with other natural variation. Overall, it is an important point but difficult to act on. Investigation of EA modelling work would be sensible to determine what is possible.

- **Headwater stream flows –** The current attribute list only deals with flows in headwater streams in respect of groundwater abstraction. One respondent felt that other stream flow modifications needed to be evaluated, particularly the many flow diversions in upland catchments generated by water company abstraction infrastructure that catches stream flow and routes it along contour lines to reservoirs. This could be assessed by an audit of water company infrastructure. *This is a key omission from the current attribute list and this is a good suggestion for addressing part of the gap. Agricultural catch-drains are another key pressure on stream flows but are less easily captured through an auditing process. A broader assessment of natural function within landscapes is currently being considered in Natural England which includes assessment of these sorts of hydrological pressures. Some cross-fertilisation of methods is needed.*
- **Level of catchment development** – One respondent felt that a measure of scale of catchment development was a key omission because it was used in a range of international literature relating to impacts on naturalness of freshwater habitats. *Catchment development is a broadscale indicator which is well-suited to situations (typical in developing countries) where there is a lack of more detailed data on pressures/modifications and their impacts. Its purpose within a more detailed and structured data framework is less clear but is perhaps most relevant for headwater catchments where there has been less information available historically. Measures of development pressure were used in a previous naturalness analysis related to reviewing the river SSSI series (Mainstone et al., Awaiting publication) and mapping priority river/stream habitat (Mainstone et al. 2014), but the assumption is that future monitoring will provide adequate representative data coverage on headwater streams in the context of the B6 attribute list. This said, an attribute of catchment development for headwater streams would be a more direct driver for keeping part of the headwater stream resource free of any significant development pressure, so is worth considering further. More generally, it could also help address any gaps in pressures (for instance, fine sediment delivery).*
- **Chemicals** – Two respondents highlighted the lack of coverage of chemicals other than basic indicators of organic pollution and nutrient enrichment. One respondent suggested using chemicals-related indicators (e.g. H4) in the 25 YEP framework to fill this gap. *This is a good suggestion that maximises the value of the relevant indicators and will be investigated.*

Table A1. Detailed consultation feedback on the list of river and stream attributes.

Naturalness component	Attributes	Comments in report	Consultation feedback
Hydrological	Flow regime – deviations from naturalised flows	Larger rivers only- from EA Water Resources Management System	One respondent suggested flow assessment could be extended to headwater streams using citizen science initiatives such as Crowdwater. *The FBA citizen science naturalness assessment method also includes hydrological assessment but there is a general problem in that naturalness of flow regime is difficult to evaluate without modelling flow in the absence of modifications. Some modifications are obvious in the field (although scale of impact on natural hydrology is still difficult to assess) but others are not. It is worthy of further consideration, bearing in mind that any data would have low associated confidence.*
	Groundwater inputs	Separate assessments of headwater streams and larger rivers – from EA groundwater monitoring and modelling	
	Floodplain function	Separate assessment of headwater streams and larger rivers - % of floodplain flooding naturally based on flood defence assets. Calculated from EA GIS floodplain layers	Respondents had concerns about the ability of the datasets used to convey a full picture of impacts on natural flooding regimes, supporting the issues raised by the report itself. One respondent felt that the portrayal is so misleading that it would be better to display nothing. *One respondent felt that Lidar data provided a potential solution. Lidar has been considered but the processing requirements proved too much for the B6 project.* However, a *previously unknown EA dataset using England-wide Lidar data to identify flood embankments is now being investigated as an alternative. It is probably best to not display data on this attribute unless a more comprehensive dataset can be used.*
Physical	In-channel structures	Separate assessments of headwater streams and rivers. Uses AMBER and EA data, potentially updated via CaBA citizen science initiative	Two respondents specifically supported further investigation of the most appropriate framing of this attribute. Concern were raised about accepting any structures in the highest naturalness class. *Proposals are currently being considered by the European Commission for framing targets for restoring 'free-flowing rivers' as part of the European Biodiversity Strategy. The proposed approach will be considered as part of further B6 deliberations.*
	Stream power	Separate assessments of headwater streams and larger rivers. New CEH modelling of the whole river/stream network.	
	Habitat Modification Score	Separate assessments of headwater streams and larger rivers using representative sampling of each. Based on River Habitat Survey data.	One respondent suggested that RHS-related attributes might best be based on the 7 underlying factors identified in a research project undertaken by Vaughan *et al.*.*We will look at the extent to which these are covered by the attributes in the current list.*
	Flow habitat mosaic		
	Riparian trees		

Naturalness component	Attributes	Comments in report	Consultation feedback
	In-channel woody material		One respondent suggested the alternative survey system MORPh could be used. *This has been considered as a potential supplement to strategic RHS survey. It is not clear how easily MORPh data could be combined with RHS data to help service these individual physical attributes but it is envisaged that MORPh data can be interpreted in the context of the FBA citizen science assessment of naturalness (next attribute in this table*). One respondent rightly pointed out that most of these attributes are not measuring naturalness/modification directly but structural habitat elements that are generally associated with naturally ecosystem function. *This was discussed in detail in Report JP016, in relation to both natural variation in these attributes between river/stream types and the ability for habitat modifications to generate high scores for these attributes. These are important considerations at site-level but are less problematic at the habitat resource level. Analysis of data by different river types helps to address natural variation. Portrayal of the whole habitat resource (including any targets based on that) will need to be cognisant of these issues,* One respondent pointed to the national dataset on tree cover generated by the Keeping Rivers Cool (KRC) Project as a source of information on riparian trees. *This is being investigated as an adjunct to the RHS attribute, which provides more detail around the interactions between tree roots and the channel.* A number of respondents highlighted the need to be clear about the respective roles of sheep-grazing and natural limitations on tree presence at higher altitudes. *This is discussed in detail in Natura England (2018) – the most appropriate approach to take for B6 is likely to be to assume all sites with RHS data in England as naturally supportive of riparian trees.*
	Riparian vegetation complexity		
	FBA physical naturalness assessment	Separate assessment of headwater streams and larger rivers. From representative sub-sampling of naturalness assessments on the FBA priority habitats citizen science data portal.	One respondent highlighted the need to develop a standard read-across between MORPh assessment and the description of naturalness classes in FBA citizen science naturalness assessment. *This is a longstanding need that requires attention.*
Chemical (water quality)	Ammonia	Rivers - from WFD reporting database. Streams – requires additional representative sampling programme of the headwater stream resource	Concern from one respondent that WFD standards for support ecological status may not be adequate for supporting all species, e.g. pearl mussel. *A different set of class boundaries could be used for naturalness but would result in a more complicated relationship with WFD assessment. WFD standards for these attributes vary with the natural character of the river and in some instances standards for good ecological status involve considerable deviations from naturalness because they are based on evidence of biological impact using UK-level analysis of routine monitoring datasets. This said, standards for high ecological status broadly reflect a high level of naturalness and so provide good characterisation of the upper end of the naturalness scale. It would be a considerable amount of work to devise an alternative system of standards for these attributes to service the B6 data framework.*
	Dissolved oxygen		
	Phosphorus		
	Nitrogen		

Naturalness component	Attributes	Comments in report	Consultation feedback
	pH		Seen by one respondent as the least useful of these chemical indicators
	Macroinvertebrates		
	Phytobenthos		Some respondents were concerned that aquatic macrophytes are not included in the attribute list. *Phytobenthos is a term intended to include both macrophytes and algae so they are included. This will be made clear in subsequent B6 outputs.*
Biological	Native species assemblage - similarity index comparing observed and reference invertebrate assemblages	Separate assessment of headwater streams and larger rivers. Requires EA data of high taxonomic resolution, including representative sampling of headwater streams	One respondent suggested using functional feeding groups as an attribute, drawing on the same EA data*. Trait-based analysis of this nature may be more appropriate than a compositional comparison of observed and predicted reference assemblages, simply because of the natural variation in assemblages at high taxonomic resolution. This will be considered further in B6 development.*
	Non-native species - combined score weighted by species impact	Requires species records collated via the National Biodiversity Network or the Biological Records Centre	One respondent felt that the Defra 25YEP indicator H2 on non-native species is currently looking very tree species-focused and would require considerable broadening to fulfil the requirements of B6. *Renewed discussion is required with H2 leads to agree how the interaction is best handled.*

One respondent suggested that the number of attributes could be condensed by the use of biological attributes if sufficient data exist to draw adequate correlations. *This suggestion encapsulates an enduring tension between the assessment of naturalness/natural ecosystem function and the asssessment of biological assemblages. Biological monitoring can be very useful in assessing impacts on chemical naturalness (water quality), particularly for toxic chemicals too numerous to monitor in their own right. Biological monitoring capable of evaluating other components of naturalness (e.g. hydrology and physical habitat) is far more complicated and requires different survey design and associated evaluation of reference conditions and assemblages. Placing reliance on biological attributes also means that the separate effects of impacts on different naturalness components would need to be teased apart (typically through subsequent investigations), and there would be no a priori management and planning possible on the basis of the assessment because the underlying causes of impacts on naturalness would be obscure. In the WFD approach to assessment of the water environment there is a high level of dependency on attributes of biological impact, which generates strengths and weaknesses – the approach to natural function in the B6 data framework aims to address those weaknesses by providing a structured and holistic assessment of all pressures/modifications on habitats.*

One respondent stressed the need for a strategic monitoring programme funded by regulatory agencies to provide the core of the data input, supported by citizen science initiatives to augment the core programme. Another respondent queried where the data would come from and urged clarity. *The proposals for the B6 data framework, are built on the same premise as proposals in the earlier report JP016. They make the best use of available data but require a core representative monitoring programme undertaken by professionals, in addition to other key datasets that are based on modelling and GIS evaluation. The needs of the B6 data framework are being considered as part of the on-going review of Defra-family monitoring programmes.*

One respondent queried where the data would come from to service the data framework envisaged and how the investment would be justified. *The framework is based as far as possible on securing data from existing sources and programmes and supporting their future development so that they are able to service the framework as fully as possible. B6 data needs have been fed into discussions over Environment Agency monitoring reform to try and ensure that future monitoring design provides core elements of B6 needs. Some attributes require data supply from Environment Agency modelling and the detail of data transfer arrangements needs to be agreed. To operationalise the indicator, a system of data processing will be required involving close liaison between Natural England and the Environment Agency. This will need to be developed, planned and resourced so that it feeds the B6 indicator and associated biodiversity reporting processes under the Nature Strategy. The justification for generating the data lies primarily with the owners of the existing sources and programmes, which is generally the Environment Agency. B6 data requirements add further justification which should help strengthen the case for generating the data and extending data generation in certain ways (e.g. for providing a representative picture of different river/stream types). The biodiversity case for requiring the data comes from the supporting material on the importance of natural ecosystem function to freshwater and* *wetland habitats (Mainstone* et al. *2016) and to ecosystems and their characteristic species more generally (Natural England 2018).*

A4. Summary of feedback on Question 2: analysis methods. Do you think that there are better ways to analyse any of the attributes that are already in the indicator, particularly to show change over time, or to improve the spatial and temporal sensitivity of the indicator (for instance through adjustment to class boundaries)? If so, please explain.

Some respondents have highlighted issues around how the natural function spectrum is currently divided up into naturalness classes for different attributes, particularly for certain attributes where the distribution of waterbodies between classes was not felt to reflect the scale of impact on naturalness (e.g. artificial in-channel structures). *The class boundaries used are not a linear division of the naturalness spectrum – boundaries are skewed to give more sensitivity at the higher naturalness levels, so that they are of more use when setting targets to protect higher levels of naturalness in parts of the habitat resource. At the same time a reasonable spread of data is needed between classes to help ensure the indicator is able to detect change. Some class boundaries need further attention and respondents have usefully pointed to those in most need. For some attributes the frequency distributions look intuitively wrong but the problem is more related to the underlying dataset (e.g. natural flooding regime).*

One respondent queried the relationship between the classification of naturalness for individual attributes and the impact on biota, drawing attention to a body of work on rivers undertaken using data from the River Habitat Survey. *The WFD approach to ecological status classification is to position class boundaries explicitly according to the level of biological impact, using the normative definitions of each ecological status class in the Directive. In the data framework for B6 we have deliberately avoided hard linkages to observed biological impacts and focused on the scale of observed modification in the attributes. What approach is most suitable is linked to the envisaged target-setting process that hangs off the data framework. The envisaged use of the B6 data framework in setting biodiversity targets under the Nature Strategy does not require that the habitat resource as a whole should achieve a specific target level of naturalness. Instead, it is envisaged that targets would be set to shift the habitat resource up to higher levels of naturalness, with some parts of the resource achieving high levels, some parts achieving modest levels and other parts achieving no or little improvement (at least in some naturalness components, for instance because of immovable constraints such as urban development and essential infrastructure). Setting strategic targets for the habitat resource needs to involve a conversation about what is achievable in different parts of the habitat resource, bearing in mind the general biodiversity and wider natural capital benefits of more natural ecosystem function and the opportunities for and constraints on achieving improvements in different locations.*

One respondent suggested that the floodplain flooding metric might be better expressed as total area of floodplain constrained from flooding rather than divided into waterbodies. *This points to a more general issue with the structuring of the data analysis. At present all attributes are analysed in ways that feed into the water body-based structure of the data* *framework. It is not easy to envisage what a mixed approach to data structuring would look like or how it would work. The problem is probably more acute with artificial in-channel structures where the water body-based structure is arguably least suited to connectivity-related impacts on naturalness. Further consideration of what a mixed data structure might look like would be sensible.*

One respondent felt that the structuring of the data analysis (based on WFD water bodies divided into headwater and larger river zones) was reductionist and that analysis at catchment level provides a more systems-based approach. *The intention of the data framework is to provide a picture of the level of natural function within the habitat resource, and the spatial resolution of the analysis has to be broadly reflective of the spatial scale of variation in impacts on naturalness. Adopting a catchment-scale spatial framework would hide a large amount of variation that we need to know about, not least in the headwater zones of catchments which have been left largely unassessed until now. There is actually a case for adopting a higher level of spatial resolution for some attributes where representative survey sites are selected on a national basis, because survey sites falling within a given waterbody are not necessarily reflective of the naturalness of the water body as a whole. However, since the data framework is intended to provide a broad national picture rather than an accurate local picture this is a minor detail - the spatial scale adopted provides a convenient framework into which data on all attributes can be placed. Catchment-scale evaluation may be more relevant for prioritising parts of the habitat resource to restore to higher levels of natural function, particularly for habitats located at the downstream end of catchments where the naturalness of the whole catchment upstream is relevant. The current spatial framework enables this type of catchment analysis because data on individual water bodies comprising a catchment can be analysed together.*

One respondent queried the spatial resolution of the B6 data framework in respect of its relationship with the current and future form of the priority river habitat map for England. The priority habitat map is also based on naturalness data and seeks to identify the most natural remaining rivers and streams in England, as a means of protecting them from deterioration and using them as illustrations of higher levels of natural function. The spatial variation in naturalness within a water body (even if it is divided into headwater and non-headwater zones) can be considerable, such that there may be no clear relationship between the B6 analysis and the priority habitat map. *This is true but not necessarily an issue. The B6 indicator framework is not intended to generate mapped outputs – some key elements of the data framework use representative data which are not amenable to mapping, whilst some other elements provide a full national picture and are amenable. The priority habitat map ideally would be based on a reach-by-reach picture of naturalness, but in reality is built from a mixture of information sources many of which are only available at water body scale. In this sense the B6 data framework has more in common with the priority habitat map than might be envisaged, but not in a good way. Over time priority habitat map will be refined using as much reach-level data as possible, so that it will achieve increasingly high levels of spatial specificity. Meanwhile, the B6 data framework will continue to be tied to representative monitoring of many attributes, which limits its spatial specificity.*

A5. Question 3: data presentation. How well do you think the wheel diagram works for portraying the complex data generated across the habitat resource? Is there a better way to present the data, bearing in mind that any part of the hierarchy within the wheel diagram can be displayed as a time series once sufficient data are available?

Most respondents felt that the wheel diagrams were a good way of displaying the complex hierarchical information involved in the data framework but that refinements could be made to make the diagrams more intuitive and clearer explanation of what they represent could be provided. One respondent felt that the diagrams were far too complicated to be understood even by experts. Suggestions have been made for changing the colour coding – one respondent suggested inverted the grey scale of the inner wheels so that white is most natural and black is least natural. Another respondent felt that that colouring of the five naturalness classes could be more intuitive - in particular, it is not intuitive that blue is the highest naturalness class and green is less natural. One respondent felt that a more structured, sequential explanation of the different components of the wheel would help. *The design of the wheel diagrams has evolved over time and they have certainly become more intuitive, but there is clearly some way to go. These suggestions are valuable for further refinement. Inversion of the grey scale might be useful although this scale is not indicating naturalness but proportion of the habitat resource within each naturalness class. A more intuitive colour scheme for naturalness could be red-to-orange-to yellow-to light green-to dark green. A more structured explanation of the diagrams would be suited to the on-line publication of the indicator where a link could be made to a bespoke page giving the explanation.*

A6. Question 4: data outputs. In time we would like to make the underlying data available. Would you use such data, and if so, what format would you like it to be in?

Only one respondent provided comments that related to this question, expressing a desire to inspect the underlying data to understand it better rather than relying on summary attributes. It can be assumed that there will be a general desire to be able to view the raw data used in the assessment. *The multiple sources of data involved in the B6 data framework makes it difficult to draw generalisations about how data are or should be made available. Most of the data being used is not generated specifically to service the B6 data framework and is available through primary sources, although the data are processed in specific ways for B6 and associated purposes. The general aim in respect of processed B6 data would be to make the data available in a bespoke repository subject to any licensing restrictions that might apply to individual datasets.*

Appendix B - Template attribute information sheet

Habitat component (rivers, streams, lakes, ponds, freshwater wetlands, estuaries, coasts): <>

Attribute title and code: <>

Rationale for inclusion: <>

Raw data source including storage location: <>

Outline description of dataset including spatial coverage, representativeness, limitations: <>

Data ownership and licensing restrictions (if any): <>

Data transfer arrangements: <>

Frequency of raw data update/data transfer: <>

Form of attribute: <>

Data processing method for generating attribute: <>

Naturalness class boundaries: <>

Storage location for raw dataset and processed data: <>