Kent Catchment White-clawed Crayfish Ark Site Selection – Desktop Study

LIFE R4ever Kent

Final

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Prepared by	Carys Hutton BSc PGCert MCIEEM Senior Ecologist Evan Shallcross BSc Technology, Data and Software Development Analyst Sky Wallis BA Assistant Ecologist Daniel Bane BA MSc Technology, Data and Software Development Analyst
Reviewed by	Jonathan Whitmore BSc MIFM Prince 2 Technical Director
Authorised by	Jonathan Whitmore BSc MIFM Prince 2 Project Director

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Contract

JBA Project Manager	Carys Hutton
Address	Epsom House, Chase Park, Redhouse Interchange, Doncaster, South Yorkshire, DN6 7FE
JBA Project Code	2023s0460

This report describes work commissioned by Natural England on behalf of the LIFE R4ever Kent project, by an instruction dated 29 March 2023. The Client's representative for the contract was Ian Emerson of Natural England. Carys Hutton, Evan Shallcross, Sky Wallis, and Daniel Bane of JBA Consulting carried out this work.

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Acknowledgements

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LIFE R4ever Kent

LIFE R4ever Kent will restore and revitalise the River Kent SAC and its wider catchment, so it is more resilient to environmental pressures. Freshwater Pearl Mussel (FPM) (S1029) is a keystone species which requires clean gravel habitats and low suspended solids/nutrient loading. Improved water and habitat quality (including H3260 habitat) will benefit other aquatic/terrestrial species including the endangered White-clawed Crayfish (S1092) and provide optimum conditions for FPM's salmonid hosts. The project will trial new techniques, provide targeted advice and training and promote better replication/communication. Natural England (lead partner) is working in partnership with South Cumbria Rivers Trust, Environment Agency and Freshwater Biological Association. The project is financially supported by LIFE, a financial instrument of the European Commission.

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Abbreviations

EPS	European Protected Species
GIS	Geographical Information System
IUCN	International Union for Conservation of Nature
LWS	Local Wildlife Site
NERC	Natural Environment and Rural Communities
NICS	Non-Indigenous Crayfish Species
OS	Ordnance Survey
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
WCC	White-clawed Crayfish
WFD	Water Framework Directive

Definitions

Ark site: a 'discrete waterbody, comprising running and/or still-water which supports a healthy, recruiting population of White-clawed Crayfish and which can be reasonably expected to sustain a population in favourable condition for the foreseeable future, without significant management intervention' (Marshall and Nightingale, 2021).

Executive Summary

Purpose

The River Kent catchment is a stronghold for White-clawed Crayfish, with the population distributed throughout the River Kent and several of its main tributaries. This report is a White-clawed Crayfish ark site suitability desktop study for determining if crayfish conservation action is possible within the River Kent catchment, Cumbria. The study was commissioned by Natural England and is part of the ongoing R4ever Kent LIFE project.

Methods

A series of three screening tests and a quantitative method was developed (using guidance from the Crayfish Conservation Manual (Marshall and Nightingale, 2021)) for the assessment of ark site suitability at different spatial scales within the River Kent catchment. Suitability was determined by a cumulative scoring process and ranked from 'bad' to 'high'. Professional judgment using a qualitative assessment was also applied to support the veracity of the results and mitigate for limitations associated with the scoring method.

Results

The desktop study determined that there is excellent potential for the development of ark sites in the River Kent catchment for White-clawed Crayfish, including at a catchment-wide scale. The table below lists the sites determined to have the greatest ark site suitability and are recommended for prioritisation in further assessment.

WFD Water bodies (in order of prioritisation)	Headwaters in the following water bodies (in order of prioritisation)	Isolated still-waters (in order of prioritisation)
Flodder Beck (GB112073071340)	River Kent - confluence River Gowan to confluence River Sprint	41 (high)
River Kent - headwaters to confluence River Gowan (GB112073071390)	River Kent - headwaters to confluence River Gowan	6 (good)
River Kent - confluence River Gowan to confluence River Sprint (GB112073071380)	River Sprint (GB112073071430)	37 (good)
River Gowan (GB112073071410)	River Mint - Upper	27 (moderate)
River Mint (GB112073071370)	River Mint	36 (moderate)
River Mint - Upper (GB112073074640)		52 (poor)

Over half of river points in the River Kent catchment achieved a 'moderate' suitability or lower, and it is recommended that these areas are interpreted as low priority for future investigation and 'less suitable' as opposed to 'unsuitable' as ark sites. The most significant vulnerabilities in the catchment are associated with the risks to water quality and biosecurity from abstractions and discharges, and the presence of recreational water activities which also pose a potential biosecurity threat. Other constraints identified were not considered to have significant influence on ark site suitability.

Over a third of isolated still-waters achieved a 'bad' suitability, primarily associated with water permanence, proximity of show-stopper species records, and/or low-scoring geology. The majority of isolated still-waters are farmland ponds which may also be vulnerable to water quality issues.

Opportunities

There are numerous barriers throughout the catchment and opportunities exist for the modification of weirs to improve their impassibility to Non-indigenous Crayfish Species (NICS), particularly those at strategic locations.

Increasing shading at ark sites will reduce the vulnerability of White-clawed Crayfish to predation (as well as potentially mitigate against the future effects of climate change on water temperature), and removal of predatory fish should be considered prior to crayfish introduction.

Public engagement and publicising conservation actions with recreational users is recommended to improve biosecurity practice and potentially alleviate risks.

A single record of American Signal Crayfish exists in the catchment. It is critical that the presence (and distribution) or absence of the species is confirmed through further survey.

Survey for White-clawed Crayfish is recommended to understand the current population and distribution within the River Kent catchment.

Further investigation of the potential ark sites proposed is recommended.

1 Introduction

1.1 Context

Natural England is working in partnership with South Cumbria Rivers Trust, Environment Agency and Freshwater Biological Association to deliver the LIFE R4ever Kent project. The project aims to restore and revitalise the River Kent Special Area of Conservation (SAC) and its wider catchment, so it is more resilient to environmental pressures. The project is financially supported by LIFE, a financial instrument of the European Commission.

The River Kent is designated as a Site of Special Scientific Interest (SSSI) and SAC for its very high densities and nationally important population of White-clawed Crayfish *Austropotamobius pallipes*. The species is listed as Endangered and declining on the International Union for Conservation of Nature (IUCN) red list of threatened species. Particular threats to the long-term survival of the species include habitat degradation, water pollution, disease, and displacement by Non-indigenous Crayfish Species (NICS), particularly American Signal Crayfish *Pacifastacus leniusculus*.

As part of the LIFE R4ever Kent project, the identification of viable ark sites for White-clawed Crayfish is being undertaken. This is in response to the identified need for proactive planning for a potential plague outbreak in the River Kent catchment, the only major English river system where White-clawed Crayfish populations are still abundant throughout. Ark site establishment is a proven conservation measure for White-clawed Crayfish where safe sites are set up to help conserve the species. In the context of this project, this also includes identifying sites which could be classified as ark sites where White-clawed Crayfish are already present.

1.2 Purpose of report

This report presents the desktop study for ark site suitability within the River Kent catchment. It is one of the first steps for determining if crayfish conservation action is possible within an area. Figure 1-1 summarises the ark site process published in the Crayfish Conservation Manual (Marshall and Nightingale, 2021).

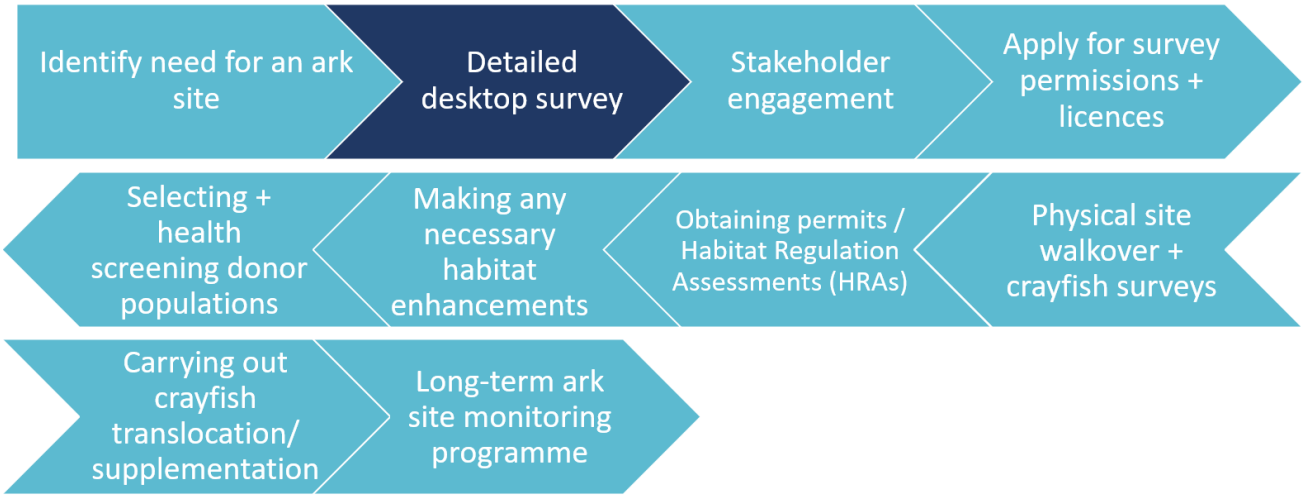


Figure 1-1: Summary of the ark site process

1.3 Aims and objectives

The desktop study will collect available relevant information within the River Kent catchment. The data will be utilised to make an initial appraisal of site suitability for sustaining long-term, White-clawed Crayfish populations. The aim of the desktop study is to develop a shortlist of potential ark sites within the River Kent Catchment.

The objectives are as follows:

- Utilise up-to-date available information in the recently published Crayfish Conservation Manual (Marshall and Nightingale, 2021).
- Consider the potential for ark sites at different spatial scales:
  - Catchment level
  - WFD water body level
  - Headwater tributaries
  - Isolated still-waters
- Record reasons for not progressing investigation of sites for use in future assessments.
- Make use of Geographic Information Systems (GIS) to ensure the desktop study is of sufficient quality when informing conservation actions.
- Consider available data relating to the topics described in the Crayfish Conservation Manual (Marshall and Nightingale, 2021).

1.4 Study area

The study area is the River Kent catchment boundary as shown in Figure 1-2, along with its component sub-catchments. Each sub-catchment is defined by the WFD water bodies and these are labelled with their WFD water body name; 'conf' is an abbreviation of 'confluence'.

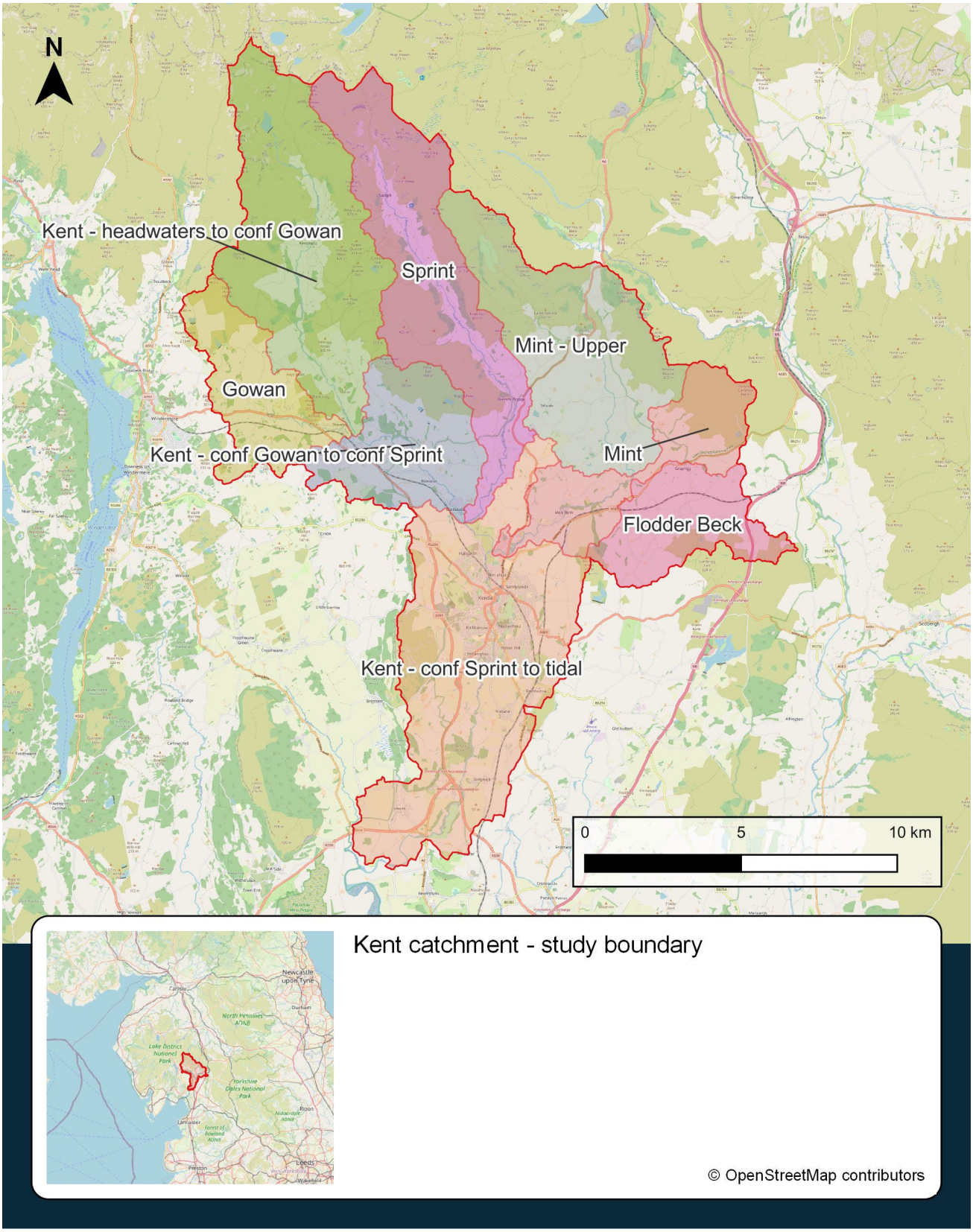


Figure 1-2: Study area

2 Methodology

2.1 Data acquisition

The Crayfish Conservation Manual (Marshall and Nightingale, 2021) provides details of data to be considered within the desktop survey. All reasonable efforts were undertaken to obtain data relevant to the study and included searches of online open-source data, and data held by Natural England and Environment Agency. A data register for the project is included in Appendix A. Details relating to show-stopper species are provided in Appendix F.

2.2 Screening and evaluation of ark site suitability

2.2.1 Spatial extent

Screening and evaluation of ark sites has been applied to the following spatial scales:

- River Kent WFD operational catchment
- Individual River Kent catchment WFD water bodies
- Individual headwater tributaries
- Isolated still-waters

2.2.2 Screening process

A screening process allows for sites to be eliminated from further assessment, whereby the first screening assesses criteria considered most critical for ark success. The approach used is a hybrid between the methods published in 'Criteria for selecting ark sites for white-clawed crayfish' (Peay, 2009) and the ark site desktop study assessment in the 'Crayfish Conservation Manual' (Marshall and Nightingale, 2021).

The existing published methods for ark site selection are most appropriate for individual sites and are not adequate for high-level and rapid screening of site suitability at large spatial scales and across multiple sites. A novel approach has been developed by JBA Consulting using GIS software (see Chapter 2.2.3) to partially automate the screening process by attributing numerical score weightings to certain criteria. There are both benefits and constraints of using a score-based approach, and these are discussed further in Chapter 2.4.

The screening process is shown in Figure 2-1. A site must 'pass' the screening test in order to progress to the next test; screening test outcomes (also referred to as classifications) of 'bad' or 'poor' suitability are eliminated from further assessment. Details of each screening test and the associated data analysed is provided in Appendix B.

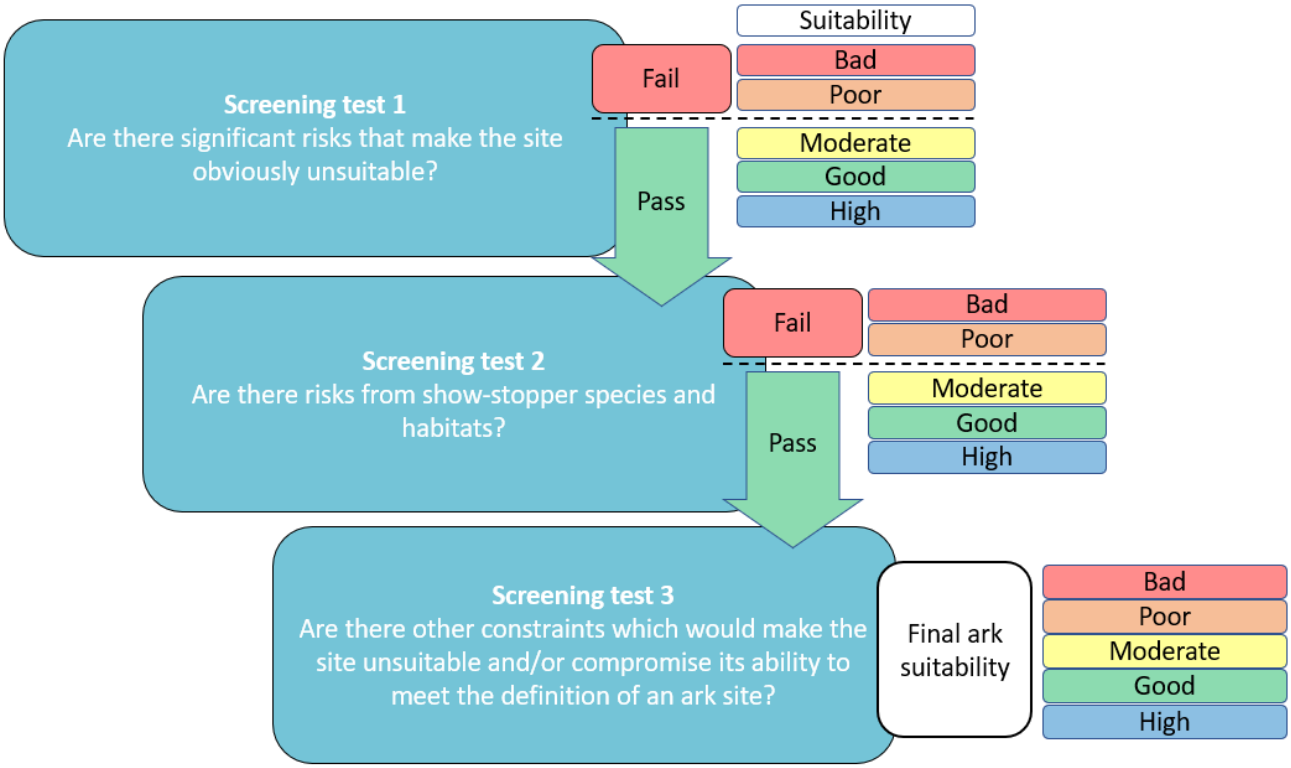


Figure 2-1: Screening process flowchart

2.2.3 GIS

The software QGIS and Microsoft Excel have been used to generate a statistical representation of sites that are the most suitable for taking forward to the next stage of ark site selection (refer to Figure 1-1).

The 'OS OpenRivers' dataset was used to create points at 200m intervals along the river network in the study area. These are referred to as 'river points' in the report. This spacing provides a granular view considered appropriate to the scope of the study.

Metadata for topics relevant to the study were manipulated so as to provide information relevant for the appraisal of ark site suitability. The datasets were then intersected with the river network (either already intersecting or placed on the network at the closest location within 50m (with the exception of 10m for barrier data, and 1km for angling data)). This generated a point-lookup dataset, snapped to the river network.

To effectively 'score' each 200m point on the river network, network analysis was used to calculate the distance from a river point to each of the datasets. In general, scoring was based on distance from a river point to a certain dataset; the closer the constraint to a river point, the lower (worse) the score awarded. For some datasets, e.g. barriers, the distance was calculated in one direction only, and the closer the point the better the score in this instance. Alternatively, for polygon data, scores were awarded depending on whether the river point is 'within' a certain dataset. A similar scoring approach was used in the appraisal of isolated still-waters but using straight-line distances instead of distance via the river network. Scoring criteria for each data set can be found in Appendix C.

A suitability score for each river point was generated for each screening test by summing the relevant scores:

Screening 1 = sum of screening test 1 scores for each river point

Screening 2* = sum of screening test 1 scores which passed + screening test 2 scores for each river point

Screening 3* = sum of screening test 2 scores which passed + screening test 3 scores for each river point

*River points which 'failed' the previous screening test are excluded and no further calculation is applied

Suitability has been ranked from 'bad' to 'high' (refer to Figure 2-1). Five equal intervals were generated using the graduated symbology function in QGIS. The values for each suitability classification are presented in Appendix C.3. The classification of the River Kent catchment and WFD water bodies has been determined by the classification with the greatest proportion of river points. For example, if 37% of river points are within the 'good' suitability threshold, and 39% of river points are within the 'moderate' suitability threshold, then the suitability classification for that water body would be 'moderate'.

2.3 Charts

Microsoft Excel was used to create charts to supplement the interpretation of results and provide a visual representation. A pie chart was produced for each spatial area which shows the proportion of river points (or isolated still-waters) within the area meeting each classification ('poor' to 'high'). A bar chart was produced for each spatial area which shows the proportion of river points (or isolated still-waters) passing or failing each screening test in isolation. For clarity, this was conducted for all river points and isolated still-waters; no sites were excluded, irrespective of whether they failed the previous screening test. This provides an informative graphic showing which group of constraints had the greatest influence on suitability classification.

2.4 Limitations

The data used in this study is based on the information available at the time and the results and conclusions are accordingly factually limited by these circumstances. Data-specific limitations are reported in Appendix A.

All reasonable efforts were made to obtain data relevant to the study (based on the list published in Marshall and Nightingale, 2021). It is possible that additional data may become available (for example, information on water-based activities such as canoeing, kayaking, Stand Up Paddle (SUP) boarding etc which are not currently included in the study). Also of importance is that a systematic survey for White-clawed Crayfish has not been undertaken in the catchment and it is reported to be likely that the species is present throughout (pers com). With the method developed for this study, it will be possible to introduce new datasets and/or update existing data sets with relative ease. This would incur additional work not included within the current scope.

The desktop study forms the first stage of ark site suitability assessment and therefore the outputs should be used for indicative purposes only; i.e. to inform which sites should be prioritised for further assessment stages.

The use of a cumulative score approach can lead to the inclusion of sites which may be subject to one or more significant constraints, e.g., it scores highly in other areas and the overall cumulative score passes a minimum threshold for ark suitability, or vice versa whereby a site is screened out based on a risk which could be readily resolved. An example of this could be where NICS are present within a site, but it otherwise scores very highly in all other criteria. To reduce the likelihood of this occurring, and to give greater confidence in the veracity of the results, the scoring approach has been integrated with the screening methodology so that sites must 'pass' each test to proceed. Although the thresholds of suitability remain relatively arbitrary, they function well as an indicator of prioritisation for future assessment. There is a level of subjectivity in the selection of criteria to test against for each screening stage however, professional judgement has been used with reference to the existing methodologies (Peay, 2009, and Marshall and Nightingale, 2021). The results are supported by a qualitative assessment and discussion so that limitations arising from the quantitative approach can be mitigated.

The ark site suitability results should be viewed in the context of the River Kent catchment only, as a way of prioritising sites within the study area. The suitability of a site (or river point) could also be interpreted as 'is this site better or worse than another site'. If the study was conducted at a national level, the suitability would be predicted to be uniformly higher across the catchment based on the assumption that the population of White-clawed Crayfish are indicative of suitable sites with limited constraints.

One of the benefits of a scoring approach is that scores can be manipulated and sensitivity levels adjusted as required. The results need to be considered holistically and treated as an indicative guide for prioritising sites for future assessment.

3 Results and discussion

The results of the ark suitability assessment are presented in a series of maps found in Appendix E, and a discussion is provided below.

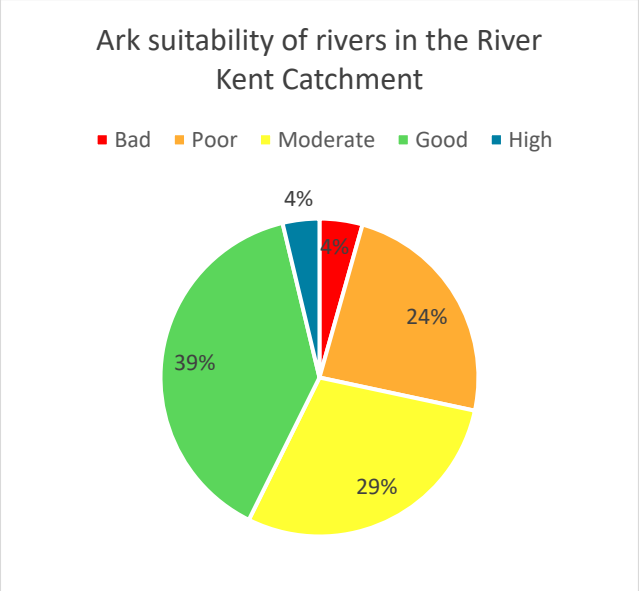
3.1 River Kent Catchment

The River Kent catchment is classified as having 'good' suitability as an ark site; with 39% of river points meeting this classification following the three screening tests (Figure 3-1). However, a large proportion of river points within the catchment were classified as 'moderate' suitability (29%), and almost a quarter (24%) of river points were classified as 'poor' suitability. Only 4% of river points were classified as 'high' suitability, and 4% were classified as 'bad' suitability. Accumulatively, river points classified as 'moderate' suitability or below account for 57% of river points within the River Kent catchment.

Almost all (99%) of river points passed screening test 1 (Figure 3-2). The points which failed are solely associated with the historic record of American Signal Crayfish in Borrans Reservoir (within the River Gowan water body).

Points failing screening test 2 (9%) are associated with the presence of show-stopper species, namely records of Red List bryophyte or lichen species, and invasive non-native plants.

Points failing screening test 3 (20%) are associated with several other constraints, but primarily correlate to the distribution of discharge and abstraction locations, which are numerous along the River Kent, River Mint, and River Sprint within the lower half of the Kent catchment. Strava heatmap shows moderate and high swimming activity in these rivers which provides potential biosecurity threat. Superficial geology for much of the catchment is till and this was ranked poorest for its ability to hold water compared to other superficial geology types within the catchment.



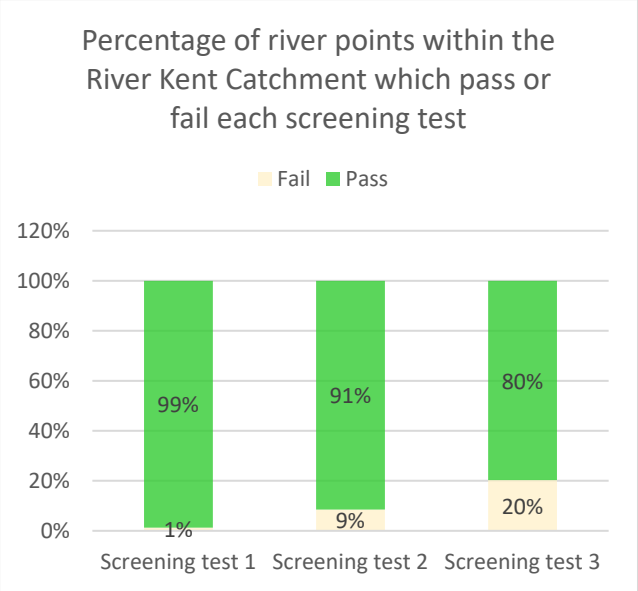


Figure 3-1: Ark suitability of rivers in the Kent catchment (left)

Figure 3-2: Proportion of river sites in the Kent catchment which pass each screening test (right)

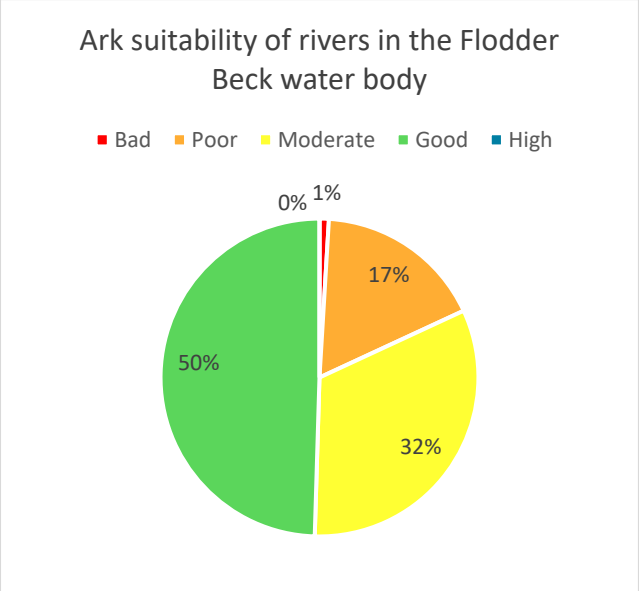
3.2 WFD water bodies

3.2.1 Flodder Beck

Flodder Beck (water body ID GB112073071340) is classified as having 'good' suitability, with half (50%) of river points in the water body meeting this classification after the three screening tests (Figure 3-3). Approximately one third of the water body was classified as 'moderate' suitability (32%), 17% as 'poor' suitability, and 1% as 'bad' suitability. No river points were classified as 'high' suitability. Accumulatively, half of river points were classified as 'moderate' suitability or below. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

All river points passed screening test 1 (Figure 3-4) and screening test 2 indicating that there are no NICS or records of show-stopper species present.

The majority of river points passed screening test 3 (82%). Those which failed are attributed to their location within lowest ranking geology types; till, and mudstone, siltstone and sandstone bedrock. The presence of flood zone 3 on Lambrigg Beck and Flodder Beck also reduces the scores.



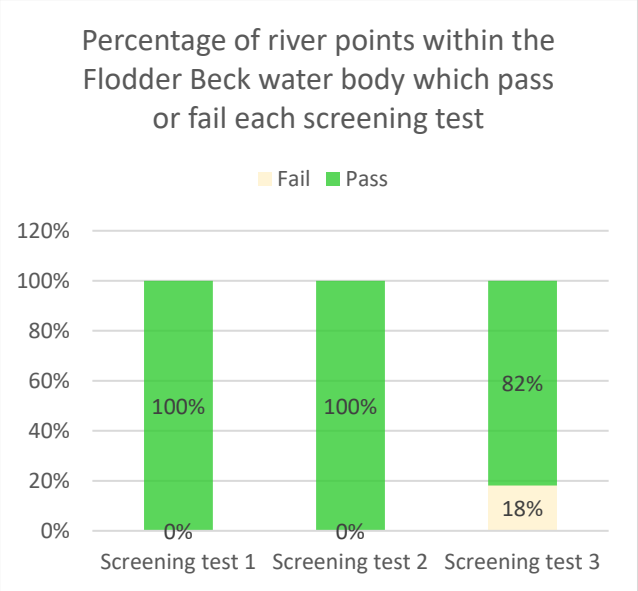


Figure 3-3: Ark suitability of rivers in the Flodder Beck water body (left)

Figure 3-4: Proportion of river sites in the Flodder Beck which pass each screening test (right)

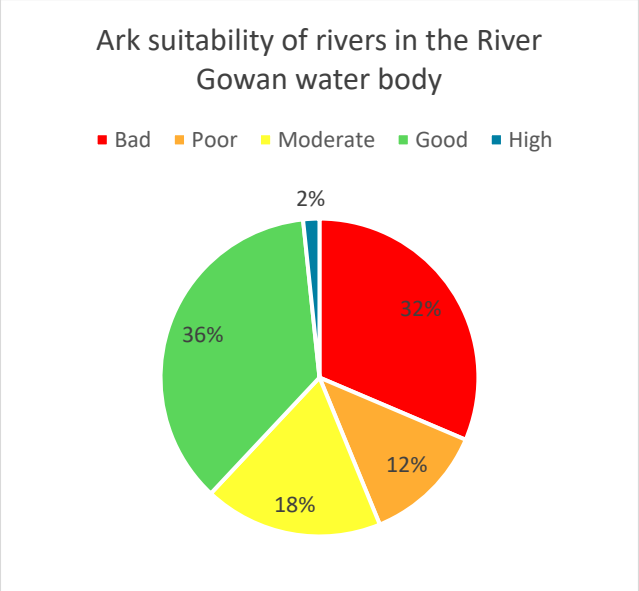
3.2.2 River Gowan

The River Gowan (water body ID GB112073071410) is classified as having 'good' suitability, with 36% of river points in the water body meeting this classification after the three screening tests (Figure 3-5). However, almost one third (32%) were classified as 'bad' suitability, 18% were classified as 'moderate' suitability, and 12% were classified as 'poor' suitability. Only 2% of river points within the water body were classified as having 'high' suitability. Accumulatively, points achieving 'moderate' suitability or below account for 62% of all river points in the water body. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

River points which failed screening test 1 (8%) (Figure 3-6) are associated with the record of American Signal Crayfish at Borrans Reservoir. Two identical records exist from 2012 (likely to be duplicates). Considering the date of the record (2012), it is possible that the species is either now widespread in the local waterways, or, as there have been no records in the last 11 years, the species is no longer present or that the individual was misidentified. Confirmation will be essential to the ark suitability further assessments in the catchment, including testing for the presence of crayfish plague *Aphanomyces astaci*.

Over three quarters of river points passed screening test 2 (77%). The river points which failed are associated with records for Canadian Waterweed *Elodea canadensis* in the upper reaches.

The majority of river points passed screening test 3 (79%). The sites which failed are associated with the considerable number of commercial and domestic discharges into the River Gowan at Ings which are likely to make downstream sites unsuitable within the water body and offtake points from the two reservoirs in the upper catchment may make the localised area unsuitable due to potentially rapid water chemistry and temperature changes. The impact of the reservoirs on water chemistry, temperature, and flows should be investigated to determine the suitability as an ark site. Flood zone 3 extends away from the main river at Ings and engulfs a couple of tributaries and floodplain. Although the tributaries are already hydrologically linked, this could exacerbate spread of NICS, disease etc if present, increasing vulnerability. Aside from the reservoir offtakes, the upper catchment is relatively suitable and the score is only limited by the less favourable geology of till (superficial) and mudstone, and sandstone and conglomerate, interbedded bedrock.



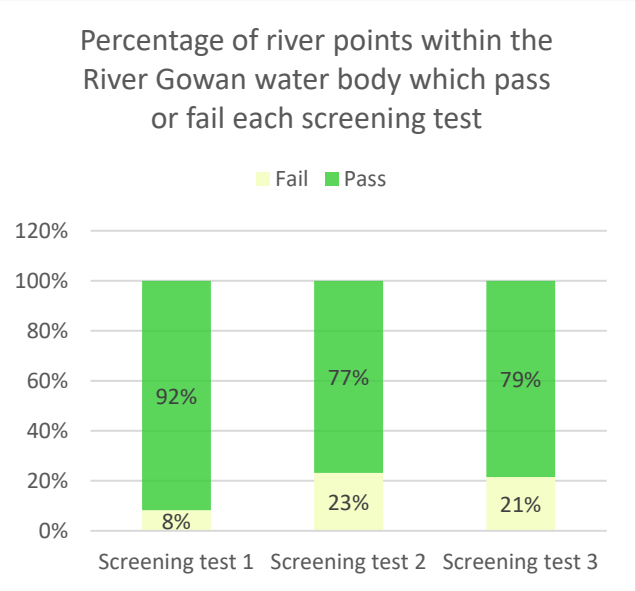


Figure 3-5: Ark suitability of rivers in the River Gowan water body (left)

Figure 3-6: Proportion of river sites in the River Gowan water body which pass each screening test (right)

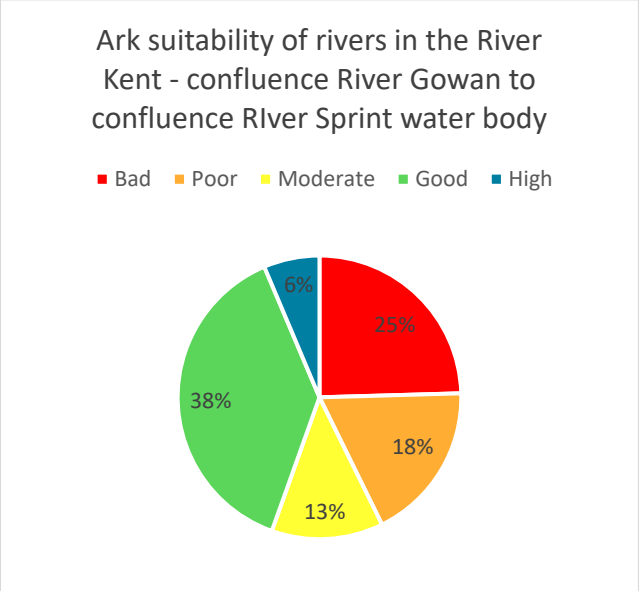
3.2.3 River Kent - confluence River Gowan to confluence River Sprint

The River Kent - confluence River Gowan to confluence River Sprint (water body ID GB112073071380) is classified as having 'good' suitability, with 38% of river points in the water body meeting this classification after the three screening tests (Figure 3-7). However, one quarter of river points in the water body are classified as 'bad' suitability (25%), 18% are classified as 'poor' suitability, and 13% are classified as 'moderate' suitability. River points classified as 'high' suitability account for 6% of the river points in the water body. Accumulatively, points achieving 'moderate' suitability or below account for 56% of all river points in the water body. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

All river points passed screening test 1 (Figure 3-8), indicating the absence of NICS, and favourable WFD ecological status.

River points passing screening test 2 accounted for 93% of all points. Those which failed can be attributed to the presence of showstopper species, namely records for Red List bryophytes and invasive plants.

River points failing screening test 3 (22%) are attributed to a number of cumulative constraints, including scattered abstraction and discharge points, location within flood zone 3, and less favourable geology types.



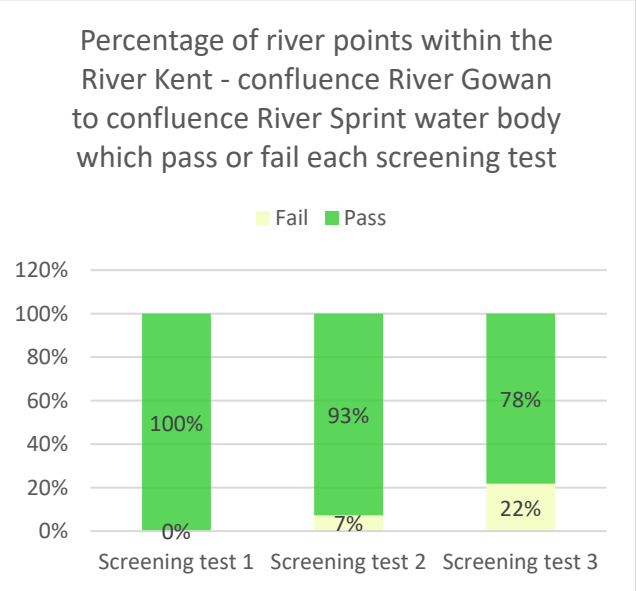


Figure 3-7: Ark suitability of rivers in the River Kent - confluence River Gowan to confluence River Sprint water body (left)

Figure 3-8: Proportion of river sites in the River Kent - confluence River Gowan to confluence River Sprint water body which pass each screening test (right)

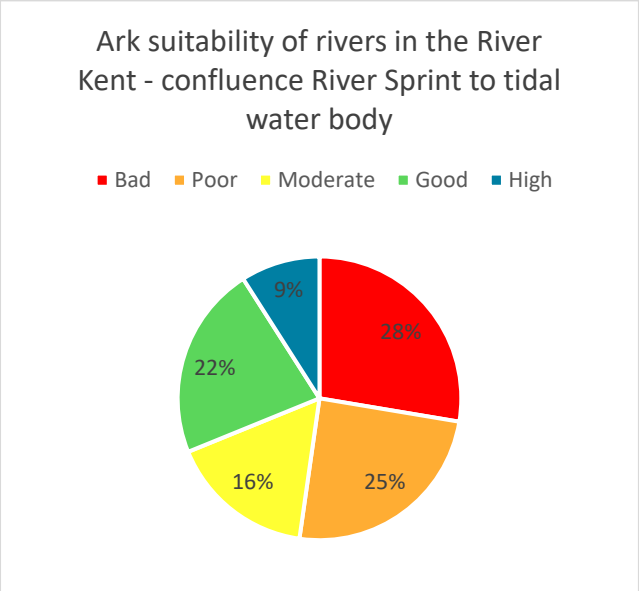
3.2.4 River Kent - confluence River Sprint to tidal

The River Kent - confluence River Sprint to tidal (water body ID GB112073071460) is classified as having 'bad' suitability, with 28% of river points in the water body meeting this classification after the three screening tests (Figure 3-9). One quarter of river points within the water body were classified as 'poor' suitability (25%), 22% as 'good' suitability, 16% as 'moderate' suitability, and 9% as 'high' suitability. Accumulatively, 69% of river points were classified as 'moderate' or below.

All river points passed screening test 1 (Figure 3-10), indicating the absence of NICS, and favourable WFD ecological status.

River points failing screening test 2 account to 21% of all river points. This is attributed to the presence of show-stopper species in the lower half of the water body, namely invasive plants and Red List species of bryophytes and lichens.

River points failing screening test 3 (22%) are attributed to the substantial number of commercial and domestic discharge points within the water body, numbering 22 in total. The assessment of water-users indicated a high density of activity within the River Kent downstream of Kendal, and moderate activity throughout the town. Bedrock is generally very favourable.



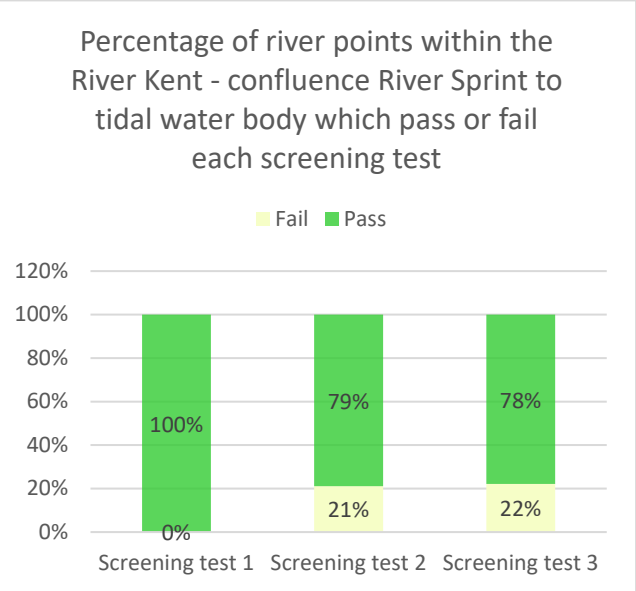


Figure 3-9: Ark suitability of rivers in the River Kent - confluence River Sprint to tidal water body (left)

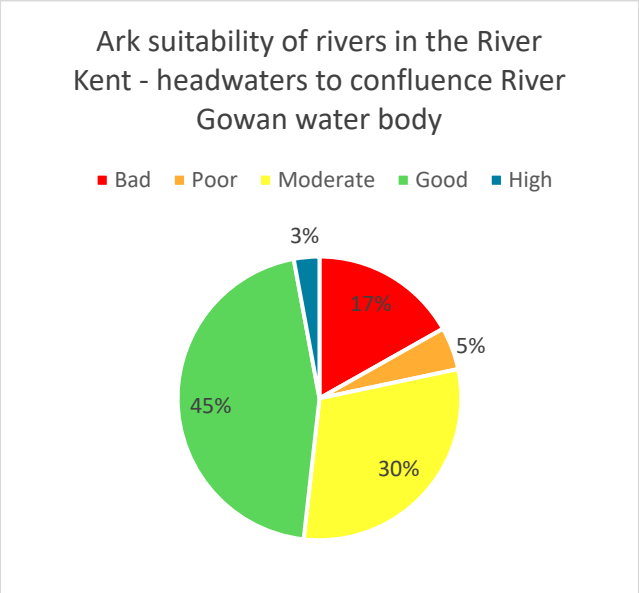
Figure 3-10: Proportion of river sites in the River Kent - confluence River Sprint to tidal water body which pass each screening test (right)

3.2.5 River Kent - headwaters to confluence River Gowan

The River Kent - headwaters to confluence River Gowan (water body ID GB112073071390) is classified as having 'good' suitability, with 45% of river points in the water body meeting this classification after the three screening tests (Figure 3-11). Approximately one third (30%) of river points were classified as 'moderate' suitability, 17% were classified as 'bad' suitability, 5% were classified as 'poor' suitability, and 3% were classified as 'high' suitability. Accumulatively, almost half (48%) of the river points in the water body achieved 'good' or 'high' suitability. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

All river points passed screening test 1 and 2 (Figure 3-12). This indicates an absence of NICS, suitable WFD ecological status, and an absence of records of show-stopper species.

Almost all (95%) of river points in the water body passed screening test 3. Barriers comprising both artificial weirs and natural waterfalls are relatively abundant in the water body which is favourable to halt or delay upstream migration of NICS. There is moderate water-use from wild-swimming between Kentmere and Staveley, and an angling club at Kentmere Reservoir. These activities present potential biosecurity risk and vulnerability and this is reflected in the scoring. There are very few abstraction or discharge locations. Flood zone 3 is limited to the River Kent and Hall Beck, with most of the headwaters outside this zone. The geology is favourable, although not the highest scoring.



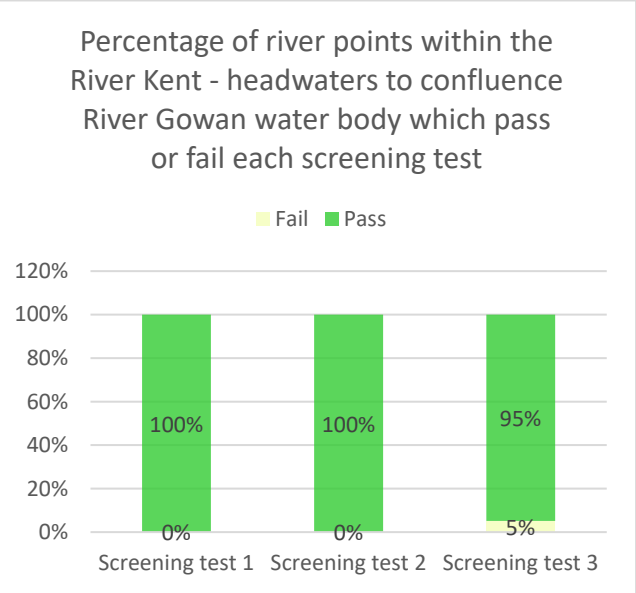


Figure 3-11: Ark suitability of rivers in the River Kent - headwaters to confluence River Gowan water body (left)

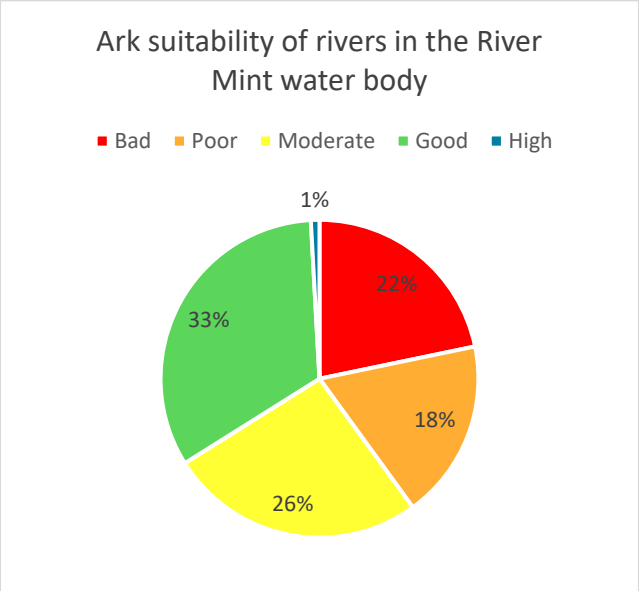
Figure 3-12: Proportion of river sites in the River Kent - headwaters to confluence River Gowan water body which pass each screening test (right)

3.2.6 River Mint

The River Mint (water body ID GB112073071370) is classified as having 'good' suitability, with 33% of river points in the water body meeting this classification after the three screening tests (Figure 3-13). However, a high proportion of sites were classified as 'moderate' suitability (26%) and 'poor' suitability (22%). 'Poor' suitability accounted for 18% or river points, and 'High' suitability accounted for 1% of river points within the water body. Accumulatively, 66% of river points were classified as 'moderate' suitability or below. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

All sites passed screening test 1 and 2 (Figure 3-14). This indicates an absence of NICS, suitable WFD ecological status, and an absence of records of show-stopper species.

River points failing screening test 3 (21%) are associated with moderate swimming activity within the River Mint throughout the water body and angling activity at Skelsmergh Tarn. There are five discharges in the lower half of the water body. The superficial geology present is the least favourable of those present in the Kent catchment (although not unsuitable), and the bedrock is a mosaic of all four types found in the catchment.



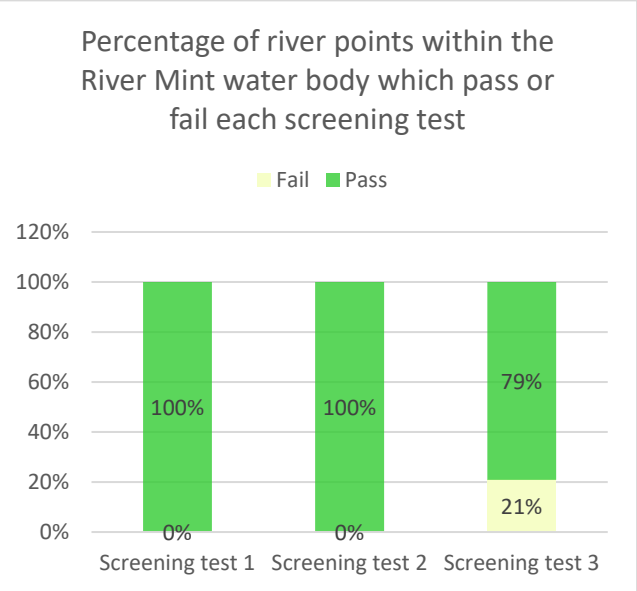


Figure 3-13: Ark suitability of rivers in the River Mint water body (left)

Figure 3-14: Proportion of river sites in the River Mint water body which pass each screening test (right)

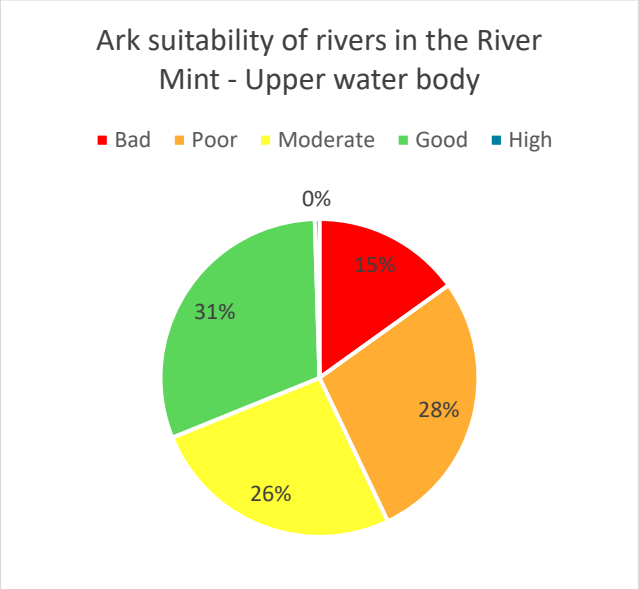
3.2.7 River Mint - Upper

The River Mint - Upper (water body ID GB112073074640) is classified as having 'good' suitability, with 31% of river points in the water body meeting this classification after the three screening tests (Figure 3-15). However, 28% of points were classified as 'poor' suitability, 26% were classified as 'moderate' suitability, and 15% were classified as 'bad' suitability. No river points were classified as 'high' suitability. Accumulatively, river points classified as 'moderate' suitability or below account for 69% of river points within the water body. This should be considered in the prioritisation of sites to investigate amongst those classified as 'good' suitability.

All river points passed screening test 1 (Figure 3-16). This indicated an absence of NICS records and favourable WFD ecological status.

Almost all (97%) river points pass screening test 2. Those which failed are associated with show-stopper species, which include Great Crested Newt *Triturus cristatus*, and Red List bryophyte species.

Approximately one third of river points failed screening test 3. This is attributed to abstraction and discharge points, which are relatively numerous within the water body. Additionally, there is a point at Kitcrag where the flood zone (flood zone 3) connects two watercourses not normally joined at the location (although they join further downstream). This means that any effort to isolate the tributary from NICS would be ineffective. The geology is mostly comprised the least favourable superficial and bedrock type(s) in the Kent catchment, although still considered suitable.



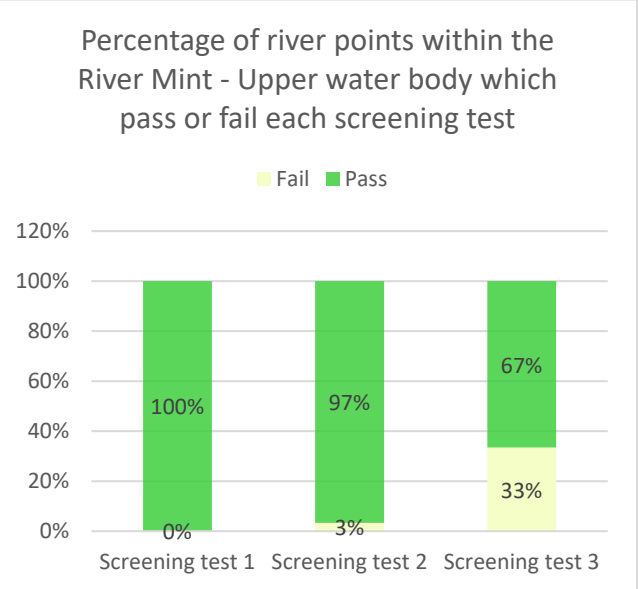


Figure 3-15: Ark suitability of rivers in the River Mint - Upper water body (left)

Figure 3-16: Proportion of river sites in the River Mint - Upper water body which pass each screening test (right)

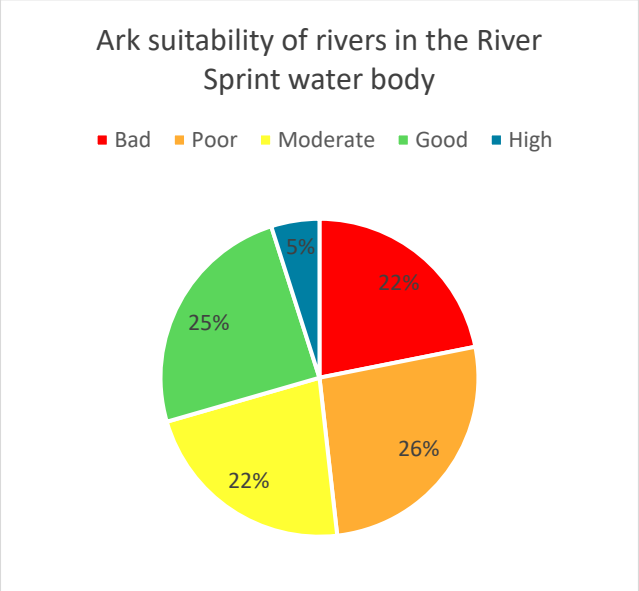
3.2.8 River Sprint

The River Sprint (water body ID GB112073071430) is classified as having 'poor' suitability (26%) (Figure 3-17), however, there are relatively equal percentages of river points being classified as 'good' suitability (25%), 'moderate' (22%) and 'bad' (22%). 'High' suitability accounts for 5% of river points. Accumulatively, river points classified as 'moderate' suitability or below account for 70% of all river points within the water body.

All river points passed screening test 1 (Figure 3-18). This indicates an absence of NICS records and favourable WFD ecological status.

River points failing screening test 2 (16%) are attributed to the presence of three records for Red List bryophyte species; two located in the middle of the catchment, and one located in the north of the catchment.

One quarter (25%) of records failed screening test 3. These almost entirely occur in the River Sprint between Garnett Bridge and Beech Hill Wood further upstream. The primary reasons for failure are moderate swimming activity in the river, abstraction points on tributaries in this region, and low scoring geology.



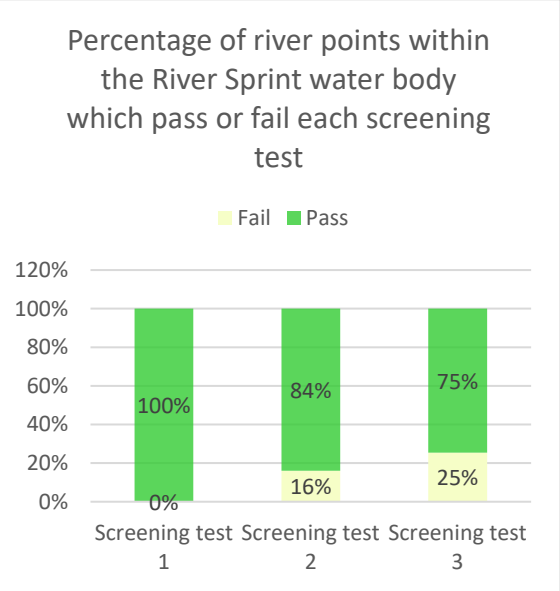


Figure 3-17: Ark suitability of rivers in the River Sprint water body (left)

Figure 3-18: Proportion of river sites in the River Sprint water body which pass each screening test (right)

3.2.9 Summary of results for WFD water bodies

Table 3-1 shows a summary of the ark suitability classifications for the River Kent catchment WFD water bodies. Six of the eight water bodies were classified as 'good' suitability, one was classified as 'poor' suitability, and one was classified as 'bad' suitability.

Table 3-1: Ark suitability classification for River Kent catchment WFD water bodies

WFD water body	Ark suitability
Flodder Beck	Good
River Gowan	Good
River Kent - confluence River Gowan to confluence River Sprint	Good
River Kent - confluence River Sprint to tidal	Bad
River Kent - headwaters to confluence River Gowan	Good
River Mint	Good
River Mint - Upper	Good
River Sprint	Poor

Figure 3-19 shows the ark suitability classification of river points within each of the water bodies, and Figure 3-20 shows the proportion of river points passing or failing each screening test for each water body. The latter shows within which water bodies constraints adversely affecting ark site suitability have the greatest influence, and which group of constraints this relates to (i.e. those grouped into screening test 1, 2, or 3). Constraints in screening test 1 (NICS records and WFD ecological status) has almost no influence in distinguishing suitability between water bodies (with the exception of the River Gowan). Show-stopper species (in screening 2) has a limited influence, affecting the suitability of five out of the eight water bodies. Constraints in screening 3 (e.g. discharges, abstractions, geology etc) have the greatest influence, with the largest impact on the River Mint - Upper water body which has only 67% of river points passing this screening test.

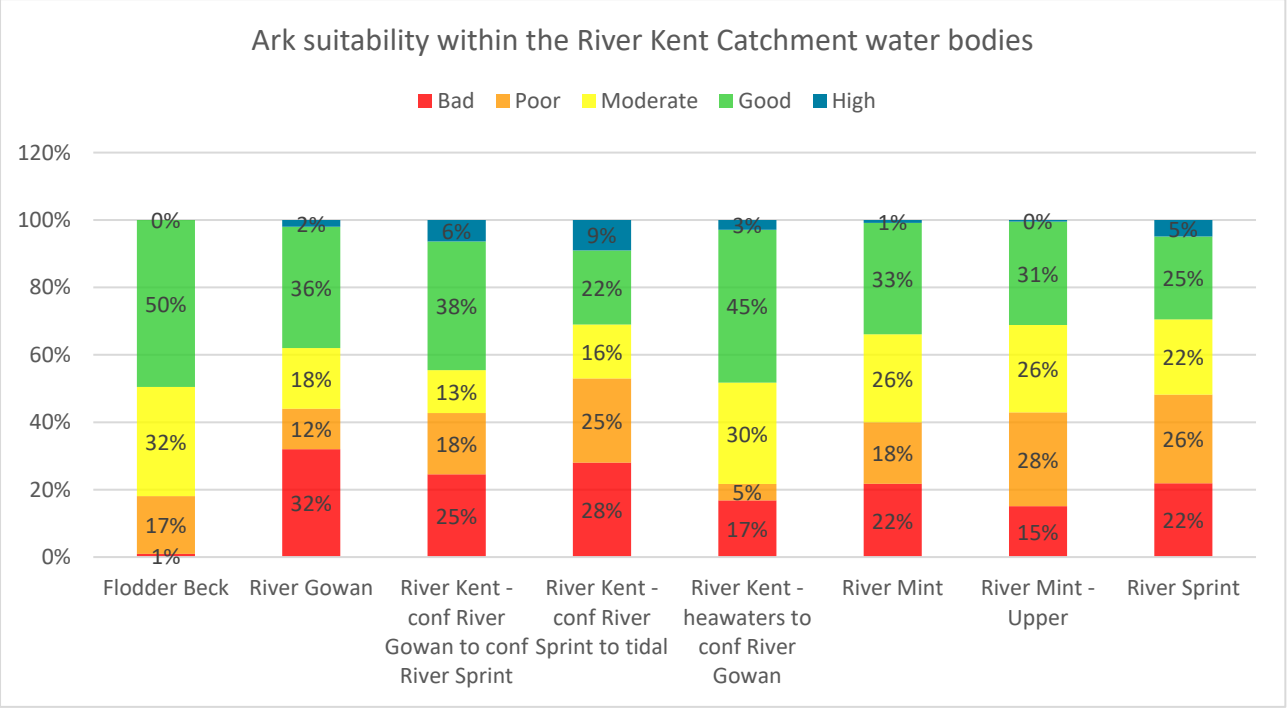


Figure 3-19: Ark suitability classification of river points within the River Kent catchment WFD water bodies

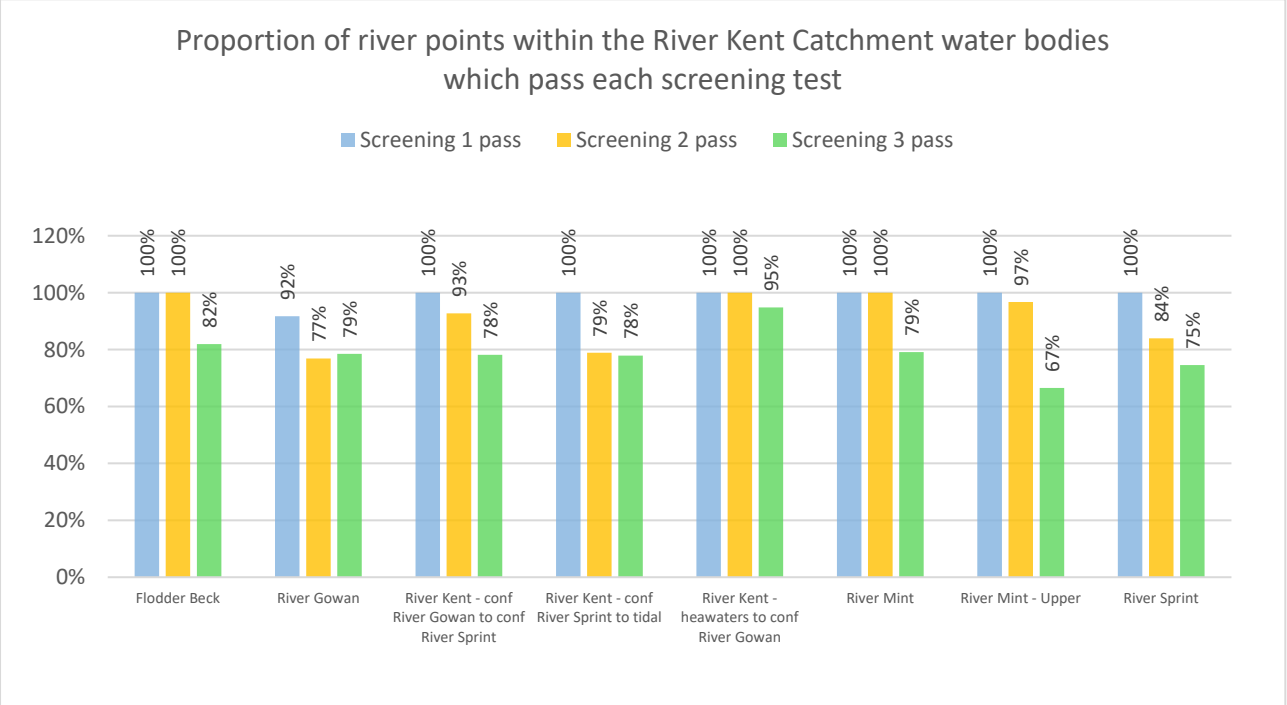


Figure 3-20: Proportion of river points within the River Kent catchment WFD water bodies which pass or fail each screening test

A further analysis of water bodies classified as 'good' ark suitability was undertaken to aid prioritisation. Figure 3-21 shows the order of priority (left being the highest priority, and right being the lowest priority) based on the accumulative percentage of river points within each water body which were classified as 'good' and 'high'. The top three priorities (in order) are Flodder Beck, River Kent - headwaters to confluence River Gowan, and River Kent - confluence River Gowan to confluence River Sprint.

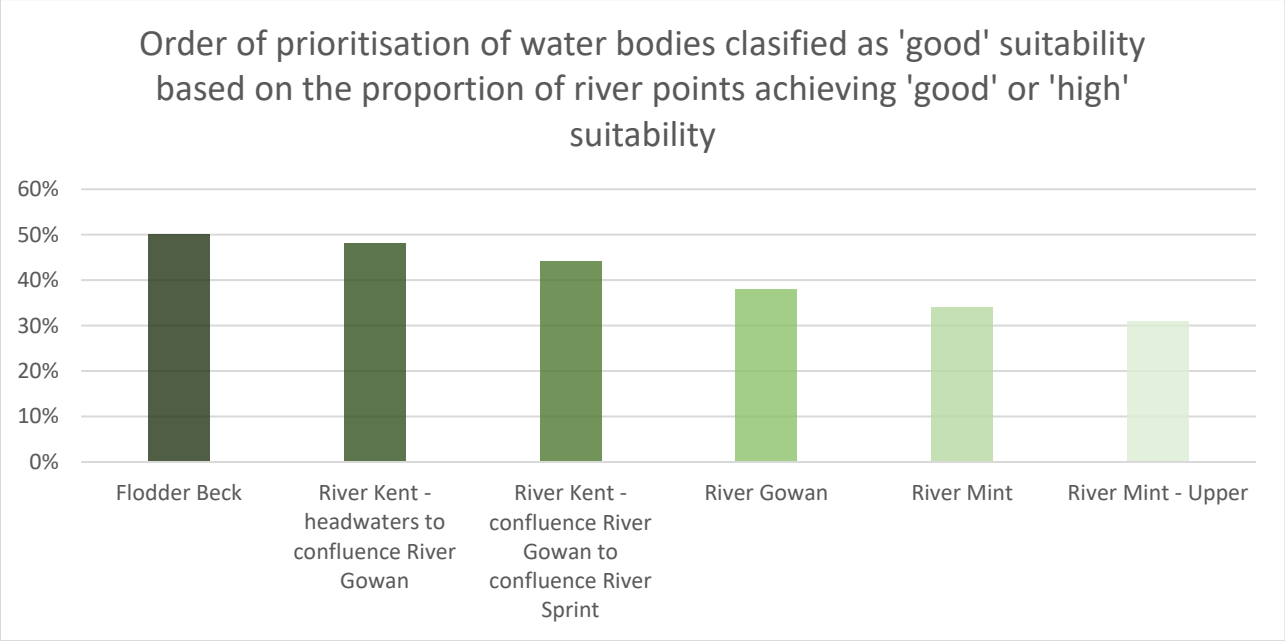


Figure 3-21: Order of prioritisation of water bodies classified as 'good' ark suitability [*Highest priority on the left, lowest priority on the right*].

3.3 Headwaters

Headwaters assessed as having the greatest potential for ark sites are discussed below and highlighted in Figure 3-22.

3.3.1 River Kent - confluence River Gowan to confluence River Sprint

The most favourable headwaters in this water body are located immediately upstream of barriers at SD488985 (at Frost Hole) and SD496986 (Potter Tarn area). These achieved a score of 'good' suitability with several points achieving 'high' suitability. It should be noted that swimming activity at Gurnal Dubs reduces the suitability of the tributary.

3.3.2 River Kent - headwaters to confluence River Gowan

The cluster of barriers at the bottom of the water body and the absence of any significant constraint makes headwaters within this water body particularly suitable, especially with several other barriers elsewhere which could provide secondary protection against NICS invasion. Headwaters above Kentmere are considered to offer the greatest ark site potential and scored mostly 'good' and 'high' following the screening tests. Assessment of the impact of releases from the reservoir should be investigated to determine the impact on the suitability of ark sites downstream. Additional opportunity exists in Hall Beck, particularly upstream of the barrier located at NY470008, and including Skeggles Water.

3.3.3 River Sprint

Headwaters in the River Sprint water body offer good potential as ark sites. Those located upstream of the barrier at NY477076 are particularly suitable, with most river points achieving a suitability classification of 'high', 'good' or 'moderate'. There are a number of barriers in sequence here, some of which could pose a significant barrier and provide potential protection from any upstream invasion of NICS. The wider area is also considered suitable, despite being classified as 'poor' because the factors influencing the score are not considered to be significant.

3.3.4 River Mint - Upper

Headwaters upstream of NY527022 are not influenced from discharges (which was considered to be the main limiting factor for water body suitability). River points were classified as between 'poor' and 'good' suitability in these headwaters; those scoring 'poor' were influenced by the flood zone score, absence of barriers, and less favourable geology; these constraints are not considered to be significant. There is a barrier downstream of the A6 in Bannisdale Beck which could be modified to offer a level of protection from NICS migration upstream (see Chapter 4.2).

Other potential is offered in headwaters upstream of the waterfall in the tributary that joins the River Mint at Kitcrag, and in Wolfhowe Gill, and Ashstread Beck. These areas achieved 'moderate' and 'good' suitability outcomes from the screening tests although there is an absence of local barriers, there are two weirs further downstream on the River Mint.

3.4 River Mint

Two headwater areas within the River Mint water body have been identified as suitable ark sites and river points in these areas are classified as 'good', or 'high' suitability. The boundaries are either drawn upstream of an abstraction point (to limit the influence this has on water availability), or a physical barrier (providing potential protection from any future upstream migration of NICS).

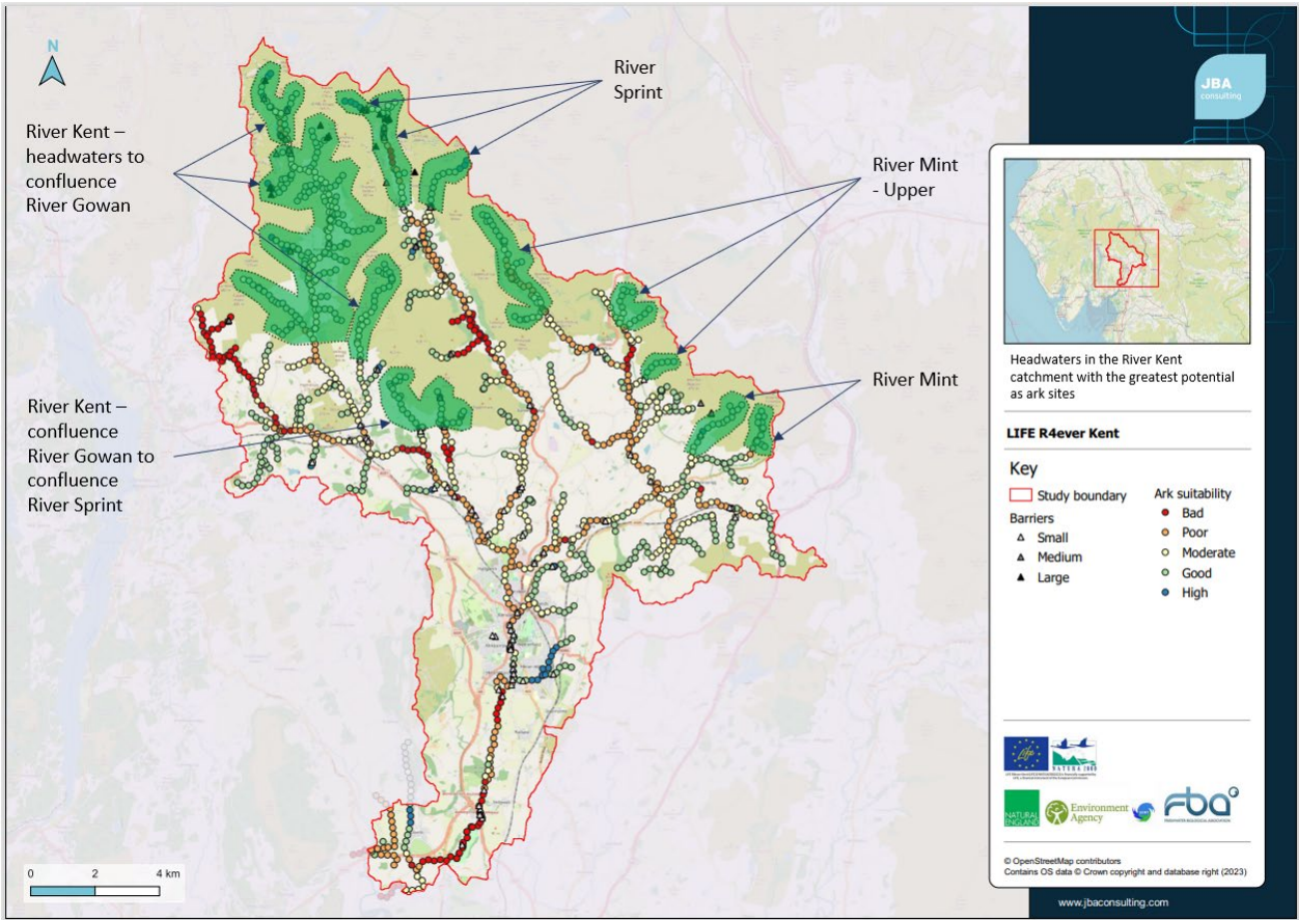


Figure 3-22: Headwaters in the River Kent catchment with the greatest potential as ark sites

3.5 Isolated still-waters

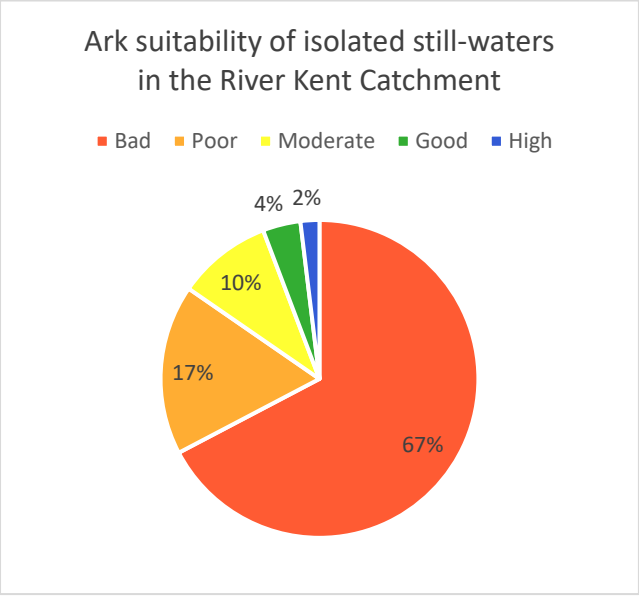
There are only 52 isolated still-waters which meet the minimum size threshold set for the study (which was 0.01ha and arbitrarily derived using professional judgement). These are almost entirely located within agricultural land in the centre of the catchment and comprise mostly of natural ponds.

Over half of isolated still-waters (67%) achieved a 'bad' suitability outcome following the three screening tests, and a further 17% of all sites achieved 'poor' suitability (Figure 3-23). Isolated still-waters classified as 'moderate' suitability accounted for 10% of sites, 4% of sites (2 sites) were classified as 'good' suitability, and one site (2%) was classified as 'high' suitability.

Approximately one third of isolated still-waters failed screening test 1 (Figure 3-24). The primary reason for sites which failed is the low likelihood or uncertainty around water permanency.

The majority of isolated still-waters passed screening test 2 (79%). Those failing are associated with records of show-stopper species including Great Crested Newt, predatory fish, and Red List bryophyte species.

Just over half (56%) of isolated still-waters passed screening test 3. The primary reason for sites not passing is because they are located in areas with less favourable geology. Superficial geology is closely associated with the appraisal of still-water ark site suitability and is ranked on its ability to hold water; an important consideration in the permanence of still-water features.



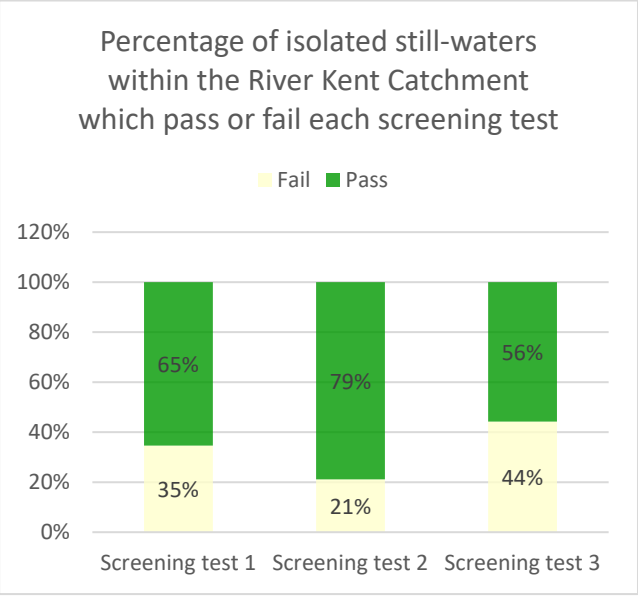


Figure 3-23: Ark suitability of isolated-still waters in the Kent catchment (left)

Figure 3-24: Proportion of isolated-still waters in the Kent catchment which pass each screening test (right)

Details of isolated still-waters considered to offer the greatest potential for ark suitability are discussed below.

Site 41 is the only isolated still-water with an outcome of 'high' suitability following the three screening tests. It is a 0.47ha pond associated with quarry workings west of Kendal (River Kent downstream of the confluence with River Sprint to the tidal water body). The only limitation identified in the screening is the proximity to aquatic invertebrate records (odonata) and superficial geology which is considered marginally less favourable than others in the catchment.

Site 6 is a smaller pond (0.03ha) adjacent to site 41. The suitability outcome was 'good' following the three screening tests and the same limitations apply.

Site 37 achieved an outcome of 'good' suitability following the three screening tests. It is a 0.39ha pond located amongst woodland located northeast of Meal Bank (River Mint - Upper water body). It is primarily limited by less favourable superficial geology. Satellite imagery shows substantial macrophyte growth at the pond edges and potential algal growth in the centre; this would need to be investigated if the site is taken forward for further ark suitability assessment.

Site 19 achieved an outcome of 'moderate' suitability following the three screening tests. It is a small pond (0.15ha) north or Grayrigg. It is situated in agricultural land grazed by livestock and is presumed to be for the purpose of providing livestock with a drinking point. Satellite imagery shows the pond to be devoid of vegetation and smooth banks, possibly concreted. It is recommended that this pond is not pursued in future investigation.

Site 27 achieved an outcome of 'moderate' suitability following the three screening tests. Satellite imagery shows it to be a medium sized (0.2ha), lined, excavation. It is presumed to be a pond but this is not confirmed. It is located in agricultural land next to a farm, east of Kendal, near to the River Kent catchment boundary.

Site 28 achieved an outcome of 'moderate' following the three screening tests. It is a medium sized pond (0.23ha) located amongst agricultural buildings and landscape, north of Grayrigg. Considering the surrounding land use and proximity to farm tracks, it is vulnerable to water quality issues. It is recommended that this pond is not pursued in future investigation.

Site 36 achieved an outcome of 'moderate' suitability following the three screening tests. It is a 0.34ha pond set within agricultural surroundings (grazing pasture, meadows, and scattered trees) located west of Burneside (River Kent downstream of the confluence with River Sprint to the tidal water body). Potential constraints include the proximity to aquatic records of predatory fish, although not within this still-water, and geology which is considered marginally less favourable than others in the catchment.

Site 45 achieved an outcome of 'moderate' following the three screening tests. It is a relatively large pond (0.53) located within an agricultural landscape, east of Watchgate. There is a cluster of ponds in this location, one of which is used for angling. Satellite imagery shows a managed lawn adjacent to the pond and a footpath around part of the

perimeter. It is considered possible this pond is also used for angling. It is recommended that this pond is not pursued in future investigation.

Site 52 (Whinfell Tarn) is a 4.83ha body of water located northeast of Meal Bank (Mint - Upper water body). Although it achieved an outcome of 'poor' suitability following the three screening tests, this is primarily associated with the underlying geology. The site is positioned in an agricultural landscape of grazing pasture and tree lines along field boundaries. A primary consideration will be water quality in the tarn as arial imagery shows expanses of algal growth on the surface. Due to the absence of other constraints it is considered suitable for future investigation.

3.5.1 Summary of results for isolated still-waters

Table 3-2 shows a summary of the ark suitability classifications for isolated still-waters which are recommended for future investigation.

Table 3-2: Isolated still-waters in the River Kent catchment recommended for future investigation

Isolated still-water reference number	Ark suitability
6	Good
27	Moderate
36	Moderate
37	Good
41	High
52	Poor

4 Opportunities

Opportunities for enhancement are well documented in Marshall and Nightingale (2021). The sections below provide a discussion of enhancement opportunities in broad terms and with reference to specific features where relevant.

4.1 Habitat enhancement

In broad terms, habitat enhancement includes physical modifications, shading, habitat quality and refuge availability, water quality, and water availability. Multiple benefits exist for habitat enhancements, for example, increasing shading can help to mitigate future effects of climate change and increased water temperatures, and improvements in water quality and habitat quality will benefit a multitude of aquatic fauna and flora, and associated ecosystem services. Site assessments are advised to accurately assess current conditions in proposed ark sites so that specific recommendations can be made.

4.2 Barriers

Certain features can be retrofitted to existing weirs to improve their suitability as a barrier to the upstream migration of NICS. Features include overhangs, smooth and non-porous clean surfaces, and modification to ensure the barrier is tied into the bankside to impede terrestrial migration upstream. There are 59 weirs reported within the Kent catchment. Those considered to be of most strategic value are located on:

- River Kent - headwaters to River Gowan water body
  - the River Kent at Staveley (3 no.)
  - downstream of Kentmere Reservoir (2 no.)
  - Hall Beck at Park House (1 no.)
- River Sprint water body
  - Garnett Bridge (1)
- River Mint - Upper
  - The River Mint near Whinfell Tarn
- River Kent - confluence River Gowan to confluence River Sprint
  - The River Kent at Bowston (3)

Effective barriers at these locations would help safeguard potential ark sites in the headwaters identified in Chapter 3.3.

Assessment of flow rate over barriers is recommended; it is reported in Marshall and Nightingale (2021) that a consistent, or above, flow rate of 0.65m/s should be maintained for the barrier to remain effective against NICS ascension.

Any modifications to barriers should also consider other potential environment objectives, for example enhancing fish passage, which may produce potential conflict of interest.

It is worth noting the abundance of waterfall barriers withing the catchment, primarily located within the headwater regions. These cannot be readily modified and an assessment of how effective they are as a barrier to NICS is recommended to improve confidence in the suitability of potential ark sites upstream.

4.3 Control/management of predators

There is an abundance of records across the Kent catchment for predator species. Most numerous and widely distributed are records for Otter *Lutra lutra* (although not recorded further north than Kentmere (in the River Kent) or Sadgill (in the River Sprint)), and American Mink *Neovison vison* (mostly limited to the lower half of the River Kent catchment). Control and mitigation is not deemed appropriate for Otter due to its European Protected Species (EPS) status. Control and eradication of American Mink is challenging and consideration should be given to whether this is likely to be sustainable and effective long term. Shading and tree cover will help reduce predation rates from both species.

Predatory fish are present, with records for European Eel, Brown Trout (from fish movement consent documentation visible to this study) and four other predatory species. Records do not indicate a high abundance (the success of individuals from the fish movement is unknown). In isolated still-waters, a drawdown is recommended where these species are suspected to be present. Individuals can then be safely removed.

There are 15 records for Great Crested Newt in the wider Kendal area. This doesn't indicate a high abundance but could reflect under reporting. Control and mitigation is not deemed appropriate due to its European Protected Species (EPS) status.

Aquatic invertebrate records are numerous and widespread across the catchment, particularly for odonata. The larvae can predate hatchling, and young-of-the-year crayfish and pose a potential threat in high abundances and in isolated still-waters. Survey for these species is recommended for isolated still-water sites which are being considered as ark sites.

4.4 NICS

There is a single record (and a duplicate) of American Signal Crayfish in the River Gowan, downstream of Stubbings Bridge (NY4308300823). It is imperative that presence/absence of Signal Crayfish is confirmed in this vicinity; it is unknown whether the individual / population has endured or become extinct or whether the record was as a result of misidentification.

The eradication of NICS is challenging and highly unlikely to be successful. Therefore, efforts should be made to manage the spread of NICS if found to be present.

4.5 Recreational water use

The primary risk from recreational water use is around biosecurity and the risk of introducing NICS, crayfish plague, disease, and other species (e.g. fish) that are not positive for the long-term survival of White-clawed Crayfish. Angling is a particular threat

due to the transfer of equipment between water bodies and the potential for nutrient loading from the use of bait.

The main opportunities to address these risks is through engagement and publicising conservation actions in priority areas. The water bodies River Kent - headwaters to the confluence of River Gowan, River Mint, and River Sprint have moderate recreational use (swimming and angling). Further investigation is recommended to identify other water sport activities (e.g. canoeing, kayaking, SUPing etc) in areas prioritised for ark sites.

4.6 White-clawed Crayfish survey

The distribution of White-clawed Crayfish is based on historical records and targeted surveys are therefore recommended in order to establish a better understanding of the population and distribution of the species in the Kent catchment.

5 Conclusions and recommendations

The Kent catchment is a stronghold for White-clawed Crayfish, with the population distributed throughout the River Kent and several of its main tributaries. The desktop study determined that there is excellent potential for the development of ark sites for the species, particularly in the headwaters, several isolated still-waters, and potentially at a water body scale in five of the WFD water bodies in the catchment. Although a significant proportion of the catchment achieved a 'moderate' or 'poor' ark suitability classification, it is recommended that these areas are interpreted as low priority for future investigation and 'less suitable' as opposed to 'unsuitable'. Consideration of existing White-clawed Crayfish populations is required so as to make a distinction between sites which can be already classified as ark sites, and areas where the species is currently absent, and can be investigated as future ark sites, i.e. where introduction of White-clawed Crayfish is possible. Conclusions and recommendations are detailed below.

5.1 River Kent catchment

The outcome of the suitability assessment for the Kent catchment achieved a classification of 'good' suitability. However, a large proportion of river points within the catchment were classified as either 'moderate' or 'poor' suitability. These were largely attributed to the cumulative impact of constraints located in the lower half of the catchment, the River Gowan, and the River Sprint. One of the main concerns is around water quality associated with the high abundance of commercial and domestic discharges. This presents a vulnerability, particularly associated with potential deterioration in water quality. Mitigation of these constraints is not realistic at the scale and cost that would be required.

5.2 River Kent water bodies

The outcome of the ark site suitability assessment for water bodies identified five water bodies classified as 'good' suitability, one with 'poor' suitability, and one with 'bad' suitability. The following water bodies (which all achieved a classification of 'good' suitability) are recommended for future assessment and are listed in order of priority based on the proportion of river points classified as 'good' or 'high' suitability.

- Flodder Beck
- River Kent - headwaters to confluence River Gowan
- River Kent - confluence River Gowan to confluence River Sprint
- River Gowan
- River Mint
- River Mint - Upper

5.3 River Kent catchment headwaters

The results of the ark suitability assessment for each water body revealed several headwater areas of 'good' and 'high' ark site suitability, and areas where constraints influencing lower suitability classifications are not considered significant. Certain headwaters within the following water bodies are recommended for prioritising in future assessment and are listed in order of priority:

- River Kent - confluence River Gowan to confluence River Sprint
- River Kent - headwaters to confluence River Gowan
- River Sprint
- River Mint - Upper
- River Mint

5.4 Isolated still-waters

The outcome of the ark site suitability assessment for isolated still-waters identified one site with 'high' suitability, two sites with 'good' suitability, and five sites with 'moderate' suitability. Using professional judgment, not all of these are recommended for further assessment. Furthermore, qualitative review of the results determined that one site (classified as 'poor' suitability) should be considered for future assessment. The following isolated still-waters are recommended for prioritising in future assessment:

- Site 41 ('high' suitability)
- Site 6 ('good' suitability)
- Site 37 ('good' suitability)
- Site 27 ('moderate' suitability'
- Site 36 ('moderate' suitability)
- Site 52 ('poor' suitability)

5.5 Opportunities

Opportunities identified at this stage include:

- Modification of weirs and maintenance of flow rates, particularly those at strategic locations. Caution is required to ensure these activities are compatible with other environmental objects, such as improving fish passage, and a water resources study would be necessary to determine feasibility.
- Increase shading at ark locations where appropriate to reduce the vulnerability of White-clawed Crayfish to predation from Otter and Mink.
- Consider a drawdown of isolated still-water sites so that undesirable fish species (e.g. species which predate upon White-clawed Crayfish) can be removed.
- Targeted surveys for White-clawed Crayfish.
- Survey of aquatic invertebrates in isolated still-waters being considered.
- Survey of isolated still-waters to determine water quality and water permanency.
- It is critical that the presence or absence of American Signal Crayfish is confirmed.
- Public engagement and publicising conservation actions with recreational users.

Site assessments are advised to accurately assess current conditions in proposed ark sites so that specific recommendations can be made.

A Data Register

B Screening tests

B.1 Rivers

Screening test	Topic	Dataset
1	Crayfish records	Non-indigenous Crayfish Species
	Historic habitat assessments	Water Framework Directive ecological status
2	Show-stopper species and habitats (see Appendix F)*	Freshwater Pearl Mussel Plants: Schedule 8 Wildlife and Countryside Act 1981 (as amended) Bryophytes, lichens Invasive plants
		Local Wildlife Site
3	Potential impacts from on-site activities	Angling
		Water-users
	Discharges	Waste Water Treatment Works
		Discharge type: reservoir
		Discharge type: commercial and domestic
	Abstraction	Abstraction
	Barriers	Barriers
	Geology	Superficial geology
		Bedrock geology
	Catchment topography & extent	Flood zone 3 (risk from flooding or inundation)

*records of predatory fish and amphibians were not included in the assessment of rivers. Fish are highly mobile and a record at a single location is not representative. Great Crested Newts do not typically breeding in rivers and therefore the larvae (which predate upon young crayfish) are not likely to be present. For both species, crayfish are more likely to be able to successfully evade predation than in isolated still-waters.

B.2 Isolated still-water bodies

Screening test	Topic	Dataset
1	Crayfish records	Non-indigenous Crayfish Species
	Water levels and climate	Water permanency
	Catchment topography & extent	Flood zone 3 (risk from flooding or inundation)
2	Show-stopper species and habitats (see Appendix F)*	Fish Amphibians: Great Crested Newt Aquatic invertebrates Plants: Schedule 8 Wildlife and Countryside Act 1981 (as amended) Bryophytes, lichens Invasive plants
		Local Wildlife Site
3	Potential impacts from on-site activities	Angling
		Water-users
	Discharges	Waste Water Treatment Works
		Discharge type: reservoir
		Discharge type: commercial and domestic
	Abstraction	Abstraction
	Geology	Superficial geology
		Bedrock geology

*records of Freshwater Pearl Mussel were not included in the assessment of isolated still-waters as the species is not associated with these habitats. Incidentally, no records for this species were returned.

C Scoring criteria

C.1 Rivers

Distance from river point (m)	Score (1=worst)	Data applied to
<250	1	Non-indigenous Crayfish Species records Show-stopper species and habitats (see Appendix F) On site activities (angling and water-users) Discharges: Waste Water Treatment Works (directional)
500	2	
1000	3	
2000	4	
>2000	5	

Distance from river point (m)	Score (1=worst)	Data applied to
<50	1	Discharges: reservoir (directional) Discharges: commercial and domestic (directional) Abstraction (directional)
100	2	
150	3	
200	4	
>250	5	

Distance from river point (m)	Score (1=worst)	Data applied to
>250	1	Barriers (directional)
200	2	
150	3	
100	4	
<50	5	

River point within bedrock geology type	Score (1=worst)	Data applied to
Mudstone, siltstone and sandstone	2	Bedrock geology
Sandstone and conglomerate, interbedded	3	
Sandstone, limestone and argillaceous rocks	4	
Limestone with subordinate and argillaceous rocks	5	
No bedrock geology	3	

River point within superficial geology type	Score (1=worst)	Data applied to
Till	1	Superficial geology
Alluvium	2	
Blown sand	3	
Raised marine deposits (undifferentiated)	3	
Glacial sand and gravel	4	
Peat	5	
No superficial geology	3	

River point within WFD status	Score (1=worst)	Data applied to
Moderate	3	Water Framework Directive status
Good	5	

River point within flood zone 3?	Score (1=worst)	Data applied to
Yes	1	Flood zone 3
No	5	

C.2 Isolated still-waters

Site contains the specific constraint?	Score (1=worst)	Data applied to
Yes	1	Non-indigenous Crayfish Species records Show-stopper species and habitats (see Appendix F) On site activities (angling and water-users) Discharges: commercial and domestic Abstraction Flood zone 3
No	5	

Distance from site (m)	Score (1=worst)	Data applied to
<250	2	Non-indigenous Crayfish Species records Show-stopper species and habitats (see Appendix F) On site activities (angling and water-users) Discharges: Waste Water Treatment Works
500	3	
1000	4	
>1000	5	

Water availability	Score (1=worst)	Data applied to
Likely poor	1	Water permanence
Unknown	3	
Likely	5	

Site within bedrock geology type	Score (1=worst)	Data applied to
Mudstone, siltstone and sandstone	2	Bedrock geology
Sandstone and conglomerate, interbedded	3	
Sandstone, limestone and argillaceous rocks	4	
Limestone with subordinate and argillaceous rocks	5	
No bedrock type	3	

Site within superficial geology type	Score (1=worst)	Data applied to
Till	1	Superficial geology
Alluvium	2	
Blown sand	3	
Raised marine deposits (undifferentiated)	3	
Glacial sand and gravel	4	
Peat	5	
No superficial geology type	3	

C.3 Suitability classification

Rivers

Screening 1	
6 - 7	Fail
8 - 10	Pass

Screening 2	
9 - 11	Fail
12 - 15	Pass

Screening 3	
40 - 43	Bad
44 - 46	Poor
47 - 49	Moderate
50 - 52	Good
53 - 55	High

Isolated still-waters

Screening 1	
8 - 11	Fail
12 - 15	Pass

Screening 2	
15 - 17	Fail
18 - 20	Pass

Screening 3	
35 – 36	Bad
37 – 38	Poor
39	Moderate
40 – 41	Good
42 - 43	High

D GIS files

The following GIS geopackage (.gpkg) files are provided with this study:

D.1 Results

- Rivers - ark suitability master copy
- Isolated still-waters - ark suitability master copy

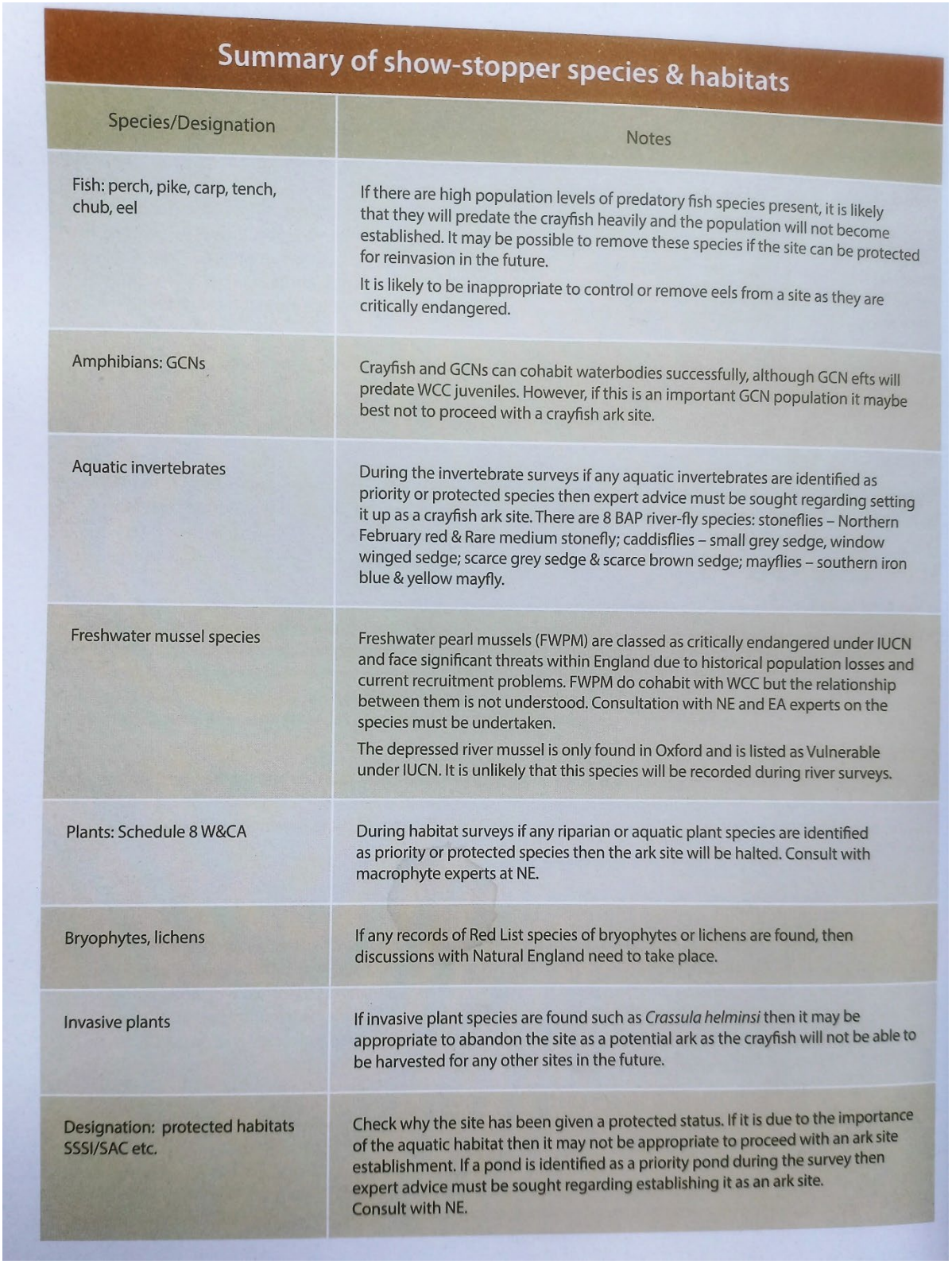
D.2 Ark suitability data

- Abstractions
- Angling sites
- Barriers
- Crayfish records - Non-Indigenous Crayfish Species (NICS)
- Crayfish records - White-clawed Crayfish
- Discharges - commercial and domestic
- Discharges - reservoir
- Fish movements
- Flood map - zone 3
- Geology - bedrock
- Geology - superficial geology
- Local Wildlife Site (LWS)
- Show-stopper species
- Waste Water Treatment Works
- Water permanence
- Water-users (based on Strava heatmap)
- WFD status - lake water bodies
- WFD status - water body catchments

E Results

F Show-stopper species and habitats

This list of show-stopper species and habitats is taken from the 'Summary of show-stopper species & habitats' table published in the Crayfish Conservation Manual (Marshall and Nightingale, 2021).



Summary of show-stopper species & habitats

Species/Designation	Notes
Fish: perch, pike, carp, tench, chub, eel	If there are high population levels of predatory fish species present, it is likely that they will predate the crayfish heavily and the population will not become established. It may be possible to remove these species if the site can be protected for reinvasion in the future. It is likely to be inappropriate to control or remove eels from a site as they are critically endangered.
Amphibians: GCNs	Crayfish and GCNs can cohabit waterbodies successfully, although GCN efts will predate WCC juveniles. However, if this is an important GCN population it maybe best not to proceed with a crayfish ark site.
Aquatic invertebrates	During the invertebrate surveys if any aquatic invertebrates are identified as priority or protected species then expert advice must be sought regarding setting it up as a crayfish ark site. There are 8 BAP river-fly species: stoneflies – Northern February red & Rare medium stonefly; caddisflies – small grey sedge, window winged sedge; scarce grey sedge & scarce brown sedge; mayflies – southern iron blue & yellow mayfly.
Freshwater mussel species	Freshwater pearl mussels (FWPM) are classed as critically endangered under IUCN and face significant threats within England due to historical population losses and current recruitment problems. FWPM do cohabit with WCC but the relationship between them is not understood. Consultation with NE and EA experts on the species must be undertaken. The depressed river mussel is only found in Oxford and is listed as Vulnerable under IUCN. It is unlikely that this species will be recorded during river surveys.
Plants: Schedule 8 W&CA	During habitat surveys if any riparian or aquatic plant species are identified as priority or protected species then the ark site will be halted. Consult with macrophyte experts at NE.
Bryophytes, lichens	If any records of Red List species of bryophytes or lichens are found, then discussions with Natural England need to take place.
Invasive plants	If invasive plant species are found such as *Crassula helminsi* then it may be appropriate to abandon the site as a potential ark as the crayfish will not be able to be harvested for any other sites in the future.
Designation: protected habitats SSSI/SAC etc.	Check why the site has been given a protected status. If it is due to the importance of the aquatic habitat then it may not be appropriate to proceed with an ark site establishment. If a pond is identified as a priority pond during the survey then expert advice must be sought regarding establishing it as an ark site. Consult with NE.

References

Peay, s. 2009. Criteria for selecting ark sites for white-clawed crayfish. Available from: https://cdn.buglife.org.uk/2019/07/Criteria-for-whiteclaw-ark-site-v1a-05April2009-1.xls (accessed 3 July 2023).

Marshall, I., and Nightingale, J. 2021. Crayfish Conservation Manual. Bristol, Rostra Publications.

JBA consulting

Offices at

Bristol
Coleshill
Doncaster
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Saltaire
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Thirsk
Wallingford
Warrington

Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
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Jeremy Benn
Associates Limited

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3246693

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