

Beaver Dam Capacity and Habitat Suitability: Spey Catchment, Scotland



March 2023

Prepared as part of a wider feasibility study into the potential return of beavers to Cairngorms
National Park by:

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*cover photo, main channel of River Spey, south of Blargie © Alan Puttock

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1. Summary

The habitat suitability and the capacity for beavers to dam channels within the study areas was assessed using beaver modelling tools developed by researchers at the University of Exeter (Graham et al., 2020). These modelling tools consist of a Beaver Habitat Index (BHI) model and a Beaver Dam capacity (BDC) model.

There is a requirement to complete an analysis of rivers catchments to assess their suitability for supporting populations of beaver. Beaver habitat suitability is determined primarily by vegetation suitability which has been classified nationally using a Beaver Vegetation Index (BVI) as well as access to water bodies. Together these two factors have been incorporated into a Beaver habitat Index model (BHI). BHI has been run nationally to develop a high resolution (5m) continuous raster product that can inform local decision making with regard to beaver reintroduction. BHI classifies habitat suitability from 0 (No access to vegetation - not suitable) to 5 (Highly Suitable)

Beavers are also well known as ecosystem engineers, having the capacity to change environments to suit their needs. The beaver engineering activity that has the greatest capacity to modify ecosystems is dam building. Dam building and the creation of ponded surface water has the ability to bring benefits (i.e. for biodiversity, water storage, flow attenuation) but also potentially management and conflict (i.e. localised inundation of land, blocking of critical infrastructure). BDC classifies reaches from no capacity for dam building to a pervasive capacity for damming.

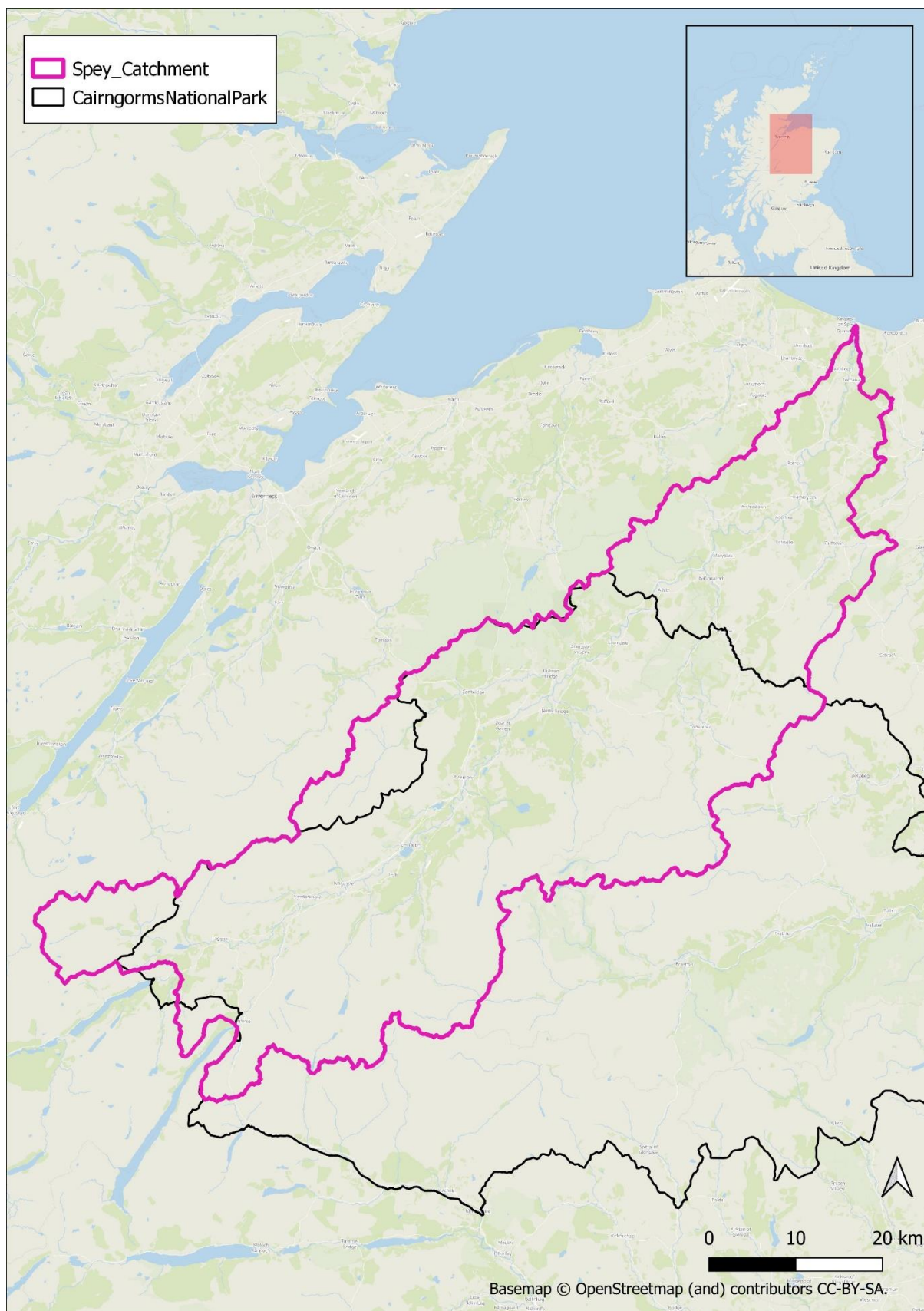


Figure 1. Study areas showing Spey catchment extent relative to Cairngorms National Park boundary

2. Modelling of beaver habitat suitability

2.1. Beaver Habitat Suitability Modelling

Summary Description: Production of a continuous description of habitat suitability for beaver. First a vegetation suitability index is created using multiple high-resolution spatial datasets from Ordnance Survey, CEH and Copernicus will be combined to provide detailed land cover/vegetation information which is classified based on empirical field observation of beaver habitat and preference. Vegetation suitability is combined with additional parameters describing stream networks and water bodies. Whilst beaver habitat suitability is primarily defined by vegetation suitability, beavers also require water for security and movement. Therefore, accessibility to water bodies (i.e. channels, ponds, and lakes) will also determine the viability of beaver occupancy and therefore are required to classify habitat accurately.

Outputs: This product provides a high-resolution (5m cell size) resource (raster Tiff format) for describing habitat suitability for beaver. This dataset can allow the user to explore which landscapes were most (or least) suitable to beaver reintroduction and also to understand where habitat enhancement might be useful to support future reintroduction.

2.2. Beaver Vegetation Index (BVI –prerequisite for BHI modelling)

Vegetation is important for classifying beaver habitat (Hartman, 1996; John et al., 2010; Pinto et al., 2009; St-Pierre et al., 2017). It was therefore critical to establish a reliable Beaver Vegetation Index (BVI) using nationally-available spatial datasets. No single dataset contained the detail required to depict all key vegetation types. Therefore, a composite dataset was created from: OS VectorMap data (Ordnance Survey, 2018), The Centre for Ecology and Hydrology (CEH) 2015 land cover map (LCM) (Rowland et al., 2017), Copernicus 2015 20 m tree cover density (TCD) (Copernicus, 2017) and the CEH woody linear features framework (Scholefield et al., 2016).

Vegetation datasets were assigned suitability values (zero to five). Zero values were assigned to areas of no vegetation i.e. buildings and values of five were assigned to favourable habitat i.e. deciduous woodland. Values were assigned based on a review of relevant literature (Haarberg and Rosell, 2006; Jenkins, 1979; Nolet et al., 1994; O’Connell et al., 2008), field observation and comparison with satellite imagery. Vector data were converted to raster format (resolution of 5 m). TCD data were resampled to 5m and aligned with converted vector layers. An inference system was used to combine these four raster datasets to create the BVI. The workflow prioritises the reliability followed by the highest value data.

Examples of highly suitable land (graded 5) include broad-leaf woodland, mixed woodland and shrub; examples of suitable vegetation (graded 4) include shrub and marsh; examples of moderately suitable (graded 3) include coniferous woodland, marsh, shrub and unimproved grassland; examples of barely suitable (graded 2) include reeds, shrub and heathland and boulders, neutral grassland; examples of unsuitable (graded 1) include heather, acid grassland, unimproved grass and boulders, bog; examples of no accessible vegetation (graded 0) include shingle and sand, buildings, rock, urban, freshwater and saltwater.

2.3. Beaver Habitat Index model (BHI)

Whilst vegetation is a dominant factor in determining habitat suitability for beaver, so is proximity to a water body (Gurnell et al., 2008), with beavers being strong swimmers, using water bodies both to provide security, as a means of escaping predators and to access foraging areas. It is thought that most foraging occurs 10 m of a watercourse/body (Haarberg and Rosell, 2006), and rarely above 50 m (Stringer et al 2018). However, greater foraging distances have on occasion been observed and as in Macfarlane et al., 2015 it has been accepted as a maximum distance in which the vast majority of foraging occurs. Therefore, to determine suitable habitat for beaver incorporating both BVI vegetation suitability and water accessibility a 100 m buffer was applied to water bodies. To do this the OS

mastermap river network and OS vector in land water bodies were combined to get the best readily available national waterbody and water course coverage.

Whilst BVI was run nationally on a 5 m scale it is best viewed as a preparatory step for BHI (and later BDC) modelling and is superseded in usefulness by the BHI dataset. It is strongly recommended that most analysis and management applications use BHI i.e. if there is an area of preferred vegetation such as willow woodland, more than 100 m from a waterbody it is thought inaccessible to beaver and therefore does not form suitable habitat.

Both BVI and BHI use a scoring system of zero to five (Table 1). Scores of five represent vegetation that is highly suitable or preferred by beavers and that also lies within 100 m of a waterbody. Zero scores are given to areas that contain no vegetation or are greater than 100 m from a waterbody. It is important to note that the habitat model considers terrestrial habitat where foraging primarily occurs and that watercourses themselves are also scored zero. It is also important to note that all scores above 1 contain suitable vegetation.

In addition to the raster layer, BHI values are associated with the reach scale Beaver Network river layer as BFI (Beaver Forage Index). Reach BFI values were obtained for two search areas, 10m (streamside) and 40 m (riparian) from the bank edge. Both search areas extend 100 m up and downstream to account for connectivity of reaches. The mean of the top 50% of BFI values in each search area was extracted to understand the suitability of the best available habitat within a given reach.

Table 1. BVI and BHI value definitions. It is critical to note that all values above 1 are suitable for beaver.

BFI and BHI Values	Definition
0	Not suitable (no accessible vegetation)
1	Not suitable (unsuitable vegetation)
2	Barely Suitable
3	Moderately Suitable
4	Suitable
5	Highly Suitable

2.4. Beaver Habitat Index maps and summary statistics for study area

Table 2. Summary habitat mapping statistics for the Spey catchment

Habitat category	Length (km)	%
Unsuitable	2989.7	43.4
Low	950.7	13.8
Moderate	749.3	10.9
High	997.3	14.5
Preferred	1203.4	17.5

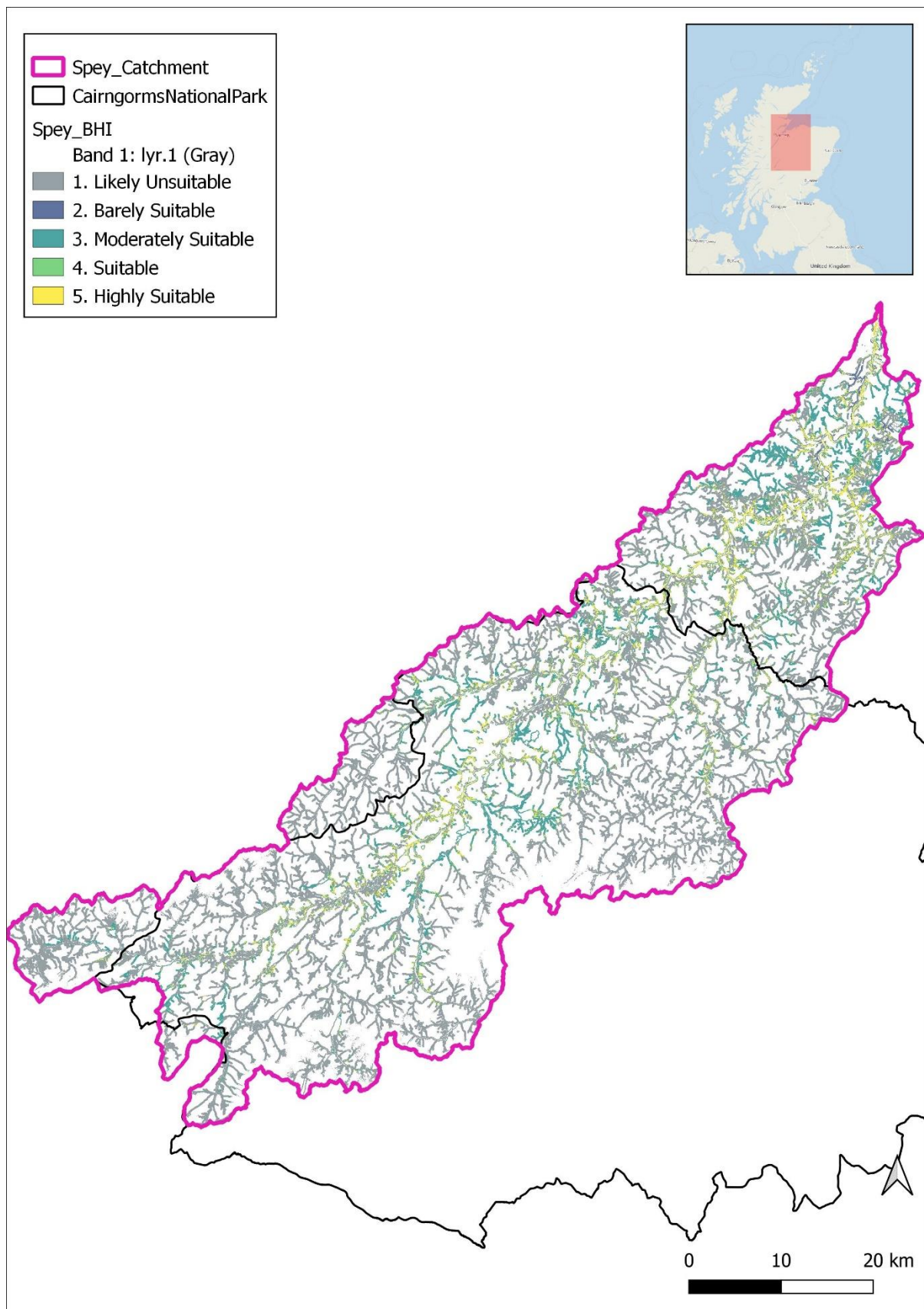


Figure 2. Beaver Habitat Index at a 5m resolution across entire study area. Contains Ordnance Survey data © Crown Copyright 2007 and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC (CEH).

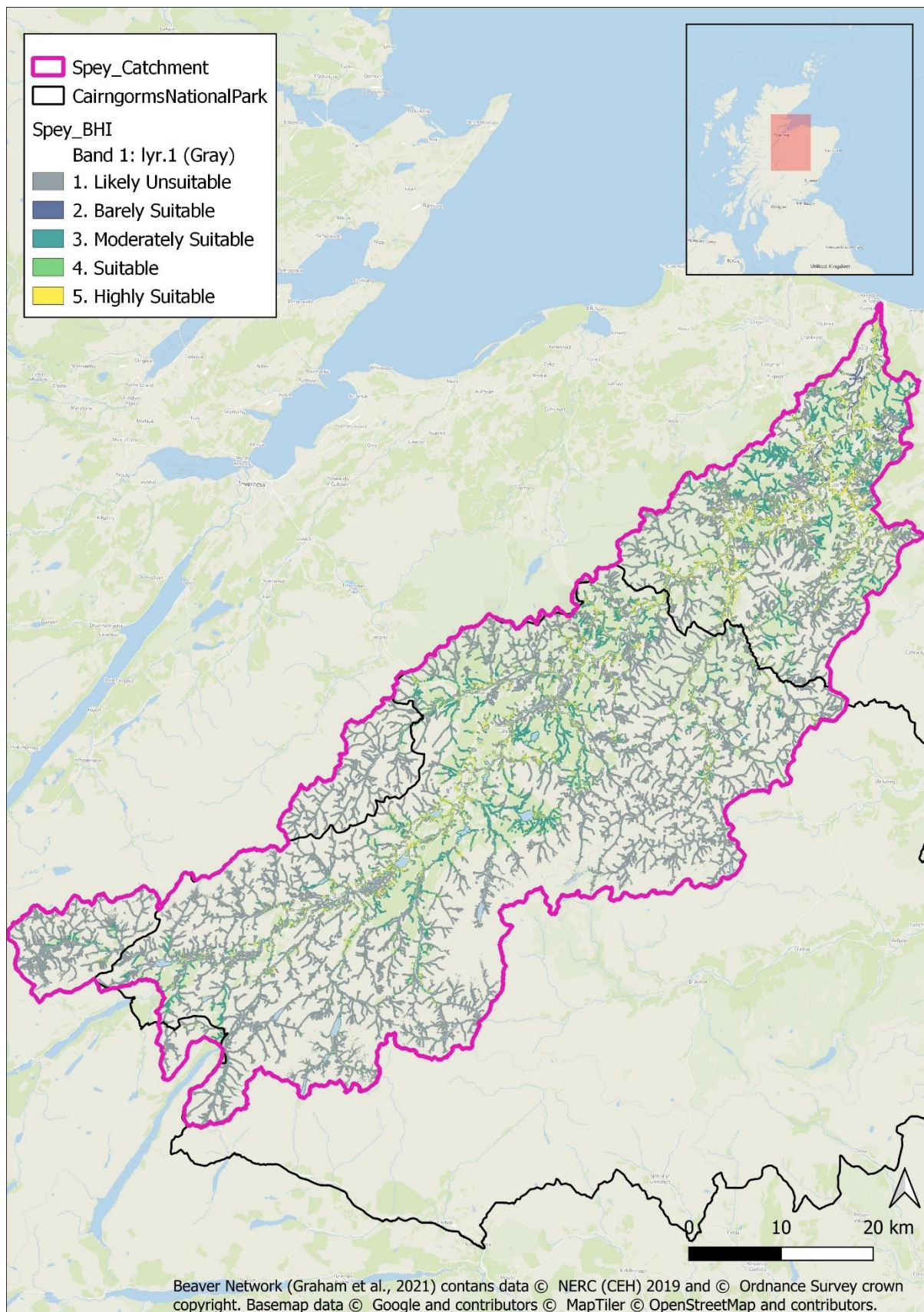


Figure 3. Beaver Habitat Index at a 5m resolution across entire study area. Contains Ordnance Survey data © Crown Copyright 2007 and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC (CEH).

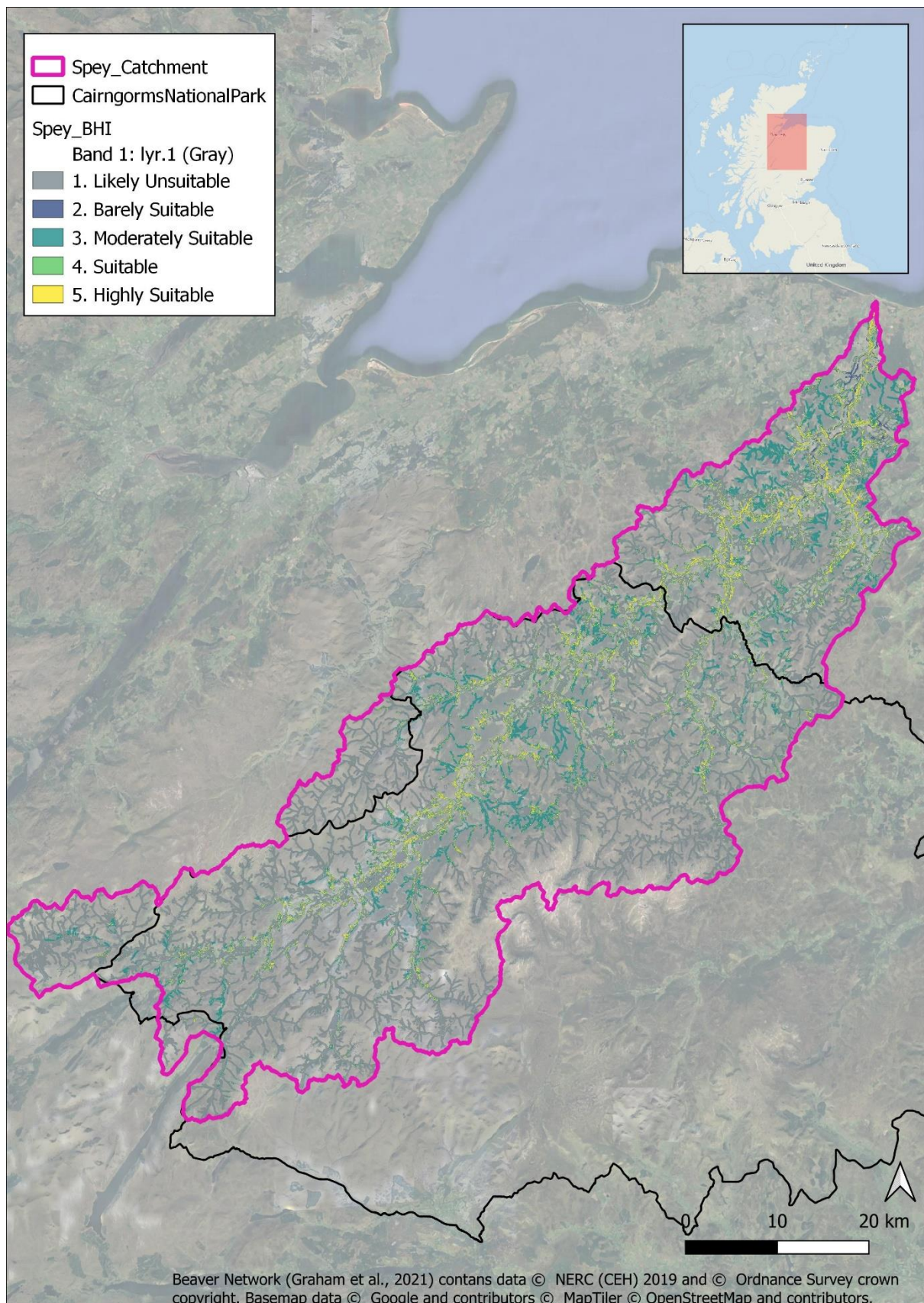


Figure 4. Beaver Habitat Index at a 5m resolution across entire study area. Contains Ordnance Survey data © Crown Copyright 2007 and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC (CEH).

2. Beaver Dam Capacity modelling

3.1. Beaver Dam Capacity (BDC) model summary

The Beaver restoration assessment tool (BRAT) was developed in North America (Macfarlane et al., 2014, 2015) to determine the capacity for river systems to support Beaver dams. The BRAT model has been further deployed in a range of different river systems to aid both Beaver recolonisation and beaver dam analogue led restoration. The BRAT model not only provides an invaluable tool for designing effective, empirically based, restoration strategies but it also indicates where Beaver dams might be constructed and therefore where they may cause potential management/conflict issues. The BRAT model structures the framework of the model around the river network itself and using a fuzzy logic approach which builds in the considerable uncertainty that is associated with beaver habitat/damnable reaches. Furthermore, it provides a range of output values to predict the dam capacity which has implications for beaver preference towards a given location.

We have therefore used the BRAT framework to develop an optimised beaver dam capacity (BDC) model for Great Britain; and although many of the datasets used are specific to GB, these could readily be adapted to enable its use globally.

The BDC model estimates the capacity of river systems to support dams at the reach-scale (c.a. 150m). The model also highlights reaches that are more likely to be dammed by beaver and estimates the number of beaver dams that could occur for a catchment at population carrying capacity. As such, this highly detailed tool would provide understanding of where dams are most likely to occur and in what densities, supporting future work on the conflicts and opportunities that might accrue from beaver reintroduction.

The model infers the density of dams that can be supported by stream reaches ($111.1\text{m} \pm 52.5$) across a catchment. Using low-cost and open-source datasets, the following attributes are calculated for each reach: (i) stream gradient, (ii) low (Q80) and high flow (Q2) stream power, (iii) bankfull width, (iv) stream order, and (v) the suitability of vegetation, within 10m and 40m of the bank, for beaver dam construction. These controlling variables are combined using a sequence of inference and fuzzy inference systems which follow an expert-defined rules system that allows for the considerable uncertainty often associated with these types of complex ecological processes.

Each reach was classified for damming capacity using five categories from none, defined as no capacity for damming to pervasive where a maximum capacity of 16-30 dams could theoretically be constructed in a km of channel. It is important to note that the model assumes both reach and catchment population carrying capacity for beaver. Therefore, in reality the maximum number of dams indicated in a category class is unlikely to occur. A full list of BDC classifications is included in Table 3.

Table 3. BDC classifications and definitions.

BDC Classification	Definition
None	No capacity for damming
Rare	Max capacity for 0-1 dams/km
Occasional	Max capacity for 1-4 dams/km
Frequent	Max capacity for 5-15 dams/km
Pervasive	Max capacity for 16-30dams/km

3.2. Beaver Dam Capacity Model maps and summary statistics for the study area

Table 4. Beaver dam capacity summary statistics for the Spey catchment

Dam capacity category	Length (km)	%
None	936.0	13.6
Rare	3418.8	49.6
Occasional	1326.1	19.2
Frequent	468.1	6.8
Pervasive	741.4	10.8

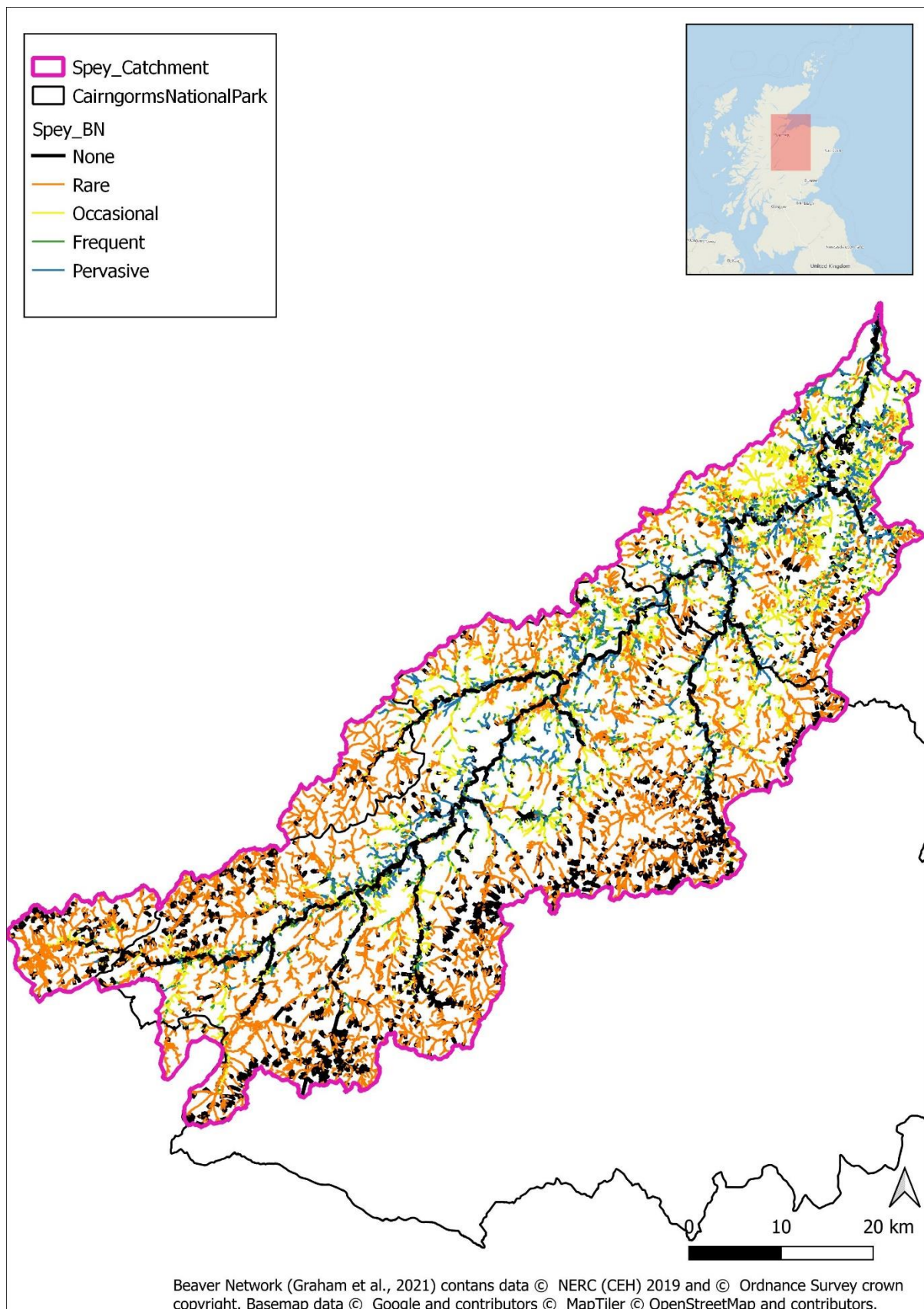


Figure 5. Beaver Dam Capacity model results for study area with catchments of interest highlighted. Contains Ordnance Survey data © Crown Copyright 2007, and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC and © Ordnance survey crown copyright.

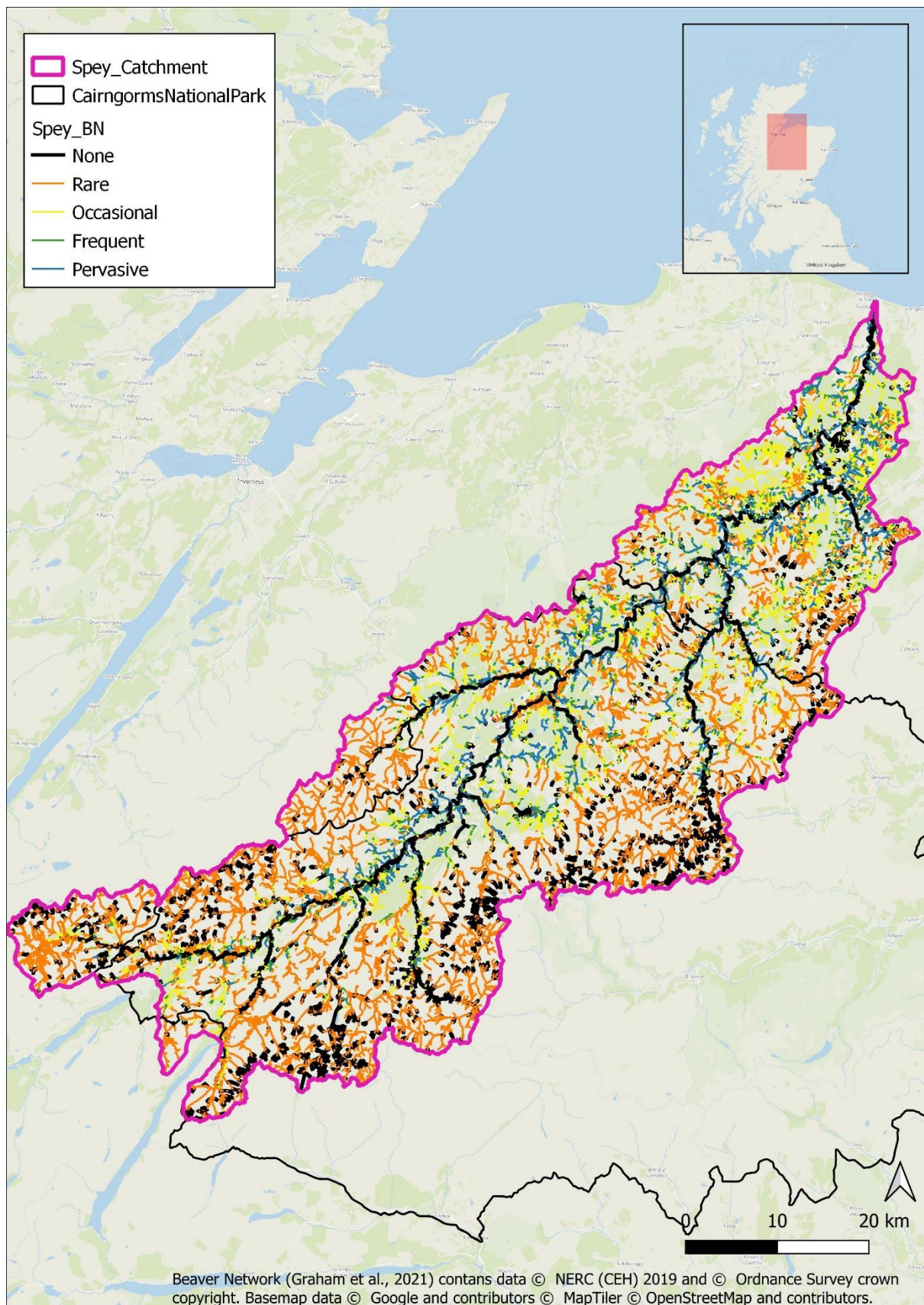


Figure 6. Beaver Dam Capacity model results for study area with catchments of interest highlighted. Contains Ordnance Survey data © Crown Copyright 2007, and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC and © Ordnance survey crown copyright.

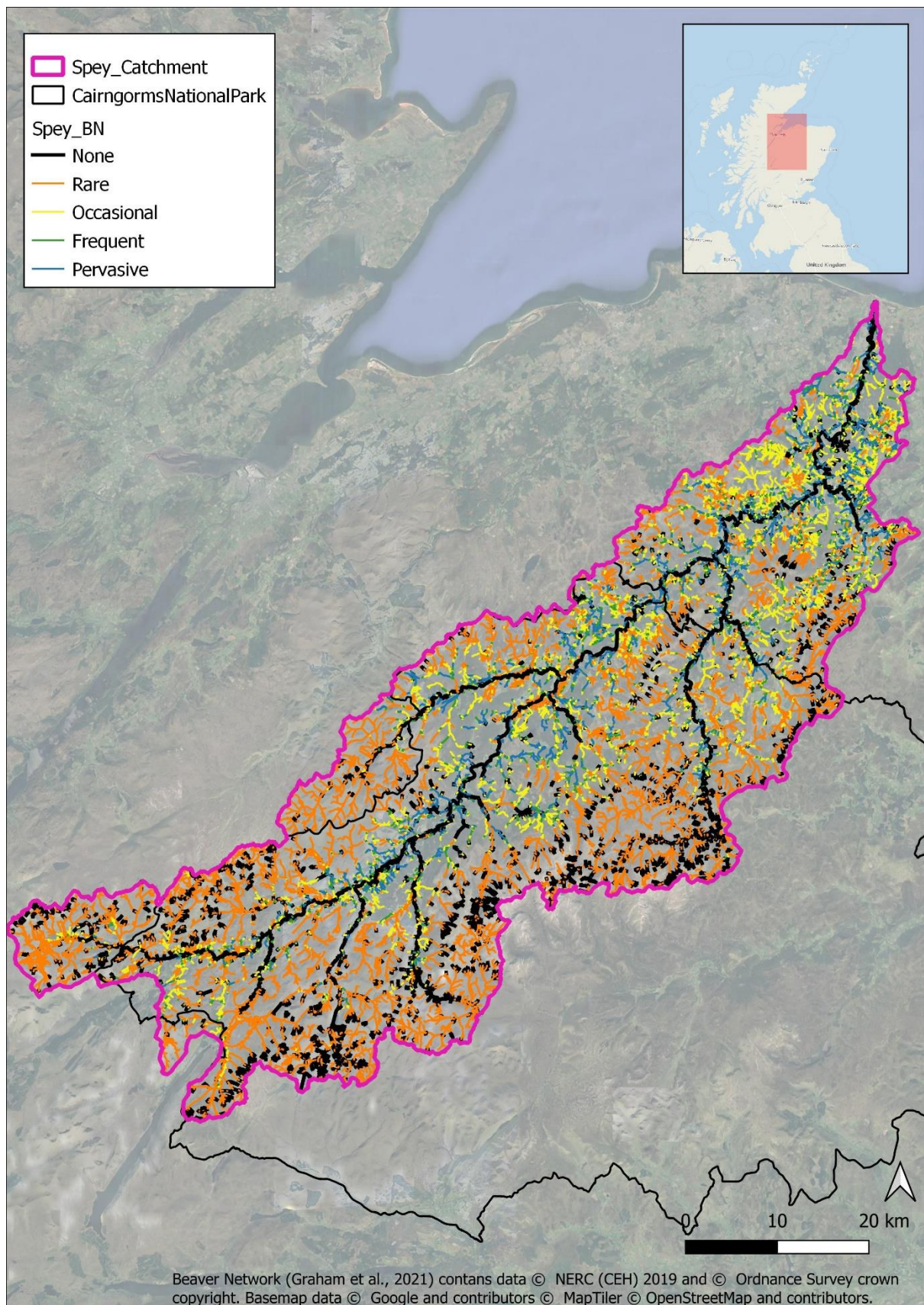


Figure 7. Beaver Dam Capacity model results for study area with catchments of interest highlighted. Contains Ordnance Survey data © Crown Copyright 2007, and some features of this map are based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC and © Ordnance survey crown copyright.

4. Beaver habitat and dam capacity model summary

The model results presented herein, illustrate that throughout Spey catchment, including within Cairngorms National Park there are extensive areas of highly suitable habitat to support beaver populations. Additionally, there are many smaller reaches, with good habitat and suitable hydrological conditions where beavers could create dams, particularly in the more lowland areas. However, model results also show the main Spey and tributaries to be too large and powerful for beavers to dam. Similarly many of the upland areas, particularly those within the NP lack suitable habitat and are also too steep to support beaver damming. These model outputs show the spatial variability in impact that could occur if beavers returned to being widespread both within the NP and the wider Spey catchment.

Combined with other components of feasibility work being undertaken, these model results will provide a geospatial basis for informing future impacts (both positive and negative) that the reintroduction of beavers could bring. Used strategically it is hoped that such data products can help maximise the benefits and minimise the conflicts associated with beaver.

Whilst useful, as with any model outputs, there are limitations and uncertainties (see Appendix 2 for caveats) which need to be considered. These model results will be ground truthed during field visits to combine model outputs with expert interpretation to reach a conclusion on the suitability of the site for beaver. Field based assessment will also consider the potential for beavers to bring positive impacts as well as the potential for management issues to arise and potential solutions to these.

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Appendix 1. Datasets used

The source datasets analysed during the current study were made available from the following locations:

OS Mastermap Water Network Layer: <https://www.ordnancesurvey.co.uk/business-and-government/products/os-mastermap-water-network.html>

APGB DTM 5m: https://docs.wixstatic.com/ugd/66c69f_482b0b6f530f4463a02626c8b194e25d.pdf

National River Flow Archive: <https://nrfa.ceh.ac.uk/data>

OS VectorMap Local: <https://www.ordnancesurvey.co.uk/business-and-government/products/vectormap-local.html>

CEH Land Cover Map: <https://doi.org/10.5285/bb15e200-9349-403c-bda9-b430093807c7>

Copernicus TCD: <https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/status-maps/2015>

CEH Linear Woody Framework: <https://www.ceh.ac.uk/services/woody-linear-features-framework>

Appendix 2. Caveats for use

Beaver vegetation and habitat index

BHI provides a resource for quantifying beaver habitat suitability with national coverage. A high (5m) spatial resolution enables it to have the capacity to inform detailed local decision making.

Examples of BHI presented overlaid on satellite imagery reflect its ability to provide a highly useful classification of beaver habitat based upon a vegetation suitability ranking and access to water (including both river network and waterbodies such as ponds and lakes). However, it is critical to note that BHI is a model rather than an absolute reflection of reality and the below caveats should be considered when using the BHI model outputs.

- Output resolution only as high as the spatial resolution of coarsest input dataset (5 m).
- Remote sensing/mapping vegetation/landuse datasets not to species level. However, beavers are generalists foraging and utilising a wide range of vegetation so this is an applicable approach. However if more detailed information is required (i.e. protected plant species) supplementary local studies and data sets are recommended.
- Whilst broad categories have been used to classify beaver suitability it is important to highlight all classes from 2 (barely suitable) to 5 (highly suitable) are thought to contain suitable habitat that beavers being resourceful generalists could utilise.
- Each dataset essentially a snapshot in time. Areas of vegetation removal or land use change may degrade vegetation suitability whilst conversely replanting and conservation schemes may improve vegetation suitability. However, combination of datasets and methodology for ranking vegetation suitability minimise the risk of areas of suitable/unsuitable vegetation being missed currently.
- Some small channels i.e. agricultural ditches and ponds may be missing or outdated in dataset meaning beavers could access or exist in such areas but not be correctly classified by BHI model as falling within 100m of a water body.

- Most literature cites 50 m as maximum foraging range of beaver (i.e. Stringer et al., 2018) however, to incorporate uncertainty, site development (i.e. beavers damming or canal building allowing them to extend their foraging range) and due to reports of further foraging we have adopted 100 m as in Macfarlane et al., 2015. There are extreme reports of beavers moving up to 250m from channel (Macfarlane et al., 2015) but this is thought to be incredibly rare and not applicable to a general widely deployed habitat model.
- Summary statistics will reflect the above requirement for access to water, hence most if not all catchments will be dominated by areas not accessible to beaver. This does not mean they will not support healthy beaver populations.
- BHI focused on vegetation suitability and distance to channel/waterbody as a computationally effective model that can be deployed nationally. However, other local factors that will restrict access to water/vegetation particular human infrastructure culverted/constrained sections walls/fences may locally limit beaver habitat suitability.
- Due to the above considerations it is always recommended that if making important and detailed decisions at the local scale, supplementary site visits are undertaken.

Beaver dam Capacity Model

The BDC model estimates the capacity of river systems to support dams at the reach-scale (c.a. 150m). The model also highlights reaches that are more likely to be dammed by beaver and estimates the number of beaver dams that could occur for a catchment at population carrying capacity. As such, this highly detailed tool would provide understanding of where dams are most likely to occur and in what densities, supporting future work on the conflicts and opportunities that might accrue from beaver reintroduction. However, as with BHI, it is important to remember BDC is a model and for all critical decisions, particularly at the local scale, understanding from modelling results should be supplemented by site visits. The following caveats in-particular should be considered for interpretation of BDC results:

- BDC is heavily dependent on the input channel network. In some areas, flow pathways can be complex and not always accurately represented by even detailed river network GIS and mapping.
- BDC modelling is a snapshot in time and will not reflect any subsequent alterations to channel networks.
- It is important to note that the model assumes both reach and catchment population carrying capacity for beaver. Therefore, in reality the maximum number of dams indicated in a category class is unlikely to occur.
- Flow conditions display a high degree of temporal variability, short term fluctuations due to rainfall events patterns and seasonal trends will alter the suitability of a channel for damming. I.e. a channel classed as having a rare capacity for damming, might see this capacity increase during drought periods, but conversely reduce to none during the wet/winter season.
- Modelling does not consider the resilience of dams. It is likely that dams in small channels with a high BDC will be more resilient than those in a larger channel with a higher stream power. However, BDC does not quantify this.
- BDC does not consider the exact spatial distribution or configuration of dams, which is also likely to be heavily dependent on beaver population dynamics.
- BDC reflects the capacity of a given reach to support beaver dams (assuming catchment beaver population carrying capacity) rather than the actual number of dams that are likely to occur. In isolation, BDC cannot predict the likely number of dams in a catchment.

- Most operational catchment boundaries used for determination of BDC extent exclude coastal and tidal reaches. Whilst these are often not suitable for beaver damming anyway it is important to highlight their omission.