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Recent changes to floodplain character and functionality in England

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ABSTRACT

Regime analysis suggests that temperate alluvial watercourses overtop their banks on average once every 1.5 years transferring water and sediment across the valley floor to form floodplains helping maintain a strong hydrological connection between in-channel and overbank form and process. Flooding also causes erosion, sediment transfer and deposition creating a variety of floodplain morphologic units and functional connectivity with the main river. The result is a morphologically and ecologically varied wetland dominated ecotone where diversity is sustained by the action and flooding and shallow groundwater processes. Floodplains are, however, sensitive to disruption and many have been significantly degraded since the Bronze Age as a result of activities that alter flooding and groundwater processes and manage vegetation communities. The current (2015) floodplain condition and trends of change since 1990, for England are presented here using land use data for 1990, 2000, 2007 and 2015. Floodplain system degradation has been found to be both widespread and severe across the whole of the country. The 1990 data set showed that intensive agriculture occupied around 38% of floodplain zones expanding to 53% by 2000 before slowing slightly to covering 62% in 2007. Between 2007 and 2015 the coverage remained relatively static (64%) with some suggestion that arable areas were being transformed to pasture. Wetland areas in the form of fen, marsh, swamp and bog have been devastated with the data sets indicating that these fundamental floodplain units have been all but lost. Upland and lowland areas are both severely impacted with a near ubiquitous loss of natural floodplain functioning. Despite this some 31% of rivers in England are classified as good or better under the European Water Framework Directive classification system calling into question the UK WFD status classification process.

1. Introduction

Floodplains have long been recognised as globally sensitive and threatened ecosystems (Petts et al., 1989). Past research shows that they are presently highly modified from their natural state and represent one of the most threatened ecosystems worldwide (Olson and Dinerstein, 1998). It is estimated that there are between 0.8 million (Mitsch and Gosselink, 2000) and 2.2 million km^2 of rivers and lake related floodplains across the world (Ramsar and IUCN, 1999) contributing to around a quarter of all land based ecosystem services (Mitsch and Gosselink, 2000). Broad estimates reported by Tockner and Stanford (2002) suggest that around 80% - 90% of floodplains across Europe are now intensively cultivated, estimates for North America suggest this figure is 46% (excluding northern Canada and Alaska) and 11% of floodplains are farmed across Africa. These estimates are supported for North America situation by Erwin (2009) who described 90% of floodplains there as 'cultivated' and non-functional. Global information on land cover and land cover change has been generated through the analysis of satellite data combined with local ground truthing (Cardille et al., 2002; Goldewijk, 2001; Ramankutty and Foley, 1999). These studies suggest that over the last 50 years, land use changes have increased impacting the biosphere more than at any other period in human history (Board, 2005). The loss of floodplains to urbanisation is also well documented, Dewan and Yamaguchi (2009), reported a loss of 31% of rivers and floodplains to urbanisation in Dhaka, Bangladesh, whilst Amoateng et al. (2018) showed an 83% loss of rivers and floodplains between 1985 and 2103 in Kumasi, Ghana. These statistics support the view that floodplain condition and functionality is in a critical situation across Europe (Wenger et al., 1990; Klimo and Hager, 2001; Buijse et al., 2002).

Dynamic landscapes exhibit high spatial and temporal environmental heterogeneity and strong speciosity (Connell, 1978). Naturally

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functioning fluvial systems represent some of the most dynamic landscapes on the planet, have a very high conservation value (Ratcliffe, 1977). They also display some of the highest biological productivity and ecosystem diversity on Earth (Tockner and Stanford, 2002), principally due to their dynamic behaviour and also their transitional nature as they form the ecotone between terrestrial and aquatic environments. However, when the natural dynamics of floodplain systems are subdued or lost the system becomes dysfunctional and the loss of dynamism results in environmental homogeneity and stasis. Diversity is reduced under such conditions with the landscape becoming dominated by a few key species best adapted to the imposed conditions (Stanford et al., 1996).

Functional floodplains are controlled by a diverse set of processes. Amoros and Roux (1988) and Junk et al. (1989) found that flood-controlled disturbances stimulate geomorphic processes and promote vegetative succession to help form complex and dynamic spatial vegetation mosaics related to floodplain morphology. Thoms (2003) elucidated further on the controls on diversity noting the role of surface and subsurface hydrological regime and disturbance processes and historic geomorphological activity is also important in influencing the floodplain template (Nanson and Croke, 1992). Of principal importance across valley bottom areas are functional wetland habitats including fen, marsh, swamp, bog and reeds. All of these are currently threatened globally (van Diggelen et al., 2006).

Severe floodplain degradation is widespread, linked to the habitat fragmentation and associated process disruption impacting the overall integrity of fluvial ecosystems (Dynesius and Nilsson, 1994; Schiemer, 1999; Tockner et al., 2008) and ecology (Junk, 1997). This degradation is principally associated with human intervention and has resulted in a severe and rapid decline in freshwater biodiversity. Direct habitat alteration linked to land use, drainage manipulation and flood control are the principal impact mechanisms (Krause et al., 2011; Tockner and Stanford, 2002; Zedler and Kercher, 2005), however, water pollution and the spread of invasive species have also contributed.

River degradation has been quantified across Great Britain following the European Water Framework Directive (WFD). Water bodies are initially categorised as 'artificial', 'heavily modified' and 'near natural' (non-designated dependent on their degree of alteration). Statistics provided by the UK Joint Nature Conservation Committee (Fig. 1) illustrate the generally poor state of UK rivers, only 31% of water bodies are currently achieving 'Good' ecological status/potential and almost no change in status level has been reported throughout the period of operation of the directive. It is interesting to note, in the context of this paper, that the classification process concentrates on in-channel condition, largely ignoring floodplain presence and this lack of consideration will undoubtedly see floodplains further ignored as part of the current WFD driven restoration agenda.

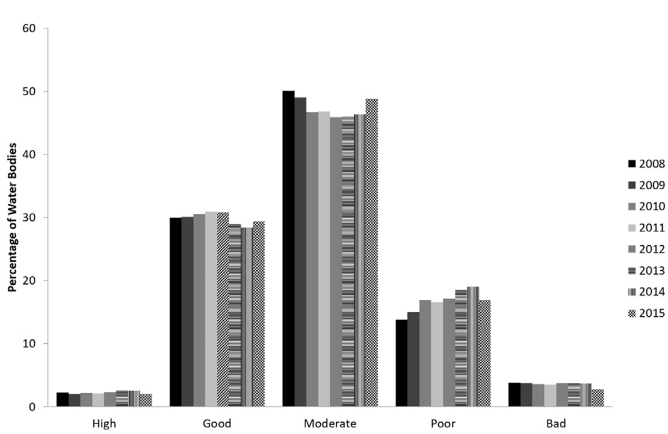

Fig. 1. Water Framework Directive status summary for UK Rivers (2008–2015).

Lewin (2013) observed that floodplain degradation has been occurring for the last 400 years and notes how the disruption to geomorphological process associated with the disconnection of rivers from their floodplains impacts patterns of erosion and deposition influencing channel dynamics and altering flood risk. Seager et al. (2012) assessed the general physical character of rivers and streams across England and Wales in 1995–1996 and 2007–2008. From a stratified random sample of the 4849 River Habitat Survey sites they estimated that only 11% of river length was 'near-natural', this figure rose to 25% when only predominantly unmodified reaches were included. Due to the failure of River Habitat Survey protocol to consider floodplain character this component of the fluvial system was neglected. A single river study by Bentley et al. (2016) reported reduced hydromorphic diversity along an historically modified length of the River Wharfe. Their findings suggest that recent and historic direct and indirect human modification of channel morphology have severely impacted system form and behaviour.

Further insight into wider modification to floodplain areas was reported by Heritage et al. (2016) in their investigation of eight rivers in England and Wales, where their floodplain connectivity and land use findings suggest that historic engineering and current management of both the channel and valley floor has been significantly impacted even on these high value systems. Floodplains along all eight watercourses exhibited a loss of geomorphic functionality and natural habitat due to farming.

These studies may be contextualised into the wider understanding of floodplain evolution through the Holocene. The character of UK floodplains has been shown to have changed significantly since the last ice age (~11 ka), responding to climatic change and anthropogenic influences (Hoffmann et al., 2008; Brown et al., 2013; Macklin et al., 2014). Climate driven change is most closely associated with early Holocene floodplain response with Macklin et al. (2014) identifying 15 flood rich periods in the UK sedimentary record and Hoffmann et al. (2008) recognising 9 for Germany. Of these, only 4 are coincident suggesting more local geographical influence on system response and this is supported by Johnstone et al. (2006) who demonstrate the greater sensitivity to flooding of upland over lowland UK catchments. Brown et al. (2018) note the presence of stable multi-thread channel systems flowing over wooded floodplains through until the Bronze Age (around 2500 BCE), where forest clearance and cultivation led to extensive fine sediment delivery and storage across valley bottoms. Subsequent intensification of agriculture has allowed this development to persist through to the present day often with several metres of fine sediment alluviation present across floodplain surfaces (see for example the River Culm and the River Frome presented in Brown et al., 2018).

Lespez et al. (2011) also note increasing fine sediment alluviation in the form of overbank deposits burying organic deposits and leading to the loss of extensive wetland habitat across Western Europe principally from the Iron Age onwards (800 BCE). The persistence of this widespread transformation to floodplain character is linked to cultivation induced fine sediment supply increase intensified by the subsequent persistence of this sediment as Colluvial and alluvial deposits (see Brown et al., 2013).

As such, floodplains in the UK and Europe have experienced alluviation and indirect and direct transformation of functional habitat over at least the last 3000 years, more recently this has intensified and this paper attempts to document these impacts with reference to floodplain habitat change over the period 1990–2015. It adopts a GIS-based approach to quantify land use change within 100-year flood zone outline analysing the impact of agricultural practices on floodplain character over this 25 year period.

2. Method

The methodology adopted by this study involved three key stages. Firstly, floodplain areas were attributed to the rivers of England. The

Ordnance Survey *Open Rivers* vector line dataset (version 04/2017) was used to define the river network, with individual rivers delineated by 'watercourse name'. To make the size of the dataset more manageable, only rivers in England where the word 'River' precedes the name were considered; therefore, including most major rivers and excluding minor tributaries. This resulted in a total of 807 watercourses being analysed; representing 24,055.42 km of England's river network. To establish the floodplain extent, 100-year return period inundation mapping was used (Environment Agency Flood Zone 3). The floodplain was segmented by river using buffers, so that each river has an associated floodplain area. The buffer search distance was 1000 m on either side of the river, meaning that any floodplain areas with bottom widths larger than 2000 m were excluded from analysis. Although this is a limitation, in practice only 2% of the total number of rivers analysed were affected by taking this approach. Furthermore, the focus of this paper is on comparing land use *change*; the spatial area analysed for this majority dataset remained the same throughout the analysis to facilitate this comparison. The analysis described below generated data on over 6700 km^2 of England's floodplain area.

Secondly, land cover data was sourced and standardized over the 1990–2015 period. Land cover data for England was provided by Centre of Ecology and Hydrology (CEH), for the years 1990, 2000, 2007 and 2015 (Fuller et al., 1994, 2002; Morton et al., 2011; Rowland et al., 2017). The 1990 version is only available as a 25 m raster, this dataset therefore required vectorization prior to analysis. Using the habitat codes, habitat descriptors were added to the 1990 and 2000 datasets, sourced from CEH documentation. Comparison of the land cover categories across the four data sets revealed an inconsistency in land cover type categories over the 25-year period. For example, additional divisions were used in 1990 and 2000, compared with the 2007 and 2015 data. It was therefore necessary to standardize the classes between the datasets to facilitate direct comparison of the land cover extents. The categories defined in the 2015 data were used as a template, and the 1990, 2000 and 2007 land cover types were appropriately matched to the schema. This resulted in the changes shown in Table 1.

Finally, these datasets were then analysed together to generate statistics relating to floodplain character. The river floodplain polygons were intersected with the land cover data (Fig. 2), and then summarized by land cover type to calculate total floodplain land cover area for each category. This was then used along with the total area of each river floodplain, to determine the percentage cover of each land cover type by river, for the four dates. This allowed the percentage change in floodplain land cover to be assessed and the same workflow was followed to calculate percentage cover rationalised to WFD water body.

3. Results

2015 areal coverage figures for all floodplain in England (Fig. 3) suggests that around 65% of the total floodplain area has been extensively altered due to agriculture. Prominent changes were to arable and horticulture with improved grazing also severely impacting natural floodplain ecology. Fen, marsh, swamp and bog, habitats more characteristic of functional floodplains, have been reduced to just over 0.5% of total floodplain area. Simple presence/absence analysis of the 2015 data set. The results (Fig. 3) support the distribution statements made previously. Natural fen, marsh and swamp habitat, was recorded on only 102 watercourse floodplains, (< 18% of the total present). All but two rivers (99.6%) are impacted to some degree by agriculture.

The 2015 data has also been used to investigate the spatial pattern of land use (Fig. 4), revealing the distribution and dominance of each category across England. Natural fen, marsh, swamp and bog is now extremely sparsely distributed across the country and, where present, it forms only a small fraction of each floodplain area (Fig. 4a). This contrasts strongly with the distribution of floodplain under arable use (Fig. 4b), this land use type dominates across the area around the Wash, Lincolnshire & Humberside, where coverage often exceeds 75% of each

Table 1
Required changes to historic land cover nomenclature to facilitate comparison over time. The first column shows 2015 land cover categories which were used in this analysis. The subsequent columns document the original land cover categories from previous datasets (1990, 2000, 2007) that were amended to match 2015.

2015	1990	2000	2007
Acid grassland			
Arable and horticulture	Tilled land (arable crops)	Arable cereals	
		Non-rotational horticulture	
Bog	Lowland bog	Bogs (deep peat)	
	Upland bog		
Broadleaf woodland	Deciduous woodland	Broad-leaved/mixed woodland	Broad leaved, mixed and yew woodland
Calcareous grassland			
Coniferous woodland	Coniferous/evergreen woodland		
Dwarf shrub heath	Open shrub heath	Dense dwarf shrub heath	
		Open dwarf shrub heath	
Fen, marsh and swamp	Rough/marsh grass	Fen, marsh, swamp	
Freshwater	Inland water	Water (inland)	
Montane habitats	Bracken	Bracken	
	Dense shrub heath		
	Dense shrub moor		
	Grass heath		
	Moorland grass		
	Open shrub moor		
Improved grassland	Mown/grazed turf		
Inland rock			
Littoral rock			
Littoral sediment	Coastal bare ground (beach/mudflats/cliffs)		
Neutral grassland			
Rough low-productivity grassland	Meadow/verge/semi-natural swards	Set aside grassland	
	Ruderal weed		
Saltmarsh			
Salt water	Sea/estuary		
Supralittoral rock			
Supralittoral sediment			
Urban	Suburban/rural development	Suburban/rural developed	Built up areas and gardens
	Urban development	Continuous urban	

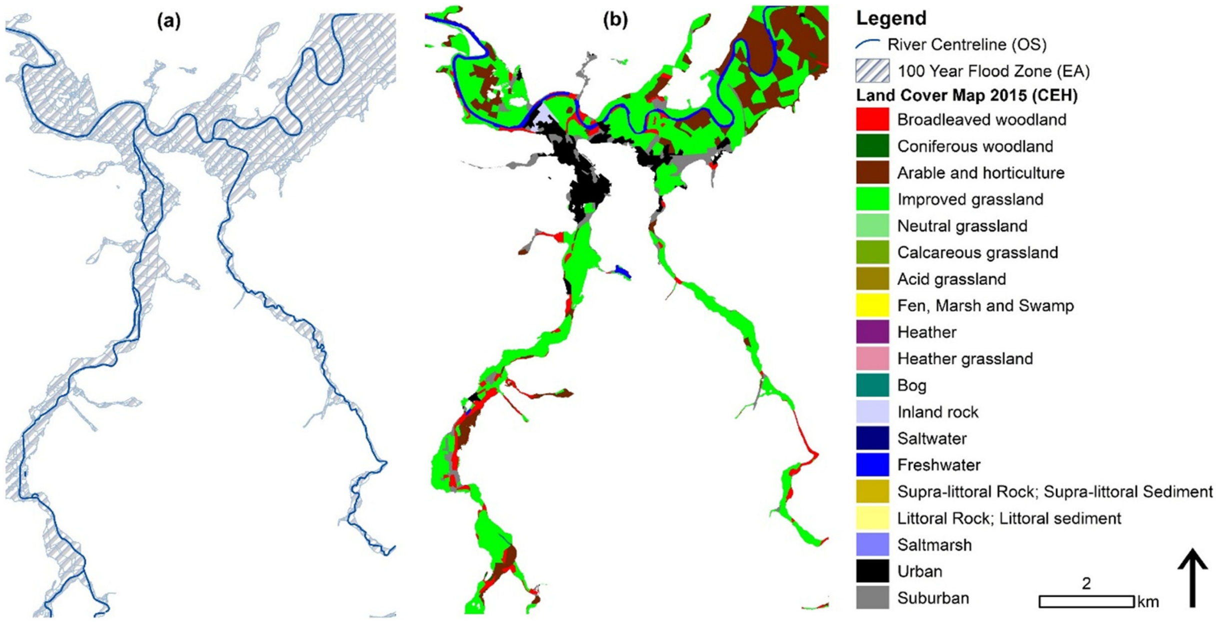

Fig. 2. GIS analysis of floodplains in England, by combining (a) a river centerline (to delineate the individual rivers) (© Crown copyright) and the 100-year flood zone extent (© Environment Agency) with (b) historic land cover maps (2015 shown here) (© NERC).

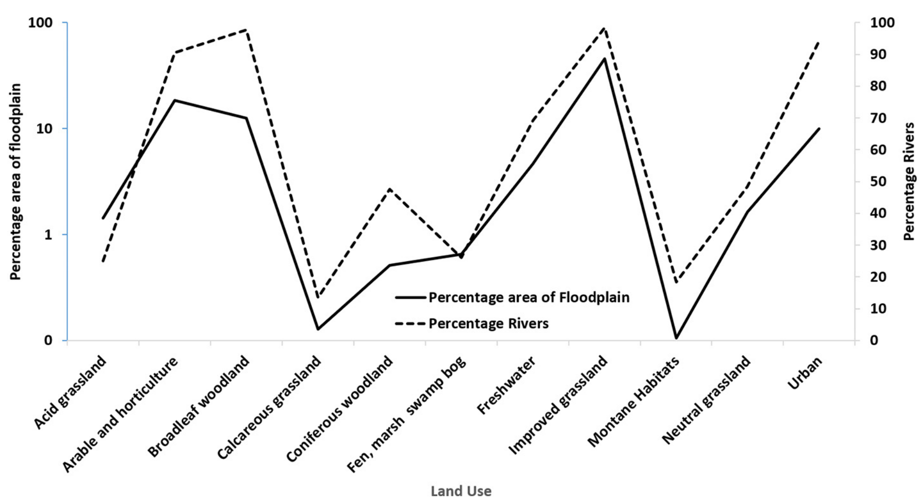

Fig. 3. Floodplain land use in 2015 averaged across all rivers in England.

river floodplain. Rough grassland, a valuable dryer floodplain habitat, is found mostly in the north and west of England (Fig. 4c). Where present it is patchy and sub-dominant with coverage levels generally below 25% of the total floodplain for each river.

Dominance of a particular land use type at a local scale was investigated through extraction of the frequency of areal coverage categories across all rivers for 2015 data. It is clear (Table 2) that almost all fen, marsh, swamp and bog is present at coverages below 1% across individual floodplain areas. Most individual floodplains exhibit neutral grassland cover of between 5 and 10% but this is still an unnaturally low figure. These statistics contrast with the strong dominance of arable and improved grassland which cover between 40% and 95% of most individual floodplains. (See Table 3.)

Changes in floodplain land use were investigated for the period between 1990 and 2015. Farming as represented by arable, horticulture and pasture (Fig. 5a) shows a clear shift in distribution toward more intensive land usage over time with the majority of rivers displaying coverage values of between 15% and 60% in 1990 rising to between 35% and 75% in 2000 before the rate of change lessens to occupy between 65% and 95% of overall floodplain area in 2007 and 80% to 95% 2015.

In stark contrast, wetland area (Fen, marsh, swamp and bog) was already severely reduced over natural by 1990 (Fig. 5b) with the majority of rivers displaying coverage of between 1% and 3% of total floodplain. Even these low values show a further significant reduction through to 2000 with percentage coverage reduced to below 1% on almost all rivers throughout England. The 2007 and 2015 land cover surveys show no significant change from the position in 2000. Uncultivated rough grassland shows similar trends with much greater areal coverage (15–50% by river) measured in 1990 declining to between 5 and 10% for the majority of rivers by 2000 and < 5% for 2007 and 2015 (Fig. 5c).

Also of interest is the degree to which individual rivers have changed their land use pattern, only 38 English rivers have shown an overall reduction in farmed area (Fig. 6a) with losses of generally < 10% whilst the rest of the rivers have seen farming use increase in the 25 year data record, most by 2 to 25% but some by as much as 80%. Wetland change over this period has seen the majority of rivers remain

Fig. 4. Floodplain land-use maps for England (a) Fen, marsh and swamp (black) and Bog (Red), (b) Arable and Horticultural (Black) and Improved grassland (Red) (c) Rough grassland. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

static (Fig. 6b) with 48 showing some improvement and a similar figure showing an equal decline.

4. Discussion

Data published by Newbold (1998) covered lowland floodplains which were estimated to originally cover some 2,000,000 ha but which had been reduced by 86% to 274,000 ha by the 1980s. Of this area only some 46,600 ha of floodplain remain protected under SSSI status (Newbold 1998). He argued that functional floodplain loss up to the 1980's was principally due to drainage which also impacts significantly on the ecology. Bailey (1998) noted at the time that the impact of agriculture on floodplain form and function had yet to be quantified. More recent studies (Foley et al., 2005; Gibbs et al., 2008; Gibbs and Salmon, 2015; Lambin and Meyfroidt, 2011) reveal that farming of floodplains has led to significant losses of biodiversity, reduced their role in flood mitigation, increased soil loss are and reduced carbon storage.

This paper presents a comprehensive nationwide assessment of current (2015) floodplain condition and trends of change (since 1990) for England. It has used land use and floodplain area information together to analyse of the degree of floodplain alteration away from a natural connected river and overbank system characterised by fen marsh, swamp and bog, toward impacted, heavily managed systems characterised by improved grassland and arable land use. The data reveals the near complete destruction of functional wetland habitat. Only small, and highly isolated remnant areas now remain occupying < 0.5% of floodplain area on less than a quarter of English watercourses.

Newbold (1998) estimated there was originally some 2,000,000 ha of lowland floodplain in the UK which had been reduced by 86% to 274,000 ha by the turn of the century. This study has found that the 100-year return period flood zone mapping developed by the Environment Agency covers approximately 563,519 ha of the UK land surface (including upland floodplains) of which only around 0.5% is now functional wetland (~3000 ha). The decline even since 1990 when there was 1.8% of floodplains covered in wetland has been severe especially when placed in an ecological context and suggests that the general figures provided by Tockner and Stanford (2002) that in Europe and North America, "….up to 90% of floodplains are already

Table 2
Variation in percentage area for key land use types 2015, (inset providing further detail at lower percentage land cover types).

	Arable and horticulture	Bog	Fen marsh and swamp	Improved grassland	Neutral grassland	Urban	Fen marsh swamp bog	Arable and pasture
0	9.12	92.34	81.39	1.28	51.28	5.47	0.00	0.00
5	21.72	6.93	16.79	3.28	40.33	47.81	97.45	2.74
10	17.34	0.18	0.73	4.01	4.38	20.07	0.91	2.01
15	11.13	0.18	0.55	3.10	2.01	7.85	0.73	1.46
20	6.02	0.00	0.00	4.38	0.73	3.65	0.00	1.28
25	6.39	0.00	0.18	4.93	0.36	3.83	0.18	2.55
30	4.74	0.18	0.00	6.20	0.18	2.37	0.18	2.37
35	4.56	0.18	0.00	7.12	0.36	1.82	0.18	3.10
40	4.01	0.00	0.18	7.30	0.36	1.46	0.18	3.83
45	2.74	0.00	0.18	6.57	0.00	1.09	0.18	3.65
50	3.28	0.00	0.00	5.84	0.00	0.91	0.00	4.38
55	2.19	0.00	0.00	8.58	0.00	0.91	0.00	3.83
60	2.37	0.00	0.00	7.85	0.00	0.55	0.00	5.11
65	0.91	0.00	0.00	5.84	0.00	0.55	0.00	6.39
70	0.55	0.00	0.00	7.66	0.00	0.73	0.00	6.93
75	0.36	0.00	0.00	4.93	0.00	0.36	0.00	7.48
80	0.55	0.00	0.00	3.83	0.00	0.00	0.00	8.76
85	1.09	0.00	0.00	3.83	0.00	0.00	0.00	9.85
90	0.18	0.00	0.00	1.64	0.00	0.36	0.00	9.12
95	0.55	0.00	0.00	1.46	0.00	0.18	0.00	10.95
100	0.18	0.00	0.00	0.36	0.00	0.00	0.00	4.20

Table 3
Percentage cover of arable, horticulture and Improved grassland for all Good status river water bodies in England (2015 data).

	Arable & horticulture	Improved grassland	Both
0	0.00	0.00	0.00
5	21.28	3.72	1.86
10	15.96	4.52	1.60
15	13.56	5.05	2.13
20	7.18	2.93	2.93
25	9.04	3.46	1.06
30	5.05	5.59	1.33
35	7.71	5.05	2.66
40	3.99	5.05	2.93
45	2.93	4.79	2.39
50	2.93	9.31	4.52
55	1.86	5.85	5.59
60	0.80	6.38	5.05
65	1.86	6.65	7.45
70	0.27	3.72	6.12
75	0.80	6.12	6.65
80	0.53	5.85	7.45
85	1.06	4.26	5.32
90	0.00	4.52	9.84
95	0.80	1.60	5.59
100	1.06	2.13	9.04

'cultivated' and therefore functionally extinct" is likely an underestimate for English rivers. The land drainage grants of the 1970's saw 84,000 ha drained with no measurable increase in agricultural yield (Purseglove, 1998) and it would appear that although such grants fell away in the 1980's the loss of wetland has continued through to 2000 and our current attempts to improve watercourse form and function through restoration is having no significant measurable impact on floodplain form and function.

Biodiversity can only be improved through increasing species numbers and extending species distribution (Andrewartha and Birch, 1954). This requires provision of the resources that are needed by animals and plants in order to reproduce and functional habitat is primary in this regard. Tockner and Stanford (2002) emphasised the urgent need to preserve existing, intact floodplain rivers and to restore functionality to those rivers that retain some level of ecological integrity. It would appear from the data on English floodplains that few if any systems fall into these categories due to the levels of change to geomorphological and ecological character and functionality. Plant and animal species associated with English river systems are already under extreme pressure and many have gone extinct on systems where they were formerly present. The prediction of a dramatic reduction and loss of floodplain species in the first 20 years of this millennium made by Tockner and Stanford (2002) has already actually occurred across England in the 20th century linked to human induced changes to form and function.

Gibbs and Salmon (2015) note the inevitability of floodplain degradation as a result of agricultural expansion. Here, our analysis for English floodplains goes further, revealing how changing agricultural practices has resulted in progressive degradation of floodplain ecosystems with trends of increasing floodplain homogenisation and the loss of nearly all functional floodplain habitats. Similarly, the link between subdued system dynamics and a loss of diversity made by Connell (1978) is amply demonstrated by the results presented here. The destruction of both natural habitat and system functionality across English floodplains has resulted in a major reduction in biodiversity and this is further exacerbated by active land-use manipulation to further suppress the natural functioning of river and floodplain systems, most notably through flood management suppressing floodplain system functioning and through alterations to the low flow regime impacting water table levels across the floodplain.

River biota are often well adapted to rapid change and populations impacted locally by an event such as a flood may be replaced by recolonisers moving in from refuge areas along the system once

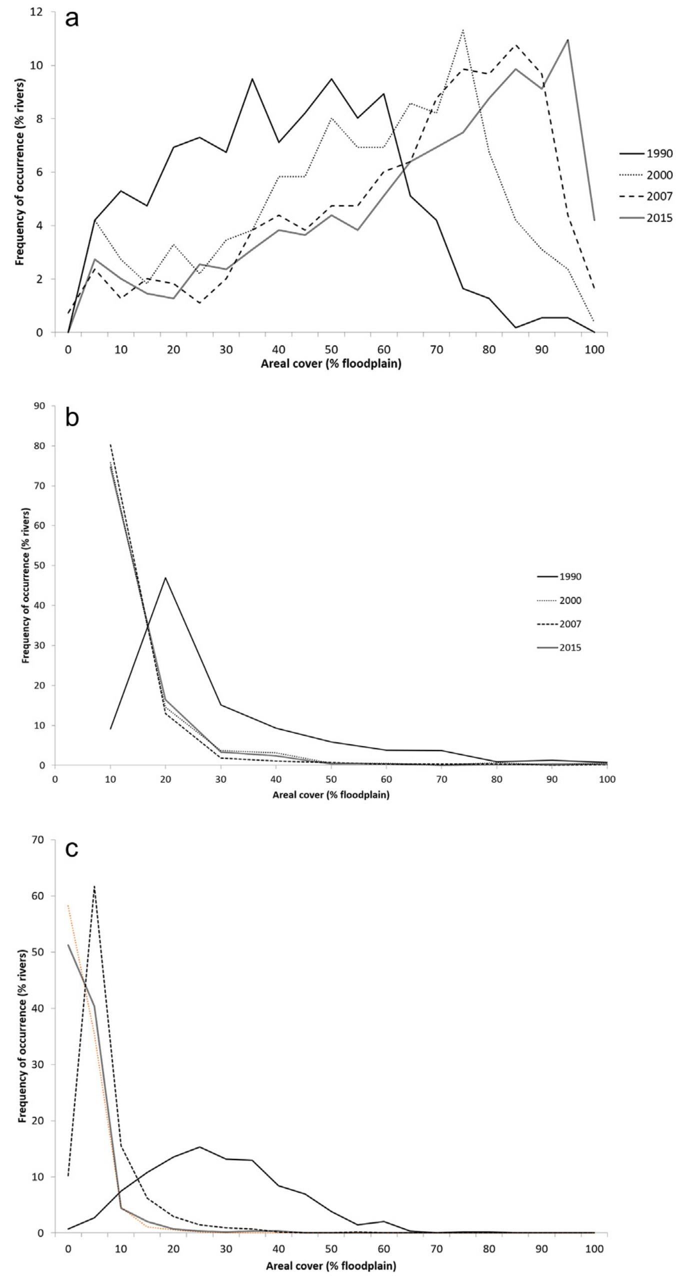

Fig. 5. Temporal change (1990–2015) in (a) farmed area, (b) wetland and (c) rough grassland measured as a percentage of total individual floodplain area across the 550 main river systems in England.

conditions return within more normal bounds. However, all species function within natural environmental limits and when these limits are exceeded, particularly for long periods of time or where they are particularly severe, then species cannot adapt and are no longer able to survive (Stanford et al., 1996). Such a situation is now near ubiquitous across English floodplains for almost all native floodplain species. Diversity has been decimated as environmental controls have been altered and are maintained in such a way that any return to natural levels is prohibited. The preponderance of a near homogenous landscape, where natural processes are almost completely suppressed and will continue to be suppressed through active management, offers little hope of any return to a more natural, dynamic and diverse system unless agricultural practices, not just on floodplains but also across the wider catchment are fundamentally altered. Small scale restoration may partially restore some river and floodplain processes, but suppression

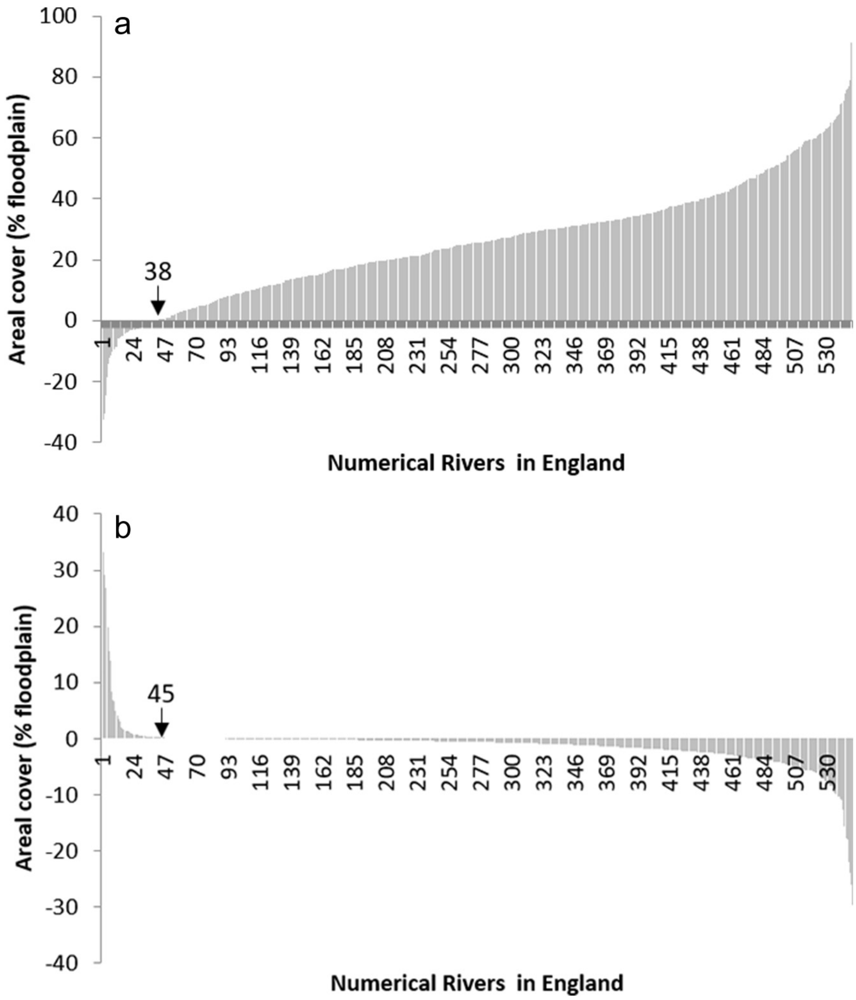

Fig. 6. Percentage change in floodplain occupation by (a) farming and (b) wetland on a river by river basis for English watercourses.

elsewhere will mean that ecological gains remain highly localised and fundamentally unsustainable into the long term.

The impact of floodplain neutering has been shown to extend beyond the valley bottom to influence the ecology of the watercourse. Aarts et al. (2004) demonstrated that overall, fish species richness and diversity declined with decreasing hydrological connectivity. This is most true for specialist rather than more generalist fish species resulting in a loss of biodiversity and one or two species proliferate. As such attempts to improve riverine fisheries must also consider the condition of the floodplain. It is suggested that our findings of near complete and persistent natural habitat loss across English floodplains is hampering the recovery of many watercourse fisheries and future efforts must concentrate on restoring floodplain as well as in-channel form and functionality.

The level of natural floodplain habitat destruction demonstrated here and in previous studies (Tockner et al., 2008; Heritage et al., 2016; Seager et al., 2012) amply demonstrate the serious loss of floodplain natural structure and functionality principally as a result of anthropogenic modification of rivers and floodplains. It is argued that this near complete loss of geomorphological and ecological functionality ranks alongside the changes from braided to anastomosed and anastomosed to alluviating single thread systems discussed by Brown et al. (2018) marking a fundamental state change.

5. Conclusions

Humans have long influenced valley bottom ecosystems with impacts recorded consistently across Europe since the Bronze Age (Brown et al., 2018), consistently suppressing the ecosystem dynamics and associated landscape disturbance regimes that sustain habitats, and biotic communities leading to permanent loss of environmental heterogeneity and biodiversity (Warren and Liss, 1980). This was reiterated by Stanford et al. (1996) who note that the proper functioning of a river and floodplain system requires that processes operating across these environments are appropriately connected. When these are severed biodiversity is reduced. It would appear from the data presented earlier that biodiversity across English floodplains has been substantively reduced and, by inference, the same can most likely be said for the river environment. It would appear that agriculture practices have not only impacted floodplain habitat character but have also impacted the process operating to maintain river and floodplain functioning. Only by addressing the impacts on controlling processes will physical attempts to restore floodplain systems achieve success. Stanford et al. (1996) also classify long term changes to river basins into three categories, water pollution, food web manipulation and imposition of barriers impacting on temperature and materials fluxes. The severing of riverine ecosystem connectivity is known to occur in all three spatial planes and is probably the most persistent influence by humans on river landscapes world-wide (Dynesius and Nilsson, 1994). This is certainly confirmed by the data presented in this paper in the case of English floodplains with major flow and sediment transfer discontinuities impacting laterally to degrade floodplain form and function and impact on biodiversity.

England has been described as a crowded country where there is a

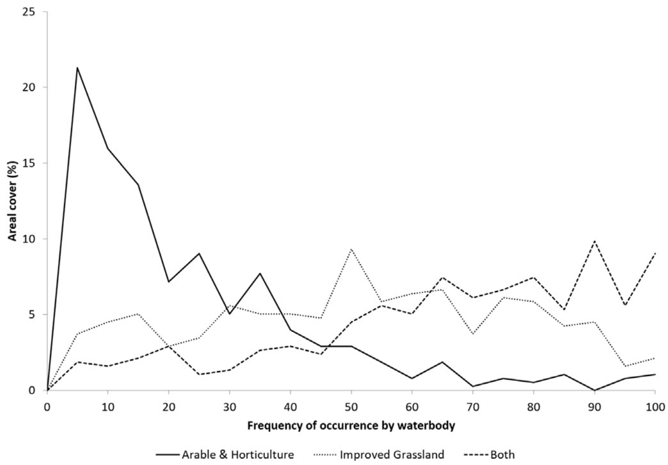

Fig. 7. Percentage of arable, horticulture and Improved Grassland for all good status river water bodies in England (2015 data).

need to strike a balance between competing demands on limited land space (Pardoe et al., 2011). Whilst Nilsson et al. (2005) claimed that flow regulation represented the most pervasive change wrought by humans on fluvial systems world-wide. In the case of England and probably for many other countries where agricultural intensification has occurred this is probably rivalled by the impact that farming has had on floodplain form and process. It was responsible for the state change to heavily alluviated valley bottoms from the Bronze Age onwards (Macklin et al., 2014) and more recently for the loss of functional geomorphic units and associated habitats and biodiversity demonstrated in this paper.

The near complete alteration of English floodplains suggests that the resultant changes to floodplain form and dynamics are now so severe that naturalisation may now be impossible. At best, current attempts to redress the balance through restoration will mean that we will end up with a set of isolated floodplain sites where partial morphologic restoration will have occurred. These sites may also display partial restoration of system functionality, however the eventual influence of persistent wider perturbations will mean that any increase in species richness will deteriorate and these sites will require increasing unforecast local management to persist. Such a conclusion is stark offering little hope of ever significantly reversing floodplain and wider linked fluvial system degradation despite concerted local effort. Contemporary human influence and land manage practice over historic time is to blame for this situation and it is clear from the trends in the data presented that little appears to have improved over the last 25 years despite initiatives and subsidies targeted at improving farming practices to impact less on the environment.

It is useful to review the figures above with the Water Framework Directive measure of river quality. The land use data for 2017 was further broken down according to current water body status generating 2975 auditable units. Each water body has an assigned status those at “Good” status (375 units) were selected. Fig. 7 illustrates the areal cover distribution for Arable and horticultural land use and improved grassland as a percentage of the overall water body floodplain area. Arable and horticulture covers in excess of 50% of the floodplain area on around 15% of Good status water bodies, this increases to around 50% for area under improved grassland and when the two are considered together between 70 and 75% of Good status waterbodies are covered by at least 50% farm land. Around half of these water bodies are utilised over 90% by farming.

These data are a stark reflection of the failure of the Water Framework Directive standards currently employed in England to consider the floodplain as part of the assessment. This has resulted in water bodies being classified at Good ecological status when their floodplain condition is almost certainly significantly degraded and their floodplain functionality lost.

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