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Making the connections. Using the ecosystem services concept to guide the sustainable management of chalk streams.

by

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Abstract

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Chalk streams are some of the most iconic and globally important freshwater ecosystems. Over the past few decades there has been a marked decline in the condition of chalk streams resulting from anthropogenic pressures. There is an urgent need to improve the ecological health of chalk streams, but this requires developing a holistic understanding of the river landscapes and establishing solutions that work for both nature and people. This thesis uses the ecosystem services concept as a lens to understand the relationships between humans and two archetypal chalk streams (the River Test and River Itchen, Hampshire, UK) with the aim of demonstrating the value of chalk streams to society, examining the governance of chalk streams, and ultimately expanding the evidence base underpinning decision making. Participatory methods were used in this thesis to allow diverse stakeholder perspectives to be elicited and evaluated.

Using a participatory process the ecosystem services provided by the case study catchments, and the specific pressures affecting them, were identified. Cultural values, particularly those associated with recreational activities, are identified as being of importance to stakeholders. Population growth, societal values towards nature, climate change and pollution are the main threats to the current and future provision of these services. A public participation geographical information systems (PPGIS) survey was utilised to identify bundles and hotspots of ecosystem services within the case study catchments, and to assess how social-ecological characteristics influence the distribution of these values. Both land cover and physical accessibility are key determinants of the areas found to be hotspots for cultural services. Physical connections between society and the rivers are therefore important, and the findings suggest that certain stakeholder groups act as gatekeepers to ecosystem service provision through their ability to limit or facilitate access. Actor roles and their influence were explored further to the actor network for the governance of ecosystem services using participatory social network analysis. Although there is a well-connected network of actors from the state, private sector, and civil society, decision-making and governance are shown to be controlled by central state actors, some of whom have limited connection to local stakeholders. Furthermore, a lack of trust between actors undermines collaboration and co-ordination in the network.

This thesis articulates a spatially explicit understanding of the value that two important chalk streams provide to society and reveals the social relationships between actors that mediate both the supply and quality of ecosystem services. Improving access to chalk streams to enhance the provision of cultural services and connection to chalk streams could improve support for chalk stream conservation, while inclusion of spatially explicit socio-cultural values in local planning, and providing local civil society actors with more power, are key recommendations for improving decision making that can ultimately lead to the sustainable management of chalk streams.

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Research Thesis: Declaration of Authorship

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I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

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3. Where I have consulted the published work of others, this is always clearly attributed;
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Definitions and Abbreviations

ACM .... Adaptive Collaborative Management

CICES .... Common International Classification of Ecosystem Services

EA.................................... The Environment Agency

ELMs................................ Environmental Land Management Scheme

ENGO .... Environmental Non-Governmental Organisation

IPBES............................... Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services

MEA .... Millennium Ecosystem Assessment

NCP................................. Nature's Contribution to People

NE .... Natural England

NGT .... Nominal Group Technique

PFAS................................ Per- and polyfluoroalkyl substances

PPGIS .... Public Participation Geographical Information Systems

SNA .... Social Network Analysis

VCT.................................. Vitacress Conservation Trust

Chapter 1 Introduction and background

Chalk streams are unique and globally important ecosystems (Figure 1.1), approximately 80% of which are found in England, with the remaining streams located in France, Belgium and Denmark (O'Neil and Hughes, 2014). As a result of their global rarity, unique characteristics, and level of threat to their ecological condition, chalk streams were designated priority habitats under the original UK Biodiversity Action Plan (Joint Nature Conservation Committee, 2024). Section 1.1 in this chapter details a) the definition of chalk streams and an overview of their distribution; b) the hydrology, morphology, and ecology of chalk streams; c) the impacts of human activities over time on chalk streams; and d) the issues with current management approaches. In doing so the broad aim of this thesis is established, to develop a holistic understanding of the relationships between people and chalk streams to expand the evidence base for decision making and ultimately lead to the sustainable management of chalk streams. This section is followed by a review of the definition of sustainability (section 1.2) and how sustainability can be explored through the ecosystem services concept, by bridging the social and ecological domains. Section 1.3 introduces and examines the ecosystem services concept, including a review of the common ecosystem service conceptual frameworks, a discussion of how the concept has been applied to riverine ecosystems, and an outline of the key criticisms of the concept. Finally, section 1.4 outlines the arguments for stakeholder participation in ecosystem service research, before detailing the aims and objectives of the thesis (section 1.5).

Figure 1.1 The River Itchen, a chalk stream, at Winchester, Hampshire, UK. Photo by Jennifer Ball (2020)

1.1 Chalk streams

In the late Cretaceous period (100.5 Mya to 66 Mya), warm seas were home to countless numbers of bivalves and microscopic marine algae, known as coccolithophores (Brenchley and Rawson, 2006). Chalk formed from the gradual accumulation and compression of the calcitic remains of these microscopic shells and coccoliths (Berrie, 1992; Glasspool, 2007). A marked recession of the sea during the early Tertiary Period left extensive outcrops of chalk, which were subsequently buckled and folded by movements of the earth into a series of waves and troughs (Glasspool, 2007). This geological displacement exposed bands of chalk in England, Belgium and France (Berrie, 1992), areas where chalk streams are found.

Today, 80% of all chalk streams, approximately 160 streams, are found in England due to the extent of chalk exposures in the South and East of the country (Mainstone, 1999; The Wildlife Trusts, 2017) (Figure 1.2). In these systems, rainwater is able to percolate down through micropores and fractures in chalk and, when blocked by an impermeable layer of rock below, accumulates in the chalk forming an aquifer. Chalk streams are dominated by groundwater flow from these chalk aquifers, with the source of the stream being springs where the water emerges at the surface. Formally, chalk streams are defined as having a baseflow index (BFI: the proportion of stream flow derived from groundwater) of 75%, with little influence from surface run-off, and 80% chalk bedrock along their course (Smith et al., 2003). The underlying geology and hydrology of chalk streams results in distinct physical, chemical and biological properties, which are outlined in sections 1.1.1 and 1.1.2.

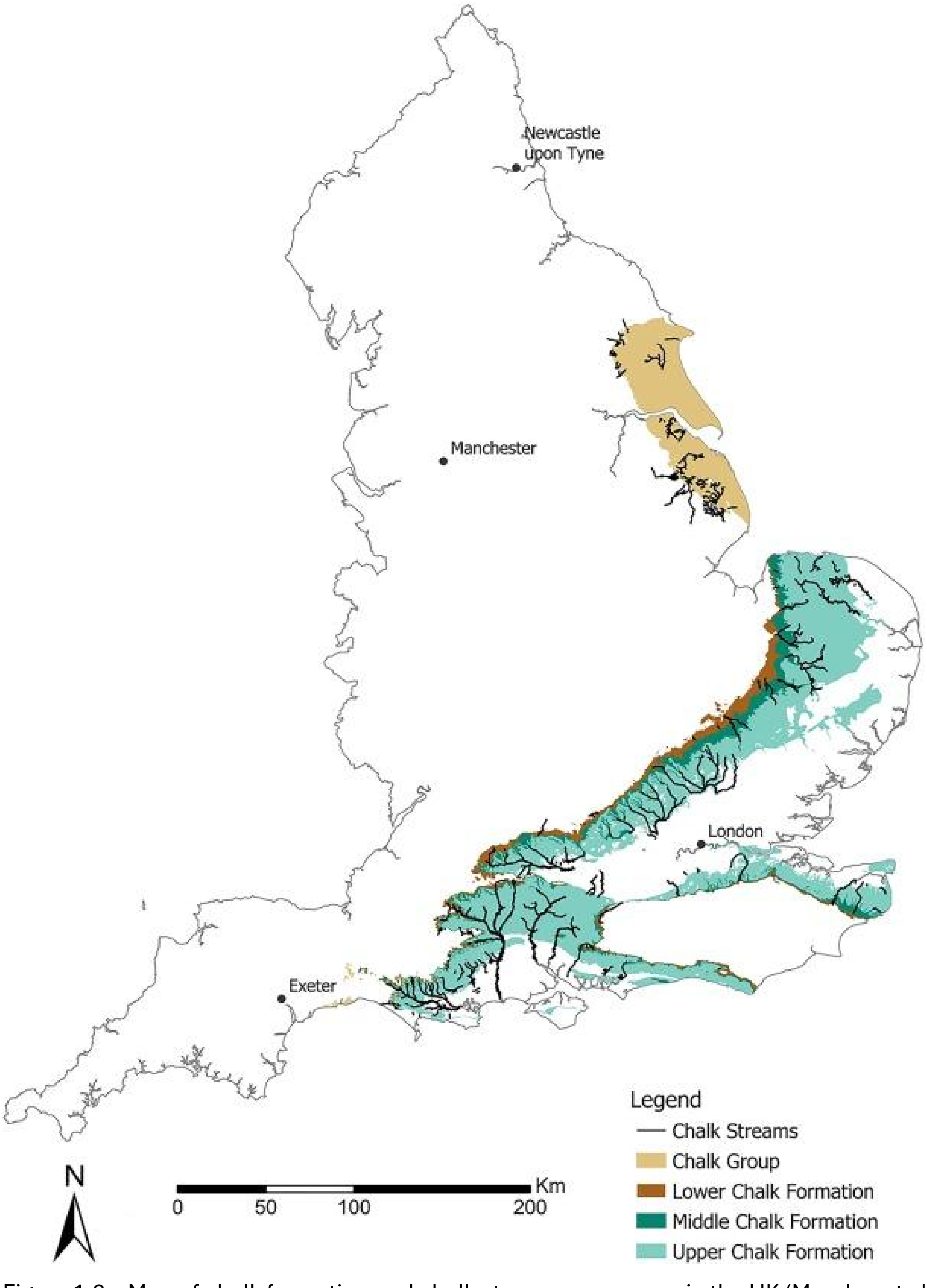

Figure 1.2 Map of chalk formation and chalk stream occurrence in the UK (Mondon et al., 2021).

1.1.1 Chalk stream hydrology, geomorphology and hydrochemistry

Chalk streams tend to exhibit less flashy, dampened hydrology, compared with streams and rivers with more impermeable geologies, a result of their geology and predominantly groundwater derived flow (Raven et al., 1998; Mainstone, 1999). The ratio between high and low flows is typically less than 10:1 in a chalk stream in contrast to those in clay-dominated catchments, which typically have ratios of 100:1. Although peak flows maybe lower in chalk streams, they last for longer and an unmodified chalk stream may flow at a bank full stage for 30% of the year, compared to 5% in other types of catchment (Rangeley-Wilson, 2021).

The flow regimes of chalk streams typically exhibit seasonal patterns reflecting the water table dynamics of the aquifer. Higher rainfall, reduced vegetation growth, and lower temperatures, in winter result in higher percolation of water and recharge of the aquifer (Berrie, 1992; Mainstone, 1999). As a result, chalk stream discharge is often higher during winter and spring, and lower during summer and autumn (Mainstone, 1999; Westwood et al., 2017). As groundwater levels rise from winter recharge, ephemeral winterbourne streams (streams which dry out periodically due to fluctuations in groundwater levels) are commonly reactivated from December to April in the upper catchment, after which flow decreases through the summer months (Smith et al., 2003; Hanrahan et al., 2003). The extent to which an aquifer is recharged during seasons of high precipitation can influence hydrological characteristics for the following year with inadequate recharge resulting in lower flows in the following year (Mainstone, 1999). However, perennial headwaters, permanent, first order streams in the upper catchments, only dry out in exceptional circumstances, while classic chalk streams in the mid-reaches of a catchment are often fed by several springs along their length and do not dry out (Smith et al., 2003).

The characteristics of the chalk (e.g. the degree of fracturing and hardness) (MacDonald and Allen, 2001) land (e.g. the extent of vegetation and the land use) (Jackson, Meister and Prudhomme, 2011) and the influence of other geologies affect an individual chalk stream's hydrology. For example, the River Nar catchment has more flashy responses compared to other chalk streams due to glacial deposits in catchment (Sear et al., 2005; Rangeley-Wilson, 2021). Accounting for geological variability, (Rangeley-Wilson, 2021) identified four types of chalk stream:

(A) Classic slope-faced stream: rise directly from and flow predominately over chalk (e.g. River Itchen and Test).

(B) Mixed-geology stream: streams that do not rise from but subsequently flow over or through chalk (e.g. Hampshire Avon and River Colne).
(C) Scarp-face stream: scarp-slope rivers that rise at the base of the chalk and then flow over gault clay, greensand beds and clay rich chalk (e.g. River Rother and Adur).
(D) Pleistocene ice-impacted stream: rise from chalk impacted by Pleistocene glacial action (e.g. River Wissey and Wensum).

At the catchment scale, chalk streams have few tributaries as they tend to form in valleys where the groundwater level intersects with the surface topography (Mainstone, 1999; Rangeley-Wilson, 2021). The low drainage density means that the stream order is low and connectivity to the landscape is limited (English Nature, 2002). Unmodified chalk streams typically have a meandering sinuous planform and can be comprised of multiple braided channels (English Nature, 2002; Rangeley-Wilson, 2021). Due to the gentle gradients over which they typically flow, their high width to depth ratios, and stable low peak discharge, chalk streams are typically low energy systems (Kemp et al., 2017). The limited hydraulic energy results in low rates of bank erosion, which alongside groundwater inputs, leads to low levels of suspended sediment, under natural conditions, providing high water clarity (Heywood and Walling, 2003; Wetherell, 2023). Background concentrations of suspended fine sediment in chalk streams are substantially lower compared with other river systems in the UK (e.g., <5 t km^{-2} $year^{-1}$ compared with > 100 t km^{-2} $year^{-1}$) (Acornley and Sear, 1999; Heywood and Walling, 2003; Cooper et al., 2008). However, their low power means that chalk streams are not able to easily mobilise their flint gravel substrates and have a limited capacity for channel modification. The relatively immobile gravel beds of chalk streams suggests that the gravel beds are remnants of time of higher energy conditions (Sear et al., 2006). In a natural state a typical chalk stream has high water clarity and a stream bed containing clean, compacted gravel and flint, with limited silt build up (Figure 1.3).

The hydrological pathways through chalk bedrock give rise to distinctive physicochemical properties of the water in chalk streams. Emergent water in chalk streams typically has a high alkalinity with a pH in the range of 7.4 – 8.3 (Berrie, 1992: Hanrahan et al., 2003) due to the levels of calcium bicarbonate dissolved in the water. Major nutrients are usually found in quantities that do not limit plant growth (Berrie, 1992), although nutrient levels are heavily influenced by human activity (Mainstone, 1999), see section 1.1.4.2 for more details. The temperature of the discharged water is relatively stable throughout the year, emerging at approximately 11°C (Crisp et al., 1982; Mainstone, 1999). The mineral rich and stable physiochemical properties of chalk streams help to support diverse biological communities (Wright, 1992) .

Chalk stream morphology can also be shaped significantly by ecosystem engineers (Rangeley-Wilson, 2021), organisms that alter ecosystems by modifying the physical and chemical environment (Briones, 2024). Larger woody materials create habitat diversity by changing the flow velocity and creating refugia and nursery habitats (Thompson et al., 2018), and riparian vegetation can fortify rivers banks (Simon and Collison, 2002). Seasonal macrophyte growth (e.g. *Ranunculus penicillatus)* (Figure 1.3) can fundamentally affect the dynamics of flow and sediment in chalk streams by causing reductions in flow velocity and increased deposition of fine sediment within a stand, at the same time driving increased velocity and scour between stands. This creates localised habitat variability, which can enhance species richness (Gurnell et al., 2006; Wharton et al., 2006). Sediment dynamics can also be influenced by bioturbators, e.g. gravel spawning fish, such as brown trout, *Salmo trutta,* who can improve sediment flow by loosening fine sediment from the riverbed as they create redds (Montgomery et al., 1996; Buxton, 2018). In contrast, benthic macroinvertebrates (e.g. caddisfly larvae, *Hydropsychidae*) can stabilise a river bed by building silk nets between sediment grains (Albertson et al., 2014).

Figure 1.3 The River Itchen, Hampshire UK, a classic slope-faced stream. The high width-to-depth ratio, clear waters, gravel bed and macrophyte stands are visible. Photo by Tim Sykes (2019).

1.1.2 Chalk stream ecology

The chemical and physical characteristics of chalk streams provide unique habitats for a wide range of freshwater organisms (Sear, Armitage and Dawson, 1999). The high levels of nutrients and stable conditions allow extensive instream macrophyte communities to flourish (Berrie, 1992), which in turn provides habitats and food for a range of invertebrate and fish species (Hearne and Armitage, 1993). Characteristic chalk stream macrophytes include crowfoot (*Ranunculus penicillatus*) and watercress (*Nasturtium officinale*) (Mainstone, 1999). The riparian margins of chalk streams can feature a range of plants including reed sweetgrass (*Glyceria maxima*), common reed (*Phragmites australis*), and hemlock water dropwort (*Oenanthe crocata*). In unmodified chalk streams where the adjacent land is uncultivated, fen, swamp, and carr wet woodland can occur (Mainstone, 1999). These areas are typically dominated by reed grass (*Phalaris arundinacea)*, tussock sedge (*Carex paniculata)* and tree species such as willow, alder and oak, that can thrive on the alkaline, moist or saturated soils.

Carr wet woodland provides shade, and the woody debris from the trees creates a more varied and dynamic channel, influencing the stream flow by providing areas of low flow that act as refuges for fish and invertebrates and areas of high flow velocity that increase the energy of the chalk streams (Rangeley-Wilson, 2021).

Habitat diversity created by different vegetation and substrate in chalk streams gives rise to a range of ecological niches for invertebrates. Invertebrates found in chalk streams include a) insects such as *ephemeroptera* (mayflies), *plecoptera* (stoneflies), *trichoptera* (caddis flies) and coleoptera (beetles); b) crustaceans, including freshwater shrimps, and crayfish; c) molluscs including snails (*gastropoda*) and mussels (*bivalvia*); and d) segmented worms (*Clitellata*) which includes leeches and flatworms (Mainstone,1999). Habitats include the interstitial spaces of the characteristic gravel substrates, which provide habitat for caddisfly larvae, and the porous substratum provided by macrophytes such as Ranunculus, occupied by suspension feeding invertebrates (Berrie, 1992; Glasspool, 2007; Pacioglu and Moldovan, 2016). Suspension feeders, particularly larval blackflies (*Diptera: Simuliidae*), play an important role in transferring sediments and nutrients from the water to the riverbed, by attaching themselves to Ranunculus stands in areas of high flow velocity (Wharton et al., 2006). The larval blackflies filter dissolved and particulate matter (organic and inorganic) from the water and convert it into faecal pellets that are carried away and deposited in areas of low flow velocity (Wotton and Malmqvist, 2001).

Chalk streams are home to a range of fish species, including Grayling (*Thymallus thymallus*), Atlantic Salmon (*Salmo salar*) and Brook Lamprey (*Lampetra planeri*) (Prenda, Armitage and Grayston, 1997; Mainstone, 1999). The chalk stream gravel beds provide ideal spawning conditions for lithophilous fish species such as Brown Trout (*Salmo trutta*) and Atlantic Salmon (*Salmo salar*), which excavate depressions in gravels, known as ‘redds’, to lay their eggs, typically between November and January. Brown Trout and Atlantic Salmon favour well oxygenated and cool water, where there is sufficient water velocity to avoid siltation (Armstrong et al., 2003). Additionally, many mammal species favour chalk stream habitats, due to the stable flow and abundance of prey, including Otters (*Lutra lutra*), Water vole (*Arvicola terrestris*) and water shrew (*Neomys fodiens*) (Mainstone, 1999; Glasspool, 2007).

Longitudinal change in conditions within chalk streams impacts the composition of biological communities. The intermittent flow conditions in the headwater winterbournes drive adaptation and so are home to specialist invertebrates that exhibit traits, such as drought-resistant eggs and high dispersal potential, that provide resilience to the fluctuating dry and wet conditions

(Armitage and Bass, 2013). There is increasing evidence that chalk stream winterbournes are important hot-spots for biodiversity in addition to the perennial reaches (Macadam, Stubbington and Wallace, 2021; Bunting et al., 2021).

The diverse and unique biotic community is arguably one of the most valuable characteristics of chalk streams and has resulted in chalk streams being labelled 'England's rainforests' (Environment Agency and Natural England, 2021). However, many chalk streams species are of conservation concern (Environment Agency, 2004), including the White Clawed Crayfish (*Austropotamobius pallipes),* Brook lamprey (*Lampetra planeri)* and Otter (*Lutra lutra*), and many chalk stream species are protected under national and international (European) laws. The presence of species that require special conservation measures features in the designation of many UK chalk stream as Sites of Special Scientific Interest (SSSI) and Special Areas of Conservation (SAC) (Rangeley-Wilson, 2021). For example, the River Itchen in Hampshire is designated as an SAC for the Ranunculus, Southern Damselfly and Bullhead populations it supports (Natural England, 2022).

1.1.3 History of human use of and impact on chalk streams in England

The influence of human society on rivers, and specifically chalk streams, can be traced back thousands of years. One of the most significant and still noticeable impacts arose from forest clearance, which increased significantly during Neolithic times, for the purpose of temporary small-scale agriculture (Thorley, 1981). The Iron Age brought more permanent forest clearance as communities became increasingly settled and organised (Thorley, 1981; Glasspool, 2007). The human population also grew, necessitating the clearance of more land (Waton, 1983). Light penetration to the bottom of the chalk streams would have increased, promoting the growth of emergent and submerged macrophyte communities, which are characteristic of the streams today (Mainstone, 1999).

The Roman occupation of Britain brought with it advances in engineering, with historical evidence of the rivers being brought under control as Roman engineers installed watermills, impounded parts of the river, and created drainage systems (Glasspool, 2007; Yoward and Yoward, 2011). Milling required the water to be diverted from the main river in man-made channels, creating new ecological habitats and changing the flow of the rivers. During the middle- ages the number of watermills increased, primarily for the purpose of power generation and flour milling (Yoward and Yoward, 2011). Chalk streams were thought to be ideal for milling due to their steady and stable flow. Although few mills are still in use, the legacy of their construction is still visible across many chalk stream landscapes, particularly the watercourses and wheel pits (Glasspool, 2007).

Damming of chalk streams to create fishponds became common throughout the Middle Ages as species such as salmon became increasingly exploited as a source of food (Glasspool, 2007). Recreational fishing was not common until the early 19th century. As the sport developed, chalk rivers began to be managed to maximise the potential for fishing through interventions such as weed cutting to improve river flow and prevent the build-up of silt (Mainstone, 1999).

The conversion of floodplains to water meadows at the beginning of the 17th century was another human influence on chalk rivers. Water meadows were man-made systems of draining and irrigating land, primarily the downstream floodplains of a river. In low-gradient chalk stream landscapes, a water meadow required labour-intensive channel construction (Mainstone, 1999; Glasspool, 2007). A main channel diverted water from the river and into a network of smaller channels, each on the crest of a small ridge, which overflowed and allowed water to enter the land. The water would then seep down into small drain channels that returned water back into the river (Cook, Stearne and Williamson, 2003; Cook and Williamson, 2007). The creation of water meadows led to the formation and stabilisation of multiple channels, which are still evident on many chalk rivers (Mainstone, 1999).

The water meadow system was designed to keep the ground constantly damp, rather than flooded, to improve agricultural efficiency. In the 17th century the value of water meadows could be two or three times higher than un-watered meadows (Bettey, 2007), recognising the increased productivity of system. In early spring the warmer water, from the aquifer fed river compared to rainfall, protected roots from frosts allowing earlier growth of grass (Bettey, 2007; Cook, Cutting and Valsami-Jones, 2017). Sheep grazed the land between March and May and then moved to other pastureland to allow the meadows to be irrigated again in early summer to produce a crop of hay. Further irrigation later in the summer could produce up to another two crops of hay (Cook, Stearne and Williamson, 2003).

Water meadows were used and continually managed up until the early 1900's, when labour shortages due to war, improved mechanisation, and the use of fertilisers led to their decline (Bettey, 2007). Water meadows are believed to have been species poor due to the grazing regime, but became more diverse after their abandonment (Glasspool, 2007). However, the cultural significance of water meadows is recognised today, and many management plans include the maintenance of channel networks (Stearne, 2007).

The biotic communities that we see in chalk streams today are likely to be significantly different from those prior to the rapid rates of deforestation experienced in the Bronze and Iron Ages, and the construction of water meadows. Chalk streams would likely have had more complex planforms without strictly defined channels. The natural inputs of woody debris from tree fall would have further increased the complexity of the channels, forming flow obstructions and retaining sediment (Gurnell and Grabowski, 2016). Light penetration would have been limited through thick vegetation, except in areas of open grassland, reducing the macrophyte community. As Mainstone (1999) highlights, this 'natural' state of the river is unlikely to be desirable or economically feasible today. Conservation efforts today reference a characteristic chalk river as having a meadow-dominated catchment, with a dominant macrophyte community and higher fish population, reflecting a state after the majority of deforestation but prior to the intensification of agriculture (Mainstone, 1999).

1.1.4 Current threats to chalk streams

Today, chalk streams face multiple threats from human activities. Chalk stream catchments are often multifunctional, with competing land uses e.g. from agriculture, housing and nature recovery, and competing stream uses, e.g. abstraction of water and recreational fishing (Mainstone, 1999; Shaw, Leung and Clarke, 2021). Consequently, there are often many pressures impacting the ecological condition of chalk streams, and many actors who, directly and/or indirectly, influence the ecological condition of chalk streams. Particular concerns have been raised about the impacts on the ecological condition of chalk streams from pressures such as climate change, water abstraction, point and diffuse pollution, physical modifications to channels, and invasive species (Mainstone, 1999; O'Neil and Hughes, 2014).

1.1.4.1 Climate change

Hydrological processes, such as precipitation and evapotranspiration, are predicted to change as a result of elevated concentrations of greenhouse gases raising global temperatures, ultimately resulting in altered flow regimes in streams and rivers (Arnell, 2003; Whitehead et al., 2006). In the south and east regions of England, scenarios project variability in mean annual rainfall depending on the scenario of carbon emissions, the time horizon, and the probability level (Met Office Hadley Centre, 2018). Under a medium emissions scenario, by 2050 annual mean rainfall could vary by 10% either way (Met Office Hadley Centre, 2018). Projections also suggest that the seasonal patterns of rainfall might change, for example with mean winter rainfall increasing by up to 40% or decreasing by 10% by 2050 under a medium emissions scenario. Seasonal extreme rainfall could increase the prevalence of flooding while a decrease in winter rainfall would impact the recharge rate of the chalk aquifer and affect flow rates.

Rivers predominately fed by groundwater are buffered from some variability in rainfall throughout the year as storage of water by the aquifer smooths out river flow (Arnell, 2003). However, when groundwater stores cannot buffer variability in flow, e.g. in prolonged periods of high rainfall, the consequences can be significant. For example, in 2014 some chalk rivers, such as the River Itchen, burst their banks and flooded farmland and towns (BBC, 2014), and climate change could increase the frequency of flooding events. Additionally, low flow regimes in chalk streams can dry out marginal habitat areas - reducing diversity, concentrating organisms into a much smaller area, increasing competition and predation, and reducing the dilution of pollutants (Mainstone, 1999). More variable rainfall is likely to result in more variable winterbourne reaches, which may extend further upstream in times of higher rainfall and more groundwater recharge and downstream when rainfall is lower with less groundwater recharge. In years with exceptionally high or low groundwater recharge, the seasonal dry or wet phases of a winterbourne could be lost (Stubbington et al., 2022).

The water temperature in chalk streams is also anticipated to increase due to climate change. Higher water temperatures pose a particular risk to salmonids as they can accelerate juvenile development, impact the timing of smolt runs (downstream migration from freshwaters to the sea by juveniles) and delay spawning migration (Jonsson and Jonsson, 2009; Simmons et al., 2021; Stubbington et al., 2022). These changes can impact the recruitment, mortality and disease susceptibility of salmonids (Jonsson and Jonsson, 2009).

1.1.4.2 Pollution

There are many sources of both diffuse and point source pollution in chalk stream catchments including sewage, agricultural and road run-off. Typical pollutants include organic pollutants, nutrients, solid loads and heavy metals (Mainstone, 1999).

Increasing the availability of nutrients within a river can affect plant growth and competition between species. Elevated levels of phosphorous in particular can have significant impacts, as this is usually the limiting nutrient in rivers (Mainstone, 1999; Mainstone and Parr, 2002). Phosphorous exists in several physical forms that contribute to the total phosphorous load, including soluble fractions in suspension and particulate forms (Shaw, Leung and Clarke, 2021). Fluvial sediments play an important role in the phosphorous dynamics of a chalk stream through their deposition, storage, and remobilisation of particulate phosphorous (Ballantine et al., 2009). The major sources of phosphorus to chalk streams are sewage/industrial effluent (point sources) and agricultural runoff (diffuse sources). Higher phosphorous levels can encourage a shift in the plant community composition and increase the abundance of filamentous and epiphytic algae, which can result in reduced in-stream light levels, drops in dissolved oxygen (due to plant respiration), and exacerbated siltation problems if fine particles are trapped by excessive growths of epilithic algae (Mainstone and Parr, 2002; Bowes et al., 2007).

Agricultural practices such as leaving the soil bare after arable harvests, which is susceptible to erosion, removal of hedgerows near rivers, and farming livestock where they can trample down the river bank, increases input of solid load into chalk streams (Grabowski and Gurnell, 2016; Collins and Zhang, 2016). Their catchments typically have thin, erosion sensitive soils, that can generate high particulate load. This is problematic as chalk streams have naturally low flow rates and lack the energy to flush through unwanted materials (Mainstone, 1999). Chalk streams rely on having low initial inputs of solid load into the system to ensure that they are kept clear and relatively free from silt. Excessive sediment load can also result in colmation in chalk streams, where fine sediment encompasses the coarser gravel substrate, forming a layer that reduces the permeability of the streambed (Wharton, Mohajeri and Righetti, 2017). Sedimentation and colmation can have significant ecological impacts as many chalk stream species thrive in the clean, gravel substrate habitats within the rivers. Macroinvertebrates can be affected by abrasion from the sediment particles, build-up of sediment in gills and filter-feeding apparatus, and burial (particularly affecting sedentary species, such as mayfly nymph e.g. *Baetis rhodani)* (Jones et al., 2012). Salmonid fish species (e.g. *Salmo salar)* embryo survival rates can decline when sediment accumulates in the gravel of redds as dissolved oxygen concentrations in intragravel water decreases reducing the supply to the egg pockets (Greig, Sear and Carling, 2005; Heywood and Walling, 2007).

Sewage effluent, outflow from watercress producers, wastewater from fish farms, and agricultural run-off all add to organic pollution concentration in rivers (Mainstone, 1999; Hubbard, Newton and Hill, 2004). These pollutants are broken down by microorganisms in the water, using up dissolved oxygen in the process. If oxygen levels are not replenished quickly, then oxygen depletion occurs, making it challenging for other species to succeed; for example, lower rates of oxygen supply were found to reduce the hatching of Atlantic Salmon embryos in chalk streams (Greig, Sear and Carling, 2007).

Run-off from urban areas, including roads, commonly includes heavy metals, elements with an atomic density greater than 6 g/cm; for example, lead, zinc and copper, and polycyclic aromatic hydrocarbons (PAHs) (Robinson et al., 2023). Heavy metals are not biodegradable and accumulate in the environment (Ali, Khan and Sajad, 2013). These heavy metals can limit the growth of aquatic organisms, and through bioaccumulation and work their way into the food chain where they are ultimately toxic to humans (Akpor, Ohiobor and Olaolu, 2014).

1.1.4.3 Abstraction

Chalk rivers are concentrated in the south and east of England, where population density is often high, the demand for water is great, and rainfall is relatively low (Mainstone, 1999). Many water companies, for example Southern Water, Thames Water, Anglian Water, & Affinity Water are operating in chalk stream regions that are classed as seriously water stressed under both current conditions and projected future scenarios (Environment Agency and Natural Resources Wales, 2013). Water is abstracted from both chalk aquifers and the surface water for use domestically and by industry, resulting in lower flow rates. Low flows are ecologically damaging, reducing flow velocity, drying out marginal river areas and concentration pollutants (Mainstone, 1999). An example of water stress occurred in 2011, when sections of The River Kennet dried up, and Thames Water shouldered much of the blame for their levels of abstraction (BBC, 2011). The catchment management plan for this area now incorporates working with Thames Water on their abstraction levels (Defra and Environment Agency, 2016).

1.1.4.4 Physical modification

Chalk stream channels have been altered over many years as human needs have changed, often for agricultural or water power purposes (Riley et al., 2009). Modifications over the last few decades, for flood management or urban development, have further altered the structure of rivers and their associated floodplains (Mainstone, 1999). Physical barriers, associated with old mills, abandoned water meadows, or abstraction points, are common along rivers. The barriers restrict the downstream flow of sediment and pollutants, which collect behind the structure, and limit upstream migration of fish, such as salmon and trout, and invertebrates without aerial life stages – restricting the opportunity for re-colonisation by these species (Mainstone, 1999).

Straightening, deepening, or widening rivers is a common procedure in flood management, with significant implications for chalk stream habitats (Mainstone, 1999). Straightening channels reduces the complexity of the river and habitat diversity. Deepening the channels by dredging limits the connectivity between the river and the landscape, scours the river bed of epibenthic fauna, e.g. the pea mussel (*Pisidium tenuilineatum*), and results in the loss of the characteristic gravel substrate used by the biotic community (Mainstone, 1999; Aldridge, 2000). The widening of the river reduces the depth of the water and limits hydraulic energy, restricting the ability of the river to transport solid load in suspension, causing siltation (Mainstone, 1999). Loss of habitat structure and diversity is common where such flood management responses have occurred (Aldridge, 2000).

Additionally, farming and fishing practice both alter the chalk streams physically. Livestock farming adjacent to rivers with unrestricted channel access can contribute to widening as the animals trample and destabilise the river banks, making them susceptible to erosion (Clary, 1999; Magner, Vondracek and Brooks, 2008). Weed cutting occurs in chalk stream for both flood defence, to increase the capacity of the channel, and to improve angling condition by maintaining open water and access for anglers (Mainstone, 1999; Old et al., 2014). However, this practice removes habitat for invertebrates, removes cover and shade for fish populations, and exposes river banks to erosion, thus increasing siltation (Aldridge, 2000; Riley et al., 2006). Weed cutting can also result in more varied water levels as in stream vegetation help to maintain water levels in Summer when discharge is lower, by increasing hydraulic roughness (Cornacchia et al., 2020).

1.1.4.5 Invasive species

Increased connectivity and globalisation of trade have increased the spread of invasive species (Meyerson and Mooney, 2007). Chalk streams are no exception and have been subject to several invasions over recent years, including from japanese knotweed (Fallopia japonica), himalayan balsam (Impatiens glandulifera), and signal crayfish (*Pacifastacus leniusculus*) (Rangeley-Wilson, 2021). The introduction of the signal crayfish, has significantly impacted the population of the native white clawed crayfish (*Austropotamobius pallipes*), the UK's only native species of crayfish (Mainstone, 1999). The signal crayfish is native to North America but was introduced from Sweden in the 1970s for harvesting, to supply the Scandanavian food market (Hampshire and Isle of Wight Wildlife Trust, 2009). Poor stock control soon led to the establishment of crayfish in chalk rivers. The invasive crayfish is larger, more aggressive and more fecund, outcompeting the native species (Hampshire and Isle of Wight Wildlife Trust, 2009; Holdich et al., 2014). Signal crayfish also carry a fungal infection, known as crayfish plague, to which native crayfish are particularly susceptible (Svoboda et al., 2017). The disease does not require the two populations to come into direct contact but is carried in water between them (Mainstone, 1999).

It is estimated that 95% of the native crayfish population has been lost, and that within 30 years the species could be entirely absent from Britain (Hampshire & Isle of Wight Wildlife Trust, 2017). Several programmes have been introduced to restore native populations, including a project run by the Hampshire and Isle of Wight Wildlife Trust (HIWWT) to breed and reintroduce native populations, and to provide guidance for river users to prevent further spread of the invasive species or crayfish plague (Hampshire and Isle of Wight Wildlife Trust, 2009).

1.1.5 A chalk stream 'crisis'

The history of modification and exploitation of chalk streams combined with the breadth and intensity of anthropological pressures today has led to degradation of the ecological condition of chalk streams. In 2019, 85% of English chalk streams failed to achieve good ecological status under the European Union Water Framework Directive (2000/60/EC), reflecting this degradation (Environment Agency, 2021b). This collapse in ecological condition is often referred to as the 'chalk stream crisis' (Rangeley-Wilson, 2021) or 'chalk stream malaise' (Defra, 2003). Chalk stream malaise describes the general deterioration in chalk stream habitat, associated with loss of key macrophytes, such as *Ranunculus spp.*, increased turbidity and siltation of gravel beds, and excessive growth of benthic and filamentous algae. These changes have been linked to a decline in salmonid and coarse fish species, and invertebrates (Sear et al., 2016; Everall et al., 2018). As low energy systems, with low bed load mobilisation, and high water residence times, chalk streams are particularly sensitive to eutrophication, nutrient inputs and sedimentation (Jarvie, Neal and Williams, 2004; Mondon et al., 2021).

The historic and continue use and modification of chalk streams reflect the temporal dynamics of ecosystem service demand and provision by the streams (Bürgi et al., 2015). Ecosystem services are commonly defined as 'the benefits people obtain from ecosystems' (Millennium Ecosystem Assessment, 2005). Concern for chalk streams has intensified over the past three decades, in part due to the growing recognition that nature provides benefits to people and underpins a healthy society. As society uses chalk streams in a variety of ways, for example water abstraction for drinking and irrigation, food provision, and recreation, their degradation not only threatens biodiversity but also human wellbeing. There is a need to understand how chalk streams and their catchments can be sustainably managed in a way that works for both rivers and society. The definition of sustainability is considered in (section1.2), and then the ecosystems services concept is reviewed, as a lens through which to understand the relationships between people and nature (section 1.3).

1.1.6 Chalk stream management

This section outlines the main approach to water body management in England and specific considerations for chalk streams. The EU Water Framework Directive (WFD) has been the main driver of the approach to water resource management in England since it was legislated in 2000 (Watson, 2015; Kochskämper et al., 2016). The WFD represented a new approach for water resources management that sought to protect and restore the ecological and physical functions of water bodies. Holistic river basin / catchment management approaches were encouraged, in contrast to earlier EU water legislation that primarily focused on single issues, such as drinking water and groundwater protection (Watson, Deeming and Treffny, 2009). In England, the Environment Agency was the 'competent authority' for implementing the WFD and was responsible for developing River Basin Management Plans (Watson, 2015).

The WFD requires citizen and stakeholder participation and to improve the river basin management planning process, the UK Government Department for Environment, Food and Rural Affairs (Defra) established the Catchment Based Approach (CaBA) in 2013, to implement a collaborative approach to water management across England (Watson, 2015). Defra's Catchment Based Approach Policy Framework (Defra, 2013) sets out the general principles to be followed in establishing partnerships at river catchment scale, with flexibility in the way that partnerships can organise themselves. The partnerships are typically hosted by an environmental non-Government Organisation (ENGO) and are supported by a coordinator from the Environment Agency. The partnership hosts are responsible for bringing together a range of organisations to collectively plan and deliver interventions to drive environmental benefits. More than 106 CaBA catchment partnerships have been established providing complete coverage of England (Collins et al., 2020).

Another key change impacting water resource management in England was the privatisation of the water companies in 1989 (Watson, Deeming and Treffny, 2009). The water companies supply customers with water and/or sewerage services, in return for money paid directly by the customers. To protect the interests of customers and the environment, three regulatory bodies were established, the National Rivers Authority (which later became part of the environment agency) became the environmental regulator, the drinking water inspectorate regulates drinking water quality, and Ofwat, the economic regulator of the water and sewage industry(Mathieu, Tinch and Provins, 2018). The regulators and water companies have significant influence over the approach to and delivery of water resources.

Despite the intention of the WFD to encourage an integrated and collaborative catchment management approach, in England the extent of involvement of citizens and stakeholders is limited. Organisations that have been involved in the WFD planning processes have limited power to influence the approach and direction of the process. Additionally, integration of water resource planning with other planning processes, such as for housing development, is limited (Watson, Deeming and Treffny, 2009).

In addition, to the critique of the approach to catchment management in England, over the past 26 years several chalk stream strategies and manifestos have been published (e.g. The State of England's Chalk Streams (O'Neil and Hughes, 2014) and Chalk Rivers – Nature, Conservation and Management (Mainstone, 1999)), most recently the Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021). These documents have called for and set out proposed changes e.g. more investment in sewage treatment works, to improve the state of chalk streams. However, despite these repeated calls for action there has been little improvement in the collective state of chalk streams, with the condition of many streams deteriorating further (Environment Agency, 2021b). Current management of chalk streams in England is not sustainable if it results in continued degradation to the ecological condition of chalk streams and the ecosystem services they provide. A different approach to chalk stream management is required. The definition of sustainability is considered further in section 1.2.

1.2 Defining sustainability

Sustainability is a concept and goal that is frequently referred to in academic research on the environment. The term has also been used by businesses, incorporated into international treaties, and adopted by political parties (Ruggerio, 2021). For example, the Sustainable Development Goals (SDGs) are a set of 17 goals adopted by all United Nations (UN) members, which drives sustainable development - prosperity that does not cause environmental degradation. Of particular relevance to chalk streams is target 15.1 of SDG goal 15, which aims for the "restoration, conservation and sustainable use of terrestrial and inland freshwater ecosystems and their services" (United Nations Department of Economic and Social Affairs, n.d.). A commonly used definition of sustainability is that it “meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987). Both the socio-economic and ecological domains are implicitly reflected in this definition: the socio-economic domain in terms of the ‘needs’ of people, and the ecological domain in terms of the impact on the ecosystems from which the resources are taken to meet those needs.

Previous work on sustainability has drawn on the capabilities approach (Nussbaum and Sen, 1993; Sen, 1999) to help define the ‘needs’ of people (Malmborg, 2021). A capabilities approach regards human wellbeing in terms of people’s freedoms. ‘Freedom’ is judged by people’s capabilities to achieve outcomes that they themselves value or have reason to value, as in that they have a right to choose between different types of life. The key implication is that ‘needs’ are inherently specific to individuals, and context-dependent, therefore a pluralistic approach to understanding ‘needs’ is required.

Sustainability must also consider equity and interconnection (Leach et al. 2018). Local communities, and the ecosystems in which they are embedded, are connected to each other. The actions taken in one place can impact the processes and actors in other places. If decisions made in one place undermine the capacity of people elsewhere to meet their needs, then these decisions cannot be considered sustainable (Schröter, Stumpf, et al., 2017). In practice, it is challenging to consider all the potential consequences of an action, but it is important to acknowledge the issue of equity. As no action can be neutral, the pursuit of sustainability is inevitably political and practically there needs to be continual negotiation between the interests and needs of different people.

Achieving or moving towards sustainability requires context-specific knowledge about the needs of people and how these needs are both reliant on and impact natural resources, requirements that the ecosystem services concept is well placed to help frame and understand (Schröter, Stumpf, et al., 2017). As shown in the next section (1.3), the ecosystem services concept offers a framework for bridging the social and ecological domains and increasingly reflects a pluralistic understanding of how different people use and benefit from nature (Pascual et al., 2017).

In the context of chalk streams, the aims of sustainable management typically refer to the conservation of chalk streams, or to restoring their ecological health (O’Neil and Hughes, 2014a; Rangeley-Wilson, 2021). While these are valid aims, as argued above, sustainable management also needs to consider the needs of people - how they are reliant on chalk streams and impact chalk streams – and to be based on a holistic understanding of both social and ecological needs. The social dimension of sustainability often has minimal consideration in chalk stream management strategies (e.g. Rangeley-Wilson, 2021). Additionally, in light of the potential impacts climate change on chalk streams (Stubbington et al., 2022), the focus of ecological restoration may need to shift from preventing the extinction of threatened species and trying to maintain biological communities as they are, or have been in the past, which may be unachievable and resource intensive, to ensuring the creation of complex and well-functioning ecosystems (Gardner and Bullock, 2021). This would shift the criteria for successful ecological restoration and how sustainability is defined for chalk streams. Well-functioning chalk stream ecosystems would then underpin the provision of ecosystem services that contribute towards human wellbeing (Bullock et al., 2022).

1.3 The ecosystem services concept

The rise of ecosystem service research and thinking over the past decades reflects a change in how we view the relationship between nature and people and has been used to communicate societal dependence on ecological systems. Although, the term 'ecosystem services' is first thought to have appeared in the scientific community in 1981 (Ehrlich and Ehrlich, 1981). A significant increase in ecosystem services research in the early part of this century followed the publication of 'The Millennium Ecosystem Assessment' (MEA) (2005), which cemented the concept not only into mainstream academia but also into the scientific policy sphere (Potschin and Haines-Young, 2011).

The MEA also provided the stimulus for several countries to incorporate the ecosystem services concept into the policy sphere. The UK undertook a national ecosystem assessment (UK National Ecosystem Assessment, 2011) and established the Natural Capital Committee to assess how society uses ecosystem services. At a global scale the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established to evaluate ecosystem services research and to improve the potential for applying ecosystem services knowledge to decision making (Potschin et al., 2016). Despite some criticisms of the ecosystem services concept, which are addressed in section 0, it is well established in academia and is also now prominent in policy and decision-making (Chan et al., 2017).

A commonly used definition of ecosystem services is 'the benefits people obtain from ecosystems' (Millennium Ecosystem Assessment, 2005). However, ecosystem services represent a means rather than an end, the end goal being sustainable human wellbeing (Costanza, 2020). There are many definitions of human wellbeing, typically focusing on objective dimensions, such as material and social attributes, or subjective dimensions that capture an individual's assessment of their circumstances (Summers et al., 2012). In section 1.3.1, the evolution of the ecosystem services concept and the main frameworks that have been developed to articulate how ecosystem services underpin human wellbeing and how ecosystem services sit within the wider context of the ecological and social domains, are reviewed.

1.3.1 Conceptual frameworks and classification systems

Ecosystem services can be placed in broader systems or frameworks, which seek to understand the interactions and links between humans and nature, bridging the ecological and social science domains. Since the publication of MEA in 2005, a diverse range of frameworks and approaches to ecosystem services have been developed that recognise the interdisciplinary nature of ecosystem services and the emergence of multiple ways of thinking about them (Potschin et al., 2016).

The Millennium Ecosystem Assessment (2005) conceptual framework sought to convey that people are part of ecosystems and that they interact with other parts of ecosystems, directly and indirectly causing change which can impact on human wellbeing (Figure 1.4). The framework assumes that the components of human wellbeing can be linked to the condition and status of the environment and seeks to convey some of the feedback loops within the system. The model also recognises the different temporal and geographical scales in which ecosystem services can be viewed and assessed – from a local community scale to a global perspective.

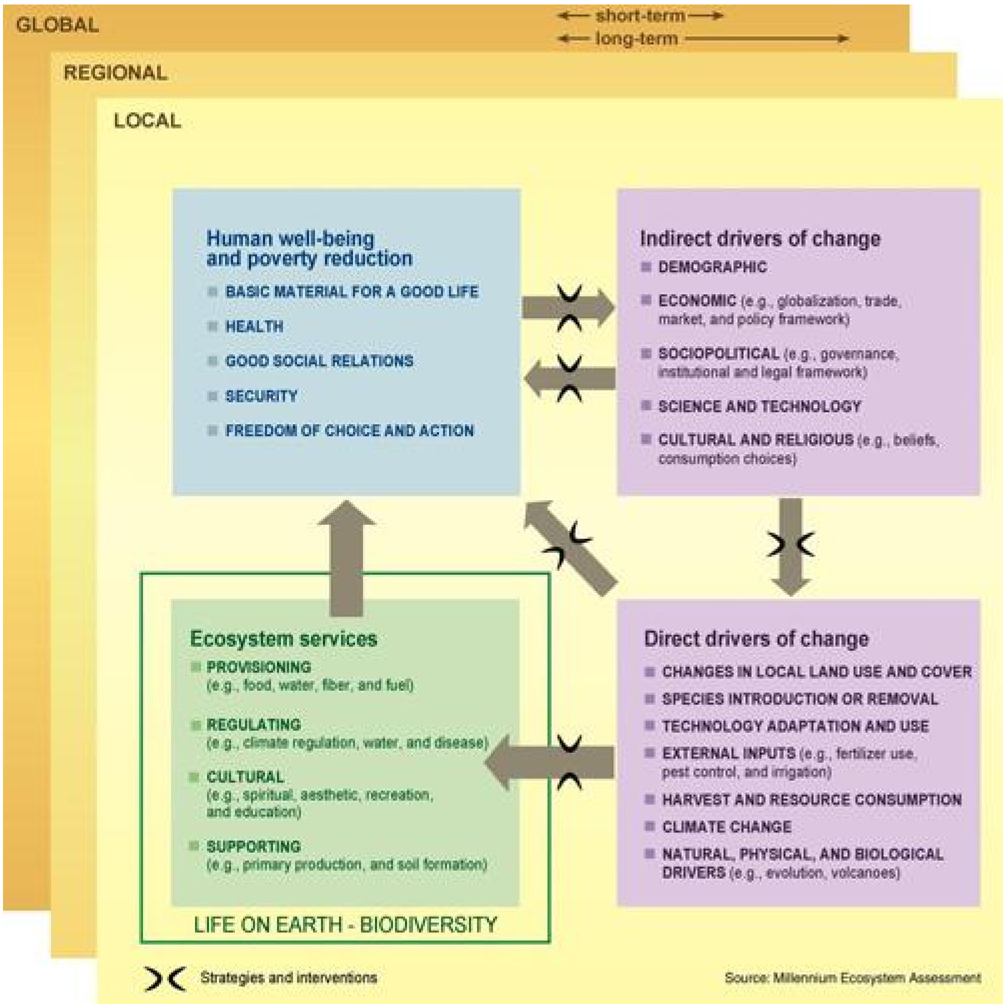

Figure 1.4 Millennium Ecosystem Assessment (2005) Conceptual Framework.

As the authors acknowledge, the framework does not and cannot convey the full complexity of interactions within the system. Another limitation of the framework is the lack of clarity in the links between ecosystems and biodiversity, the provision of ecosystem services, and the change in human wellbeing.

The MEA (2005) divides ecosystem services into four broad categories: provisioning ecosystem services (products obtained from ecosystems, including the supply of freshwater for drinking, and fish); cultural ecosystem services (nonmaterial benefits such as recreational activities including swimming or canoeing, the aesthetic beauty of rivers, or their spiritual significance among many communities); regulating ecosystem services (the benefits obtained from the regulation of ecosystem processes, such as erosion prevention or water purification); and supporting ecosystem services (processes that are necessary for the production of other ecosystem services, such as nutrient cycling and habitat provision). Supporting services can also be considered ecological processes rather than as services per say, and have been largely dropped in the scientific literature in the nearly 20 years since publication of the Millennium Ecosystem Assessment (Hein et al. 2006; Carpenter et al. 2009)

1.3.1.1 The cascade model

The cascade model (Haines-Young and Potschin, 2010) (Figure 1.5) was an attempt to present the links between ecosystems and human wellbeing, particularly the process that occurs before the provision of final ecosystem services. This is an element that is not included in the MEA framework.

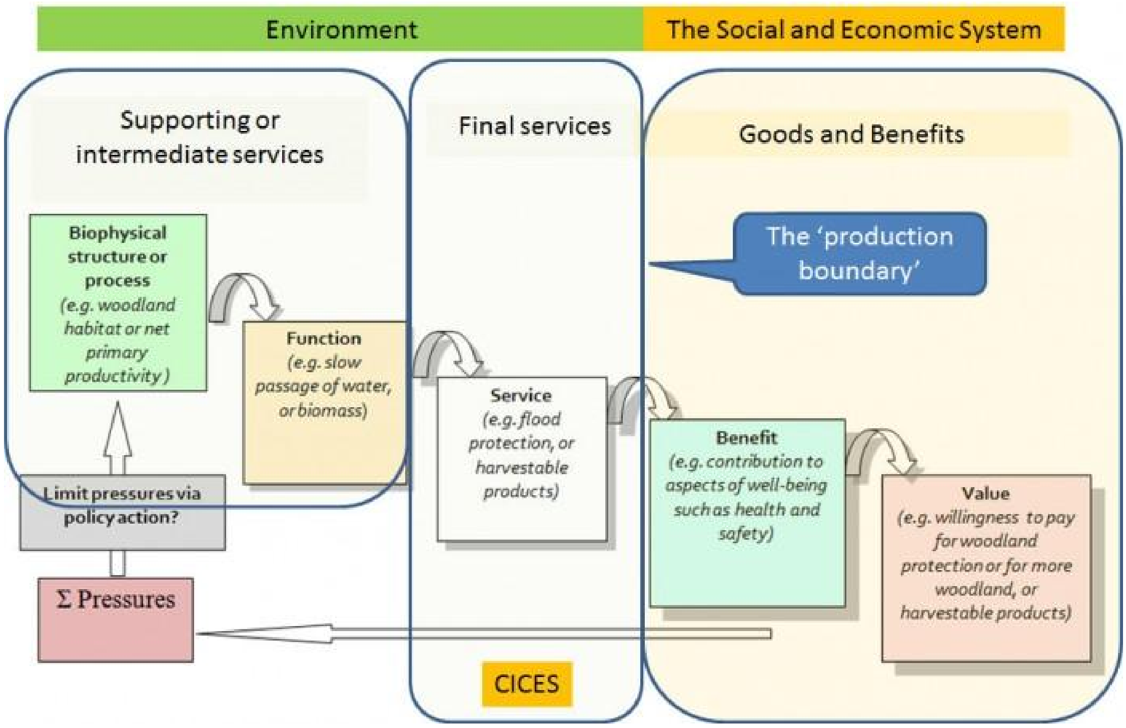

Figure 1.5 The cascade model initially proposed by Haines-Young and Potschin, (2010) modified Potschin and Haines-Young, (2011).

The cascade model presents a pathway starting with ecosystem structures and processes, which give rise to a series of ecosystem functions, defined as the potential that ecosystems have to deliver a service (De Groot et al., 2010). For example, primary production (a process) is required to maintain a viable population of trees (a function), which can then be harvested to provide timber resources (a service). For practical purposes, a structure or process may be defined as a particular habitat type i.e. a woodland, which then gives rise to a series of properties or characteristics, its functions. The term ecosystem function is referred to as an 'intermediate service' in many studies (Fisher et al., 2008).

Ecosystem services are the final outputs of an ecosystem that directly contribute to a product or to a benefit. In this context, a benefit is something that positively alters a person's wellbeing. One service can have numerous benefits. For example, food can provide nutrition, pleasure and cultural identity (De Groot et al., 2010). Similarly, benefits can contribute to many aspects of wellbeing, for example, health, security or enjoyment. In this cascade, benefits are separated from values, on the basis that the same benefit can be valued to a greater or lesser extent by different groups, at different times, and in different places (De Groot et al., 2010; Potschin and Haines-Young, 2011). Like in the MEA (2005) model, the cascade includes some feedback loops, particularly emphasising the impact of human drivers of change on ecosystems.

The cascade model implies that the nature–people relationship is relatively linear and does not reflect the true complexity of the system (Costanza, 2016), which has many feedback loops and interactions. Although arguably, given the complexity within just an ecological system, a degree of simplification is required to create a pragmatic and usable ecosystem services framework.

1.3.1.2 Common International Classification of Ecosystem Services (CICES)

The CICES framework (Haines-Young and Potschin, 2018) was created as an attempt to provide a framework that could navigate between the different typologies of ecosystem services that have evolved and to make comparisons between different studies and landscapes. Designed around the idea of a hierarchy, the CICES framework uses three of the MEA categories, provision, regulating and maintenance, and cultural services, and then subdivides and nests the ecosystem services into 'divisions', 'groups' and 'classes'. For example, water abstracted from a river for drinking would be classified in the 'provisioning' section, 'water' group, and the 'surface water for drinking' class. Supporting services are not included in the CICES framework as they are solely for classifying 'final' services. The CICES framework has become widely used in ecosystem services studies (e.g. Cusens, Barraclough and Måren, 2021) and serves to create a transferrable and transparent system for classifying ecosystem services.

1.3.1.3 IPBES conceptual framework

IPBES was established as an independent body, open to member countries of the United Nations, with the aim of better conserving biodiversity, advocating for its sustainable use, and therefore ensuring human wellbeing in the long term. IPBES created a conceptual framework through a participatory process with a wide range of experts and stakeholders, based on the MEA framework (Díaz et al., 2015). The IPBES framework provides a perspective on the main connections between humans and nature (Figure 1.6) and to facilitate the integration of diverse stakeholders and knowledge systems, e.g. both academic science and local and indigenous knowledge, is deliberately broad and inclusive. The term ‘nature’s contributions to people’ (NCP) was created to recognise the contributions and benefits, both positive and negative, that people obtain from nature (Pascual et al., 2017). NCP is largely akin to ecosystem services and while there are some differences in the way that the terms NCP and ecosystem services are understood, in practice the two terms are frequently used interchangeably (e.g. Cusens, Barraclough and Måren, 2021).

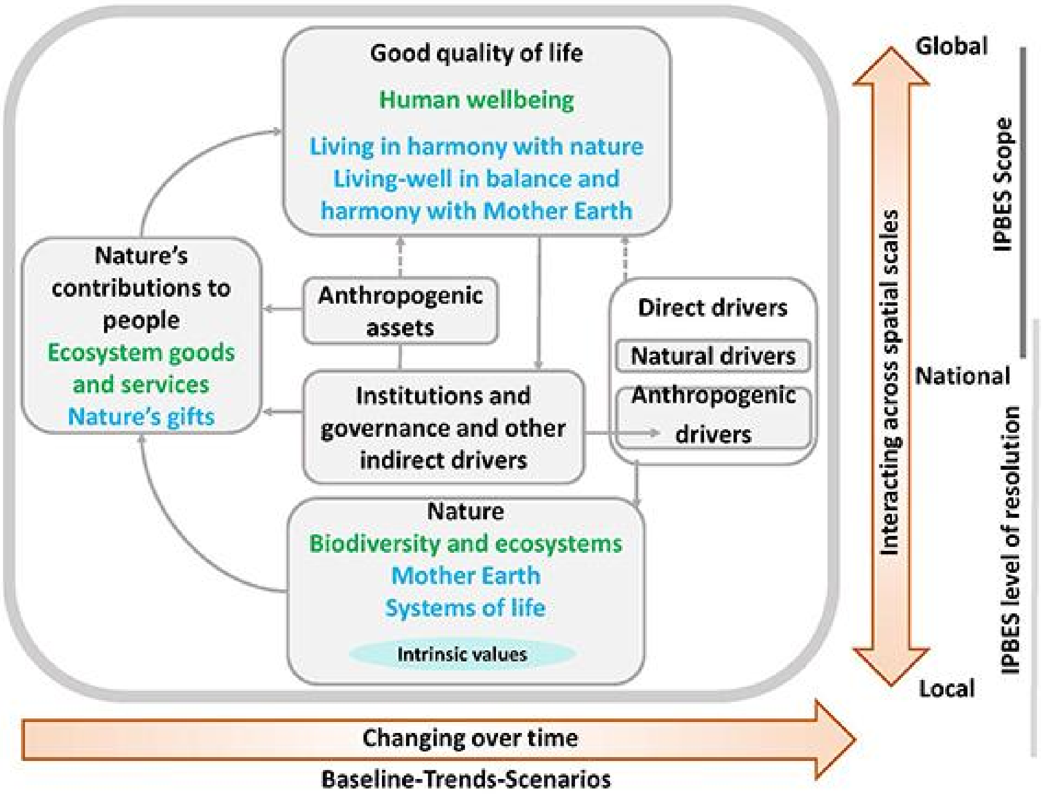

Figure 1.6 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework (Díaz et al., 2015).

1.3.2 Ecosystem service valuation

Valuation of ecosystem services is often a key part of assessments for decision making and planning. In the context of ecosystem services value is often defined broadly as importance or usefulness and as 'held values, principles, and moral duties' (Díaz et al., 2015). Three broad categories of value are typically described in the ecosystem services literature, biophysical, socio-cultural and economic, reflecting the variety of ways in which people ascribe meaning to nature (Castro et al., 2014). The biophysical value typically refers to a measure of importance of the components of nature or the processes that arise from the interaction of these components. Socio-cultural values recognise the importance of ecosystem services to people in non-monetary terms. Finally, economic value expresses the importance of ecosystem services to people in monetary terms. These different forms of valuation are not considered to be alternatives to one another, but instead complementary forms of value. Recognising and integrating different forms of value is known as value pluralism. However, socio-cultural valuation is increasingly advocated for as it can help to capture more of the social values of ecosystem services, many of which are missed in economic valuation, particularly less tangible, cultural services such as 'inspirational services' (Scholte, van Teeffelen and Verburg, 2015).

1.3.3 Riverine ecosystem services

Understanding the unique characteristics of an ecosystem is an important part of an ecosystem service assessment. In the case of freshwater ecosystems, particularly rivers, consideration must be given to the hydrological connectivity (Grill et al., 2019). Rivers are hydrologically connected to wider landscapes and so the actions taken in their catchments, while not necessarily geographically close to the rivers, can influence their condition. This is particularly relevant for chalk streams, which in addition to being connected by surface water flows, are also connected by flows of water into groundwater aquifers that are the primary source of water for these rivers (Mainstone, 1999).

Most ecosystem service studies on rivers occur at either a catchment or reach scale, and few studies focus on the whole river (i.e. the whole length of a river but not the whole catchment) as a spatial unit (Hanna et al., 2018). The directional connectivity of rivers makes it challenging to disentangle ecosystem services provided at smaller spatial scales, such as a reach from the wider river network (Linke, Norris and Pressey, 2008). There can also be a disconnect between where ecosystem services are produced and where they are provided, for example water quality at the point of abstraction for drinking will be dependent on upstream influences as well as proximal factors (Brauman et al., 2007). In contrast studies that consider ecosystem services across a catchment tend to focus on a range of ecosystem services provided by freshwater and terrestrial ecosystems (e.g. Trabucchi et al., 2014) and often a full range of riverine ecosystem services are not incorporated into studies, particularly when evaluated primarily through mapping, where rivers are represented by a line on the map despite the influence of a river extending far beyond its active channel (Gurnell et al., 2016). However, careful consideration must be given to the interactions and trade-offs between ecosystem services at different scales (Felipe-Lucia, Comín and Bennett, 2014) and ultimately the purpose of the study.

Defining the scope of ecosystem services associated with rivers is an important consideration for riverine studies. For water-related services it is important to consider how water is used, for example beneficiaries may be consuming water, using it *in situ* e.g. swimming in a river, or taking advantage of the products of a freshwater system e.g. consuming fish from a river (Brauman et al., 2007). Studies often examine a combination of these services for a freshwater ecosystem. For rivers, these are often termed riverine ecosystem services and encompass services provided by rivers and services that are not provided 'within' the rivers but are related to them (Hanna et al., 2018) e.g. flood mitigation and recreational activities such as walking alongside rivers.

Rivers have been shown to provide a wide range of ecosystem services, including water supply, food provision, hydropower, recreation, aesthetic appreciation, flood mitigation, and carbon sequestration (Gutiérrez and Alonso, 2013; Hanna et al., 2018). However, there is disparity in the extent to which different ecosystem services have been included in assessments. Provisioning and regulating services have been more frequently studied whereas cultural services are frequently omitted from studies or reduced to just consideration of recreational services (e.g. Acuña et al., 2013). There is a need to ensure that cultural services are not omitted from studies, or only partially considered, as they can frequently be perceived as some of the most important ecosystem services to stakeholders, and their omission risks drawing incorrect conclusions for decision making. Bridging this knowledge gap is likely to require drawing on the perspectives of a wide range of stakeholders to ensure a diversity of backgrounds, uses and experience are represented in ecosystem service studies (Kai M.A. Chan, Satterfield and Goldstein, 2012).

There are fewer studies on freshwater ecosystem service compared with other ecosystems, and proportionately fewer still for rivers, when compared with other freshwater ecosystems such as lakes and wetlands (Vári et al., 2022). The challenging of managing the unique characteristics of rivers, the high degree of connectivity with terrestrial landscapes, the directional flow, and linear features, in ecosystem service research is perhaps what prevents them from being more extensively studied (Tomscha, Gergel and Tomlinson, 2017). However, the importance of the ecosystem services they provide requires that more effort is made to examine and understand riverine ecosystem services.

1.3.4 Criticisms of the ecosystem services concept

Despite its widespread use, the ecosystem services concept has attracted criticism. It is argued that the primarily anthropocentric construct of nature promoted by the ecosystem services concept minimises biocentric, intrinsic views of nature (Schröter et al., 2014) and is considered to fit poorly with non-Western scientific knowledge systems. Other worldviews consider the relationships between people and their environment reciprocally, with an ethic of co-dependence and care that does not neatly translate into the narrowly defined services provided by ecosystems to people (Tengö et al., 2017). For example, in New Zealand ancestral Mäori consider rivers as kin, that humans should be take care of for future generations (Gurnell et al., 2016). However, frameworks such as the IPBES framework do reference the need to consider diverse worldviews and explicitly include intrinsic values of nature (Díaz et al., 2015). Additionally, the use of the ecosystem services concept to summarise and synthesize complicated social-ecological data can mask important nuances in the data, for example, relating to social justice (Dawson et al., 2017), winners and losers among ecosystem service beneficiaries (Daw et al., 2016).

Concerns have also been raised about the concept of ecosystem services that converts nature into a tradeable commodity (Martin-Ortega et al., 2019). The economic framing and conceptualization of nature's value in monetary terms can lead to the development of property rights on specific ecosystem services or on the land that produces these services. In turn, this can lead to the creation of markets (institutional structures of sale and exchange) and a process of commercialisation that can often involve privatisation. Payments for ecosystem services schemes demonstrate this phenomenon (Luck et al., 2012). By framing ecosystems and the benefits people obtain from them in a market context, there is a risk that inequalities in access to these markets will be perpetuated (Dempsey and Robertson, 2012). It is also argued that ethical and moral arguments for conservation are undermined by considering nature in economic terms (Schröter et al., 2014).

Despite these criticisms, the concept of ecosystem services is being used extensively in both policy and practice. It is therefore important to try to understand how the concept can be best used to reach sustainability goals, while at the same time being mindful of these criticisms. Arguably, the ecosystem services concept can be viewed as an additional lens that can be used alongside a biocentric perspective (Schröter et al., 2014) and the way that the ecosystem services concept is applied determines the extent to which some of the above criticisms are valid. For example, considered inclusion of stakeholders in an ecosystem services assessment process can help to elicit pluralistic views of nature and ensure the integration of different knowledge systems (Lau et al., 2019a; Lopes and Videira, 2019). Using socio-cultural valuation can also allow the inclusion of ecosystem services without reducing preferences to monetary values.

1.3.5 Application of the ecosystem services concept in this thesis

There are a variety of frameworks and models to depict ecosystem services systems, each with its own merits. At the heart of all the frameworks discussed in section 1.3.1 is the notion that ecosystem services, provided by nature, contribute to changes in human wellbeing. Similarly, all the frameworks highlight drivers of change or pressures as important parts of the system to consider, recognising how humans alter ecosystems or ecosystem services in ways that impact human wellbeing. However, the IPBES framework is the only one to explicitly include governance and institutions as a key component in human-nature relationships. Given that chalk streams in England have multifunctional catchments with many stakeholders who have different values and interests, using a framework that explicitly acknowledges the importance of governance and institutions and integrating different sources of knowledge is crucial and so the IPBES framework has been used in this thesis to guide and organise the research. However, the term ‘ecosystem services’ rather than ‘nature’s contribution to people’ is used, recognising that the two terms are broadly synonymous. Additionally, the CICES classification system is used as a tool to classify ecosystem services as it provides a clear, structured approach that can be applied easily in practice. How to define and classify ecosystem services is not just an academic issue but is central to operationalising the ecosystem services concept – a key part of this thesis. Finally, the ecosystem services concept is considered to be a lens through which to view nature-people relationships and is complementary and additional to biocentric views and arguments for nature conservation (Chan et al., 2017).

1.4 Stakeholder inclusion in ecosystem service research

Stakeholder inclusion in ecosystem services research and decision-making is increasingly viewed as essential if the process and outputs are to have integrity and credibility (Potschin et al., 2016b). Three commonly used arguments are used to advocate for stakeholder participation in environmental decision-making. Firstly, stakeholders have a legitimate right to influence decision-making processes that affect them or the groups they represent. Secondly, that trust and confidence in the decision-making process is enhanced when stakeholders are involved. And finally, that the quality of outcomes from a process are enhanced through stakeholder involvement as decision-making is exposed to a wider base of knowledge, values and priorities (Reed et al., 2009). Stakeholder involvement is particularly important to equitable management and the long-term sustainability of ecosystem services because how ecosystems and their services are managed is a societal choice and stakeholders have a legitimate right to shape and influence decisions that impact their livelihoods and wellbeing (Potschin et al., 2016).

Previous ecosystem services assessments have demonstrated the value of stakeholder engagement. For example, land managers of the Cilliwung river in Jakarta, Indonesia, proposed that the river be channelised to avoid annual flooding. However, when Vollmer et al. (2015) conducted household surveys on ecosystem services provided by the river, the importance of access to the river and its riparian zone for local wellbeing became evident. The researchers went on to propose an alternative management plan in which the river was surrounded by a floodable park, preserving the ecosystem services provided by the river access. Engaging with local communities provided decision makers with the evidence to consider alternative management strategies that met the needs and interests of the local community and avoided implementing a 'solution' to floods that restricted the provision of other ecosystem services.

For stakeholder involvement in a research process to be considered truly participatory, the research must be co-constructed with those affected by the issue being studied, e.g. stakeholders and community members, for the purpose of bringing about real-world impact, and should be characterised by genuine and significant participation throughout the research process (Cargo and Mercer, 2008). Participatory research is often conceptualised as existing on a spectrum of engagement from researcher driven processes, to studies which share decision making with community partners (CTSA Community Engagement Key Function Committee Task Force on the Principles of Community Engagement., 2011). In reality, the degree of engagement can vary through the research process, and the overall approach will be specific to the context of the research (Vaughn and Jacquez, 2020).

Despite the intention of participatory research to move away from hierarchical relationships between researchers and participants, power imbalances between participants, and between participants and academic researchers, can still occur. Participatory methods have the potential to reinforce and reproduce existing socio-political structures if they only promote the voices and values of those who are most articulate and easily accessible in a community (Durham Community Research Team, 2011; Jamshidi et al., 2014). Consideration must be given to the local context (e.g. socio-economic and cultural context) in which participatory research is to be enacted, to building trusted relationships between researchers and stakeholders, and to managing power dynamics to ensure that the participatory research process is effective (Reed et al., 2018).

Recognising that considered participatory research approaches can aid our understanding of ecosystem services and local social-ecological systems (Sabater, Elosegi and Ludwig, 2021), this approach may offer a route to improved decision-making and better outcomes for chalk streams. Exploring the relationships between people and chalk stream, using the ecosystem services concept and a participatory research approach, could provide useful additional evidence to underpin decision-making, improve the quality of outputs, and increase the legitimacy of the research process.

1.5 Thesis aims and objectives

Recognising that there has been a marked decline in the ecological health (section 1.1.5) of globally important chalk streams, the primary aim of this thesis is to develop a holistic understanding of the relationships between people and chalk streams to expand the evidence base for decision making and ultimately lead to the sustainable management of chalk streams. To do this, the ecosystem services concept is applied to a combined case study catchment to articulate the value of chalk streams to society and to explore the governance of ecosystem services as a route to improve the quality of ecosystem service provision. In addition, the thesis aims to address a knowledge gap regarding approaches for including cultural services in riverine ecosystem service assessments. The specific aims and research questions of each of the data chapters are stated in Table 1.1.

1.6 Thesis overview

Chapter 3 identifies the ecosystem services provided by the case study rivers, the specific drivers of change that affect them, and how these drivers interact with each other. The results of the identification of ecosystem services in Chapter 3 are used to inform the selection of ecosystem services for the participatory spatial mapping in Chapter 4 (see Table 1.1 and

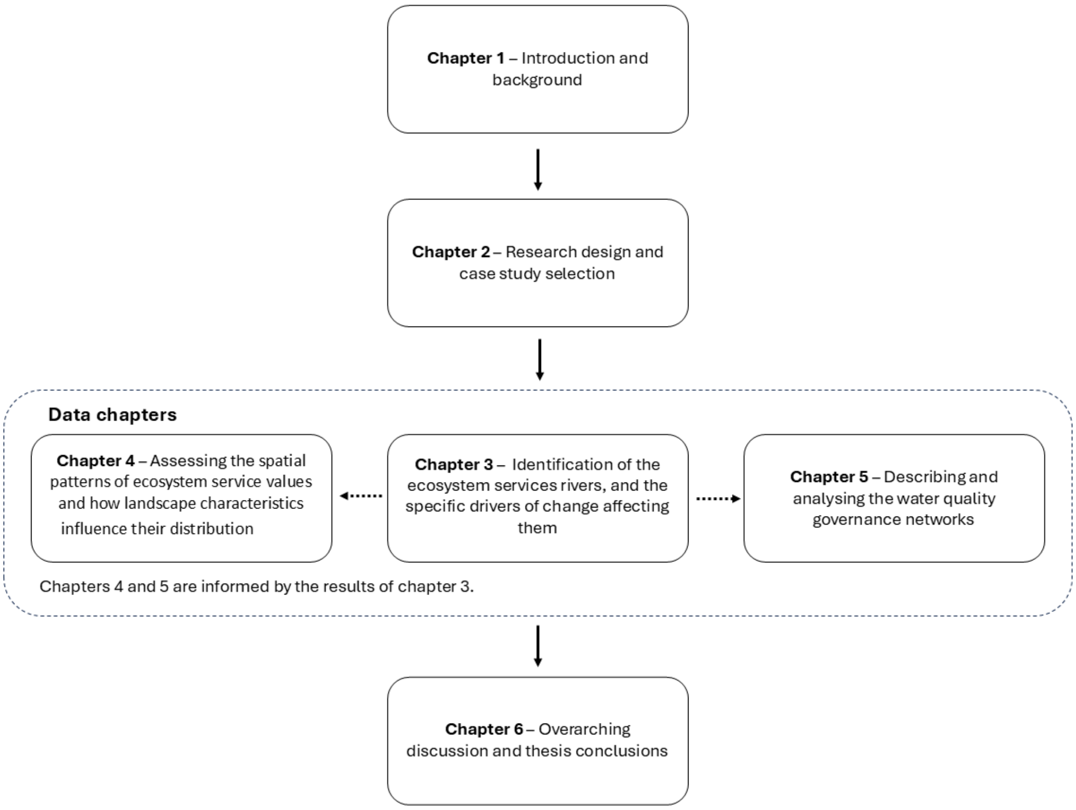

Figure 1.7 for the connections between chapters), which goes on to identify spatial bundles and hotspots of ecosystem service values and analyses how landscape characteristics influence the distribution of the bundles. The results of Chapter 3 were also used to inform the scope of Chapter 5, which describes and analyses the governance network for water quality for the rivers in the case study.

Table 1.1. Logic framework for the experimental chapters of the thesis

Issue & overarching thesis aim	**Data chapter aims**	**Research questions**	**Methods**
Globally important chalk stream ecosystems are in poor ecological health and urgent action is required to improve their conditions. This requires developing a holistic understanding of how these river landscapes can work for both people and chalk streams.	Chapter 3. To identify the riverine ecosystem services provided by the case study catchments, and the specific drivers of change affecting them.	1. What ecosystem services are provided by the River Test and River Itchen, UK and which are of importance to local stakeholders? 2. What drivers of change shape the rivers and the ecosystem services they provide, and which drivers of change are of most importance? 3. How do these drivers of change alter and influence each other?	A participatory process that included the use of structured freelisting questionnaires and stakeholder workshops
This thesis uses the ecosystem services concept as a lens to understand the relationships between humans and two archetypal chalk streams (the River Test and River Itchen, Hampshire, UK) with the aim of expanding the evidence base for decision making and ultimately leading to the sustainable management of chalk streams.	Chapter 4. To assess the spatial patterns of the ecosystem service values for the case study rivers and examine how landscape characteristics influence their distribution.	1. Where are the hotspots of ecosystem service values within the chalk stream corridors? 2. Are there distinct spatial bundles of ecosystem service values and where do these bundles occur? 3. What landscape characteristics are associated with the spatial bundles?	An online public participation geographical information system (PPGIS) survey combined with secondary data analysis
	Chapter 5. To describe and analyse the water quality governance networks, with reference to integrated and adaptive governance, to make recommendations to improve governance and outcomes for water quality.	1. What are the main structural characteristics of the water quality governance networks, as determined by flows of finance, information, and pressure? 2. Who are the key actors in water quality governance, what role do they play and how do they influence water quality governance? 3. What interventions could be undertaken to improve the governance of water quality?	Participatory social network analysis (using the Net-Map approach) through individual interviews. Follow-up workshop with interviewees to collectively analyse the amalgamated interview results

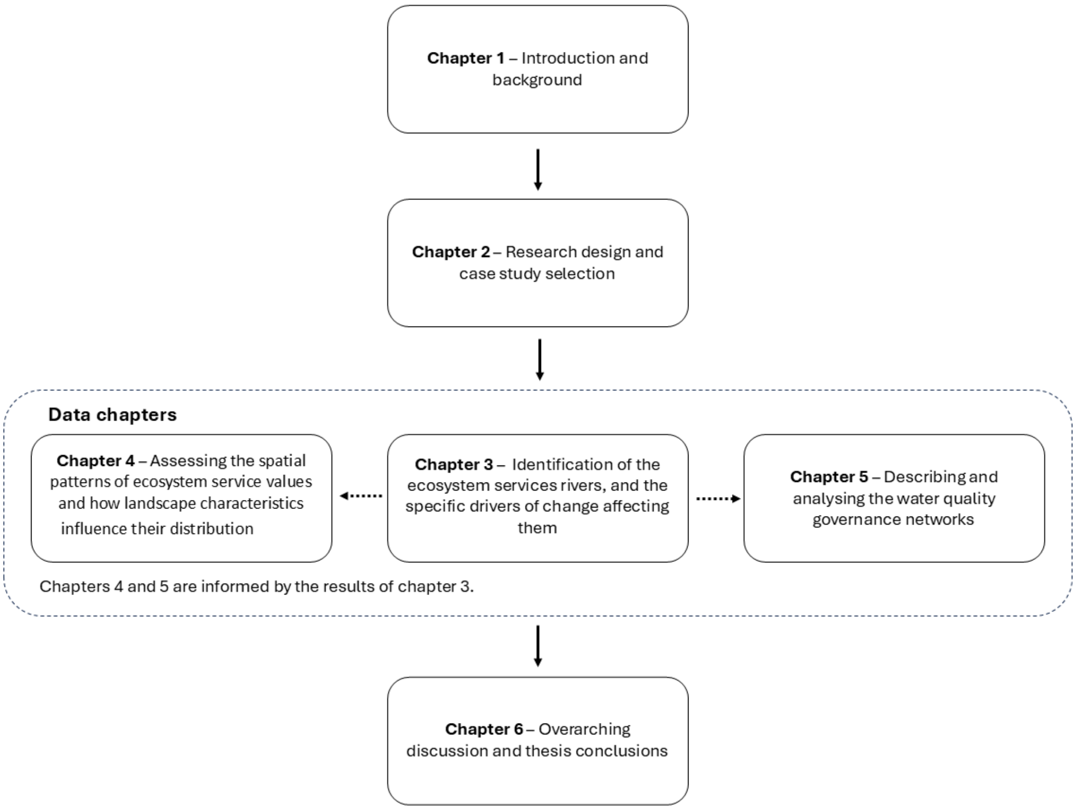

Figure 1.7 Schematic of the thesis structure and connections between chapters.

Chapter 2 Research design

2.1 Overarching research approach

The involvement of stakeholders is increasingly sought and embedded into ecosystem services research and decision making (Hauck et al., 2016; Schoonover et al., 2019). Stakeholders, in the context of the environment and ecosystem services, are commonly defined as those who are affected, have an interest in, or influence over a decision-making issue based on the definition by Freeman (1984) (Reed, 2008; Potschin et al., 2016b). The arguments for including stakeholders in environmental decision-making form three broad categories; 1) individuals and groups have a legitimate right to influence decision making processes that have potential implications for them; 2) when stakeholders are involved in a process, their trust and confidence in the decisions and the institutions involved is enhanced, helping to build social cohesion and reduce conflict; and 3) stakeholder participation improves the outputs and outcomes of decision-making processes by widening the evidence base and by revealing different stakeholder values and priorities to decision makers (Reed, 2008; Hauck et al., 2016; Potschin et al., 2016b). Stakeholder participation is particularly advocated for in situations characterised by complexity and uncertainty, where there are many stakeholders who hold multiple values - characteristics commonly associated with ecosystem services and the social-ecological systems of which they are part (Barnaud et al., 2023). Through stakeholder participation processes different forms of knowledge are integrated, including experiential knowledge, which enhances the quality, richness and relevance of outputs, despite uncertainties (Hauck et al., 2016; Langemeyer et al., 2018). Participation in ecosystem service decision-making can also be a bottom-up form of governance, facilitating multi-stakeholder collaborative management of ecosystem services (Barnaud et al., 2018).

Approaches to stakeholder participation in sustainability / environmental science arise from several research paradigms including participatory research, knowledge co-production, collaborative research, and transdisciplinary research (Gibbons et al., 1994; Reyers et al., 2010; Wiek et al., 2014; Norström et al., 2020). Despite differences in their specific approaches, these research paradigms all aim to facilitate collaboration between academics and non-scientific stakeholders in the process of knowledge production, in order to address societal problems (Wiek et al., 2014). For simplification, these different research paradigms are referred to as ‘participatory research’ for the purpose of this thesis (Wiek et al., 2014). Participatory research can be defined as an umbrella term for research designs, methods, and frameworks that use systematic inquiry in direct collaboration with those affected by the issue being studied for the purpose of action or change (Vaughn and Jacquez, 2020). Participatory research methods value authentic and meaningful participation, that is methods that offer "the ability to speak up, to participate, to experience oneself and be experienced as a person with the right to express yourself and to have the expression valued by others" (Abma et al., 2019, p.127).

Participatory research is often conceptualised as existing on a spectrum of engagement from researcher driven processes, to studies which share decision making with community partners (Figure 2.1) (International Association of Public Participation (IAP2), 2018). In reality, the ways in which stakeholders participate and the degree of engagement in the research are likely to vary through the research process, and the overall approach will be specific to the context of the research (Vaughn and Jacquez, 2020). There is not one 'correct' way to do participatory research, instead researchers must choose methods that can best represent stakeholder interests, that suit the available resources e.g. time and funding, and that will achieve the desired outputs, both in terms of research evidence and real-world impact (Vaughn and Jacquez, 2020; Duea et al., 2022). While there are some methods that are more 'participatory' by design e.g. action learning sets, conventional research methods such as surveys and focus groups can also be appropriate if used in a participatory manner, for example a focus group could be co-designed and co-facilitated with stakeholders (Vaughn and Jacquez, 2020; Scher et al., 2023).

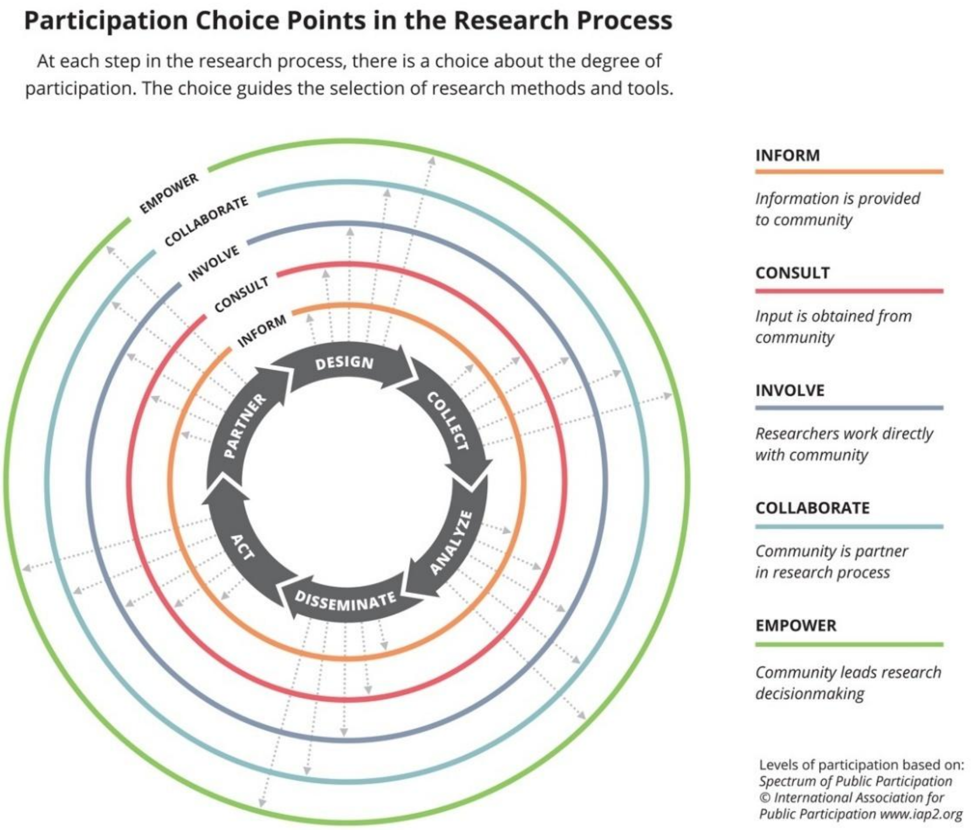

Figure 2.1. Participation choice points in the research process (Vaughn and Jacquez, 2020) based on the Spectrum of Public Participation (International Association of Public Participation (IAP2), 2018)

There are number of examples of where participatory approaches to environmental decision-making have failed to deliver the desired environmental and social outcomes (e.g. Gerrits and Edelenbos, 2004; Staddon, Nightingale and Shrestha, 2015) and so understanding the factors that can influence the success of participatory processes is important. The context of the participation, for example the socioeconomic, cultural, and institutional context, plays a role in determining the outcomes of a participatory process. Specific contextual factors such as the existence of a participatory culture and prior experiences of participation may significant impact the success of a participatory process (Reed et al., 2018). Additionally, process design factors that significantly increase the likelihood of successfully achieving desired outcomes include, legitimate representation of stakeholders, high quality facilitation, structured processes for eliciting and aggregating information, participation of stakeholders throughout a project, and face to face interactions between participants (Devente et al., 2016; Reed et al., 2018). Effective management of power dynamics between participants, so that all participant contributions are valued, through good facilitation, can help to reduce the likelihood of conflict arising and to mediate conflict when it does arise (Vella et al., 2015). Researchers should consider contextual factors, process design, and power dynamics when undertaking participatory research.

The research approach in this thesis is guided by the aims and principles of participatory research, recognising that it can aid our understanding of ecosystem services and local social-ecological systems (Sabater, Elosegi and Ludwig, 2021). A participatory process was undertaken with the stakeholders of a paired chalk stream catchment, those of the River Test and River Itchen, in Hampshire, UK. For further details about the case study catchments, see section 2.3. The research process was initiated through discussion with a local conservation organisation (Vitacress Conservation Trust (VCT)). VCT convene several stakeholder groups for different sub-catchments of the River Test and River Itchen and an overall forum for stakeholders from across the catchments. Having a mandate from a trusted local organisation has been found to contribute to the success of participatory processes (Boeraeve et al., 2018). The researcher attended stakeholder meetings, to listen, discuss research ideas, and build trust. The research design was developed with suggestions from the VCT board of trustees and stakeholders, however ultimately decisions were made by the researcher, and there were no conflicts of interest between the researcher and VCT.

2.2 Primary methods used in each research chapter

This section provides an overview of the primary methods used in each of the research chapters and the rationale for the selection of these methods.

2.2.1 Freelisting questionnaire and stakeholder workshops (Chapter 3)

The identification and selection of context-relevant ecosystem services are critical steps in ecosystem services research (Mascarenhas et al., 2016; Ebner et al., 2022). As ecological processes only become ecosystem services when someone values them or benefits from them, identifying and prioritising ecosystem services involves subjective judgments (Förster et al., 2015). Involving stakeholders in ecosystem service assessments is crucial to understand the context around ecosystem service provision and to acknowledge the multiple perceptions and perspectives people hold of ecosystem services (Lopes and Videira, 2016; Zoderer et al., 2019; Ebner et al., 2022). However, ecosystem services are commonly identified based on biophysical or economic data, available modelling tools, or data from other sites (in the form of benefit transfer), with stakeholders only being involved later in the ecosystem service assessment process (Menzel and Teng, 2010; Mascarenhas et al., 2016). Engaging stakeholders to identify what matters can avoid important ecosystem services being missed and unsubstantiated assumptions being made about priority ecosystem services and values (Kai M.A. Chan, Satterfield and Goldstein, 2012).

Social-cultural valuation of ES investigates the importance that people assign to ecosystem services, reflecting their perceptions and values (Scholte, van Teeffelen and Verburg, 2015). Socio-cultural approaches have been applied to study perceptions of ecosystems and their management (Ruiz-Frau, Krause and Marbà, 2018), to understand which ES are prioritized by different stakeholders (Bidegain et al., 2019; Zoderer et al., 2019), and to explore people's perceptions of ecosystems and ES in greater depth (Soriano et al., 2018; Lau et al., 2019b). However, socio-cultural approaches remain underrepresented compared with biophysical approaches and economic valuation methods to assess ecosystem services (Reynaud and Lanzanova, 2017; Martín-López et al., 2019).

Participatory methods to have been used in several studies to identify and prioritise ecosystem services with stakeholders (Ruiz-Frau, Krause and Marbà, 2018; Ebner et al., 2022; Masao et al., 2022). Common approaches include surveys, semi-structured interviews, workshops, or including ecosystem service selection as part of a broader process such as participatory scenario planning (Hauck et al., 2013; Malinga et al., 2013; Mascarenhas et al., 2016). Approaches using semi-structured interviews and questionnaires use either open ended questions or a pre-established list of ecosystem services (Iniesta-Arandia et al., 2014; Lopes and Videira, 2016). An open ended question approach was selected for this research, instead of using a pre-defined list of ecosystem services, so that participants were not bound in their responses, which can result in biased responses or miss the potential diversity of ecosystem services (Kai M A Chan, Satterfield and Goldstein, 2012; Mascarenhas et al., 2016). Freelisting is one method that uses open ended questions to invite participants to list things within a domain of interest, in whatever order they come to mind (Quinlan, 2017). The data collected therefore reflects participants' familiarity with the items in a domain and locally prominent items (Quinlan, 2005) and allows inferences to be made about their cultural importance. Although the freelisting technique originated in anthropology and has predominately used for ethnobotanical studies (Zambrana et al., 2018), it has also been used to elicit and prioritise ecosystem services (Levine et al., 2017). In this study, a freelisting questionnaire was used to identify ecosystem services and establish those of particular importance, for more details see section 3.3.3.1.

After identifying and prioritising ecosystem services, stakeholder workshops were used to identify and assess drivers of change. Drivers of change are a key component in the IPBES framework, directly and indirectly impacting ecosystems and the services they provide (Díaz et al., 2015a). Drivers of change are commonly assessed using spatial modelling of primary data (Gomes et al. 2021), expert elicitation (Isbell et al., 2022), and literature reviews (Smith et al., 2019). However, participatory methods (primarily using interviews and workshops) have been used in a few studies local scale studies to capture knowledge that may not be documented in academic research and the local context, particularly regarding how drivers of change impact ecosystem services provision (Iniesta-Arandia et al., 2014; Hoffmann, García Márquez and Krueger, 2018; Masao et al., 2022).

A workshop is a commonly used and versatile approach in participatory research that enables active participation of a group to explore a domain of interest by collectively learning, discussing, problem-solving, and reflecting (Hu, 2024). Workshops were selected instead of interviews or questionnaires are they are interactive, dynamic and enable a two-way flow of information (Honey-Rosés et al., 2020). Specific methods and/or facilitation techniques were then used to design and structure the workshops. Structured workshops (as oppose to unstructured workshops) are known to be valuable when a stakeholder group is diverse, the issue being discussed is complex, and to ensure all participants have the opportunity to be heard (Honey-Rosés et al., 2020). In the first of the two workshops conducted in Chapter 3, the workshop structure and activities were based around nominal group technique (NGT). NGT aims to achieve group consensus and action planning on a chosen topic. This approach provided a structure for participants to first individually identify drivers of change, providing an opportunity for all participants to contribute, and then time to reflect and discuss in small groups, in order to build consensus on the most important drivers of change. Brainstorming individually and in small groups, as oppose to large groups, has also been shown to be more effective, leading to the generation of more, and more comprehensive, ideas (Paulus et al., 1993). NGT was selected, instead of similar techniques such as Delphi, as it is designed for face to face sessions rather than using questionnaires that are undertaken remotely (Varga-Atkins et al., 2011). For further details about the method see section 3.3.4.2. In the second workshop the ‘1, 2, 4, all’ facilitation technique was used to review and build upon the outputs of the first workshop. The technique invited participants to consider the questions individually, then in pairs, and finally in small groups, providing time for individual reflection and the opportunity for all voices to be heard (Liberating Structures, 2024).

2.2.2 Public Participation Geographic Information System (PPGIS) Mapping (Chapter 4)

Place based information on ecosystem services plays an important role to address many policy questions, e.g. deciding where to restore ecosystems so that multiple ecosystem services are delivered. The availability of spatially explicit information describing ecosystems and the flow of their services is therefore essential for effective decision-making (Maes et al., 2012). Ecosystem services maps are also a practical and important tool for operationalising the ecosystem services concept; efficiently communicating complex spatial information (Martnez-Harms and

Balvanera, 2012). Maps can be used to articulate trade-offs and synergies for ecosystem services as well as spatial congruence or incongruence between the supply, flow and demand of ecosystem services, with ecosystem service maps tending to present either biophysical, economic, or social-cultural values (Burkhard and Maes, 2017).

There are many different approaches to ES mapping, for example extrapolating values from primary field data, using models that extrapolate ES values based on proxies or value transfer, or interviewing ES beneficiaries (Martnez-Harms and Balvanera, 2012; Burkhard and Maes, 2017). A tiered approach to ecosystem service mapping has been proposed (Grêt-Regamey et al., 2015), advocating for consideration of the depth of understanding required from the study, e.g. deeper understanding of the processes underlying the spatial distribution of ecosystem services, when deciding on the most appropriate method. A tier one study, where only an overview of the ecosystem service values and their presence and absence is required, might therefore just require linking ecosystem service values to land-cover classes. Where, in contrast, a tier three study that requires an understanding of the socio-economic processes, might require more complex methods e.g. linking field data to spatial data using regression or modelling (Grêt-Regamey et al., 2015). Alongside considering the aims of the study the approach taken to mapping should consider the types of ES being mapped, the geographic scale being considered, and the time and resources available(Burkhard and Maes, 2017).

Different categories of ecosystem services are mapped using different types of indicator and therefore methods and models. Provisioning services are mapped on their actual use or demand and, as provisioning services involve the extraction of resources, mapping often relies on official statistical data such as crop harvests. In contrast, regulating services tend to be assessed using indicators of supply that are based on the underlying ecological processes. Biophysical models that simulate these underlying ecological processes tend to be used when mapping regulating services. However, valuing and mapping cultural services can be a challenge. Cultural services are considered to be non-material benefits related to human perceptions, attitudes and beliefs, and as a result are not readily transferred from one place to another. As a result of their intangible nature, many cultural services are challenging to quantify and value, and assessments of cultural ecosystem services are mostly limited to recreation and tourism. For example, mapping and analysing actual use of an area, based on survey data, to provide information on how ecosystems contribute to recreation (e.g. Raudsepp-Hearne, Peterson and Bennett, 2010).

Participatory mapping, where stakeholders and citizens contribute to the creation of a map, is an increasingly utilised approach, particularly for mapping cultural services (Plieninger et al., 2013; Brown and Fagerholm, 2015; Ramirez Aranda, De Waegemaeker and Van de Weghe, 2023). Participatory mapping approaches are commonly known as Public Participation GIS (PPGIS) or Participatory GIS (PGIS) (in this thesis, the acronym PPGIS is used) and refer to the use of spatially explicit methods for capturing perceptions, knowledge and values of individuals or groups (Fagerholm et al., 2021). PPGIS can be applied to ecosystem services assessment where stakeholders identify and map a range of ecosystem services that originate from their place-based, local knowledge (Burkhard and Maes, 2017). The location-specific mapping communicates the assigned values, i.e. individuals judgement regarding the value of ecosystem properties that contribute to their wellbeing, thereby identifying the location of ecosystem services. Typical methods used in PPGIS approaches include surveys, either administered face-to-face or online, and workshops (Fagerholm et al., 2021). PPGIS provides a means to capture and value aspects of ecosystem services that cannot be evaluated without the participation of stakeholders and citizens. In particular, PPGIS has been shown to be better capture cultural services as it can directly capture socio-cultural perceptions, preferences, and values towards ecosystem services (Brown, Helene Hausner and Lægreid, 2015). This can help to avoid bias towards more easily valued ecosystem services and a more comprehensive understanding of the trade-offs between ecosystem services (Burkhard and Maes, 2017).

As cultural services were identified by stakeholders as particularly important and salient in Chapter 3, a mapping approach that captured these ecosystem services was necessary. Previous studies have used social media data to map cultural services, but PPGIS analysis has been shown to provides more fine scale data that better captures non-use values of ecosystem services, when compared to approaches using social media data (Muñoz et al., 2020). As such, PPGIS was used as the primary method in Chapter 4 of this thesis, due to its ability to capture cultural ecosystem services. An online survey was used to undertake participatory mapping with stakeholders and the general public for the case study catchments. More details about the method can be found in section 4.3.

2.2.3 Social network analysis (Chapter 5)

Governance is one of the most important factors in enabling or weakening the success of conservation and environmental management (Bennett and Satterfield, 2018). Environmental governance considers the institutions, structures, and processes that determine who makes decisions, how decisions are made, what actions are taken, and how effectively the actions lead to sustainable environmental and social outcomes (Lockwood et al., 2010; Armitage, De Loë and Plummer, 2012). It is now commonly acknowledged that environmental governance is a multi-actor and multi-purpose, involving a range of state and non-state actors with different needs and views, as oppose to government, where a single designated actor has control (Armitage, De Loë and Plummer, 2012). As a result effective environmental governance relies on co-ordination, collaboration, negotiation, conflict resolution, and knowledge sharing between actors (Bodin and Prell, 2011). A social relational approach is increasingly used to study these social factors, viewing actors in the context of their relationships with others, and how the pattern and structure of those relationships, influence governance outcomes. Actors are not viewed as isolated individuals, or collectively as an organic whole, but as related entities, who through their social structure, give rise to emergent properties (Bodin and Prell, 2011), acknowledging that both the attributes of individuals and the social structure influence social factors and therefore governance outcomes. A social relational approach also acknowledges that there are both formal social relations (e.g. those recognised in government processes) between actors and informal social relations, both of which contribute to a social network. A social relational approach is used in Chapter 5 to examine the governance of the case study chalk streams.

The primary method for studying social relations is social network analysis (SNA) (Chaffin, Floyd and Anzollitto, 2024). SNA is a method to map, quantify, and analyse the patterns of connections between actors. SNA is underpinned by graph theory, where individuals or groups are represented by 'nodes' or points, and their social relations, or other types of connection, such as a flow of resources or money, are represented by 'edges' or lines between the nodes (Scott, 2012). Both the network structure and the attributes of individuals can be captured and analysed, using quantified measures (for details of the quantified SNA metrics used in this thesis see **Error! Reference source not found.**).

Typically SNA is undertaken in interviews by generating actor lists, followed by systematic questions about links between each pair of actors. The process is typically quite time consuming for participants, with few learning opportunities for them as the data is taken away and analysed by researchers. Additionally, the focus on quantitative metrics in SNA provides researchers with limited understanding of the underlying reasons for a particular network structures. As a result the basic method has been adapted over time. Net-Map (Schiffer and Hauck, 2010) was developed to provide a participatory SNA approach that provides learning opportunities for participants (e.g. by visually depicting the network with them and providing opportunities for participants to reflect on and analyse the network structure) and that captures qualitative information on actor roles, motivations, and perceptions to complement the traditional quantitative structural data. Net-Map has been applied to many environmental governance questions and contexts, using a range of methods, including individual interviews and group workshops (Hauck et al., 2015; Schröter et al., 2018; Winkler and Hauck, 2019), and has become the most widely used, if not only, participatory SNA approach (Cortés-Calderón et al., 2025). Net-Map is used in Chapter 5 of this thesis due to the proven effectiveness of the approach for examining environmental governance using a social relational approach. In this thesis the Net-Map approach was primarily applied using individual interviews, but supplemented by a collective workshop with participants, to analyse and interpret the data (after an initial round of analysis to aggregate the network results). By involving participants in the research analysis the participatory nature of the process was enhanced, improving the quality of the analysis and augmenting the learning opportunities for participants. For further details about the methods see section 5.3.

Where to draw a boundary for SNA is a balance between a broad enough view to capture a meaningful view of a network but not too broad that the findings are not useful (Scott, 2012). Water quality governance, in the case study catchment, was used as a boundary for the social network analysis research as it was considered to be a contextual and geographical boundary that was specific enough for participants to understand, but broad enough to develop meaningful insight (Bodin and Prell, 2011). Water quality was selected as the contextual boundary as it was identified as a significant issue in Chapter 3, due to point source and diffuse pollution, and because water quality is an important contributor to many final ecosystem services provided by chalk streams, e.g. recreation (Keeler et al., 2012).

2.3 Case study catchments

The research in this thesis focuses on two neighbouring chalk stream catchments, The River Test and River Itchen in Hampshire, UK (Figure 2.2). The River Test and River Itchen are archetypal 'classic' chalk streams (as defined in section 1.1) meaning that they are fed by springs arising from a chalk aquifer and flow over predominately chalk bedrock (Rangeley-Wilson, 2021), only transitioning to sands and clays in the lower reaches. Both rivers are designated as Sites of Special Scientific Interest (SSSI) (Natural England, 1996, 2000), a conservation designation under the United Kingdom's Wildlife and Countryside Act (1981) that aims to protect the best wildlife and geological sites for distinct habitats (e.g. flood pasture) and species (e.g. Southern damselfly, *Coenagrion mercuriale*). Additionally, the River Itchen is designated as a Special Area of Conservation (SAC) under Directive 92/43/EEC, the Habitats Directive (Communities European, 1992) due to its communities of species such as the European bullhead, *Cottus gobio* and *Ranunculus spp* (JNCC, n.d.).

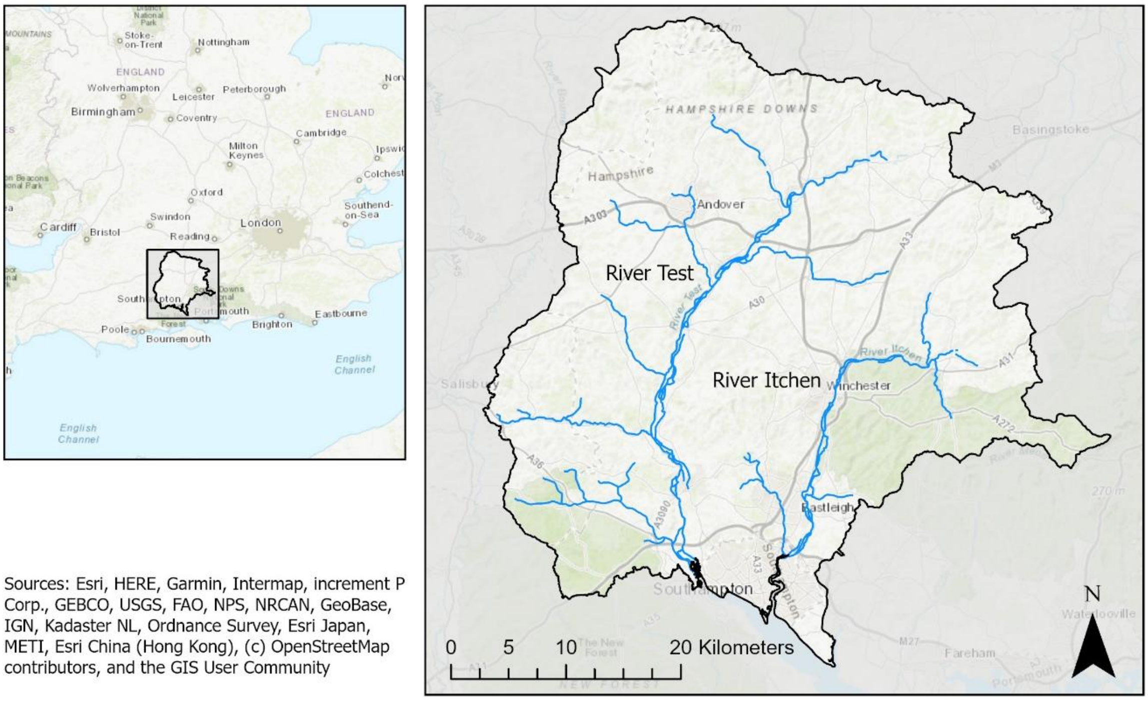

Figure 2.2. Location of the River Test and River Itchen, Hampshire, UK, showing the boundary of the catchment. The combined catchment is approximately 1,760 km^2.

Both catchments are highly managed and multi-functional. Land use in the upper and middles reaches of the catchments is predominantly rural with land use dominated by arable and pasture, with some woodland and dispersed settlements (Environment Agency, 2013). In contrast, the lower catchment is more urbanised particularly around the City of Southampton where both rivers flow into Southampton Water Estuary. The rivers have a globally important role in recreational fishing and are considered to be the birthplace of modern fly-fishing (FlyFish Circle, 2024).

Both the River Test and Itchen have been heavily modified over many centuries for a variety of uses including power generation, transportation, and agriculture. As a result, the river channels are highly modified, with a high density of weirs and many channelised and widened reaches (Glasspool, 2007; Environment Agency, 2013). What is left of the infrastructure today is used to manipulate water levels primarily for angling and ecology. Additionally, catchment scale land-use has resulted in high diffuse pollutant input and associated nutrient enrichment (Fones et al., 2020), fine sediment run-off (Zhang et al., 2017), and over abstraction (Environment Agency, 2019). Ecologically, both rivers are considered highly degraded and suffering from “Chalk Stream Malaise”, a deterioration from the classic chalk stream habitat (Defra, 2003; Shaw, Leung and Clarke, 2021). In 2019, 52% of the River Test and 50% of the River Itchen Water Framework Directive monitoring sites failed to achieve ‘good ecological status’ (Environment Agency, 2021b). Physical modification of the channel was the primary driver of these failures (Test = 75%, Itchen = 42%) (Environment Agency, 2021a). In addition, in 2013 all eight Sites of

Special Scientific Interest (SSSI) on the River Test and all six on the River Itchen were found to be in 'unfavourable ecological status' with 5 of the sites on the River Test considered to be in 'declining' condition (Environment Agency, 2013).

Table 2.1. Characteristics of the River Test and River Itchen

	River Test	**River Itchen**	**Information source**
Length (km)	142	89	(Environment Agency, 2013)
Catchment surface area (km^2)	1260	470	(Environment Agency, 2013)
Mean annual discharge m^3/s	6.69	4.6	Mondon (2024)
WFD ecological status Chemical status	Poor Fail	Good Fail	(Environment Agency, 2021b)

2.3.1 Rationale for case study selection

The River Test and River Itchen were selected as a case study in part due to the research partnership with Vitacress Conservation Trust (VCT), who are based in these catchments. As trusted conveners of stakeholders across the catchments VCT were able to facilitate contact with stakeholders. However, the River Test and River Itchen are also regarded as two of the 'finest' chalk streams in the world as they are both 'classic' chalk stream catchments, ecological important, and have globally important history related to recreational fishing (Environment Agency, 2022; FlyFish Circle, 2024). Although each chalk stream will have unique characteristics, and some have a significantly more urbanised catchments, the poor ecological condition of the River Test and River Itchen, and the pressures causing this degradation are shared with many other chalk stream catchments (Rangeley-Wilson, 2021). Findings from this case study will therefore likely be applicable to many other chalk streams and the approach used in this thesis replicable in other catchments.

Chapter 3 Using participatory methods to advance understanding of chalk streams: stakeholder perspectives on ecosystem services and drivers of change.

I conceived of the idea for this chapter and designed the methodology with support from Kelvin Peh, Rob Holland, and Jake Snaddon. I managed the project and recruited participants. I designed the freelisting questionnaire and administered all of the questionnaires with participants. I designed the workshops and facilitated them with support from Liz Allinson-Thomas and Evelyn Pina-Covarrubias. I analysed and interpreted the data with input from Kelvin Peh, Rob Holland, and Jake Snaddon (stakeholders were able to input into the data interpretation via the second workshops). I wrote the first draft of the manuscript and revised the manuscript based on feedback from Kelvin Peh, Rob Holland, and Jake Snaddon.

3.1 Abstract

At a global scale we understand the many drivers of change that impact freshwater ecosystems. However, the local context is important as these drivers vary in their nature, magnitude, and impact between catchments. Chalk streams are particularly sensitive and unique freshwater habitats. Approximately 80% of all chalk streams globally are found in England, where they support a unique and diverse biotic community. Understanding the drivers of change shaping globally important chalk streams, and the ecosystem services they provide, is essential to ensuring their sustainability.

A participatory process was conducted with stakeholders of the River Test and River Itchen in Hampshire, UK, to identify and prioritise ecosystem services, identify and assess the impacts of drivers of change, and examine the connections between the drivers. The participatory process was based around a freelisting questionnaire and a series of workshops. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework was used as a means of classifying and structuring the drivers of change.

The results revealed a range of ecosystem services provided by the rivers, with cultural services such as recreation the most salient. Many different drivers of change for the rivers were identified, with climate change and pollution considered important direct drivers, and population growth and societal values and attitudes considered key indirect drivers of change. The results also highlighted the importance of further research into the impacts of legacy pollution and the probable hydrological impacts of climate change, at a catchment scale.

Developing a holistic view of drivers of change that explicitly recognises underlying drivers is important when developing future chalk stream management strategies, as without addressing these underlying drivers, the direct drivers of change resist intervention. Improving access to the rivers to help local residents develop a connection to them, addressing institutional weaknesses, and actions to mitigate the impacts of population growth, for example, reducing demand for water, could help to improve outcomes for these chalk streams.

3.2 Introduction

Freshwater ecosystems are continually being shaped by human activities that often result in their degradation, for example the fragmentation of rivers from dams, water pollution from agriculture and industry, and abstraction of water for human consumption, agriculture and industry (Gozlan et al., 2019; Borgwardt et al., 2019; Su et al., 2021). This is evidenced by a global decline in freshwater species of 83% since 1970 (WWF, 2022). However, the rapid rate of degradation of freshwater ecosystems not only poses a risk to biodiversity but also to the ecosystem services they provided (Dodds, Perkin and Gerken, 2013; Albert et al., 2021). Freshwater ecosystems provide a broad range of important ecosystem services including freshwater for drinking, food provision, carbon sequestration, nutrient regulation, and opportunities for recreation (Hanna et al., 2018). The risks to freshwater ecosystems, and ecosystem services they provide, is recognised in the United Nations Sustainable Development Goals (SDG), where target 15.1 requires the “restoration, conservation and sustainable use of terrestrial and inland freshwater ecosystems and their services”.

There is particular concern about the poor ecological state of chalk streams (Rangeley-Wilson, 2021) and the ecosystem services they provide. Chalk streams are distinctive groundwater fed water bodies. Approximately 80% of all chalk streams globally are found in England, occurring only where the chalk bedrock meets the earth’s surface, making them globally rare. As a result of the groundwater dominated flow that arises from chalk aquifers, the water chemistry and hydrology of chalk streams are distinct, consisting of relative alkaline waters, with high clarity and a relative stable temperature. As a result chalk streams support a particularly diverse biotic community (Sear, Armitage and Dawson, 1999), which has resulted in chalk streams being referred to as ‘England’s rainforests’ (Environment Agency and Natural England, 2021).

To improve the ecological state of chalk streams, we need to understand the drivers of change that positively or negatively impact the condition of these ecosystems. At a global scale there is evidence of a series of broad and consistent drivers of change that negatively affect freshwater ecosystems (Isbell et al., 2022; Reid et al., 2018; Vörösmarty et al., 2010), including climate change, emerging contaminants, and invasive species. However, the importance of these drivers vary spatially, and the local context is an important determinant of the nature, direction, and intensity of the drivers (Culhane et al., 2019; Graziano, Giorgi and Feijoó, 2021). For example, the extent of artificial and agricultural land cover within a catchment has been shown to alter the risk to the supply of ecosystem services (Culhane et al., 2019). Studies at a local scale have demonstrated that forming a holistic understanding of drivers of change and the pathways of impact can support the effective management of freshwater ecosystems and the ecosystem services they provide (e.g. Graziano, Giorgi and Feijoó, 2021; Jiménez-Segura et al., 2022; Ricaurte et al., 2017), by helping to articulate the local socio-ecological context and highlight leverage points for driving positive change.

While a recently published Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021) and previous research on chalk streams (e.g. Cooper & Hiscock, 2023) identify some of the drivers of change for chalk streams, e.g. water pollution, a comprehensive overview of drivers for change that also considers indirect, underlying drivers, and their importance. Additionally, there has been little exploration of the broader suite of ecosystem services provided by chalk streams, beyond consideration of water for drinking and industrial use, and the impacts of drivers of change on these ecosystem services.

3.2.1 Participatory approaches

Participatory research is increasingly recognised for its role in aiding our understanding of local social-ecological systems (Sabater, Elosegi and Ludwig, 2021). Participatory research focuses on co-constructing research with those affected by the issue being studied, e.g. stakeholders and community members, for the purpose of bringing about real-world impact, and is characterised by genuine and significant participation throughout the research process. Participatory research is often conceptualised as existing on a spectrum of engagement from researcher-driven processes, to studies which share decision making with community partners. In reality, the extent of engagement can vary through the research process, and the overall approach will be specific to the context of the research (Vaughn and Jacquez, 2020).

When participatory research is applied and undertaken successfully it can help identify problems, capture knowledge that has not yet been recorded, empower action, reframe power dynamics, and help to generate more effective policies or management strategies (Norström et al., 2020; Tengö et al., 2014). However, despite the intention of participatory research to move away from hierarchical relationships between researchers and participants, power imbalances between participants, and between participants and academic researchers, can still occur. Participatory methods have the potential to reinforce and reproduce existing socio-political structures if they only promote the voices and values of those who are most articulate and easily accessible in a community (Durham Community Research Team, 2011; Jamshidi et al., 2014). Consideration must be given to the local context (e.g. socio-economic and cultural context) in which the participatory research is to be enacted, to building trusted relationships between researchers and stakeholders, and to managing power dynamics to ensure that the participatory research process is effective (Reed et al., 2018).

Several studies were identified that involved stakeholders in the process of identifying drivers of change and also, in some cases, ecosystem services. The studies covered a range of landscapes including, grasslands, mountains, river catchment and mountain lakes (Chalmers and Fabricius, 2007; Iniesta-Arandia et al., 2014; Hohenthal et al., 2015; Babai, Jánó and Molnár, 2021; Ebner, Schirpke and Tappeiner, 2022). The research approaches typically included a combination of semi-structured interviews, questionnaires, focus groups, and workshops (Butler et al., 2014; Iniesta-Arandia et al., 2014; Babai, Jánó and Molnár, 2021). The stakeholders included in the studies varied from focusing on particular stakeholder groups such as farmers (Babai, Jánó and Molnár, 2021), to a more typical approach where a broad range of stakeholders were included e.g. local residents, local government, non-governmental organisations, and researchers (e.g. Hohenthal et al., 2015; Ebner, Schirpke and Tappeiner, 2022). Participatory research was found to advance knowledge by providing details of the local context, in particular by enhancing understanding of the underlying drivers of change and adding historical perspectives (Babai, Jánó and Molnár, 2021; Chalmers & Fabricius, 2007). Local knowledge also proved useful in prioritising the impact of drivers of change, understanding pathways of impact, and in generating management and policy recommendations (Butler et al., 2014; Hohenthal et al., 2015; Iniesta-Arandia et al., 2014). However, participant recruitment (achieving a balanced representation of stakeholders) and managing the power dynamics between participants were considered some of the main challenges of participatory approaches (Ebner, Schirpke and Tappeiner, 2022; Mendoza & Prabhu, 2006), although not all studies reflected on these aspects of the process (e.g. Giakoumis & Voulvoulis, 2018). Adopting a participatory approach offers the opportunity to add both breadth and depth to the existing knowledge of the drivers of change for chalk streams and to empower stakeholders to take action to improve outcomes.

3.2.2 Aim and research questions

In this paper, the IPBES framework was used to guide a participatory research process, and as an analytical framework to identify and assess the drivers of change that shape two chalk stream catchments, those of the River Test and River Itchen in Hampshire, UK. By developing a holistic overview of drivers of change with stakeholders the study aimed to develop an understanding of the breadth of drivers impacting the chalk streams, and the ecosystem services they provide, and assess the relative importance of the drivers of change. By classifying these drivers using the IPBES framework into "direct", "indirect to direct" and "indirect" drivers the connections between drivers of change, how they alter and influence one another, are analysed. The study addressed the following research questions:

1. What ecosystem services are provided by the River Test and River Itchen, UK and which are of importance to local stakeholders?
2. What drivers of change shape the rivers and the ecosystem services they provide, and which drivers of change are of most importance?
3. How do these drivers of change alter and influence each other?
4. What are the implications of the assessment for decision makers?

3.2.3 Conceptual framework

The IPBES conceptual framework (Díaz et al., 2015) has influenced ecosystem services research over the past decade. The framework provides a perspective on the main connections between humans and nature and emphasises a plurality of values and interests. Within the IPBES framework, drivers of change are classified as: (1) direct drivers, the direct impacts on ecosystems resulting from human activities to meet their needs and wants, e.g. pollution; (2) 'indirect to direct' drivers, the actions to meeting human needs and wants that directly affect nature e.g. fishing and aquaculture; or (3) indirect drivers, which operate diffusely by influencing and propelling 'indirect to direct' drivers, e.g. population growth (Balvanera et al., 2019). These are important distinctions that help to illuminate the underlying causes (indirect drivers) of direct drivers. For example, population growth (indirect driver) can influence the extent of fishing to meet the nutritional needs of a population (indirect to direct driver) resulting in resource extraction (direct driver) from aquatic ecosystems. Despite their importance, indirect drivers have received less attention regarding their impact on nature than direct drivers

(Chan et al., 2020). The framework establishes some sequential links between drivers and other components in the framework - direct drivers cause changes in nature and subsequently nature's contribution to people (NCP) (broadly synonymous with ecosystem services). Direct and indirect drivers can also affect other drivers through other causal pathways, and some indirect drivers link straight through to NCP, for example, changes to governance and institutions (Brondizio et al., 2019).

3.3 Methods

3.3.1 Overall approach

For details of the case study catchments see section 2.3. The research process was initiated through discussion with a local conservation organisation (Vitacress Conservation Trust (VCT)). VCT convene several stakeholder groups (e.g. land owners, government agencies, businesses, and local residents) for different sub-catchments of the River Test and River Itchen and an annual overall forum for stakeholders from across the catchments. The primary researcher attended stakeholder meetings, to listen, discuss research ideas, and build trust. The research design was developed with input from the VCT board of trustees and with stakeholders at the group meetings. Figure 3.1 provides an overview of the research process. The data collection primarily consisted of an unstructured questionnaire based on a freelist (Quinlan, 2005), a technique for eliciting the contents of a cognitive domain, and workshops that generated both quantitative and qualitative data. The process was iterative, where after input from stakeholders, the results were processed and then collective analysis and interpretation of the results was facilitated with stakeholders. The balance of input between the academic researcher and the research partners and stakeholders varied throughout the research process. The data collection and analysis stages were the most collaborative stages (as data was collected from stakeholders and in the second workshop stakeholders were able to review the initial analysis and provide comments), in contrast the write-up of results has been led by the primary researcher, with no input from stakeholders. However, the approach is 'participatory' in that it was a collaborative approach, co-constructed with a wide range of stakeholders and community members (for more details see section 3.3.2 and table 3.1), for the purpose of action or change (Vaughn and Jacquez, 2020). The research ethics approval for this study was granted by the University of Southampton (ref. number 46078). Informed consent was given by all participants.

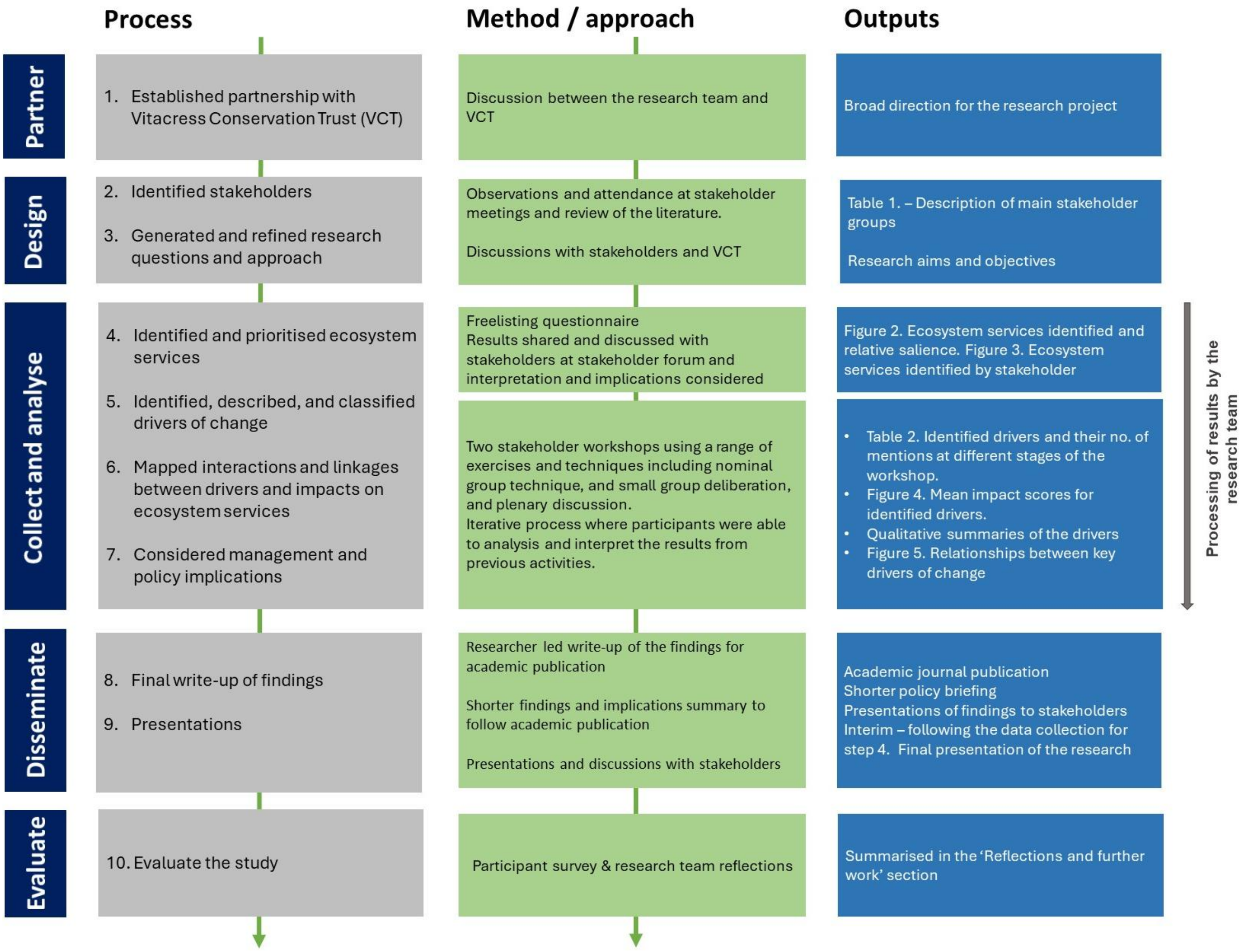

Figure 3.1 An overview of the key steps in the participatory process and the associated methods and outputs.

3.3.2 Stakeholder identification

There are many definitions of stakeholders that vary by context (Reed et al., 2009). For the purpose of this study a definition of stakeholders by Freeman (1984) was adapted as follows: a stakeholder is any individual, group or organisation that has an interest in, or an influence on, ecosystem services provided by the River Test or River Itchen and can contribute to, or is affected by, the degradation of chalk streams and their associated ecosystem services. As a starting point for identifying stakeholders, the primary researcher attended and observed regular meetings of established stakeholder fora and groups in the River Test and River Itchen catchments. These stakeholder fora and groups were organised by Vitacress Conservation

Trust (VCT) to bring together a range of stakeholders to discuss issues, posit solutions, and mediate conflict, with the purpose of driving action to protect and restore the River Test and River Itchen. The VCT fora and groups have been shown to be influential, in part due to the broad range of stakeholders they brought together (Ball et al., 2022), including land owners, academics, environmental non-governmental organisations, local residents, representatives from environmental regulators, and business (such as watercress growers and water companies). The stakeholder fora were therefore used as a foundation for stakeholder identification but were supplemented with searches on the internet and literature. Ten main stakeholder groups were identified, their categories and descriptions are summarised in Table 3.1. These stakeholder groups provided the basis for the recruitment of participants for freelisting questionnaires and workshops.

Table 3.1 The main stakeholder groups, a description of their roles, and the number of each stakeholder group who participated in the freelisting questionnaire and workshops.

Stakeholder group	Description	Freelisting questionnaire #	First Workshop #	Second Workshop #
Aquaculture	Several fish farms and salad growing (e.g. watercress) companies are based along the rivers, abstracting water from the river and then discharging it after use.	4	1	-
Environmental Non-Governmental Organisations	There are many NGOs with a focus on nature protection involved and interested in chalk streams. Recognised for striving for change that favours nature and the environment. Many NGOs have well-developed networks of members, donors and can mobilise supporters. Additionally, some NGOs manage riparian land.	3	6	5
Farmers	Much of the Test and Itchen catchment is used for a mixture of arable and livestock farming. Farmers make land use decisions and abstract water from the rivers	2	1	-
Fishery owners and users	Significant areas of the River Test and River Itchen are run as recreational fisheries. Fishery owners can influence the management of rivers and have influence through their membership.	1	2	1
Other governance actors	Actors involved in governance who are not covered by other stakeholder categories e.g. local councils and parish councils. Some of these stakeholders are land and riparian owners.	1	1	1
Government – environmental protection agencies	The Environment Agency is the primary environmental regulator for chalk streams. However, since both the River Test and River Itchen rivers have been designated areas of conservation protection, Natural England also has regulatory responsibilities. Additionally, Natural England is an advisor to the central government on chalk streams.	4	7	6
Local residents	The local residents directly interact with the rivers primarily through recreation. Individually, local residents do not hold much influence but collectively have power.	38	1	2
Private land and riparian owners	Much of the land adjacent to the River Test and River Itchen is privately owned. Ownership of a river bank also gives riparian rights to the rivers in the majority of cases. Where the river constitutes a boundary of land ownership, riparian rights extend to the middle of the watercourse. These private owners can make decisions about land and river management, which can have a significant influence. Through organisations such as the Test and Itchen Association, land owners have collective influence on decision making.	3	2	1
Private water companies	The water companies in England are privately owned. Two companies abstract water from the river and groundwater and perform sewage treatment work along the rivers.	-	-	1
Researchers	Researchers from both academia and consultancies have an interest in chalk streams. The influence of this group stems from the creation and dissemination of knowledge, which can inform policy making.	1	2	1

3.3.3 Data collection

3.3.3.1 Freelisting questionnaire

An unstructured questionnaire based around a freelist (Appendix A.1), a technique for eliciting the contents of a cognitive domain (in this case, ecosystem services associated with the River Itchen or River Test) that can reduce the framing that occurs through using a pre-defined list, was used to identify ecosystem services. The questions and prompts in the questionnaire used the term ‘benefits’ or ‘interactions’ instead of ‘ecosystem services’ to ensure that all stakeholders understood the questions easily. Participants were asked to list the ways in which they benefitted from the River Test or River Itchen, either in writing or verbally. The order in which the services occurred to the participants was recorded. The participants were then asked to review the list of benefits they had identified and select the five that were ranked from 1 (most) to 5 (least) important.

Participants were recruited using a combination of purposive sampling, to elicit views from specific stakeholder groups (using existing stakeholder networks as a start point for recruitment) and convenience sampling, to elicit the views of local residents across the catchments. The convenience sampling was carried out at six locations across the catchments and on different days of the week in an effort to capture views from a broad range of people. This approach was taken to limit the possibility for respondents to self-select in their interest in the river. The researcher was aware of the potential bias of self-selecting who they approached and made efforts to counteract this e.g. as soon as the researcher was available, they approached the next passer-by. No incentive or compensation was offered for completing the questionnaire. Recruitment of participants stopped when further questionnaires did not elicit any new responses and the relative frequency of responses appeared to be stable. Sixty-one participants completed the questionnaire.

3.3.3.2 Workshops

The workshops took place in person in November 2018 and November 2022 in Hampshire, UK. Due primarily to COVID-19 restrictions, the second workshop was held later than intended. The workshops were facilitated by trained members of the research team. Using a series of activities at the workshops, knowledge about the drivers of change and their impacts on key ecosystem services was gathered. The protocols for both workshops (Appendix A.2) were piloted with groups of academics not connected to the project. The workshop format, timings, and activities were revised after feedback from the pilot participants. With the permission of the participants, the audio from the workshops was recorded to facilitate the analysis.

To identify and prioritise drivers of change for the River Test and River Itchen, activities for the first workshop were designed based on the nominal group technique (NGT). NGT involves asking participants to individually reflect and generate ideas on a predetermined question and then collectively reflect and prioritise ideas (Hugé and Mukherjee, 2018). Elicitation processes such as NGT that allow participants to reflect on their initial thoughts, listen to others, and aggregate their results, perform better, and reduce bias (Burgman et al., 2011; Drescher et al., 2013). Participants were invited to individually identify drivers of change and score their impacts, recording their thoughts in writing. Participants were then divide into five mixed stakeholder groups. In these groups, participants followed a structured deliberation to build consensus on the five most important drivers of change (Hugé and Mukherjee, 2018). Once these drivers had been agreed on, participants then discussed the impacts of the drivers on the River Test and River Itchen and some of the ecosystem services they provide; recreation, aesthetics, water for drinking, agricultural and industrial use, food provision, and biodiversity. The ecosystem services selected for consideration in this activity were based on the results of the freelisting questionnaires. Those selected were deemed important to stakeholders and represented different categories of ecosystem service, e.g. provisioning, regulating, and cultural services. Participants could consider impacts on the supply, demand, and /or flow of the ecosystem service. A participant in each group was asked to write down the outcomes of the group discussion.

Between the workshops, the primary researcher used the data collected from the first workshop to produce a model of the drivers of change, their connections, and the impact pathways. At the second workshop, participants reviewed the model and were asked to consider whether any drivers or pathways were missing or had changed, whether the visualised model was easy to understand, and what knowledge gaps they could identify.

Feedback was collected at the end of the workshops from participants using a short survey (Appendix A.3). Additionally, the workshop facilitators reflected on and evaluated the workshops collectively.

3.3.3.3 Workshop participant recruitment

Participants for the workshop were recruited purposively using a stakeholder list maintained by VCT for their stakeholder forum and groups, and supplemented with internet searches. A purposive sampling approach focuses on selecting participants based on characteristics of interest, in this case the stakeholder groups to which they belong. As group performance can be enhanced by diversity (Page, 2007) efforts were made to recruit participants who represented a breadth of ages and genders, but pragmatically also had to account for who was willing and able to take part in the study. A total of 23 participants attended the first workshop and 18 participants attended the second (Table 3.1). Two participants in the first workshop also participated in the second workshop.

3.3.4 Data analysis

3.3.4.1 Freelisting questionnaires

The questionnaire responses were coded according to the Common International Classification of Ecosystem Services (CICES), as it provides a comprehensive categorisation for ecosystem services (Haines-Young and Potschin, 2018). Six additional classifications for reported benefits that did not align with a specific CICES category, were introduced. These additional categories were named using both the original terminology used by respondents and the ecosystem services literature. Additionally, stakeholders reviewed the category names and definitions at a presentation of the results. R-studio (v4.1.1; R Core Team, 2021), and a freelist-specific analysis package, Anthrotools (Purzycki and Jamieson-Lane, 2017), were used to calculate measures of relative importance, including frequency, average rank, and Smith's salience index value (S) (Smith and Borgatti, 1997) for aggregated data. Smith's salience index (S) is a function of both the frequency with which a term is mentioned during a freelisting exercise, that is, the number of participants who include the term in their respective lists, and a function of the term's average position on the lists produced by the participants (Appendix A.4). Terms that are positioned relatively high on people's lists, i.e. mentioned early on, and are mentioned relatively often, get the highest salience scores. Scores are presented on a scale from zero to one, where one is the highest salience.

3.3.4.2 Workshop data

The data from the workshop were analysed both quantitatively and qualitatively. The datasets were viewed as complementary, where the data enrich one another (rather than using one dataset to validate the other), providing a more detailed understanding of ecosystem services and the drivers of change (Nightingale, 2009). Individual responses from all participants were coded based on the IPBES driver categories. An impact score was calculated for each category of driver of change, by multiplying the likelihood and consequence scores for each individual response, and then aggregating them (for details of the scoring see A.2.1). The analysis was performed in Excel and R (v4.1.1; R Core Team, 2021).

The audio recordings from the workshops were transcribed and imported into NVivo (QSR International Pty Ltd, 2020) for analysis, along with the written group responses. A form of thematic analysis called template analysis (Brooks et al., 2015), a flexible approach that allows the inclusion of both inductive and theory-driven codes and descriptive and interpretative themes, was used to guide the analysis of the data. A coding template was developed iteratively. The research questions, the IPBES conceptual framework and driver categories, and the codes developed from the individual written responses, were used to develop an initial codebook. The transcripts were analysed and coded based on these initial codes. From readings of the transcripts, additional codes were inductively created (generated by the data), to supplement the initial coding template. All the transcripts were then reread and coded with respect to these new codes, to iteratively refine the coding structure, and ensure that it was applied consistently to all transcripts. Statements about different types of drivers of change, the process of consensus building, and the impacts of drivers of change on rivers and their ecosystem services were coded, noting the sequencing of impacts and any links and interactions between drivers.

3.4 Results

3.4.1 Identified ecosystem services

Of the 61 people who responded to the freelisting questionnaire (Table 3.1), 32 were female and 29 male and their ages ranged from 18 to 82 years old. The respondents gave 318 observations, an average of 5.21 per respondent, and identified 23 ecosystem services. In addition to the CICES categories, six additional observations were made: access, altruistic value, biodiversity, connection with people, employment, and stewardship. Of these six additional ecosystem services, I classified three (altruistic value, connection with people, and stewardship) as cultural services based on my understanding from participants that these ecosystem services constituted non-material benefits. The remaining three additional observed ecosystem services were classified as 'other' (Figure 3.2).

Cultural services were the most mentioned services, comprising 11 of the 23 services. The four most salient ecosystem services were all cultural services (Figure 3.2) with active recreation being the most salient (S = 0.74). In comparison, only three provisioning services and four regulating and maintenance services were mentioned by respondents. Water for drinking and material use was the most salient provisioning service, while maintaining habitats was the most salient regulating service. Several participants noted the employment opportunities provided by the rivers, for example, through work in recreational fisheries.

The ecosystem services identified varied by stakeholder group (Figure 3.3). Cultural services were more salient for all groups but particularly for local residents, farmers, and those involved in governance. Provisioning and regulating services were more likely to be mentioned by researchers, those involved in aquaculture, stakeholders in a professional environmental role, i.e. with ENGOs or environmental protection agencies, and local residents. Local residents were able to identify almost all ecosystem services with the exception of spiritual and symbolic cultural services.

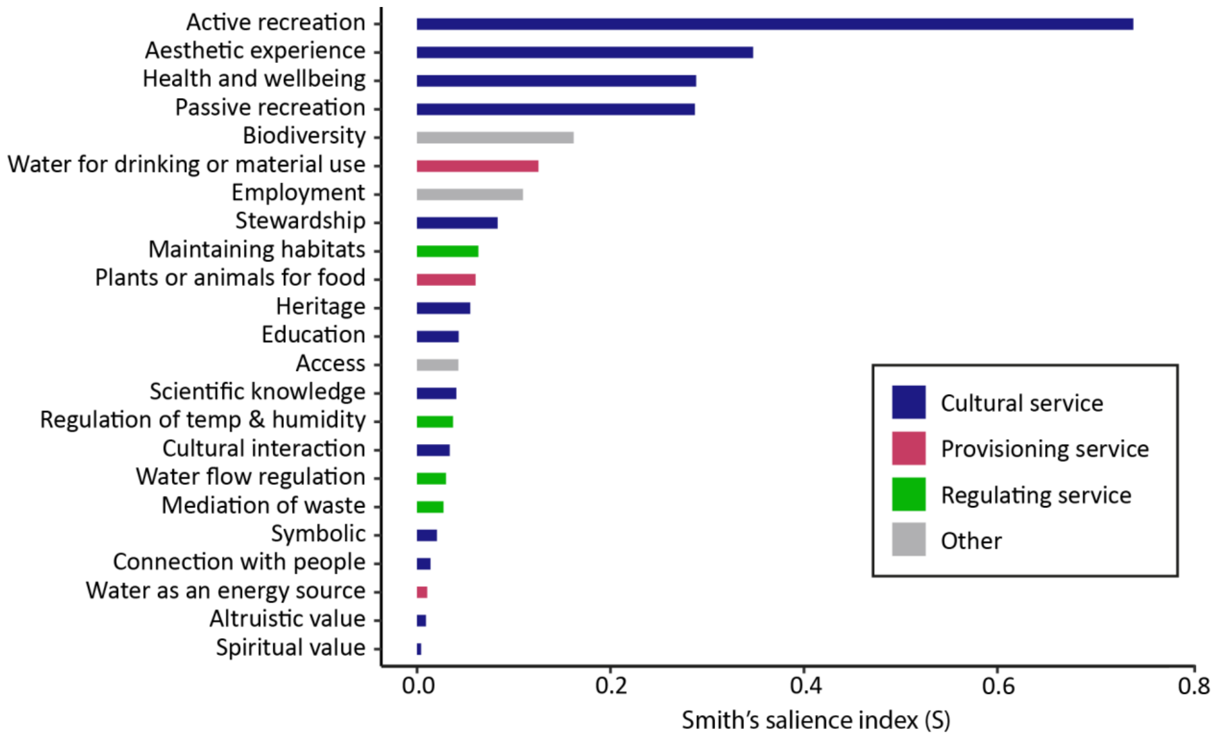

Figure 3.2 Relative salience, using Smith's salience index (S) (Smith & Borgatti, 1997), of the ecosystem services mentioned in freelisting questionnaires with stakeholders of the River Test and River Itchen. Where the maximum value is 1, meaning the most salient, and the minimum value is 0, indicating the least salient. The colour of the bars reflects the ecosystem services category.

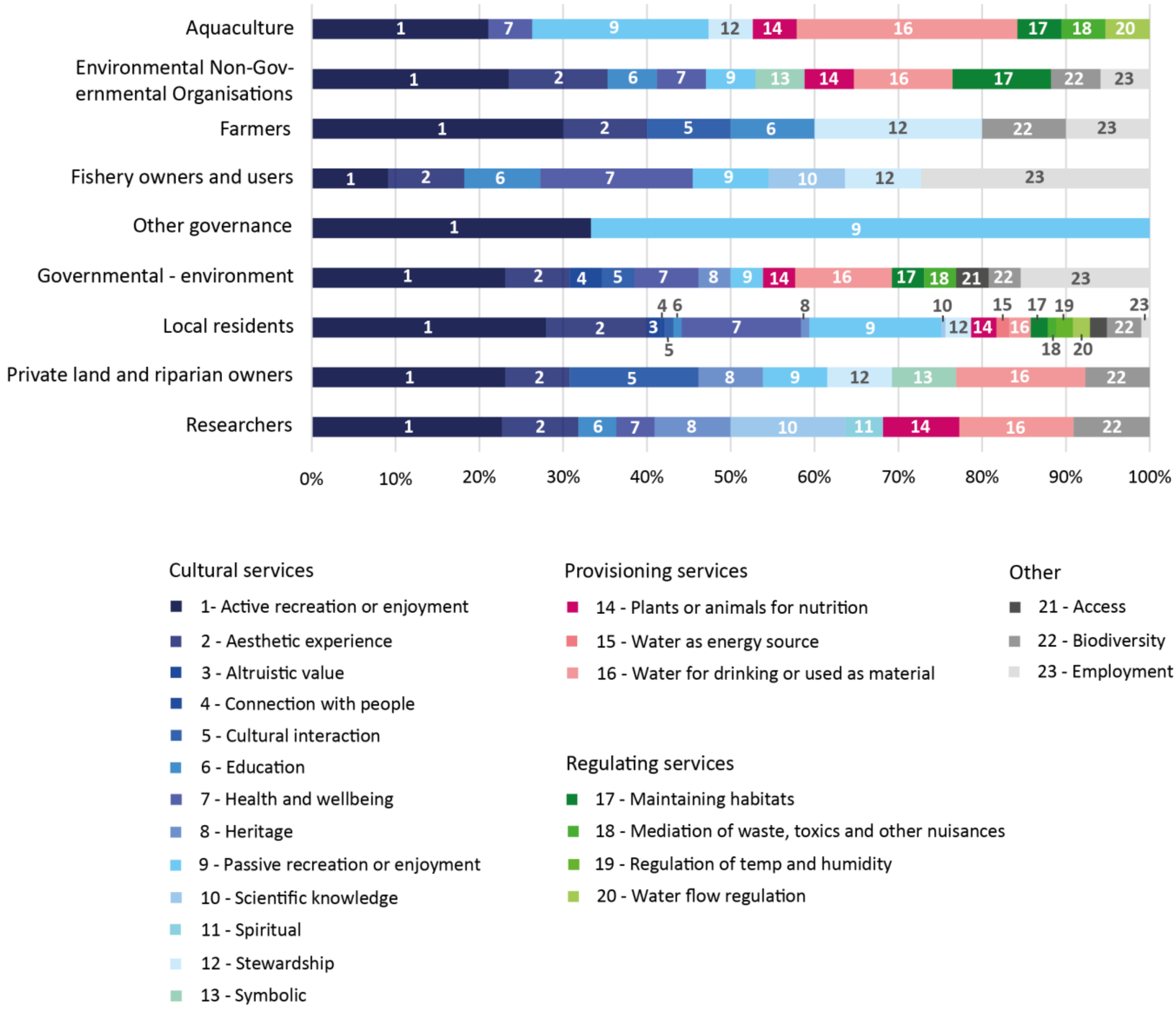

Figure 3.3 Ecosystem services identified by stakeholders for the River Test and River Itchen in the freelisting questionnaires by stakeholder group and shown as a percentage of the total responses for the group. No responses were received from private water companies.

3.4.2 Findings from the workshops

This section summarises the drivers of change identified in the individual exercise, the interactions between drivers, and provide details on the process of building consensus to prioritise drivers of change. Summaries of each of the priority drivers (as prioritised by participants in the group consensus building) are provided.

3.4.2.1 Identifying drivers of change

Workshop participants (Table 3.1) were able to identify many direct and indirect drivers of change for the River Test and River Itchen, listing a total of 187 items (in the initial exercise to individually identify drivers) which I coded into 13 broad categories of drivers (Table 3.2). The drivers most frequently mentioned were the needs of the population, governance and policy, climate change, pollution, and hydrological change. Climate change, demographic change, hydrological change, and pollution were perceived to have the highest median potential impact on the River Test and River Itchen (Figure 3.4). For a breakdown of perceived impact scores by stakeholder group see Appendix A.5.

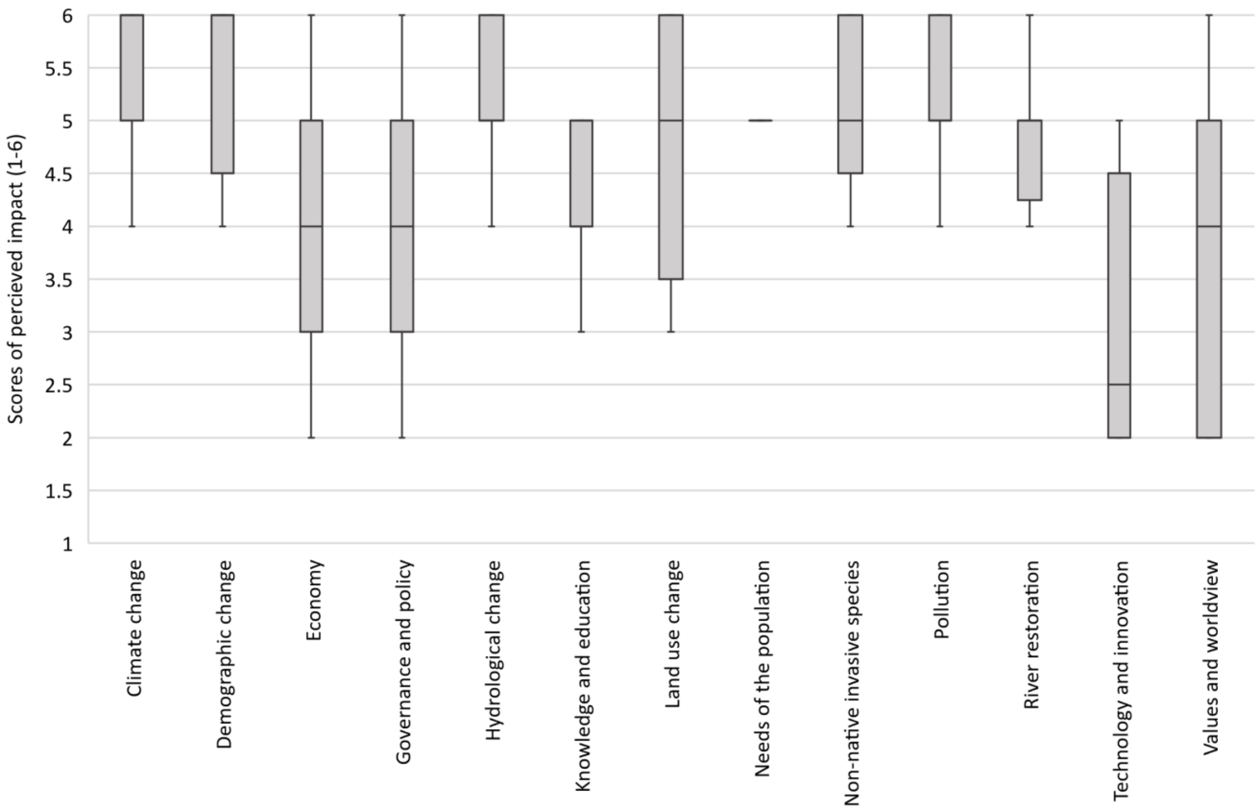

Figure 3.4 Perceived impact scores for drivers of change for the River Test and River Itchen as assigned by participants in the first workshop. The horizontal bars indicate the median and upper and lower quartiles. A score of 6 indicates the largest impact and a score of 1 indicates the smallest impact.

Table 3.2 Drivers of change identified by participants that impact the River Test and River Itchen and their associated ecosystem services.

Driver	Description	Individual exercise # of mentions	Individual exercise % of mentions	Group exercise # of mentions	Group exercise % of mentions
Climate change	Impacts of climate breakdown including anticipated temperature rise, change to the patterns of precipitation, and sea level rise	24	12.8	6	24.0
Demographic change	Human population increase in the catchment areas	5	2.7	4	16.0
Economy	Impacts of economic policies such as austerity, reducing public spending for environmental protection and regulation	7	3.7	-	-
Governance and policy	Change in environmental and agri-environmental policy, e.g. farming subsidies, legislative changes due to Brexit, and expansion of river restoration	34	15.5	5	20.0
Hydrological change	Variability in surface water and groundwater flows increasing the incidence of flooding and drought	11	5.9	-	-
Knowledge and education	Environmental education improving public awareness of and appreciation for chalk streams	5	2.7	-	-
Land use change	Conversion of agricultural land and deforestation as causes of catchment land use change	5	2.7	-	-
Needs and aspirations of the population	Impact of human activities to satisfy needs including water abstraction, food production (both from agriculture and aquaculture), housing development, transport infrastructure & recreation	59	31.6	2	8.0
Non-native invasive species	Impact of current non-native invasive species and future introductions of non-native species displacing native species	9	4.8	-	-
Pollution	Change in pollutants, the concentrations of pollutants, and incidence of severe pollution events	20	10.7	4	16.0
River restoration	Improvement of river habitat and enhanced connectivity of rivers with the floodplain	8	4.3	1	4.0
Technology and innovation	Research improving understanding of chalk streams and technology providing solutions for issues such as pollution	4	2.1	1	4.0
Values and attitudes	Change in values and attitudes towards chalk streams, driving pro-environmental behaviours such as reducing water use	9	4.8	2	8.0

3.4.2.2 Interactions between drivers

The thematic analysis of the group deliberation exercises and the discussion in the second workshop identified many interactions between drivers of change. Many participants recognised that the River Test and River Itchen and the ecosystem services they provide were under stress from the combined impacts of many drivers of change. Participants identified links between drivers and recognised how indirect drivers connect to direct drivers (Figure 3.5). An initial model developed by the research team based on the outputs of the first workshop was refined following feedback from participants.

Local population growth is a key underlying cause of change to the River Test and River Itchen, increasing the demand for needs like food, water, housing and infrastructure. Societal values were also considered an underlying driver that affected governance and policy and the economy. A feedback loop was observed between values and behaviours and recreation. The opportunities to access and participate in recreation on or along the rivers develops a connection to the rivers that shifts values. In turn the change in values creates more demand for recreation.

Climate change was frequently mentioned as a driver that would exacerbate the impacts of other drivers, for example by further reducing river flows (through altered rainfall patterns), which increases the concentration of pollutants and intensifies the stress on organisms. In contrast, river restoration was often viewed as a mitigation against other drivers, e.g. climate change, by enhancing the resilience of chalk streams through improved habitat quality.

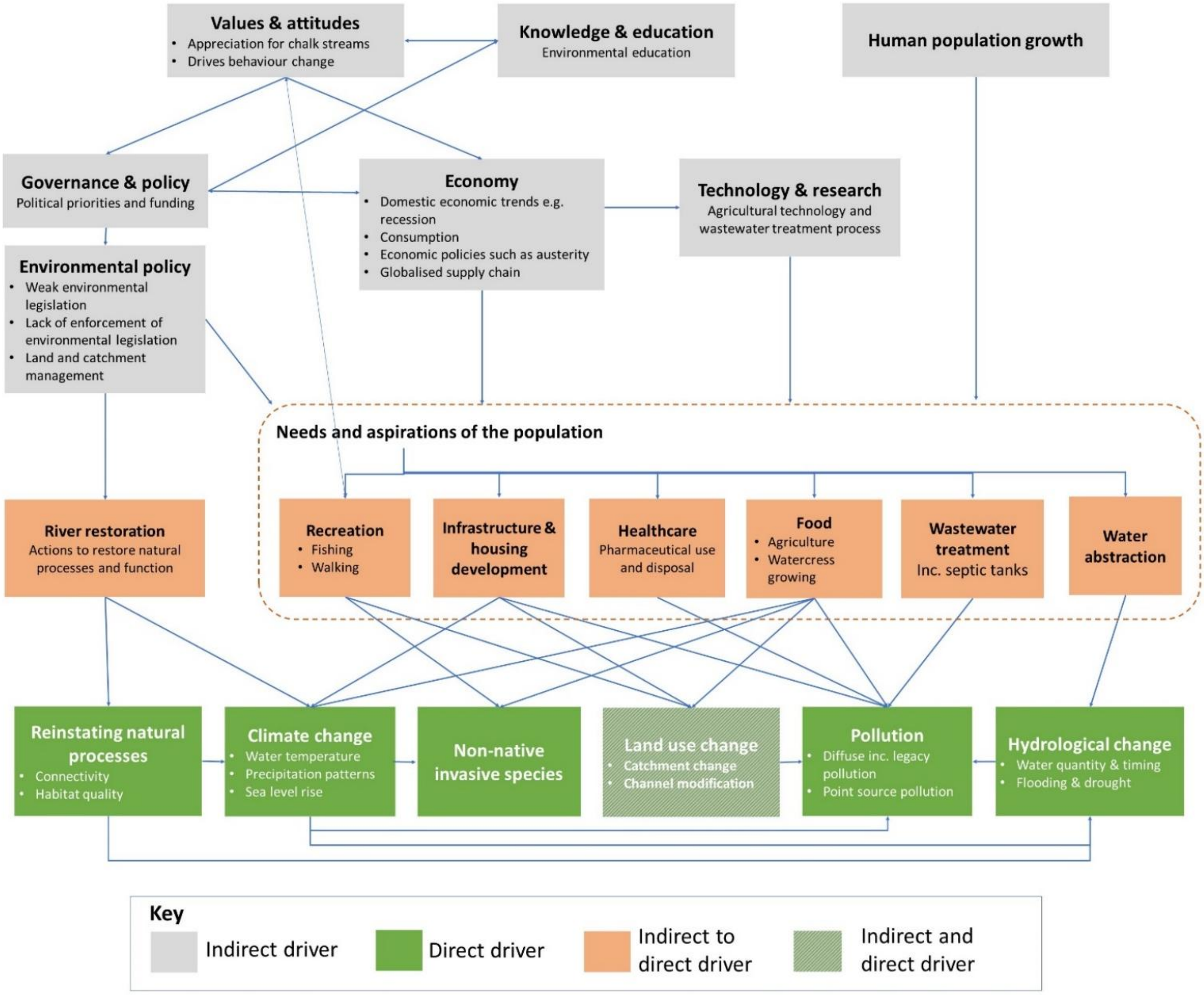

Figure 3.5 The relationships between drivers of change as identified by workshop participants.

3.4.2.3 Prioritisation and consensus building

Through the process of group deliberation and prioritisation, the list of key drivers was reduced to eight, with 20 of the 25 responses identifying just four drivers: climate change, demographic change, governance and policy, and pollution (Table 3.2). An overview of the eight drivers that were prioritised through the consensus building exercise, using the outputs from the thematic analysis, is provided below.

3.4.2.3.1 Indirect drivers

Demographic change, governance and policy, values and behaviours, and technology were identified as important indirect drivers (Table 3.2). Four groups identified population growth as a key driver. There was strong agreement about the trajectory of demographic change, with participants describing how the population of the catchment is currently increasing and is expected to continue to do so for the next decade at a rate that exceeds the average rate for England. The participants recognised how population growth was a significant underlying cause of increased demand for water, and for land use change due to the development of new housing and infrastructure.

Three groups identified elements of governance and policy as key drivers of change. The discussion between participants focused on the strength of environmental legislation and regulation, and levels of funding. The reduction in funding was perceived to have weakened the enforcement of environmental legislation, for example failing to enforce pollution legislation and therefore deterring further incidents of pollution from occurring. Weak environmental legislation and enforcement were particularly linked to higher levels of pollution from activities such as agriculture and wastewater treatment.

Two groups cited a shift in values and attitudes towards nature as an important driver. Participants perceived that the values and attitudes of the public help to drive political action to improve the environmental state of chalk streams and prompt behaviour change, such as reducing water use. The improved connection to chalk streams, and increased environmental education about the issues affecting rivers, were considered reasons for the shifts in attitudes. Several participants referred to the “Blue Planet Effect”, the increased awareness and action regarding plastic pollution, that resulted from the BBC nature documentary Blue Planet, as evidence for the potential for education and awareness to bring about change. While both groups ultimately agreed that attitudes towards chalk streams would shift favourably for improvement in the environmental state of chalk streams, there was considerable uncertainty in the trajectory for this driver. Some participants highlighted a growing fear of nature among some groups in society and how connection to nature was important to reverse this trend.

One group identified technology and research as an important driver of change. Current and future developments in agricultural technology, including vertical farming and genetic modification of crops, and developments in wastewater treatment technologies, were noted as key technologies.

3.4.2.3.2 Indirect to direct drivers

Two indirect to direct drivers were identified: ‘needs and aspirations of the population’ and river restoration (Table 3.2). The term ‘needs and aspirations of the population’ is used as an umbrella term to capture human actions to satisfy basic needs, for example, agriculture to satisfy the need for food, and aspirations such as the desire for recreation. The key ‘needs’ and activities identified through the consensus building exercise were wastewater treatment, water abstraction, and recreation. A key area of discussion centred around recreation (such as fishing, walking, and swimming) and the access required to facilitate these activities. The discussion revealed opposing views regarding access to the river. Some participants considered that recreation causes damage to the rivers through erosion of the riverbanks and littering. Conversely, many participants considered recreation to be a positive and necessary activity to foster connection between people and nature and ultimately drive pressure to conserve and care for rivers. Many participants noted that there is currently little public access to the rivers and that as the demand for recreational opportunities is likely to increase with the expected increase in population, the pressure on areas of the river with access would intensify.

One group included river restoration, activities that improve the river habitats and longitudinal and lateral river connectivity, as an important driver. Participants expected an increase in river restoration noting the growing momentum behind these activities and anticipated potential new funding opportunities from policies such as 'biodiversity net gain', an approach to development that aims to leave the natural environment in a better state than before development took place.

3.4.2.3.3 Direct drivers

Pollution and climate change were identified as the key direct drivers (Table 3.2). All groups identified climate change as one of the most important drivers. One group included climate change twice, splitting the driver by impact. There was certainty in the direction of the driver, the overall warming of the climate, and the groups identified several impacts for the River Test and River Itchen resulting from climate change. These included changes in the quantity and timing of water flows, increased water temperatures, and increased salinity in the lower parts of the rivers due to a rise in sea level. However, there was uncertainty about the likely changes in surface water flows resulting from changes to patterns of rainfall and the consequent impact on groundwater levels in the chalk aquifer. Despite this uncertainty, participants noted that the incidence of droughts and flooding was likely to increase.

Pollution was highlighted as a key driver by three groups, with one group including diffuse and point-source pollution as separate drivers. Many causes of pollution were identified, including agriculture, pharmaceuticals, sewage treatment and septic tanks, production of plastics, commercial watercress growing, and run-off from roads. These activities result in the addition of a wide range of pollutants to rivers and their aquifer, including phosphate, sediment, microplastics, pesticides, and pharmaceutical chemicals. Two groups highlighted the importance of understanding historic pollution, particularly nitrates, due to the lag time between pollution occurring, the subsequent accumulation in the chalk aquifer, and the emergence in the surface water springs. The impacts of legacy nitrate pollution were identified as a knowledge gap.

There was some uncertainty in responses concerned with pollution. Most groups indicated that they expected pollution to increase, but this view was not unanimous, with one group anticipating a decrease in pollution due to action by environmental regulators and pressure from civil society and affected stakeholders, such as fisheries. However, participants noted that improvements were only likely to be seen in known pollutants, and they anticipated that environmental legislation would lag behind the use of emerging contaminants.

3.5 Discussion

3.5.1 Understanding the full spectrum of ecosystem services is crucial

The high salience of cultural services to stakeholders (Figure 3.2) emphasises the importance of ensuring that cultural services, particularly those other than recreational services, are adequately captured in ecosystem service assessments (Kai M.A. Chan, Satterfield and Goldstein, 2012; Hanna et al., 2018). Omitting cultural services from ecosystem services assessments is likely to create an unbalanced perspective of what is valued, as it is not uncommon for cultural services to be recognised by stakeholders as important when they are included (Chan, Guerry, et al., 2012). In turn, the omission of cultural services could lead to poor decision making and potential conflict between stakeholders. As economic valuation methods are considered to poorly capture many cultural services, incorporating socio-cultural methods in ecosystem services assessments is crucial to facilitate understanding (Chan, Guerry, et al., 2012; Scholte, van Teeffelen and Verburg, 2015). Recognition of cultural services is limited in the most recently published chalk stream strategy (Rangeley-Wilson, 2021). Including cultural services in future strategies could help to articulate some of the broader uses of chalk streams by stakeholders and acknowledge any trade-offs with other ecosystem services.

Stakeholders perceived and valued the ecosystem services provided by chalk streams in different ways. Not all stakeholder groups identified the provisioning and regulating services that the rivers provide, despite the majority of participants benefitting from these ES, such as water for drinking. The omission of these ES is likely to be due to a lack of information, a factor known to influence socio-cultural values, which limits people's ability to recognise the importance of a particular ES (Scholte, van Teeffelen and Verburg, 2015). This particularly applies to intangible ES such as regulating services that are less commonly perceived by beneficiaries. Providing stakeholders with a holistic view of the ES provided by chalk streams, may help them to acknowledge the perspectives of others and could facilitate a more nuanced discussion about the trade-offs and prioritisation of ES. For example, education sessions provided by local ENGOs could include explicit mention of the regulating and provisioning services provided by chalk streams and stakeholder forums could facilitate discussions about ecosystem service values.

While participants were able to identify a broad range of ecosystem services, it is recognised that some of the categories they identified would be considered 'benefits' rather than ‘ecosystem services in several frameworks, such as the ‘cascade model’(Haines-Young and Potschin, 2010) . For example, ‘employment’ or ‘health and wellbeing’ change a person’s wellbeing and so would be classed as benefits. Identifying these benefits may represent the beginning of a process to understand the links between human wellbeing, ecosystem services, and biodiversity. Greater comprehension of these links by stakeholders and communities may help to develop their sense of connection with the rivers and ultimately a better appreciation of their value.

The breadth of knowledge about ecosystem services displayed by some residents presents an opportunity for further research. Harnessing and developing this knowledge through projects such as spatial mapping of ecosystem services, or by involving local people in citizen science research to assess and measure ecosystem services or ecosystem functions, e.g. water quality of the rivers, could further enhance our understanding of the ecosystem services provided by the River Test and River Itchen. Additionally, citizen science projects can enhance the environmental literacy of participants and develop collaborative relationships between researchers and communities (Schröter et al., 2017).

3.5.2 Action to address and mitigate indirect drivers of change is needed

As with most freshwater ecosystems, the River Test and River Itchen and their ecosystem services are shaped by many drivers of change, which operate on a variety of spatial scales (Reid et al., 2018). The main impacts of these drivers include altering the quality and flows of water, reducing river connectivity, and degrading habitats. By explicitly establishing the pathways of impact from indirect drivers through to direct drivers of change, the importance of understanding both direct and indirect drivers of change for social-ecological systems is clear. The direct drivers for the River Test and River Itchen are underpinned by many interacting indirect drivers, and without addressing these, the direct drivers resist intervention (Ehrlich and Pringle, 2008) and the efforts of management actions are limited.

The underpinning values and attitudes are key indirect drivers that influence other drivers, such as governance and the economy. Therefore, understanding values and attitudes is imperative in moving towards a sustainable future (Chan et al., 2020). Values can be defined as abstract ideals and guiding principles in life and are typically trans-situational, in contrast to attitudes which are specific judgements regarding an object (Hanel, Foad and Maio, 2021). The values held by a population that concern nature, ecosystem services, and what constitutes a good quality of life, affect attitudes towards nature and subsequently the policies and norms that modulate behaviour regarding nature. While changing values is often considered to be a long and challenging process, the potential scale of change is significant. Although the importance of the national and international context in shaping values is recognised, activities at a catchment scale can also contribute to this shift. The results highlight the role of education and opportunities to connect to nature in contributing towards changing social values and attitudes, a view supported by academic literature (e.g. Gifford, 2011). As access to rivers to facilitate connection with nature was a contentious issue, it would be worth deliberating further to understand the concerns of land owners and to find ways to help improve access to the rivers. Using a trusted convenor, such as VCT, to mediate and facilitate this discussion is important. Additionally, the value of projects such as 'Watercress and winterbournes' (Hampshire and Isle of Wight Wildlife Trust, 2023), which aim to connect local residents with the rivers through education programmes, community champions, and literature and art festivals about the rivers, should be recognised for their role in educating people and shifting social attitudes. Expanding the reach of these activities to people who would not normally engage with the rivers would strengthen their impact.

Population growth has been and is expected to be a significant indirect driver of change, which reflects current population trends for the south-east of England (Office for National Statistics, 2022). However, this driver is hard to change at a local, or even national scale, and so an important consideration is the societal response to this growth. At a catchment scale this response should include considered and integrated land management so that any development resulting from the increased population is sensitive to the potential impacts on the rivers. Understanding the current and expected spatial distribution of the population within the catchments is an important component of land management, analysis that could be undertaken by local researchers. Changing consumption patterns would also help reduce some of the impacts of an increasing population (The Royal Commission on Environmental Pollution, 2011; Balvanera et al., 2019). For example, reducing the demand for water by local residents and industrial water users, such as agriculture and aquaculture, could help reduce abstraction from the rivers.

The current and potential institutional weakness (in this study, where a state chooses not to enforce rules) identified by participants, while problematic, provides a significant opportunity to improve environmental outcomes for the rivers if remedied. The House of Commons Environmental Audit Committee has previously acknowledged poor enforcement of environmental legislation regarding water pollution (Environmental Audit Committee, 2022). Alongside stronger enforcement of existing legislation, there are opportunities to use other policy levers to improve chalk streams, such as through the delivery plan to achieve statutory environmental targets as required by the Environment Act (2021).

3.5.3 Understanding time lags for detecting impacts from drivers of change

The temporal aspect of the drivers was not always well understood. In particular, the time lag between the discharge of pollutants, their journey into groundwater, and subsequent impact on the surface water of rivers is not well understood and warrants further research. Contaminants, such as phosphorous, can also be bound and stored in sediment on the channel bed and remobilised at a later date, which also contributes to uncertainty on the temporal impacts of pollution (Ballantine et al., 2009). Legacy pesticides have been detected in the River Test and River Itchen (Robinson et al., 2022), although they are no longer approved for use. However, there is no good understanding for all pollutants, particularly nitrates and phosphorous. Developing this knowledge could help improve management interventions and allow better evaluation of their success. This finding ties in with the growing global recognition of issues related to legacy pollution. Of particular interest are the issues associated with per-and polyfluorinated alkyl substances (PFAS), which are known as 'forever' chemicals due to their persistence in the environment (Brunn et al., 2023). PFAS chemicals are typically arise from industrial processes, as they are used in the manufacture of waterproof and stain resistant materials, fire-fighting foam, paper, and non-stick kitchenware, which then make their way directly or indirectly (e.g. through wastewater) into freshwater environments (Cordner et al., 2024; Ford and Ginley, 2024). Further recognition and research into the temporal dimension of pollutants is required.

In addition, lag times in the hydrological and ecological response to climate change are not well understood. Further research to model the probable hydrological change for the catchments and research to identify key ecological thresholds and the potentially stepped response of ecological communities to climate change, would help develop more effective management strategies for the rivers (Stubbington et al., 2022).

3.5.4 Recognising the broader governance context

While actions for actors operating at a catchment scale have been highlighted above, it is important to acknowledge the broader governance context. Decision making for water policy primarily lies with central state actors, while responsibility for implementing policy is arguably increasingly directed towards local civil society actors and local authorities (Watson, Deeming and Treffny, 2009). This can be problematic because it may reduce the accountability of central government and provide an opportunity to deflect the blame for failures towards the actors tasked with implementing the policies. Failures in policy implementation by actors at a local level can be driven by a lack of resources and limited perceived legitimacy by other actors (Jagadananda and Brown, 2020). Additionally, the involvement of non-state actors and local actors in delivering policy can give the appearance of a collaborative governance structure, but local actors may have limited ability to influence decision making (Barnes, van Laerhoven and Driessen, 2016; Watson, Deeming and Treffny, 2009). In trying to give agency to local stakeholders by highlighting actions they may take to address the challenges facing chalk streams, we should not diminish the role and responsibilities of central government or private actors, such as water companies, in mitigating the impacts of drivers of change. For example, the recently published Land Use Framework Consultation (Defra, 2025) offers an opportunity for strategic land use decision making that explicitly recognise the need for nature restoration, demonstrating the potential role of central government actors.

3.5.5 Reflections

Participants were strongly engaged throughout this study and the evaluation survey highlighted that they mainly found the process useful for understanding the concerns of others and gaining new knowledge. Furthermore, several participants commented that it had allowed them to step back and appreciate the ‘bigger picture’. The primary researcher, and other workshop facilitators, and participants perceived the workshop atmosphere as positive and inclusive, but observed that it would have benefitted from being longer to allow more time to consider the implications of the findings. Combining individual, small group, and plenary activities, helped to ensure that all workshop participants were heard. The considered allocation of participants into the small groups ahead of the workshops also helped to manage the social and power dynamics. The primary researcher did not observe the significant dominance of any individual during the workshops, although some individuals were more forthcoming with information and ideas than others.

An important element of any participatory study is the selection and recruitment of participants. Participants in the workshops were predominately from environmental protection agencies and ENGOs, which may have influenced some of the findings, for example prioritising drivers that they are more likely to have been familiar with, such as pollution. Some stakeholder groups were not well represented at the workshops, notably representatives of water companies (an issue mirrored at many of the VCT stakeholder groups), which may have introduced some bias into the results of the study. It is possible, as water companies are often identified as the cause of issues in chalk streams, that previous stakeholder events have led to unconstructive dialogue between water companies and other stakeholders, which makes them reluctant to participate. While broadening the representation would have been preferable, pragmatism about who was able and willing to participate was required. In future work, recruiting representatives from county and town councils, particularly individuals with a responsibility for local planning or flooding, as population growth and land use change are such significant drivers of change for these catchments, would be valuable. It is possible that additional drivers may have been identified with a broader suite of participants, or they may have expressed the nature of the drivers and their impacts in different terms.

3.6 Conclusion

Although we have a broad understanding of the drivers of change impacting freshwater ecosystems globally, the specific nature and the relative importance of the drivers of change vary with the local context. Using a participatory process I have identified the multitude of indirect and direct drivers that are shaping two globally important chalk streams, the River Test and River Itchen, and the ecosystem services they provide. Identifying direct and indirect drivers of change helped to develop pathways of impact and highlight the underlying causes of change that need to be addressed to improve the ecological condition of chalk streams in the long term.

By using and developing the pathways of impact I identified, future chalk stream strategies could highlight interventions to mitigate and manage underlying causes of change. Additionally, expanding the focus of existing chalk stream strategies to include other ecosystem services beyond biodiversity would be beneficial – helping to acknowledge and manage any trade-offs between ecosystem services, such as between access and recreation, and biodiversity. Further work to understand the spatial distribution of ecosystem services could help to identify trade-offs and shape spatially explicit management strategies, with priority areas of focus.

The participatory process generated a breadth of drivers of change and clear indications of their relative importance, their connections, and the local context. Additionally, the process provided an opportunity for participants to learn from each other and understand alternative perspectives, demonstrating the value of participatory processes as both a means and an end. Although some of my findings are context specific, my work demonstrates that developing a holistic understanding of drivers of change, and using a participatory process to do so, can deepen stakeholder understanding and help to generate locally relevant management implications. As such this participatory process could be applied to other catchments and other important habitats.

Chapter 4 Participatory mapping reveals spatial patterns of ecosystem services for chalk stream catchments in England.

I conceived of the idea for this chapter and designed the methodology with support from Kelvin Peh, Rob Holland, and Jake Snaddon. I managed the project and recruited participants. I analysed the data with support from Rob Holland, interpreted the data with input from Kelvin Peh, Rob Holland, and Jake Snaddon. I wrote the first draft of the manuscript and revised the manuscript based on feedback from Kelvin Peh, Rob Holland, and Jake Snaddon.

4.1 Abstract

Chalk streams are globally important habitats that are being degraded by anthropogenic drivers of change. Developing a holistic understanding of the relationships between chalk streams and people can aid sustainable decision making. The ecosystem services concept provides a way to explore and examine these relationships, particularly how humans derive benefits from nature. Recognising how ecosystem services vary quantitatively and spatially across different social-ecological contexts is important for informed decision making. A Public Participation Geographical Information Systems (PPGIS) survey was conducted for two chalk streams, to identify hotspots and spatial bundles of ecosystem service values and assess how landscape characteristics influence the distribution of these values. Participants mapped 2,732 points along the river corridors, predominantly mapping recreational and aesthetic values. Three spatial bundles of ecosystem service values were identified - cultural landscapes, multifunctional landscapes, and ecosystem services value coldspots. The co-occurrence of recreational values and biodiversity values in the 'cultural landscapes' hotspots bundle emphasises the importance of the mental and physical co-benefits people receive from recreational activities in nature. Accessibility was an important factor influencing ecosystem service value distribution and was positively associated with the cultural landscapes bundle. Some landcover types, particularly woodland and agriculture, were associated with the ecosystem service value bundle distribution but accessibility is likely to be the predominant influence. Expanding access to the rivers, particularly in light of the population growth within the catchment, is recommended to meet the likely increase in demand for recreation and to improve connection between people and the rivers. Including spatially explicit ecosystem

service values in decision making processes can help to develop a more nuanced understanding of the relationships between people and nature and are more likely to create recommendations that have the support of local stakeholders.

4.2 Introduction

Society in the United Kingdom (UK) is facing complex and interconnected sustainability challenges. Human activities such as land use change are driving a decline in biodiversity that threatens our own wellbeing through the subsequent degradation in ecosystem services (Kremen and Merenlender, 2018). The biodiversity crisis is particularly acute in freshwater ecosystems which, despite covering just 1% of the planet's surface, are home to 9.5% of described animal species. In these ecosystems there has been a decline in monitored populations of freshwater species of 85% since 1970, a rate that far exceeds the decline in terrestrial or marine populations (Reid et al., 2018; WWF, 2022; The Rivers Trust, 2024).

Chalk streams are particularly unique and sensitive freshwater ecosystems. Dominated by groundwater from chalk aquifers, chalk stream flow has a relatively high alkalinity, a stable temperature profile, and relatively high clarity due to physical filtration through the chalk. The unique water chemistry and flow regime give rise to a diverse biotic community (Sear, Armitage and Dawson, 1999). However, in England, where approximately 80% of all chalk streams are found, the streams are under pressure from a range of drivers of change including land use change and climate change, which have resulted in poor water quality, reduced stream flows, and degraded habitats. In turn, the decline in biodiversity and degradation of chalk streams threatens the important ecosystem services that they provide as shown in Chapter 3. To ensure the health of chalk streams and the continued provision of ecosystem services, we need to develop a holistic understanding of these river landscapes and establish solutions that work for both nature and people.

The ecosystem services concept provides an effective way to understand the relationships between humans and nature (Schleyer et al., 2017). Initially derived to help demonstrate the importance of biodiversity for human wellbeing (Ehrlich and Mooney, 1983), the ecosystem services concept is now a mainstream way of exploring social-ecological systems and informing land-use planning (Longato et al., 2021). The ecosystem services concept has helped to demonstrate the value of the environmental beyond 'just' a particular species or habitat, by demonstrating how biodiversity underpins benefits that are directly linked to human wellbeing such as clean air or water for drinking. Ecosystem services is now a mainstream concept in work on social-ecological systems and is evident in land-use and planning policy. However, translating ecosystem services knowledge into actionable policy still presents a challenge. Historically, monetary valuation of ecosystem services has received substantial focus and political interest, but this approach risks commodifying nature and fails to account for the diverse ways that people value nature, many of which cannot be valued in monetary terms (Pascual et al., 2017). As such, there has been increasing recognition of the need to integrate economic and biophysical valuation approaches for ecosystem services with socio-cultural approaches (i.e. preferences and importance of ecosystem services in non-monetary terms) to better capture the full value of ecosystem services and the multiple ways that nature contributes to our wellbeing (Scholte, van Teeffelen and Verburg, 2015).

PPGIS surveys offer an approach for mapping socio-cultural ecosystem service values. While mapping ecosystem services is not new, participatory mapping that asks people to spatially locate ecosystem service values on maps is a more recent development, and one that enables an assessment of the social complexity of ecosystem services (Brown and Fagerholm, 2015). The underlying assumption is that participatory ecosystem services mapping elicits assigned environmental values, identifying spatially explicit attributes that contribute to human wellbeing (Fagerholm et al., 2016). Participatory mapping provides a means to operationalise the ecosystem services concept by articulating multiple values, providing an understanding of place-based experiences and knowledge, and offers a route to generate action-oriented recommendations.

Participatory mapping of ecosystem service values has been shown to be particularly effective at identifying cultural ecosystem services. Traditional ecosystem services mapping and other assessment approaches have often either overlooked cultural services altogether, have limited assessment of cultural services to recreational ecosystem services, or relied on proxy measures for cultural services, e.g. using proximity to settlements or landcover as a proxy for recreational ecosystem services (Brown & Fagerholm, 2015; Eigenbrod et al., 2010). PPGIS offers an opportunity to enhance the quality of spatial ecosystem services knowledge, particularly for cultural services, by directly involving the people that derive the cultural ecosystem services, in identifying and locating ecosystem services using place-based, local knowledge. Mapping ecosystem service values provides a bridge between held values (what is important to a person), and assigned values (landscape features of importance), and so PPGIS is ideally suited to identify cultural ecosystem services (Brown, Helene Hausner and Lægreid, 2015). The prominence of cultural services in PPGIS is likely due in part to the ecosystem services typology provided to participants being limited to cultural services, and because cultural services are based on personal experience. As our interactions with and knowledge of nature shape our perceptions of ecosystem services (Scholte, van Teeffelen and Verburg, 2015), non-experts are more likely to value cultural ecosystem services which they experience regularly, in contrast to other categories of services, e.g. regulatory services, which are less experiential. Regardless of the reason for the inclusion of cultural services in PPGIS, improving the quality of ecosystem services mapping is particularly valuable for land use planning and management.

Through its ability to reveal place-based local knowledge, PPGIS provides an opportunity to explore and describe the spatial patterns of ecosystem services and assess how landscape characteristics influence these patterns (Brown, Helene Hausner and Lægreid, 2015). Some of the most frequently used landscape data that have been analysed with mapped ecosystem service values are land use / land cover, roads, topography, and built infrastructure (Brown et al., 2015; Palomo et al., 2014; Plieninger et al., 2013). Understanding how landscape characteristics like these are associated with the distribution of ecosystem service values can inform land use decision making by illuminating the potential impacts of land use change and highlighting landscape trade-offs and synergies. Using ecosystem service bundles, sets of ecosystem services that co-occur across space or time (Raudsepp-Hearne, Peterson and Bennett., 2010), is a common way to assess landscape characteristics (e.g. Cusens, Barraclough and Måren, 2021; Plieninger et al., 2019). Ecosystem service bundles provide a way of characterising the degree of multifunctionality within a landscape and help to reveal trade-offs and synergies between ecosystem services. Studies have explored how ecosystem service bundles vary with landscape characteristics such as landcover, accessibility, and topography, to improve understanding of human – nature interactions and to improve landscape decision making (Cusens, Barraclough and Måren, 2021; Plieninger et al., 2013).

Comparatively few PPGIS studies have examined ecosystem service values for rivers and riparian corridors, with most river studies conducted at a catchment scale (e.g. Paudyal et al., 2015; Stosch et al., 2022). In these studies, PPGIS was used to improve data in a data poor area in Nepal (Paudyal et al., 2015) and to unearth conflict between stakeholder groups and land use competition (Stosch et al., 2022). In both studies the outputs provide a limited view on the spatial distribution of ecosystem services associated with the rivers in these catchments. A person's relationship with a river is likely to differ when considered in the context of a much broader landscape compared to when it is the direct focus, so while understanding river systems at a catchment scale is vital, there is also a need to understand how people connect with, and value, rivers and their riparian zones (Vári et al., 2022). The PPGIS studies that have examined these finer scale ecosystem service value relationships were all conducted on river reaches within urban green spaces and primarily focused on assessing cultural services (Gottwald, Albert and Fagerholm, 2021; Jones et al., 2020; Ramirez Aranda, De Waegemaeker and Van de Weghe, 2023). However, these studies demonstrate the value of understanding how ecosystem services vary spatially and quantitatively across river corridors for facilitating effective and informed decision making.

There has been increasing focus and scrutiny of the management of chalk streams in England because of their importance and sensitivity. A recently published Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021) establishes a vision for future of these globally important ecosystems and proposes policy changes to restore and protect them. This study aims to complement the strategy by helping to articulate the relationships between chalk streams and people. PPGIS is used to assess the spatial distribution of riverine ecosystem service values for two chalk stream landscapes, those of the River Test and River Itchen in Hampshire, UK, to enrich the understanding of the relationships between people and chalk streams and inform decision making. The following research questions are addressed:

1. Where are the hotspots of ecosystem service values within the chalk stream corridors?
2. Are there distinct spatial bundles of ecosystem service values and where do these bundles occur?
3. What landscape characteristics are associated with the spatial bundles?
4. What are the implications for chalk stream management and land use decision making?

4.3 Methods

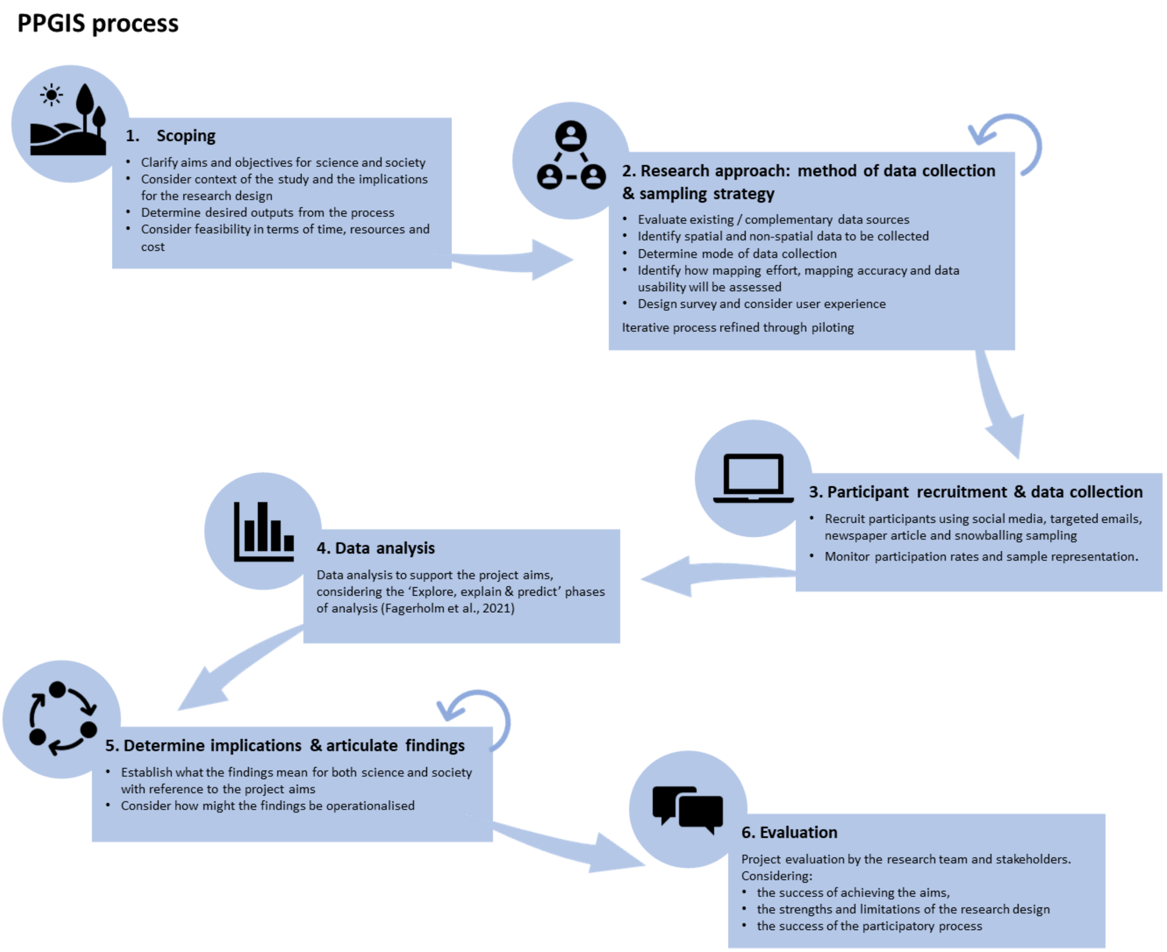

Figure 4.1 PPGIS approach and process (based on Fagerholm et al., 2021, 2022; Loc et al., 2021).

4.3.1 Overall approach

The PPGIS approach and process was based on recommendations from Fagerholm et al., (2021, 2022) and Loc et al. (2021), and is documented in Figure 4.1. For details of the study catchments see section 2.3.

4.3.2 Survey design and ecosystem service typology

The ecosystem services typology and survey design was developed in three stages. First, the results from Chapter 3 that identified locally important ecosystem services were used as the basis for the ecosystem services value statements included in the survey. Secondly, the wording of the ecosystem service statements, and the design of the online participatory mapping survey, were also based on previously published PPGIS ecosystem services studies (e.g. Cusens, Barraclough, and Måren, 2021; Plieninger et al., 2019). Finally, the survey was piloted with 10 academics, who were unconnected to the project but familiar with chalk streams, and 10 non-academics, comprised of citizens who were resident in the chalk stream catchments. Feedback from the pilot surveys was used to refine the wording of the survey and the ecosystem service statements. The statements (Table 4.1) were broadly aligned with the Common International Classification of Ecosystem Services (CICES; Haines-Young & Potschin, 2018). However, as I also needed to ensure that the ecosystem service statements were locally relevant and could be understood by non-experts, the final ecosystem service statements represent a balance between this and the commonly accepted ecosystem service typologies. I define riverine ecosystem services as those provided directly within the rivers, e.g. food provision of freshwater fish, as well as ecosystem services that are associated with them, e.g. recreational activities such as walking along the banks of a river (Hanna et al., 2018).

The final survey was created using Maptionnaire (Mapita Oy, 2019, https://www.maptionnaire.com/). Maptionnaire has been successfully used in other PPGIS studies to spatially identify ecosystem services, for example mapping landscape values in areas of France and Norway (Ernoul et al., 2018; Cusens, Barraclough and Måren, 2021), although it has not previously been used specifically for a river corridor. Participants were provided with a list of eight ecosystem service values and in addition could map any other locations they deemed to be important (see Appendix B.1 for the survey questions). The number of ecosystem service statements was capped at nine, as increasing the number of statements has been shown to dilute the number of points that are mapped rather than encouraging participants to map more points (Brown et al., 2015). The order of the statements was randomised, so that they appeared in a different order in each survey, to ensure that any mapping fatigue (where participants later responses are not as comprehensive as their earlier responses) did not influence the responses to the same ecosystem service statement each time. The base map in the survey displayed basic topography, roads, and place names. An area of analysis, a 1 km buffer, was delineated around the river, to allow the exclusion of pins which did not contribute to the understanding of riverine values.

To map the ecosystem service values, survey participants used pins to identify locations that they considered for the values listed. Participants were able to zoom in and out of the map to ease the process of identifying locations. Participants were able to map as many or few points as they liked. The spatial locations of the different markers were recorded for each participant, along with a timestamp for when the marker was placed, and the zoom level at which the marker was placed. Participants were asked to provide socio-demographic data, to respond to statements about their environment worldview, and to provide qualitative comments about the attributes of the river that they valued. To establish the overall accuracy of mapping the survey asked participants to first locate where they live on the map, and then to provide a postcode for the location. These two attributes are compared as an indication of the accuracy of mapping.

Table 4.1 Ecosystem service statements included in the participatory mapping survey.

Ecosystem value	**Ecosystem service category**	**Ecosystem service statement as written in the mapping survey**
Health and therapy	Cultural	I feel better in this place because it benefits my physical health and / or mental health
Food provision	Provisioning	I appreciate the food that I can harvest or is produced in this place
Economic	Other	I value this place as it provides me with work or a source of income
Connection to others	Cultural	I enjoy spending time with other people in this place
Culture & heritage	Cultural	I appreciate the local cultural, cultural heritage, or history in this place
Recreation	Cultural	I spend time outside walking, cycling, swimming, fishing, boating or watching wildlife in this place. Which activity do you take part in here?
Biodiversity and wildlife	Other	I appreciate the plants, animals and ecosystems in this place
Aesthetics	Cultural	I enjoy the beautiful scenery, sights and sounds in this place
Other	Other	This place is important to me for a reason not previously mentioned.

4.3.3 Data collection

An online participatory mapping survey was considered to be the most appropriate and feasible approach for data collection. As the project was designed during a period of restrictions implemented by the UK government in response to the COVID-19 pandemic, the feasibility of other approaches to data collection and recruitment of participants, such as in-person workshops, face-to-face surveys and postal surveys, was reduced. The use of an online survey limits response to those who have the means to access the internet and are IT literate and ideally, the online survey would ideally have been supplemented with in-person data collection and hard-copy maps. The online survey was open from the 8 June 2020 to 19 December 2020. Survey participants were recruited using various methods including: targeted email lists comprising local actors such as land owners, farmers, and ENGO employees; social media posts; and an article about the project in a local newspaper. Snowballing sampling, encouraging survey participants to share the survey details with others, was also used. Despite efforts to seed the survey widely across social media, to try and achieve a representative sample of the catchment population, as the sample is not random and it is recognised that caution should be taken when generalising the results. The final number of respondents was 292.

Ethics approval for this research was obtained from the University of Southampton (Ref. 52410). All participants gave implicit consent in accordance with conditions set by the University of Southampton.

4.3.4 Data Analysis

All spatial and statistical data analysis was conducted using R (R Core Team, 2021). The data was downloaded from Maptionnaire as a csv file before being analysed in R.

4.3.4.1 Hotspot analysis

Kernel densities, a technique for smoothing probability by applying a probability density function to each data point, were used to visualise the ecosystem services hotspots mapped by participants, producing one map for all mapped points and maps for each individual ecosystem service (Brown & Fagerholm, 2015; Cusens, Barraclough and Måren, 2021). The kernel density estimates were calculated using the density function in R. A cell size of 100m and a band width appropriate for each ecosystem service was used to calculate the kernel density estimates (Brunsdon and Comber, 2019).

4.3.4.2 Ecosystem service bundles

Bundles of perceived ecosystem service values (groups of repeatedly co-occurring ecosystem services) were assessed at a grid scale. A 1 km grid size was used as it was large enough to capture multiple points per cell, in line with similar studies (Schwartz et al., 2021; Cusens, Barraclough and Måren, 2021). The cell point densities of each ecosystem service were calculated and any cells that did not contain any mapped points were removed. Before further analysis Principal Component Analysis (PCA) was used to reduce the dimensionality of the data (Brown and Fagerholm, 2015; Plieninger et al., 2019). Components that explained at least 65% of the variance were selected. The resulting factors were rotated using varimax rotation. Hierarchical clustering was applied to the factor loadings to determine the best number of clusters using the ‘hclust’ function and setting the method to ‘ward.D2’. Finally, the mean number of points of each ecosystem service value per grid cell per cluster was calculated and visualised using rose diagrams using ggplot2 (Wickham, 2016).

4.3.4.3 Multinomial logit modelling

A multinomial logit model was used to predict the probability of a grid cell belonging to a particular ecosystem service bundle given changes in landscape characteristics. Differences in the spatial bundles (the dependent variable) were tested, using bundle 1 as the baseline, in relation to six explanatory independent variables (see Appendix B.2 for the data sources of the variables). Five of these variables were the proportion of land within each grid cell covered by 1) woodland, 2) agriculture, 3) grassland, 4) freshwater and 5) built-up areas. In addition, the length of path (in km) within each grid cell was used as an indicator of the extent of access to the landscape (Plieninger et al., 2019). The analysis was performed using the nnet package in R (Venables and Ripley, 2002). Note that as bundle 1 is the baseline group the estimated coefficients are therefore interpreted in relation to this bundle. Simulated predictions for each independent variable for each bundle were carried out using the ‘multinom’ function in the MNLpred package in R (Neumann, 2021). The predictions are based on simulated draws of regression estimates from their respective sampling distribution.

4.4 Results

4.4.1 Socio-demographics and representativeness of respondents

Overall, 292 respondents completed the survey (Table 4.2). The study respondents differed to the general population (using the County of Hampshire as a closest approximation for the catchment areas). Respondents were more likely to be female ($X^2 = 5.02$, $p < 0.05$) and were typically older than the general population ($X^2 = 69.58$, $p < 0.001$). Respondents were over-representative of retired or self-employed ($X^2 = 22.91$, $p < 0.01$) and had higher levels of education ($X^2 = 143.7$, $p < 0.001$).

Table 4.2 The socio-demographics of survey participants and the population. Numbers in the 'Study' column represent the number of respondents and percentages relative to the total number of survey respondents. Percentages in the 'Population' column represent those for inhabitants of the study area (using the County of Hampshire as a closest approximation for the catchment areas), as reported in census data and population forecasts.

Variable	**Study**		**Population**
	n	**%**	**%**
Sex			
Female	161	55.1	50.6
Male	118	40.4	49.4
Other	2	0.7	-
Prefer not to say	4	1.4	-
Not answered	7	2.4	-
Age range			
18 - 24	6	2.1	11.7
25 - 34	31	10.6	15.5
35 - 44	59	20.2	15.2
45 - 54	68	23.3	16.7
55 - 64	74	25.3	15.7
65+	46	15.8	25.3
Not answered	8	2.7	-
Education			
GCSE / 'O'level or equivalent	21	7.2	28.0
'A'level or equivalent	46	15.8	23.0
Undergraduate degree or equivalent	109	37.3	42.0
Postgraduate degree or equivalent	110	37.7	
No formal education	2	0.7	6.0
Not answered	4	1.4	1.0
Employment status			
Employed full-time	121	41.4	42.3
Employed part-time	44	15.1	14.6
Self employed	39	13.4	10.4
Retired	60	20.5	15.2
Student	15	5.1	6.5
Unemployed and actively looking for work	3	1.0	3.0
Unemployed and not actively looking for work	8	2.7	8.0
Not answered	2	0.7	-

4.4.2 Mapped ecosystem service values

4.4.2.1 Data quality, data usability & mapping effort

Of the 95% of respondents who provided both a geolocation and a postcode, 92% of these had accurately mapped their home location and 8% were mapped inaccurately. This indicates that the majority of respondents were able to accurately locate places on the map provided. Responses from partially completed surveys and points from completed surveys that lay outside of the buffer zone (190 points) were removed from the analysis. The median time to complete the survey was 8 mins 38 secs (mean time 17 mins 23 secs).

4.4.2.2 Mapped ecosystems services

Overall, 292 respondents mapped 2,732 individual points referencing ecosystem service values, an average of 9.4 points per respondent. Recreation was the most mapped category with 584 points (see Appendix B.3.1). The least mapped categories were ‘food provision’, ‘economic’ and ‘other’ with 108, 57 and 32 points, respectively. Walking was the most commonly mapped recreational activity (423 points) (see Appendix B.3.2), followed by watching wildlife (246 points), cycling (132 points) and fishing (102 points). Swimming (65 points) and canoeing and kayaking (16 points) were the least mapped recreational activities. In general hotspots of ecosystem service values were found closer to settlements, for example towns such as Winchester, Alresford and Romsey, which are located near the rivers (Figure 4.3).

The relative number of pins placed varied by stakeholder (Figure 4.2 and Appendix B.3.3). Conservation practitioners were more likely to map ‘biodiversity and wildlife’ values (37% of mapped ecosystem service values), while those who ran businesses mapped relatively more points of economic value (30% of mapped ecosystem service values). The general public were more likely to map points associated with ‘recreation’ or ‘aesthetics’ than other ecosystem service values.

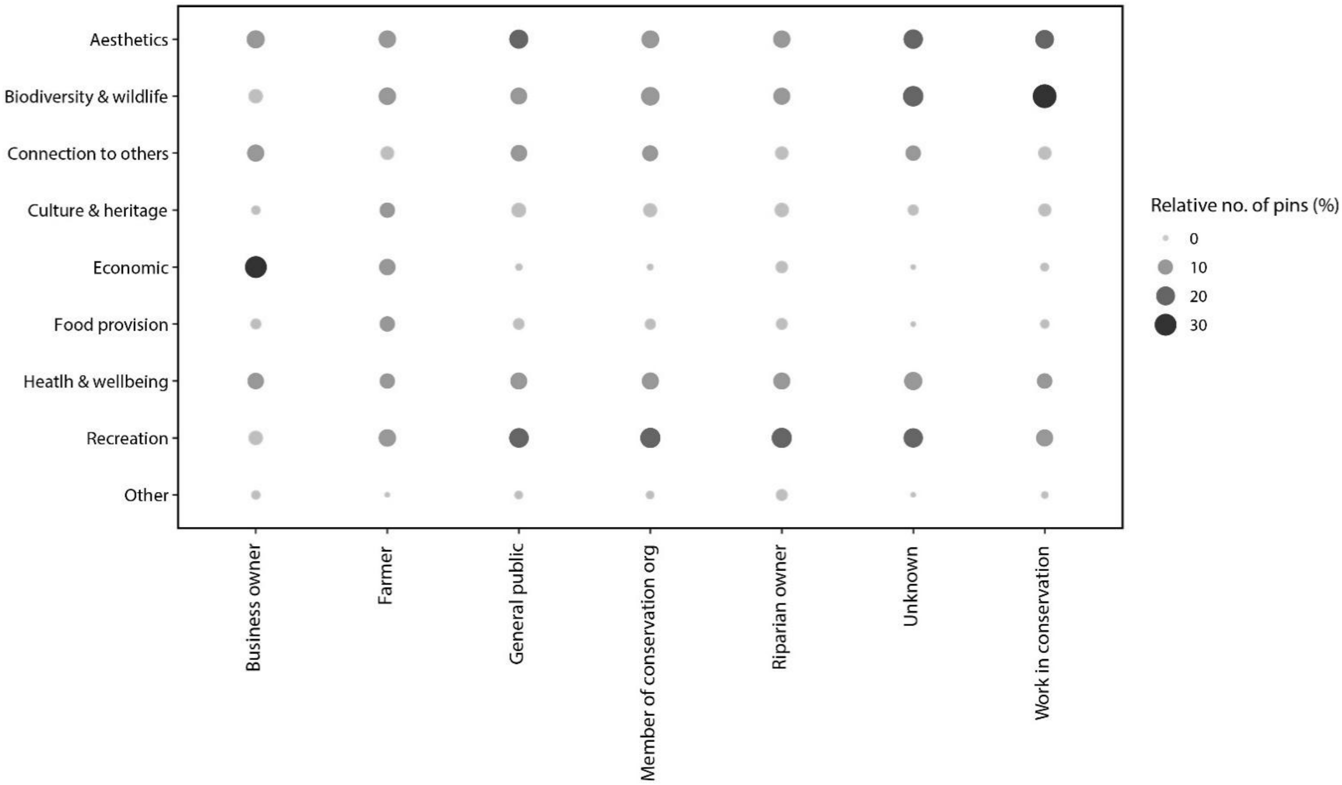

Figure 4.2. Relative number of pins as a proportion of the total for each category of stakeholder.

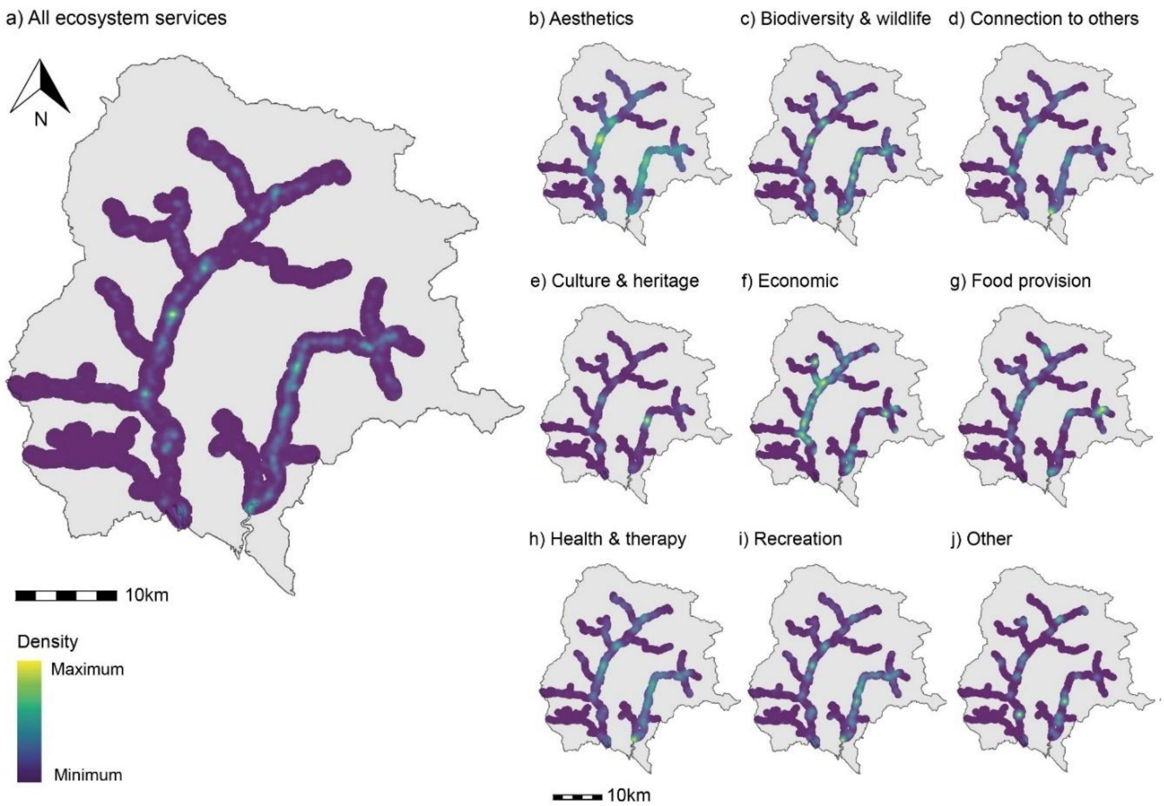

Figure 4.3 Heat maps of the point density distributions for (a) all ecosystem services (b-j) each ecosystem service for the River Test and River Itchen. The colour scale shows the minimum and maximum value for each map.

4.4.2.3 Ecosystem service bundles and landscape characteristics

PCA analysis identified two factors that explained 66.7% of the variance with factor loadings. Hierarchical cluster analysis of the first two varimax rotated PCA scores identified three distinct bundles of perceived ecosystem services at the grid scale (Figure 4.4). I classify these as; (i) 'coldspots' (Bundle 1, n= 397 cells), places where participants identified very few ecosystem services, (ii) 'multifunctional landscapes' (Bundle 2, n = 53 cells), characterised by a relatively even spread of identified ecosystem service values across all categories, and (iii) 'cultural landscapes' (Bundle 3, n = 46 cells), places dominated by recreation values, aesthetic values and to a lesser degree other cultural values. In the 'multifunctional landscapes' bundle, fishing comprised a greater proportion of the total recreational activity (19%), while walking was a lower proportion of the total (31 %), compared to bundles one and three (bundle 1 - fishing 10%, walking 44%, bundle 3 – fishing 9%, walking 37%)

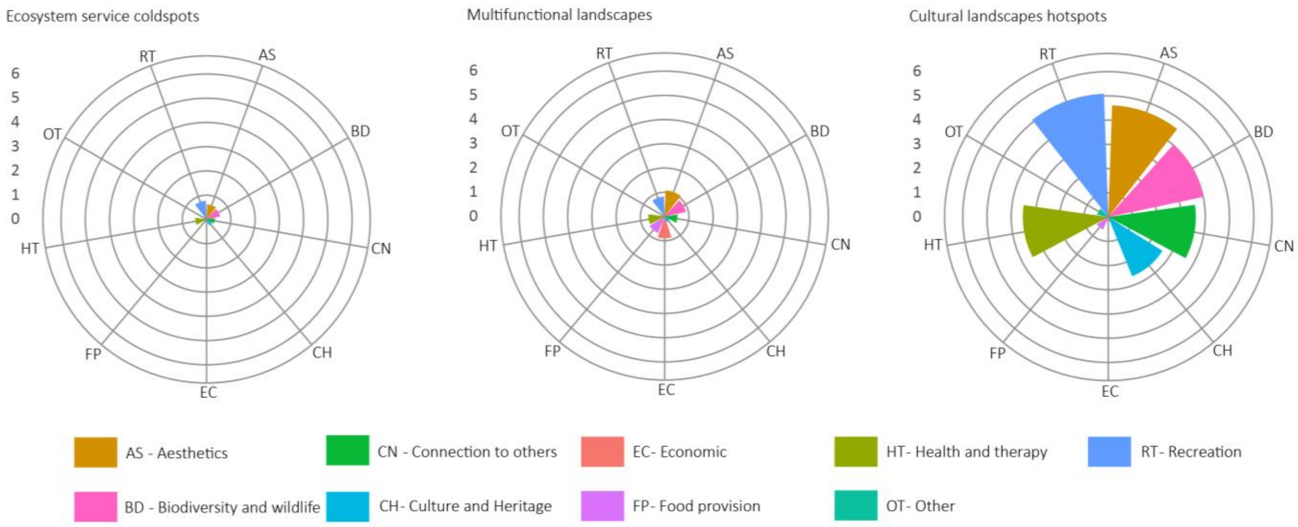

Figure 4.4 Three bundles of ecosystem service values showing the mean number of points of each ecosystem service value per grid cell per cluster.

The landscape characteristics influencing the probability that a given grid cell belongs to a particular ecosystem service bundle were estimated through a multinomial logit model. The likelihood ratio for the model ($X^2(12) = 90.04$, $p < 0.001$) suggested that the predictive power of the model was reasonable compared to an intercept only model. The Nagelkerke pseudo R^2 also indicated that the model has moderate predictive power (pseudo $R^2 = 0.23$), as with many environmental studies, the real world complexity and potential numbers of landscape characteristic variables, and other variables, that influence the distribution of ecosystem service bundles is high.

The multinomial logit model revealed the landscape characteristics that were significant predictors of the bundles (Table 4.3. and Figure 4.5). The simulated predictions indicated that the 'coldspots' bundle was negatively associated with levels of access (using length of path as a proxy) and proportion of freshwater cover. Higher proportions of agricultural landcover and woodland cover were significant predictors of the 'multifunctional landscapes' bundle. Additionally, 'multifunctional landscapes' was the only bundle for which the proportion of built-up areas was a significant predictor and showed a positive response to increasing proportions of the built environment. Higher levels of access (using length of path as a proxy) were a significant predictor of 'cultural landscapes', with increasing levels of access associated with this bundle. Both increasing proportions of agricultural landcover and woodland cover were negatively associated with the 'cultural landscapes' bundle. Proportion of freshwater and proportion of grassland were not statistically significant in the multinomial model.

Table 4.3 Results of the multinomial logit model. Bundle 1 'coldspots' is used as the reference category. *** indicates a p-value < 0.001.

	Bundle 2 - mutlifunctional landscapes			Bundle 3 - cultural landscapes hotspots		
Variable	**Coefficients**		**Std Error**	**Coefficient**		**Std Error**
(Intercept)	-4.65841	***	0.27202	-1.75969	***	0.48362
Proportion woodland	3.07709	***	0.73078	-6.56696	***	0.38317
Proportion grassland	0.78169		0.05766	7.03002		0.17338
Proportion agriculture	2.36354	***	0.45899	-1.38667	***	0.72771
Proportion water	13.59090		0.26896	12.45865		0.40673
Proportion built-up	2.01030	***	0.54197	-0.42585		0.67345
Path length	-0.00015		0.00033	0.00080	***	0.00021
Log likelihood	-271.276					
Nagelkerke Psuedo R^2	0.23					

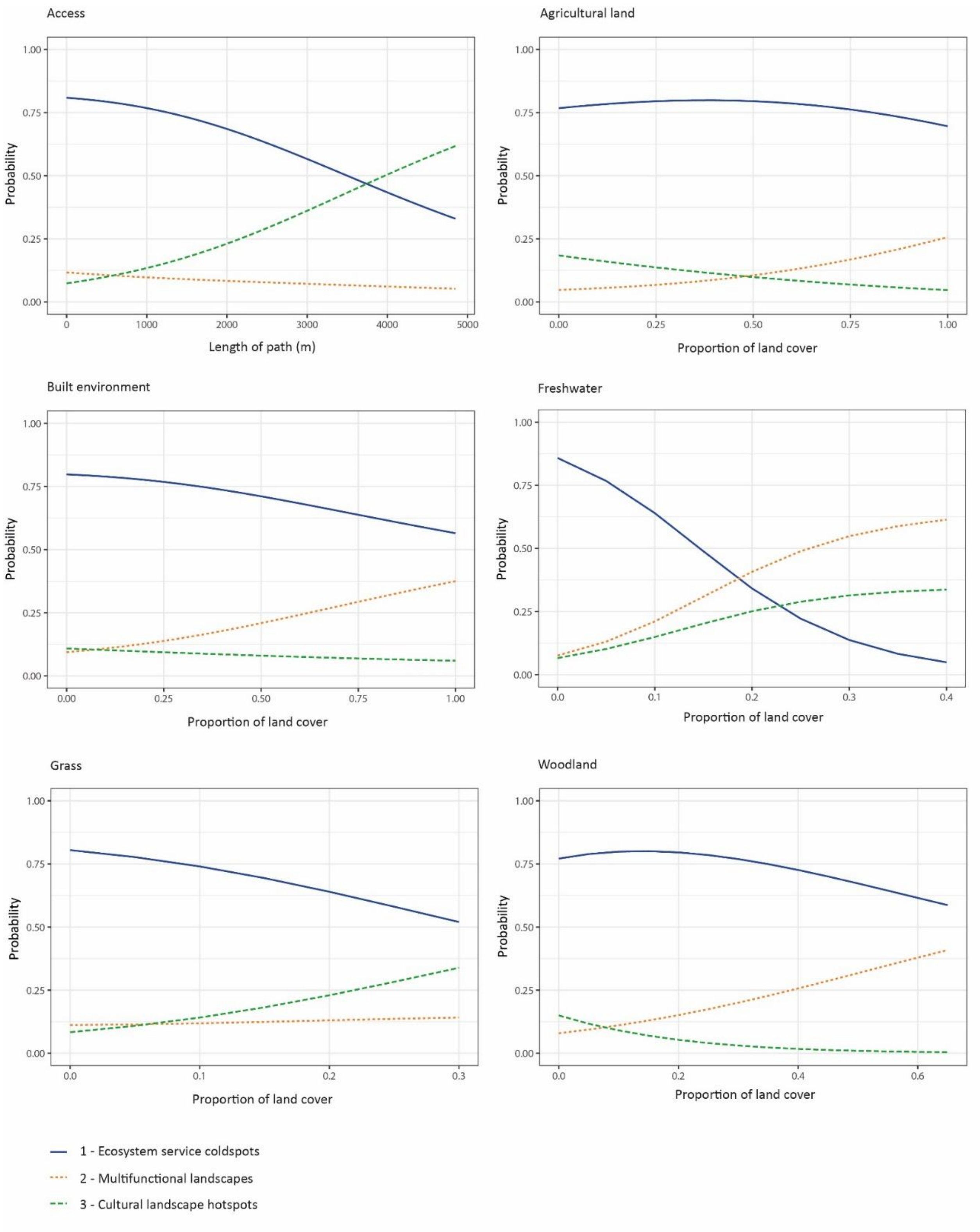

Figure 4.5 Simulated predictions using the multinomial logit model for the spatial bundles. The curves indicate the probability of a specific spatial unit belonging to each of the bundles given an increase in the value of the landscape predictor.

4.5 Discussion

4.5.1 Chalk streams connect people and nature

As well as being important biodiversity hotspots, the River Test and River Itchen are also places that connect people and nature through a range of ecosystem service values. My study highlights the importance of chalk streams for cultural ecosystem service values such as recreation, aesthetic appreciation, and biodiversity appreciation, although the relative importance of ecosystem service values varied between stakeholder group. Participants mapped substantially more ecosystem service values for each cultural service statement than for provisioning or economic ecosystem services. Although this predominance of cultural services is frequently a feature of PPGIS studies, particularly those with a European context, it does not account for the extent of the difference between the number of points mapped for any one cultural service and those for other ecosystem service values. This demonstrates one of the strengths of using PPGIS methods, namely its ability to advance the mapping of cultural ecosystem services, since this is challenging using biophysical indicators or social media data. Participatory methods are important to ensure that cultural service values are reflected in landscape planning.

Chalk streams were valued for recreation more than any other ecosystem service value by the general public, which is also consistent with other European studies (Baumeister et al., 2020; Cusens, Barraclough and Måren, 2021; Fagerholm et al., 2016), although this varied by stakeholder group. Participation in outdoor recreation is increasing in England with the growing recognition of the benefits of outdoor recreation for wellbeing, and the proportion of visits to rivers has increased over the past 3 years (Natural England, 2023). The River Test and River Itchen do not have any formally designated bathing areas (Defra, 2025) but wild swimming is one of the identified recreational activities. Exercise has physical wellbeing benefits through improved cardiovascular function for example, but there is also evidence that species and ecosystem diversity have positive mental wellbeing benefits (Aerts, Honnay and Van Nieuwenhuyse, 2018). Additionally, the benefits of being on or near ‘blue’ space (aquatic environments) for health and wellbeing are starting to be recognised (Britton et al., 2020). Recreation appears to mediate between blue spaces and health and wellbeing (Murrin et al., 2023). The co-occurrence of recreation, biodiversity appreciation and health and therapy values particularly in the ‘cultural landscape’ bundle appear to reflect the role of outdoor recreation in facilitating improved wellbeing.

The bundles identified demonstrate that there are patterns of ecosystem service values across the river corridors. There are distinct hotspots of cultural services, coldspots with low values for all ecosystem services (which are predominantly found along the smaller tributaries as oppose to the main river channel), and multifunctional landscapes where almost all ecosystem services are equally valued. All the bundles that were identified in this study show multiple co-dominant ecosystem service values, although they differ between bundles. This contrasts with other PPGIS studies where the bundles have only one or two dominant ecosystem services (Cusens Barraclough and Måren, 2021; Plieninger et al., 2019). The different landscape scale, a river corridor instead of a broader landscape, may influence the nature of the bundles (Felipe-Lucia, Comín and Bennett, 2014). Further exploration of the way that ecosystem service interactions vary at different spatial scales, e.g. reach, corridor and catchment, would be interesting to explore. PPGIS ecosystem services studies typically find more synergies and fewer trade-offs between ecosystem services than biophysical ecosystem services bundling studies (e.g. Crouzat et al., 2015; Queiroz et al., 2015) a finding supported by these results. Combining biophysical and socio-cultural methods may therefore give a more holistic picture of ecosystem services in the river corridors and expand the knowledge base for land use planning (Bagstad et al., 2017; Scholte, van Teeffelen and Verburg, 2015).

4.5.2 Access and landcover are important determinants of ecosystem service bundle distribution

The use of the multinomial model offers insight into how landscape characteristics affect the distribution of the bundles of ecosystem service values. Physical accessibility (path access) is crucial for determining the distribution of 'cultural landscapes'. This is consistent with previous PPGIS studies that have found accessibility is important for determining mapped cultural ecosystem service values (Fagerholm et al., 2016; Muñoz et al., 2020), particularly recreation (Paracchini et al., 2014). The role of accessibility in determining the provision of cultural services highlights the need to consider the extent of public access around the rivers. 'Cultural landscapes' are concentrated within a small area of land within the river corridors and with anticipated population growth of approximately 5% between 2018 and 2028, the demand for cultural services and pressure on accessible areas of land is likely to increase. Expanding the extent of public access in the river corridors would help to reduce pressure on the rivers. A first step towards achieving this could be to conduct a recreation opportunity review akin to Paracchini et al. (2014) for the rivers, including consideration of the impact of expanding the right to access waterways and any conflict that might arise (Church, Gilchrist and Ravenscroft, 2007). While woodland and agricultural landcover were negatively associated with the 'cultural landscapes' bundle it is uncertain whether this is due to a lack of access in these landcover types or due to a genuine preference for areas that are not wooded or agricultural.

The 'multifunctional landscapes' bundle shows a diverse range of ecosystem service values distinctive to the other bundles identified and shares some similarities to bundles from other studies that represent areas of shared high value (Cusens, Barraclough and Måren, 2021; Plieninger et al. 2019). Also consistent with these studies, higher proportions of built-up areas, woodland, and agricultural land were significant predictors for determining 'multifunctional landscapes'. The woodland and agricultural landcovers likely support the supply of food provision and economic ecosystem service values. The slight negative association between the extent of access and the 'multifunctional landscapes' bundle is likely to be the result of the type of recreation carried out, with a higher proportion of fishing compared to walking. Recreational fishing on the River Test and River Itchen (accessible primarily via private fisheries and requiring financial resources) and walking (requiring public access) have different infrastructure needs and so higher levels of access are not as important for the recreation represented by this bundle.

The 'coldspots' bundle, where people identified and allocated few ecosystem services, was the most extensive in the river corridor, aligning with findings from other PPGIS ecosystem services studies (Plieninger et al., 2019). The negative association between access and this bundle suggests that the lack of path infrastructure likely contributes to low ecosystem service values as access is necessary for experiencing cultural services. This bundle shows negative association with all the landcover types suggesting other factors, for example, topography, might influence its distribution.

4.5.3 Implications for land use and river decision making

These results come at a time where there is debate about how to manage landscapes to support biodiversity and reduce carbon emissions, while also supporting the livelihoods and needs of people. It is recommend that the datasets be incorporated into existing biophysical ecosystem service databases for the River Test and River Itchen, for example the Test & Itchen Catchment Partnership database (Test & Itchen Catchment Partnership, 2023). Integrating these datasets would allow a more nuanced understanding about the ecosystem services provision of the rivers, as there is limited spatially explicit data for cultural services at present. The study findings emphasise the importance of public access and diverse landcover in supporting ecosystem services. Facilitating dialogue with local landowners to understand the barriers and motivations to expanding access to the rivers would be beneficial. At a wider scale, agri-environment schemes, currently the Environmental Land Management Scheme (ELMs) in England, could be used as a tool to create broader co-benefits for citizens, for example by incentivising wider access to land to facilitate the provision of cultural services. Improved access to the rivers could strengthen human – nature connection and pro-conservation attitudes (British Ecological Society, 2023). Although, any expansion of access would need to be mindful of potential negative impacts on chalk stream ecosystems from bankside erosion or the spread of invasive species (Seekamp et al., 2016).

4.5.4 Reflections and further work

The socio-demographic data from this study suggests that the sample is weighted towards older, female respondents, when compared with the population of Hampshire (broadly aligned with the catchment population), which may have introduced bias. However, it is not clear if the results would have been substantially different with a more representative sample and could indicate that the 'users' of the rivers differ to the catchment population.

The value placed on recreation and other cultural services in this study is not necessarily surprising. However, the spatial distinction between areas valued for walking and those valued for fishing, is a more surprising and important finding that indicates that financial resources (required to access private fisheries) determine access to areas with the capacity to provide recreational benefits. Further work to explore the uneven distribution of ecosystem service benefits to different stakeholder groups, and how management and governance can help promote more equitable access, would be of value (Locatelli et al., 2025). In addition, as recreational activities that take place alongside rivers e.g. walking, cycling and running, were mapped significantly more than in-stream activities e.g. swimming and kayaking, further work to understand the extent to which river ownership prevents in-stream recreation and the potential value of in-stream recreation would be of interest.

There are also additional areas for potential further research. Respondents were also only asked to map areas that they positively valued and were not asked about areas that they did not value. The absence of mapped points likely indicates that an area is not valued, potentially due to a lack of access or the quality of the habitat, but future research could assess this more formally using a similar method to explicitly capture areas that are not valued. Additionally, further work to understand in more detail the aesthetic preferences of the rivers by different stakeholder groups could facilitate decision making. Lastly, integrated biophysical and socio-cultural analysis using a framework such as the one developed by Bagstad et al. (2017) would be useful to understand how these approaches compare and can aid decision making.

4.6 Conclusions

As well as being important habitats for biodiversity, chalk streams are also key places that connect humans and nature. The findings show a diverse range of ecosystem service values are provided by chalk streams, however it was found that stakeholder groups assign importance to different ecosystem services. Recreational values were particularly valued by the general public, while those working in conservation placed importance on biodiversity and wildlife values. The bundling approach combined with a multinomial logit model shows that there are distinct bundles of ecosystem services found in the River Test and River Itchen corridors (the main channel and tributaries), the distribution of which is influenced by landscape characteristics and accessibility. Hotspots of cultural service values are associated with higher access but are found in a small proportion of the river corridor. The co-occurrence of recreational values and biodiversity values in this bundle emphasises the importance of the mental and physical co-benefits people receive from recreational activities in nature. Expanding access to the rivers, particularly in light of the population growth within the catchment, is recommended to meet the likely increase in demand for recreation and to improved connection between people and the rivers. Incorporating these spatially explicit ecosystem service values for the River Test and River Itchen into decision making processes can help to develop a shared vision for these important chalk streams that has the support of local citizens.

Chapter 5 Improving governance outcomes for water quality: Insights from participatory social network analysis for chalk stream catchments in England.

This chapter is published as:

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I conceived of the idea for this chapter and designed the methodology with support from Kelvin Peh, Rob Holland, and Jennifer Hauck. I managed the project and recruited participants. I collected the data for 14 of the 15 interviews (Amy Lovegrove conducted the other interview). I analysed the data with support from Jennifer Hauck, interpreted the data with input from Jennifer Hauck, Kelvin Peh, Rob Holland, and Jake Snaddon. I wrote the first draft of the manuscript and revised the manuscript based on feedback from Jennifer Hauck, Kelvin Peh, Rob Holland, Jake Snaddon and Gail Taylor.

5.1 Abstract

Globally important chalk streams in England are in poor ecological health, in part due to inadequate water quality. Addressing this issue requires an understanding of the governance systems that surround water quality. The complexity and uncertainty inherent in hydrological systems has led to the emergence of integrated and adaptive forms of governance. In these multi-actor governance systems, the structure of the relationships between actors (the social network) has been shown to affect governance processes and outcomes.

Using participatory social network analysis, we mapped and analysed the social networks for the River Test and River Itchen in Hampshire, UK, to identify actors and their roles, determine the network characteristics, and identify interventions to improve governance.

Although the results suggest a well connected network of actors from the state, private sector and civil society, we find that decision making is not decentralised. Bureaucratic governance by central state actors dominates. However, trust in these central state actors and private actors in the networks is low, which undermines collaboration and co-ordination in the network. Devolving authority to local actors, building trust in the networks, and improving connections to important actors could help to improve governance outcomes for water quality.

5.2 Introduction

Freshwater habitats are some of the most threatened in the world due to pressures such as over abstraction, impoundment, the impacts of climate change, pollution, and invasive species (Dudgeon et al., 2006; Vörösmarty et al., 2010; Naiman and Dudgeon, 2011). Globally, freshwater species have seen a decline in monitored populations of 85% since 1970, a rate that far exceeds measured decline in terrestrial or marine populations (WWF, 2020). Society obtains many important ecosystem services from freshwater habitats including drinking water, food provision, recreational opportunities, and energy production (Dodds, Perkin and Gerken, 2013; Hanna et al., 2018). Impairing the quantity and quality of freshwater ecosystems therefore threatens our wellbeing (Vörösmarty et al., 2010).

Poor water quality is a significant reason for the impaired health of many rivers in England. Despite efforts to improve ecological health and water quality, driven by the implementation of the EU Water Framework Directive 2000/60/EC (WFD) legislation, in the latest assessment in 2019, no rivers in England were classified as being of good chemical status and only 14% of good ecological status (Defra, 2020). This has implications as around 80% of the global distribution of rare chalk streams are found in England. Elevated levels of sediment, nutrients and chemicals arising from a range of domestic, industrial and agricultural sources have been identified as key barriers to improving the ecological health of these globally important ecosystems (Rangeley-Wilson, 2021). In order to improve water quality, a better understanding of the human and social dimensions of the challenge is important (Bennett et al., 2017), in particular the design of the governance system for ensuring adequate water quality (Lemos and Agrawal, 2006; Gupta, Pahl-Wostl and Zondervan, 2013).

5.2.1 Governance and social network analysis

Governance of water is inherently complex. Water is in constant flow, moving around the system, being continually used and discharged, with different water users and actors who influence water resources at different spatial scales (Pahl-Wostl, Jeffrey and Sendzimir, 2011). Further complexity arises from the connectivity of water with other sectors, as decisions made in other spheres such as land management, agriculture, and energy generation, can impact water (Pahl-Wostl et al., 2020). Uncertainty from future changes to the biophysical and social components of the system for example, the impacts from climate change or from emerging contaminants (Reid et al., 2018), adds additional complexity.

Alternative approaches to the governance of water have emerged in recognition of this multi-actor complexity and inherent uncertainty, shifting away from state-centred, hierarchical control. Two of the more widely known alternative approaches to water governance are Integrated Water Resource Management (IWRM) and adaptive governance (White, 1998; Pahl-Wostl, 2015). IWRM emphasises the need for joined-up planning between the sectors responsible for economic and social development, and natural resources, to achieve sustainable water governance (White, 1998; Gupta, Pahl-Wostl and Zondervan, 2013). IWRM favours a participatory approach to governance that combines knowledge from a range of actors (Pahl-Wostl, Jeffrey and Sendzimir, 2011) and a focus on river basins and catchments as management units, rather than management being determined by administrative or political boundaries.

Adaptive governance is a form of environmental governance with an additional focus on adaptive capacities to reorganise in response to changing social and biophysical circumstances. Adaptive co-management (ACM) is a way of operationalising adaptive governance (Folke et al., 2005). Evidence suggests that a collaborative arrangement of actors from a diverse range of sectors and user groups are more likely to establish adaptive processes than other types of system (Sabatier et al., 2005; Baland and Platteau, 2005; Ostrom, 2015). These arrangements are often referred to as polycentric networks or co-management structures, where power, rights and responsibilities are shared between different state, private and civil society actors (Carlsson and Berkes, 2005; Huitema et al., 2009), often through less formalised decision-making structures. This flexible system of actors facilitates an iterative process where social and ecological knowledge is tested through experimentation and the management of social-ecological systems is revised accordingly.

The success of the collaborative arrangements that underpin IWRM and ACM is posited to be influenced by several factors that shape the collaborative process and the resulting outcomes (Ansell and Gash, 2008; Emerson, Nabatchi and Balogh, 2012). These factors include repeated quality interactions (fair and open communication between a balanced representation of actors) which in turn can foster trust, commitment and understanding between actors, often referred to as social capital. Additionally, for collaboration to generate an agreed outcome the capacity for action must be developed, facilitated by leadership, knowledge, resources, and institutional arrangements. The starting conditions at the beginning of collaboration, for example power imbalances and levels of trust, also determine the success of the process. Many of these factors are relational in nature and emphasise the importance of examining the connections and relationships between actors when evaluating governance.

There has been increasing use of social network analysis (SNA) to empirically study the formal and informal relationships between actors in natural resource governance, and how they are associated to governance processes and outcomes (Crona and Bodin, 2010; Sandström and Rova, 2010; Ward et al., 2020). SNA has been used to examine aspects of water governance in a range of contexts, including understanding networks of resilience communication for the UK water sector (Ward et al., 2020); institutional transitions in the Klamath river basin, USA (Chaffin et al., 2016); governance arrangements in the Mkindo catchment, Tanzania (Stein, Ernstson and Barron, 2011); formal and informal networks in urban water management in Indonesia (Larson et al., 2013); collaborative governance for floodplain management in The Netherlands (Fliervoet et al., 2015); and stakeholder networks underpinning collaborative water governance in Chile (Rojas et al., 2020). SNA has been successfully used in these studies to evaluate transitions to sustainable modes of governance (Chaffin et al., 2016), identify problems with water governance arrangements, for example inadequate adaptive capacity (Rojas et al., 2020) and pinpoint interventions to improve water governance (Stein, Ernstson and Barron, 2011). These studies demonstrate that SNA provides a means to evaluate governance arrangements for water quality and highlight interventions to improve outcomes.

We consider a network analysis approach useful when evaluating integrated and adaptive governance for two reasons. First, a polycentric network is often perceived as a social network of actors and acknowledges that actors, other than those with formal authority, may play a role in decision making and management (Carlsson, 2016). Secondly, it is not just the actor characteristics, but also the pattern of interactions between actors, i.e. the network structure, that can determine the processes and outcomes of governance (Friedkin, 1981; Bodin and Crona, 2009). Therefore, certain network characteristics can enhance or diminish processes and properties that underpin integrated and adaptive governance, (**Error! Reference source not found.**) (Bodin, Crona and Ernstson, 2006). For example, densely connected networks can facilitate the development of social capital (trust, reciprocity and connectedness) making it easier for people to collaborate, and aid social learning by enabling actors to share and combine different types of knowledge (Pretty and Ward, 2001; Folke et al., 2005).

5.2.2 Co-producing network knowledge

Co-production of knowledge has emerged as a key approach to tackling complex social-ecological problems, acknowledging that science and society shape each other, and that solutions to complex problems are more effective when produced via pluralistic processes (Norström et al., 2020). Participatory social network analysis is increasingly used to co-produce network knowledge (Hauck *et al*. 2015). For example, Rojas et al. (2020) combined SNA with a broader participatory process to understand collaborative water governance in Chile but the participatory process was not specifically linked to the SNA, which limits the conclusions of the SNA. Likewise, Ward et al. (2020) used a participatory approach to explore resilience communication in the UK water sector; they provided advanced quantitative analysis but did not present or analyse any qualitative data from their participatory workshop. We aim to build on the approaches of these studies and include qualitative data collection to provide additional understanding in our analysis.

5.2.3 Aim and research questions

In this paper we use participatory SNA to describe and analyse the water quality governance networks, with reference to integrated and adaptive governance, for the River Test and River Itchen catchments, two chalk streams of international importance, to make recommendations to improve governance and outcomes for water quality. To do so we address the following research questions:

1. What are the main structural characteristics of the water quality governance networks, as determined by flows of finance, information, and pressure?
2. Who are the key actors in water quality governance, what role do they play and how do they influence water quality governance?
3. What interventions could be undertaken to improve the governance of water quality?

Research question	Analytical approach	Theory driven features of interest	Metrics and how they link to features of interest
1. What are the main structural characteristics of the water quality governance networks, as determined by flows of finance, information, and pressure?	Network level metrics and qualitative analysis of the interviews and workshop	Features considered to be important for governance (adapted from Bodin et al., 2006): Trust Communication Adaptive capacity Learning and knowledge production Heterogeneity	Density – the total number of ties in a network divided by the total number of possible ties (Granovetter, 1973). Used as an indicator of: • Trust - dense networks can foster trust (Coleman, 1990), • Communication - is enhanced in densely connected networks and can facilitate collective action (Bodin and Crona, 2009), • Heterogeneity - high density can produce homogeneity of experience and reduce innovation (Oh, Chung and Labianca, 2004). Network centralisation – variation in the centrality scores (Freeman, 1978). Used as an indicator of: • Adaptive capacity - a centralised network may be more easily coordinated for collective action, an indicator of adaptive capacity (Sandström and Carlsson, 2008b), • Learning - more centralised management can reduce experimentation and learning (Shaw, 1981). Diversity of actors – the number of actor categories. Used as an indicator of heterogeneity - polycentric governance requires a diverse range of actors (Sandström and Carlsson, 2008a; Tuda et al., 2021).
2. Who are the key actors in water quality governance, what role do they play and how do they influence water quality governance?	Node level metrics and qualitative analysis of the interviews and workshop	How are actors able to use their position in the network to exert influence. Central positions may give influence, e.g. facilitating better access to information (Burt, 1992).	Node level metrics • Perceived influence rating – assigned by interviewees to each actor they identified to allow fuller analysis of actor influence in relation to network position. • Degree centrality - the number of direct connections coming in or out of a node. Having many ties has been shown to positively impact influence (Degenne and Forse, 1999). • Betweenness centrality - the number of times a node acts a bridge for the shortest path between two other nodes (Freeman,

		What other roles are actors adopting e.g. brokers, knowledge generators, stewards, leaders (Olsson, Folke and Berkes, 2004).	1978). An actor who sits between other actors can influence the flow of resources (Bodin and Crona, 2009). Brokers may learn about a range of actors in the network, and be able to facilitate new connections, or limit connection, in response to change (Granovetter, 1973; Burt, 2004).
3. What interventions could be undertaken to improve the governance of water quality?	Collective analysis via the workshop and qualitative analysis of the individual interviews	Features considered to be important for co-producing outcomes (Norström et al., 2020): context-based, diversity of knowledge, goal-oriented.	No quantitative metrics analysed

5.3 Methods

5.3.1 Study location

We selected the River Test and River Itchen catchments in Hampshire, UK (Figure 5.1), for our study as they are two of the best examples of chalk streams in the world (Mainstone, 1999; Environment Agency, 2022). The River Test and River Itchen have conservation designations that offer them an increased level of protection. Both rivers are designated Sites of Special Scientific Interest and the latter also has a Special Area of Conservation designation, a strictly protected site under the EU Habitats Directive (Communities European, 1992), due to the quality of its *Ranunculus* habitat and its populations of threatened species (Hampshire County Council, 2003). The two catchment areas are frequently treated as a single unit for management purposes (Environment Agency, 2022) and their combined area covers approximately 1,760 km^2 (hereafter, the catchment). Land cover in the upper and middle reaches of the catchment is dominated by pasture and arable land, with several urban centres. While in the lower reaches both rivers flow through predominantly urban areas before flowing into Southampton Water estuary (Environment Agency, 2022; Test & Itchen Catchment Partnership, 2021).

Alongside their ecological value, chalk streams are economically and culturally important. Humans have modified and made use of the River Test and River Itchen water courses and floodplains for thousands of years, for example, by impounding the river to create fish ponds, installing water mills, and establishing irrigation systems (Glasspool, 2007). Currently, the rivers and their aquifers are a main source of water for drinking and agricultural use, they support the industries of watercress cultivation and fish farming and offer a space for recreation and aesthetic enjoyment. The River Test and River Itchen are some of the most famous fly-fishing rivers in the world and they are home to many recreational fisheries (Test & Itchen Catchment Partnership, 2021). As a result of the diverse ways in which the rivers are used, there are a number of individuals and groups with a stake or interest in the rivers.

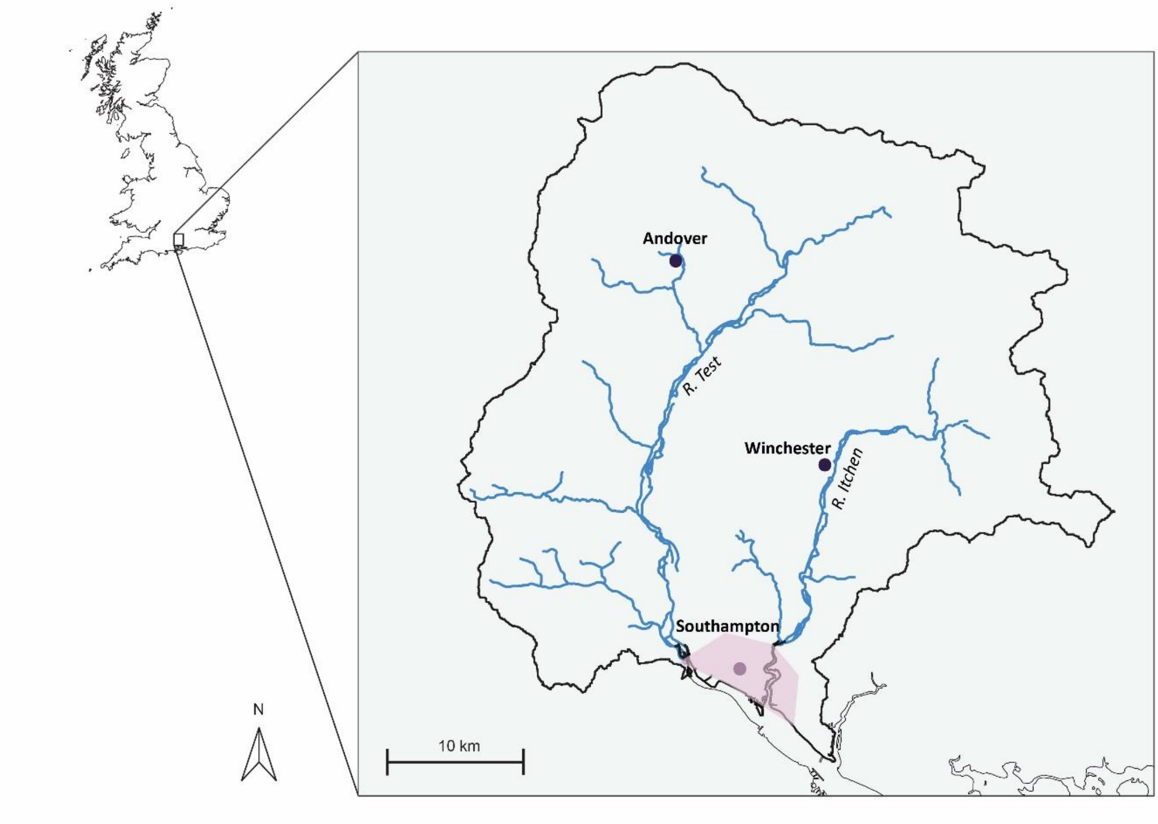


Figure 5.1 Catchment map of the River Test and River Itchen, Hampshire, UK.

5.3.2 Overall approach

We used Net-Map (Schiffer and Hauck, 2010; Hauck et al., 2015), a participatory SNA method that uses a semi-structured process to draw a network visualisation with interviewees based on their perceptions – the way they understand and observe the network. Through the construction of the visualised network, the interviewee is encouraged to describe the network structure, discuss the relationships between actors, and reflect on the network structure as a whole. In designing our approach, we recognised that effective co-production processes should be context-based, bring together different types of knowledge, expertise and actors, and be goal-oriented (Norström et al., 2020; Miller and Wyborn, 2020). Therefore, results of this analysis were then presented and discussed in a participatory workshop with the interviewees, to reflect on the network visualisation, co-analyse findings, and to produce interventions to improve governance. Collecting quantitative network data and qualitative narratives, as well as data from the workshop, allowed triangulation between these different data sets. We view these data sets as complementary, in that we are not solely focused on using one set of data to validate another, but rather that the quantitative and qualitative data enrich one-another, helping to provide a more detailed understanding of the governance network (Nightingale, 2009). See the 'Data analysis' section 5.3.4 for further details.

Ethics approval for this study was granted by the University of Southampton (Ref no. 52980) and informed consent was obtained from all participants in writing.

5.3.3 Data collection

We conducted individual interviews with 15 stakeholders, each of which lasted for between 1 hour 20 minutes and 3 hours, between October, 2019 and November, 2020. We identified interviewees through a combination of purposive and snowball sampling: we began by interviewing stakeholders we knew to be involved in the network (i.e. stakeholders that were known to have an influence on, interest in, or were impacted by water quality of the River Test and River Itchen), and then used the network visualisations produced in these interviews to identify other stakeholders. We recruited stakeholders who represented a range of spatial viewpoints (i.e. national to local) and sectors (i.e. state, private, and civil society). For a list and description of the interviewees see Appendix C.1. Only one person we approached declined to be interviewed. We stopped recruiting interviewees when further interviews did not elicit a significant amount of additional information. The number of interviews in this study is commensurate with that of similar research using Net-Map (e.g. Hauck et al., 2015; Winkler and Hauck, 2019). Eleven of the interviews took place in person, at a location of the interviewee's choice, and four interviews were conducted virtually due to COVID-19 restrictions implemented by the UK Government. All of the interviews were recorded with the interviewee's permission.

We conducted three pretest interviews with other academics to help refine our interview protocol and to ensure that interviewees were able to use the term 'water quality' as a boundary for the network (see section 2.2.3). The interviews followed the three main steps of the Net-Map process (Figure 5.2):

1. Interviewees identified actors who are involved in water quality governance for the River Test or River Itchen catchments. The actor names were written down on actor cards, post-it notes in our case, and attached to a large sheet of paper.

2. Links between actors were then recorded by drawing arrows between the actor cards. Interviewees were invited to map three types of relational ties: information, financial

and pressure. Interviewees were asked to give examples of the links they described. Information ties were defined as any means of providing details relating to water quality to another actor. Financial ties were defined as any financial link between actors that related to water quality including, but not limited to, grants, subsidies, fines, and payments for goods or services. We defined pressure as attempts to persuade or coerce another actor into action that relates to water quality, this could be via formal (e.g. statutory powers) or informal means (e.g. public protest).

3. Each actor identified in the network was assigned a perceived influence rating. Interviewees were given 40 playing blocks to distribute across the actors they identified. The more playing blocks allocated to an actor, the more influence they were perceived to have. The number of playing blocks assigned to each actor was recorded as their influence value.

In addition, we also invited interviewees to reflect on the network visualisation they produced. For the full interview protocol, and details of adjustments to the protocol for the virtual interviews, see Appendix C.2.

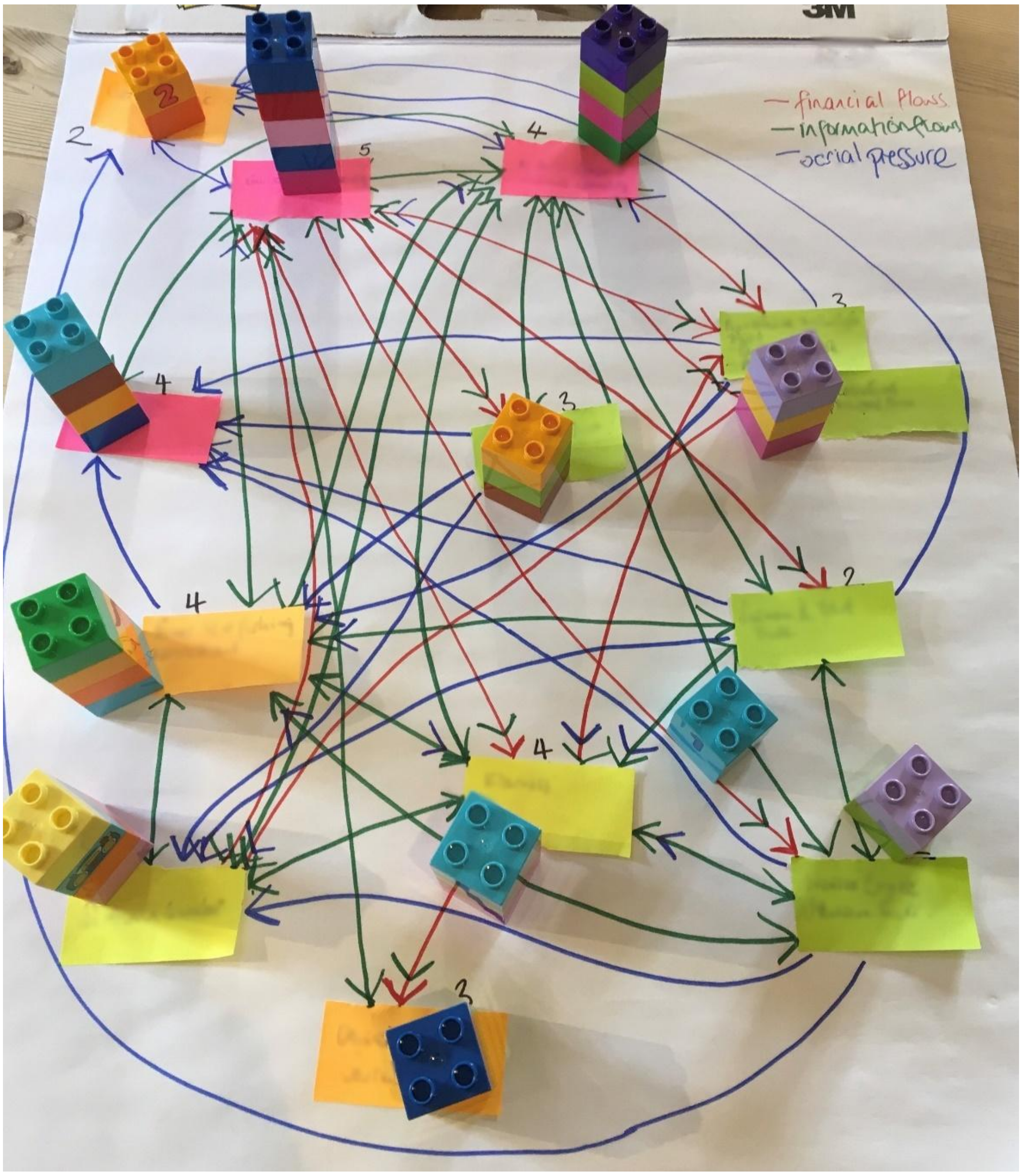


Figure 5.2 A Net-Map network visualisation. The image has been altered to anonymise the actors identified in the interview. Arrows indicate the direction of flow of a particular tie. Arrows in both directions indicate a reciprocal flow.

We then invited all the interviewees to attend a half day workshop on 10 May 2021. We digitised and amalgamated the visual networks produced in the individual interviews (for details see the data analysis section 5.3.4) and used these to allow the group to reflect on the network structure, to facilitate collective analysis of the network, and to discuss interventions to improve governance (for the workshop protocol see Appendix C.3). We piloted the workshop with a group of eight academics, who were unconnected to the project but able to reflect meaningfully on the workshop design due to prior experience of running or participating in workshops. Their feedback was used to refine the protocol, network visualisations, and workshop facilitation.

Seven of the 15 original interviewees participated in the final workshop, which was recorded with their permission. The questions for the workshop were guided by the initial interpretations from the qualitative structural analysis (see the data analysis section 5.3.4), for example an initial interpretation of relatively high density in the network underpinned a workshop question regarding whether there was trust in the network. The workshop participants also completed a short survey to allow us to evaluate the success of the method for generating actions and for facilitating social learning (for the survey see Appendix C.4). The workshop took place virtually due to restrictions implemented by the UK Government throughout the COVID-19 pandemic.

5.3.4 Data analysis

The visual networks were digitised by creating adjacency matrices, listing every actor horizontally and vertically and noting the presence or absence of a link between pairs of actors. We used Visone (Brandes and Wagner, 2004) to visualise and analyse these matrices. Amalgamated networks were created, one for each type of connection, and one overall network, by counting how many times a particular actor, or type of connection between two actors, was mentioned across all of the interviews. The average assigned influence value for each actor was calculated by normalising and averaging the perceived influence ratings given by participants in each interview, we then normalised these average values. **Error! Reference source not found.** provides an overview of our analytic approach for each research question, lists the network and node level quantitative metrics we have calculated, and details how these metrics are connected to features of governance. For details of the specific calculations see Appendix C.5. We calculated correlation values using Kendall's tau, as the data were not normally distributed (Sharpiro-Wilk $W(76) = 0.94$,$p < 0.05$), using R Statistical Software (R Core Team, 2016).

Having calculated the network and actor metrics, we then used a qualitative structural analysis approach as suggested by Herz, Peters and Truschkat (2015) to guide our analysis of the network visualisation and qualitative data. A list of questions about the network structure and actor positions and roles was generated, underpinned by SNA theory (see **Error! Reference source not found.**) and guided by the network and actor metrics we calculated. For example, 'Which actors connect otherwise unconnected actors?', 'Are there areas of the network which have more ties than others?', 'Which actors are central in the network?'. This process helped us to develop a series of initial interpretations about the network and further questions to pose to the qualitative data. For example, 'The network has a high density of connections. Does this high density foster trust?', 'Actor X occupies a central position in the network but does not have high influence, why?, 'Several individual citizens are relatively central in the network, why do they occupy these positions?'. This process helped to embed a structural approach in the qualitative analysis by sensitising the qualitative analysis to points of interest underpinned by SNA theory. The qualitative data were deductively coded using Nvivo.

A summary of interventions to improve governance that arose from the workshop was generated by reviewing the discussion from the workshop. The summary of interventions was circulated to participants by email, which they reviewed and approved. These actions were triangulated to findings from the analysis of the interview data to strengthen our understanding of the issues and actions. We also used the initial interpretations and questions generated by the qualitative structural analysis of the interview data to analyse the qualitative data from the workshop in order to refine our findings.

We have anonymised all actor names, with the exception of state actors, in order to maintain confidentiality. We took this approach as state actors are easily identified from descriptions of their roles and information about their work is publicly available.

5.4 Results

5.4.1 Network characteristics and patterns of flows

Interviewees identified 74 different actors (organisations or individuals) involved in the governance of water quality that operate at local, regional, national and international scales. The majority of the interviewees were identified as actors in the network by themselves or others. Actors were assigned to one of 20 categories based on their primary role within the catchment, as determined from the qualitative data from the workshop and individual interviews, see Table 5.1 for descriptions of the actor categories. The actor categories were developed using qualitative data from the interviews. We considered the interests and motivations of the actors, and the types of organisation (e.g. differences in their ownership) when defining the categories. In instances where an actor had multiple roles, we used evidence from the qualitative data and our judgement to determine which category to assign them to. Aggregating the actors into categories helped to ensure actor anonymity as actors may have been identifiable in a disaggregated network visualisation.

Interviewees identified 1,173 ties across the three types of flow; information, finance and pressure, between the 74 actors. The overall network (Figure 5.3) had a centralisation of 61% and a density of 0.16. The network formed one structure, with the exception of the rail network, who was unconnected to other actors. The majority of ties identified by interviewees were flows of information (66%) and the ties of information had a relatively high density of 0.14, when compared to the ties of finance and pressure, which had densities of 0.03 and 0.04 respectively (Figure 5.4).

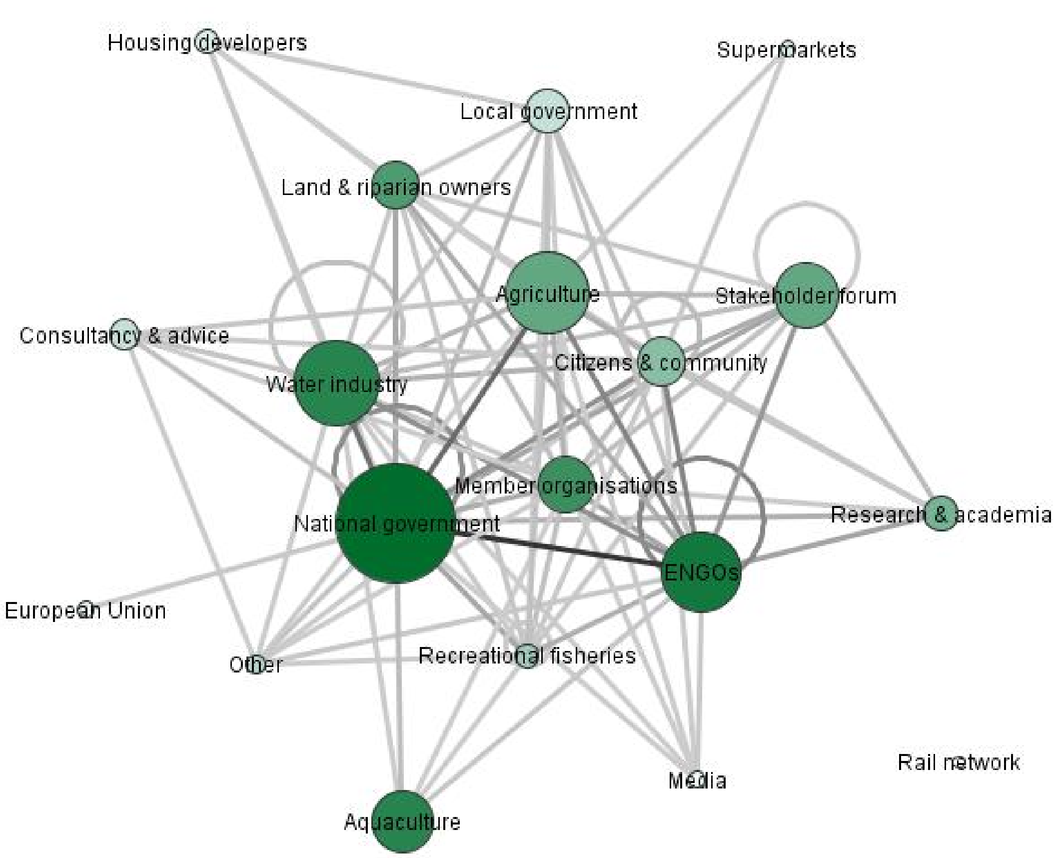
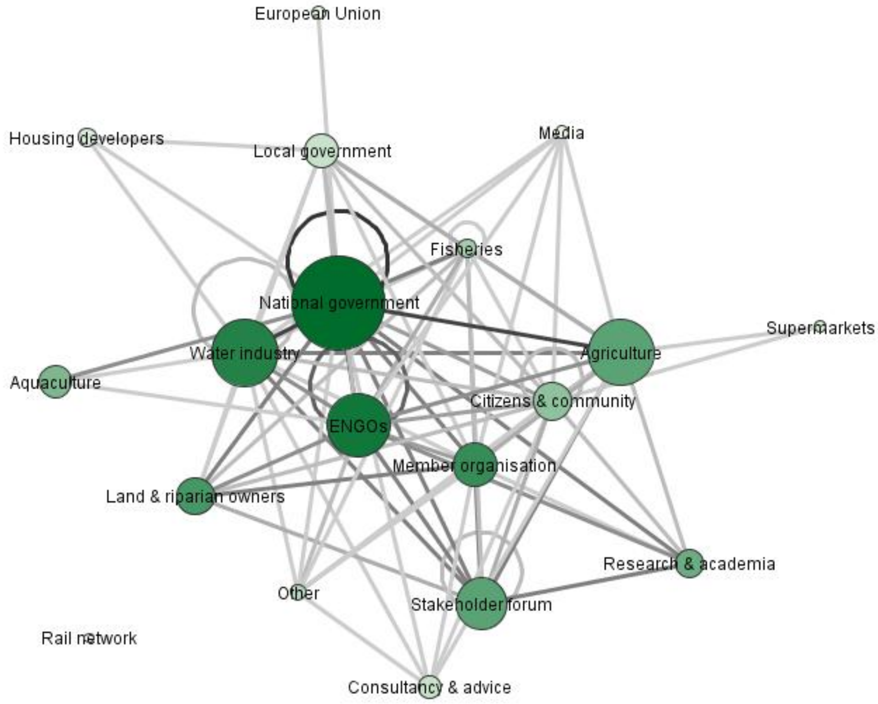
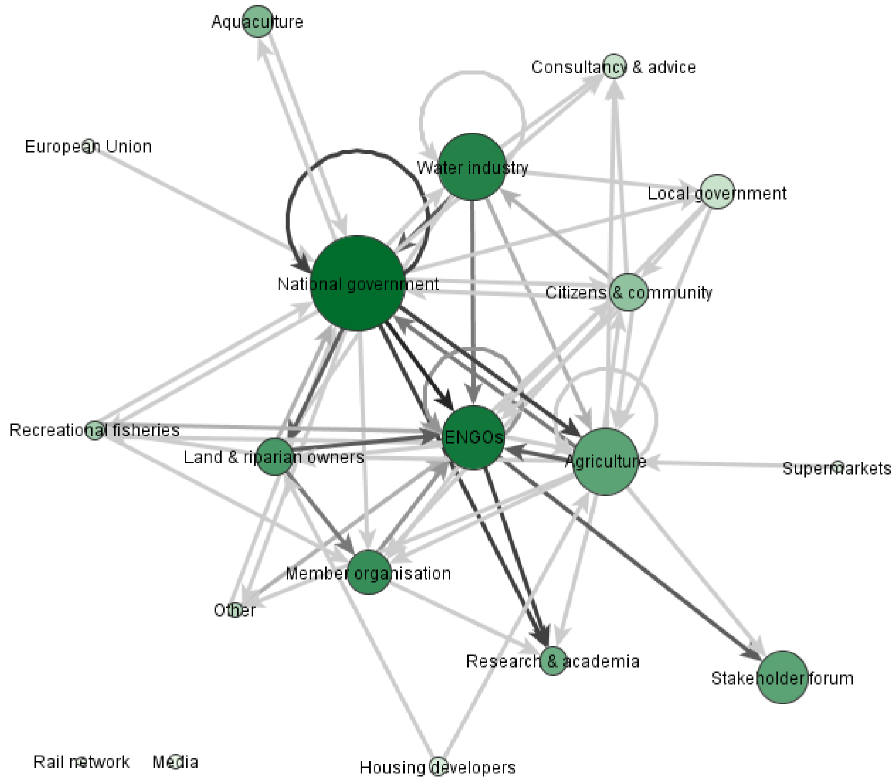


Figure 5.3 Aggregated governance network of information, financial and pressure flows as perceived by interviewees. Circle size indicates the maximum perceived influence of a particular actor category (calculated from the perceived influence ratings given by interviewees to each actor they identified), the larger the circle the higher the influence value. Circle colour indicates the number of times an actor group was mentioned, the darker the circle the more times a group was mentioned. Line colour indicates the number of times a link was mentioned, darker lines indicate more mentions.

a) Information



b) Finance



c) Pressure

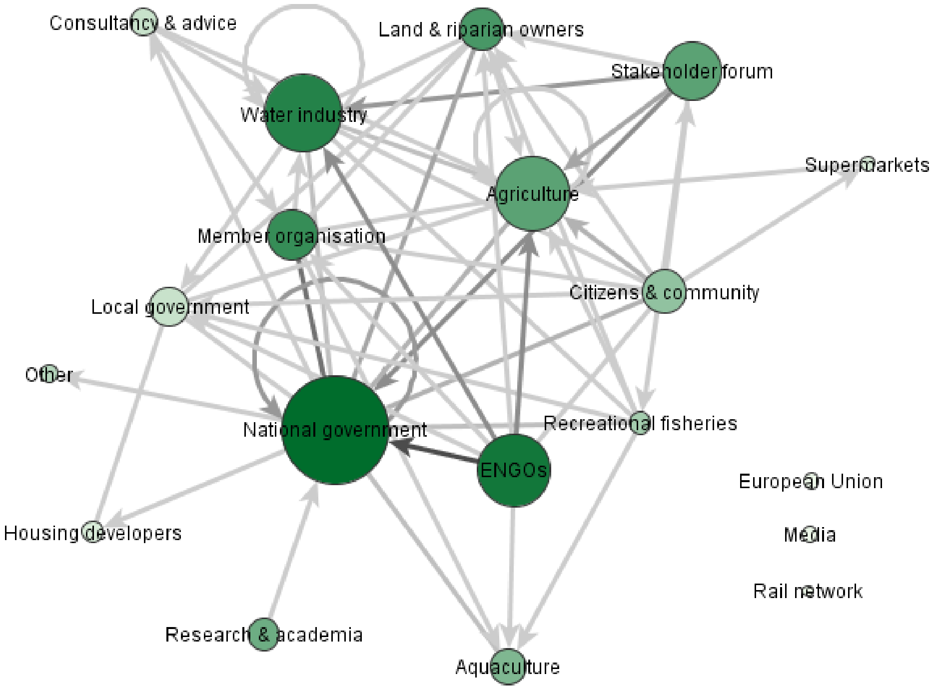


Figure 5.4 Network visualisations a) information, b) finance and c) pressure. Circle size indicates the maximum perceived influence of a particular actor category (calculated from the perceived influence ratings given by interviewees to each actor they identified), the larger the circle the higher the influence value. Circle shade indicates the number of times an actor group was mentioned, the darker the circle the more times a group was mentioned. Line shade indicates the number of times a link was mentioned, darker lines indicate more mentions. A line without a directional arrow represents a reciprocal connection, e.g. information flowing in both directions between actors. Unidirectional flows are depicted with an arrow, which indicate the actor category the flow is going to. Flows between actors within the same actor category are indicated by a circular line.

Ties of information were all reciprocal i.e. information flowed in both directions (Figure 5.4). However, the qualitative data indicated that the extent of the information flows varied, with some being weaker ties of basic information exchanges, for example emails from individual citizens to the Environment Agency (EA) reporting an issue, and others stronger ties of more extensive communication, for example, running and chairing local stakeholder fora. In addition, we noted several themes in information flows. Information flows indicated that the relationship between some actors went beyond information sharing to collaborating and partnering to facilitate action or solutions. For example, ENGO, state and private actors, partnered to develop, fund and deliver a project to protect and restore local chalk streams. Additionally, civil society actors co-ordinated responses to government consultations. Collaborating to generate research and data was also a strong theme. Local universities, ENGOs and local citizens collaborated to identify knowledge or evidence gaps and facilitate research and data collection, for example to understand the impacts of particular pollutants on biotic communities, or to collect detailed water quality data. Flows of information related to regulation were prominent. Interviewees noted communication between regulated industries, such as the water industry, and the EA to share technical regulatory details, advice and progress updates, and also communication on progress updates and regulatory initiatives were provided by the EA to civil society actors. In return, civil society actors reported issues to the EA, for example incidents of pollution, and shared data. Sharing advice was also a noticeable theme. Often this was from state actors or private consultants to private business, farmers and landowners, focused on ways to reduce pollution. For example, Natural England (NE) provided technical advice to farmers about how to reduce diffuse pollution through land management options such as buffer strips, hedgerows and cover crops.

Financial flows (Figure 5.4) were typically unidirectional, for example, a flow of grant money from a donor to a recipient. At a national level, funds flow from central government to key state actors such as EA, NE, Ofwat and Rural Payments Agency. These funds were either used directly by these actors or distributed to local actors in the network. Examples of the fund flows include: the Rural Payments Agency managed agri-environment grants and checked compliance with land management standards in exchange for funds; the EA co-funded river restoration schemes with landowners; and the EA and NE co-administered funding to organisations and land owners that then delivered projects to improve the condition of waterbodies or halt their decline. As the main environmental regulator, the EA also received licence and permit funds and collected fines. At a local level, there were further sources of funds. Through membership donations the general public supported ENGOs, funds which were then used to run projects to protect chalk streams. Individual landowners provided one-off donations to particular ENGOs, for instance, to fund a particular legal challenge against the state. Collectively, riparian owners funded membership organisations who advocated on their behalf on water quality issues. Local ENGO, state actors, and private actors co-funded research projects on catchment water quality, for example to understand phosphorous inputs into chalk streams. Private actors provided funds to farmers to change land management practices to reduce pollution, which was viewed as a more financially efficient way to achieve favourable changes in water quality.

A range of both formal and informal ways to pressure other actors (persuade or coerce them into action related to water quality) were identified (Figure 5.4). Flows of pressure were centred around the EA. Pressure was exerted from the EA to the industries they regulate, including the water industry, aquaculture and agriculture, via formal legal mechanisms and more informal conversations. These regulated industries pushed back on the EA with regard to the standards and targets they were expected to adhere to. The flows between regulated industries and the EA were therefore reciprocal flows, in contrast to many of the other flows of pressure, which were unidirectional. Civil society actors, such as ENGOs and individual citizens, pressured polluting industries directly through conversations or letters, but also indirectly by pressurising the EA, sometimes informally by personal conversation or through more formal channels threatening legal action. Additionally, civil society actors, particularly ENGOs, attracted media attention to water quality problems in chalk streams as a way of garnering public attention and pressure.

Influence and pressure appear to be related. Although we are not able to quantify this relationship, we note actors with high influence values are prominent in the pressure network. For example, the EA have the highest influence value and are able to both exert pressure on other actors due to their regulatory role, while at the same time being the recipient of substantial pressure. Similarly influential actors who are perceived to be the cause of problems with water quality, for example the water industry and agriculture, are recipients of pressure.

5.4.2 Key actors and their role in governance

Interviewees were able to differentiate between the aspects of an actor's role that related to water quality governance and those focused on other components, such as water supply. For descriptions of the main actor categories (those mentioned by more than five interviewees) and their roles in governance see Table 5.1. For the node level metrics for each actor group see Table 5.2. For the node level metrics disaggregated by actor see Appendix C.6.

Interviewees noted different types of influence exerted by actors in the network, which we categorised as financial, legal, land use, political, expert, and social capital. We define these types of influence as follows: legal influence is achieved through statutory laws; political influence is influencing law making through lobbying or being directly involved in formulating laws; land use influence refers to the influence exerted by the decision making of landowners; financial influence is influencing decision making by directing financial resources; expert influence is the ability to direct decision making due to a perceived level of knowledge not held by other actors; and finally, influence derived from having social capital i.e. many, reliable and trustworthy relations.

We noted a positive correlation between the number of times an actor was mentioned and their perceived level of influence ($r_\tau = 0.67$, $p < 0.05$). However, there were some exceptions. Ofwat, a statutory financial regulator, was not frequently mentioned but considered relatively influential, in contrast to several membership organisations, who were frequently mentioned but have a lower influence values. Actors who are more salient are often more influential, but some actors appear to be perceived as involved in governance with limited influence over governance processes and outcomes. Similarly, actors with higher degree centrality were more influential ($r_\tau = 0.64$, $p < 0.01$). However, we noted similar exceptions, for example Ofwat had low centrality but relatively high influence, in contrast to some ENGOs who had high degree centrality but limited influence. We attribute this in part to the type of influence these actors were perceived to have and the remit of their role. Ofwat has regulatory power and so has formal influence over other actors and a direct role in decision making regarding investment in improving water quality. In contrast many ENGOs were seen as relevant to the governance network but their influence was informal and reliant on connecting with others to exert any influence. This suggests that while an actor's influence is impacted by their position in the network, the type of influence they exert is also an important factor (Bodin and Crona, 2009).

Influence and pressure also appear to be related. Although we are not able to quantify the relationship we note that the EA, who have the highest influence values and degree centrality, are at the centre of the pressure network. Similarly influential actors who are perceived to be the cause of problems with water quality, for example the water industry and agriculture, are recipients of pressure.

Table 5.1 Descriptions of the main actor categories (those mentioned by more than five interviewees) and their role in governance, as determined by the network and qualitative analysis. We have singled out actors within these categories for discussion where their role differs to others, or where they have a relatively high level of influence.

Actor category	Description & role
Agriculture	Farmers were viewed as the fourth most influential actor (influence value: 0.49) due to their role in managing large areas of land in the catchments and the potential impact of their decisions on water quality. Several interviewees perceived that despite this influential role, agriculture receives less pressure than other industries due to the more diffuse nature of agricultural pollution and the large number of individual farmers within this industry. Farmers were considered by many interviewees not to be as engaged with water quality issues as other polluting industries, for example aquaculture, in part due to their lack of representation at catchment stakeholder forum meetings.
Aquaculture	Watercress growers and fish farms were singled out as industries that impact water pollution, through their discharge of water directly into the rivers, although their influence on governance is considered lower than other polluting industries such as agriculture. One company within this group was singled out for their engagement with the issue of water pollution and their leadership role; establishing stakeholder forums and coming 'to the table' to talk to other stakeholders, and investing in conservation projects in collaboration with Environmental Non-Governmental Organisations (ENGOs). This was reflected in their higher influence value of 0.06, compared to the group average of 0.05. Although there is little collaboration and co-ordination between companies within this sector, these actions are perceived to have encouraged other companies within the sector to engage in discussions about water quality.
Citizens and community	Several individuals were highlighted in the interviews and collectively they played key roles in the network: they brokered information flows between other actors, notably connecting MPs and other political figures into the network; provided 'on the ground' local knowledge about the state of the rivers; took on leadership roles; were a source of finance; held state actors to account; and facilitated scientific research projects. The most influential individuals (highest influence value: 0.16) were considered to have built considerable social connections and trust, or to have influence via their financial resources. Some local community groups were mentioned due to their role in citizen science projects or in flagging up concerns about their local rivers, but in general were not well connected to the rest of the network and were perceived to have low influence (influence

Actor category	Description & role
	value 0.05). The general public were referenced for their role as water users and polluters, as funders of some ENGOs, and for their potential collective influence on issues such as water quality. The general public were perceived to have low influence (influence value: 0.13) but several interviewees noted a shift in public interest and engagement with the issue of water pollution, and the potential for their influence to be greater.
Environmental Non-governmental Organisations (ENGOs)	Collectively ENGOs in the network played several key roles: acting as a broker of information, notably between the general public and the rest of the network; as a broker of finance; pressurising and lobbying state actors and regulated industries; gathering evidence and undertaking independent monitoring; and bringing in new sources of finance. Some of these roles, e.g. water quality monitoring, had been adopted in response to the perceived failure of the state regulator to carry them out effectively. The influence values for individual ENGOs varied considerably (influence values between 0 and 0.45), partly reflecting different approaches by ENGOs to influencing governance and partly the resources available to each ENGO. Some ENGOs used collaborative partnerships to deliver solutions and undertake research while others used direct pressure, for example initiating legal challenges. The latter approach was generally perceived to be more influential.
Land and riparian owners	Due to their ability to make direct decisions that impact water quality, land and riparian owners were mentioned by many interviewees, but the level of influence attributed this actor category varied. Some interviewees viewed the ability of land owners to make direct decisions about land management as influential, while others perceived the actions of individual landowners to be relatively insignificant.
Member organisations	Several member organisations were involved in the network, bringing together individual actors with shared interests for example, farming, riparian ownership, and land ownership. These organisations often provided advice to members, acted as a conduit for the concerns of members, and lobbied the state on behalf of their members. The perceived collective influence of these organisations was low (influence value: 0.08) and they were only moderately central in the network (degree centrality: 0.29). Their limited influence was attributed to the lack of financial resources of the smaller organisations, and due to water quality not being a priority of many of the larger membership organisations.
National government	The Department for the Environment and Rural Affairs (Defra) played an important role in setting the direction of and allocating primary funding for two influential state actors Environment Agency (EA) and Natural England (NE). Despite this role they were not identified by the majority of interviewees. The EA were perceived to be the most influential actor (influence value: 1) and primarily responsible for water quality through their roles in managing permits for water abstraction and discharge, monitoring water quality and compliance with standards, and undertaking river restoration projects. As well as being the most influential actor, the

Actor category	Description & role
	EA were also the most well connected, having ties to the majority of other actors (degree centrality score of 1.45) and acting as a bridge between otherwise unconnected actors, as shown by having the highest betweenness score (0.22). The EA played a role in distributing financial resources to civil society actors for projects, such as river restoration, and for academic research projects. The EA were a hub for pressure - receiving pressure from NGOs, the local community, and the industries they regulate, and then applying pressure back to the regulated industries. NE were perceived to have a role in regulation due to their responsibility for the monitoring and compliance of designated sites, and to have influence as advisors on standards for water quality and as advisors to farmers. Due to having a more significant role as advisors rather than regulators NE were not viewed as being as influential (influence value: 0.79) as the EA. However, their significant links with farmers were seen to be particularly important as the agriculture sector was not perceived to be well connected to other actors.
Research and academia	Universities were the main source of new scientific knowledge in the network for example, providing new information on the effects of water pollutants. One local university had a long history of undertaking scientific research projects associated to chalk streams. Funding for research came from environmental regulators, ENGOs, and local individuals. Despite many interviewees emphasising the importance of underpinning decision making with scientific knowledge, the influence of academic institutions was relatively low (influence value: 0.12). This was attributed to limited dissemination of the research findings and little implementation of any recommendations, e.g. the findings did not influence policy making.
Stakeholder forums and partnerships	Stakeholder forums & partnerships were recognised as having a key role in convening stakeholders and brokering information, as reflected in their centrality values: the second highest degree value, 0.55 and a moderately high betweenness value, 0.21. There were two established stakeholder forums for the rivers, where a range of actors - state, businesses, and civil society - came together to discuss the conservation of the rivers, focusing on water quantity and water quality. The forums were perceived to have several roles: brokering information between different actors, many of whom are only connected via the forum; applying pressure to those seen as responsible for water pollution; expressing the collective viewpoint of the forum members in government consultations; and giving space to opposing views. One of these forums was perceived as relatively influential (influence value: 0.3) due to the broad range of stakeholders present at the meetings and the quality of the chairperson. Additionally, the Test & Itchen Catchment Partnership (T&ICP), a Defra supported mechanism to deliver catchment based, collaborative approach to land and water management, brought together civil society, state and private actors. The perceived influence of the T&ICP was low (influence value: 0.12), but interviewees varied in their assessment; some noting that the

Actor category	Description & role
	convening power, shared decision making and co-ordination that the T&ICP provides makes a positive contribution to governance, but others believed that the T&ICP could be more effective.
Water industry	The main water company covering the catchment supplied water and sewerage services to residential and industrial customers. They were perceived to be the third most influential actor (influence value: 0.51) because of their direct impact on water quality from discharging treated sewage into the rivers and indirectly by concentrating pollutants by abstracting water from the rivers and groundwater. The main water company was connected to many other actors in the network (degree centrality: 0.93) but some of these connections were unidirectional - incoming flows of pressure from other actors without a reciprocated flow. Trust in the water companies appeared low, resulting from historic behaviour regarding sewage discharges and their lack of attendance at stakeholder forums. Water companies were in a unique position of being regulated by both environmental and financial regulators (Ofwat). This regulatory divide was perceived to be one of the reasons preventing water companies from reducing their impact on water quality - the financial regulator prevents investment in necessary resources, e.g. upgrading sewage systems.

Table 5.2 Attributes of aggregated actor categories, ranked by the number of times the actor group was mentioned across the 15 interviews. ENGOs = Environmental Non-Governmental Organisation. Two measures for influence, degree centrality and betweenness centrality are provided: the average for the actor category; and the highest value or any one actor within that category.

Actor category	**# of times mentioned**	**# of actors in category**	**Average influence**	**Highest influence**	**Average degree centrality**	**Highest degree centrality**	**Average betweenness**	**Highest betweenness**
National government	15	9	0.26	1.00	0.44	1.45	0.037	0.222
ENGOs	14	8	0.19	0.79	0.52	0.97	0.023	0.055
Aquaculture	13	2	0.05	0.06	0.52	0.82	0.026	0.051
Water industry	13	5	0.11	0.51	0.38	0.93	0.016	0.066
Member organisations	11	5	0.08	0.21	0.29	0.80	0.009	0.042
Land & riparian owners	10	1	0.01	0.01	0.58	0.58	0.017	0.017
Agriculture	9	1	0.49	0.49	0.70	0.70	0.053	0.053
Stakeholder forum & partnerships	9	3	0.05	0.10	0.55	0.62	0.021	0.025
Research & academia	8	4	0.12	0.30	0.19	0.42	0.001	0.004
Citizens & community groups	6	12	0.07	0.24	0.25	0.50	0.007	0.022
Recreational fisheries	5	5	0.03	0.13	0.21	0.42	0.001	0.006
Other	4	3	0.01	0.02	0.10	0.21	0.000	0.000
Consultancy & advice	3	5	0.05	0.08	0.10	0.13	0.000	0.000
Local government	3	5	0.10	0.10	0.15	0.25	0.002	0.007
Other industry	3	1	0.06	0.16	0.12	0.12	0.000	0.000
Housing developers	2	1	0.21	0.21	0.16	0.16	0.000	0.000
Supermarkets	2	1	0.06	0.06	0.05	0.05	0.000	0.000
European Union	1	1	0.09	0.09	0.07	0.07	0.000	0.000
Media	1	1	0.00	0.00	0.20	0.20	0.000	0.000
Rail network	1	1	0.03	0.03	0.00	0.00	0.000	0.000

5.4.3 Interventions to improve the governance of water quality

Participants responded to the visual network presented in the workshop with interest and curiosity. The discussion provoked by the network was open and participants expressed that the workshop offered a safe space to share their thoughts. No single participant dominated the conversation, but several of the participants knew each other well and so engaged in the discussion to a greater extent than others. The facilitator invited contributions from quieter members of the group to balance the conversation. Initial surprises on viewing the visual network were the amount of pressure links to the EA compared with NE, and the lack of influence of some of the NGOs. Participants were largely in agreement about the main issues, e.g. the limited connections to the regulator Ofwat. There were differences of opinion, e.g. regarding the extent of actions taken by farmers to tackle water pollution, but these were discussed respectfully.

The positions in the network of Ofwat and the citizens were of particular interest to participants. Despite their important role approving capital investment by water companies to mitigate water pollution, Ofwat were perceived to be less central in the network than participants expected and had few ties to civil society actors. Participants recognised a need to improve communication with Ofwat and suggested that actors should be identified who could help to build relationships between Ofwat and key civil society actors. Additionally, the general public were perceived to be poorly connected to other actors in the network. Participants recognised the general public as a potentially important actor due to their ability to apply collective pressure to local and central government to act on water quality. Fostering an appreciation of the rivers by the general public was viewed as an important foundation for building engagement with the issue of water quality. Improving access to the rivers (e.g. by encouraging private landowners to provide temporary access and tours of the rivers) was suggested as a way for the general public to develop an appreciation of chalk streams, improve connections to other actors in the network and give the general public more influence in the governance network.

Improving the effectiveness of stakeholder fora was also identified as an action. Some key actor groups were not directly connected to some of the stakeholder fora, e.g. agriculture, and the group discussion highlighted that other key actor groups do not consistently attend meetings (such as the Vitacress Conservation Trust stakeholder fora), e.g. water companies. Participants reflected that improving representation at stakeholder meetings and encouraging regular attendance could help to improve communication and facilitate more effective discussions.

A significant theme in the workshop was trust in the network. Participants observed that there was a lack of trust in certain actors, particularly state environmental regulators and advisors, and private companies, although often at an organisational rather than individual level. The lack of trust was attributed to perceived under resourcing of environmental regulators and advisors and a belief that these organisations could not carry out their roles effectively. In the case of private actors the lack of trust was associated to historic behaviours and their perceived motives. Repairing trust was identified as an action but participants found it challenging to identify tangible ways to do so.

Participants highlighted the importance of scientific knowledge in underpinning decision making, which contrasted with the low influence values and degree centrality of academic institutions in the network. There was acknowledgement that more could be done to improve how new knowledge was disseminated around the network and applied in management practices. Making better use of existing channels, such as established stakeholder forums and networks, and creating new ones, for example, connecting with actors via social media, were proposed.

The issues and actions identified by the group covered a range of scales, from local changes (e.g. improving the representation at stakeholder meetings) to national scale actions (e.g. increasing the financial resources of environmental regulators to improve regulatory enforcement). On occasion the group found identifying tangible actions to mitigate the issues challenging, for example how to build trust in the network.

5.5 Discussion

A key finding is that regulatory enforcement is the main mechanism for maintaining and improving water quality in the catchment. There are a mix of state, civil society, and private actors in the network who appear well connected, suggesting polycentricity. However, our analysis indicates that decision making is actually relatively centralised with the Environment Agency (EA) and Natural England (NE) holding significant decision making influence as a result of their regulatory and advisory roles. Civil society actors in particular have relatively limited influence on water quality decision making. Notably, the formalised mechanism for collaborative management in the network, the Test & Itchen Catchment Partnership, is not perceived to have significant influence. These findings indicate that governance is predominantly bureaucratic (Pahl-Wostl, 2019), characterised as hierarchical, state-led and rule driven, consistent with the findings of Watson, Deeming and Treffny, (2009). The lack of formal authority devolved to local actors in the network limits their ability to affect change.

Despite being central in the network there is an evident lack of trust in the EA and NE due to a perceived inability of these actors to carry out their responsibilities adequately, a failure often attributed by interviewees to underfunding from central government. This finding contrasts with Coleman's (1990) assertion that many connections between actors foster trust, as the network is relatively densely connected for a network of its size (Stein, Ernstson and Barron, 2011; Fliervoet et al., 2015). Additionally, the motives and transparency of private actors were also questioned, leading to degree of corporate distrust. Much of the distrust of state and private actors was 'rational' – based on perceptions of past actions (Coleman and Stern, 2017). Flows of pressure around the network were primarily directed at these state and private actors, often as efforts to hold these actors to account, for example ENGOs threatening judicial reviews, or to mitigate a perceived lack of transparency, for example citizens instigating freedom of information requests. As trust is an essential factor for successful collaboration and ACM, environmental regulators and private actors need to repair trust (Olsson, Folke and Berkes, 2004; Ansell and Gash, 2008). Trust enables actors to better understand the needs and perspectives of others and contributes towards a 'shared motivation' between actors, which facilitates better collaborative processes and ultimately actions (Emerson, Nabatchi and Balogh, 2012). Identifying tangible actions to facilitate trust building was a challenge for participants. However, there are principles and actions that can underpin repair: honesty, making changes to address problems, regular quality communication, ensuring transparent and legitimate procedures, and time (Coleman and Stern, 2017; Cvitanovic et al., 2021). Once established, trust can help to sustain engagement between actors to address an issue such as water quality (Emerson, Nabatchi and Balogh., 2012).

Features important for adaptive co-management (knowledge generation, communication, and collaboration) were identified in the governance network. Local actors were committed to underpinning decision making with scientific knowledge and generating new knowledge and understanding about water quality and chalk streams. Direct observations of the rivers were often the catalyst for research projects and ENGOs, academic institutions, and local citizens collaborated to carry out and fund the research. However, there is a disconnect as the outcomes of the studies do not often find their way into management and policy decision making, particularly at a national scale. The low influence value attributed to research and academia reflects this disconnect. Completing the learning cycle so that new knowledge can easily be incorporated into decision making is an important part of improving the adaptive capacity of the network. This requires better connections between the EA and NE, at a national level, who are primarily responsible for decision making, and local actors such as universities. Local actors have also established spaces for communication and collaboration in the form of stakeholder forums. The forums provide opportunities for ‘principled engagement’, repeated high-quality interactions that help to foster trust, understand and commitment between actors (Ansell and Gash, 2008; Emerson, Nabatchi and Balogh, 2012). Workshop participants recognised the importance of improving representation at these meetings to ensure a full range of knowledge and perspectives to facilitate considered decision making. Additionally, the forums may provide a space for more targeted interventions to repair trust in the network and a structure on which to build further collaborative opportunities, particularly if local actors are given more authority to effect change.

Both the results of the interviews and workshop highlight the need to improve connections with Ofwat and the general public to facilitate communication and collaboration. Ofwat are primarily only connected to private water companies in our analysis, which may limit and bias the information that they receive. Forging connections from civil society actors to Ofwat may help influence decision making. Through activism and public will, the shared recognition of a problem, the general public has the potential to influence decision making (Leiserowitz, 2019). Improving connections with the general public to improve understanding and engagement with the issue of water quality is therefore important.

Further attention should also be given to the integration of land and water governance. Land-use decision makers, in particular local government and developers, are not central in the water quality network and have little influence, suggesting weak integration of land-use decision making with water quality governance. This limited integration may be exacerbated by a spatial mismatch between primarily national scale decision making for water (via central government) and local level land-use decision making (Watson, Deeming and Treffny, 2009). As catchment land-use is such a significant driver of water quality, better integration is needed to improve governance outcomes.

5.5.1 Limitations, reflections and further work

Participants strongly engaged with the Net-Map process and our follow-up survey indicated that participants found the strengths to be that it offered a new perspective on the issue of water quality, and that the collective discussion provided an opportunity to understand more about the concerns of others, and to develop shared actions. The visual map served as an effective boundary object (Hauck *et al*., 2015), creating a space for social learning and co-production of knowledge. The atmosphere during the interviews and the workshop was very positive. Both the researchers and participants reflected that the follow-on workshop would have benefitted from being longer to allow time to consider how to implement the identified interventions. However, as the workshop was held online we recognise that a longer session may have resulted in fatigue.

As the Net-Map process is based on the perceptions of participants it is important that the selection process collects a broad range of perspectives. We did not experience any significant challenges in recruiting interviewees for the first stage of the process and we achieved broad representation. However, representation at the follow-on workshop was more limited; fewer private sector actors were present at the workshop and this may have created some bias in the results e.g. not eliciting their perspectives on the value of stakeholder meetings. While it would have been preferable to broaden the perspectives of the participants at the workshop we also needed to be pragmatic and work with those who were able to take part at that stage.

The research plans were impacted by the COVID-19 pandemic and the restrictions implemented by the UK government, resulting in four of the interviews and the workshop being conducted online, rather than in person. However, other than influencing the planned duration of the workshop, as we felt that an online workshop needed to be shorter, we do not believe that these changes will have substantially affected the results of our research and they may have made it easier for some participants to have been involved as it reduced the time and travel required.

The network data collected are a snapshot, a static view of a dynamic network. Further research to understand how the anticipated policy changes might impact water quality governance, for example the implications of the Environment Act (2021) and environmental land management schemes (ELMs) (Defra, 2023), would be useful to maximise the potential beneficial impact from these changes. Additionally, further understanding of the longer term resilience of the network, particularly how it is impacted by the removal of key individuals. As an important action from our work is to develop trust in the network, more research to understand how to facilitate this in a complex governance network would be valuable. Longer term engagement with the stakeholders in this network is also desirable to make the most of the research partnership and maximise the impact of the findings.

5.6 Conclusions

Chalk streams are priority habitats in England and important global ecosystems. Using participatory SNA in the River Test & River Itchen catchments has shown some of the complexity that underpins water quality governance. An ‘optimal’ network structure cannot be determined and the limitations of SNA in assessing governance are recognised. However, the findings provide a visualisation of the current formal and informal arrangements and suggest areas where interventions might improve outcomes for water quality, based on the theory behind integrated and adaptive governance, and SNA. The impact on water quality from changing governance arrangements is not necessarily direct but can change the processes that underpin decision making. Improved decision making in turn enhances the outcomes for water quality (Sandström and Carlsson, 2008b).

Governance for the River Test and River Itchen is relatively hierarchical with central government actors, in particular the Environment Agency and Natural England, holding most influence. Local actors carry out important roles but ultimately have a limited role in decision making. While vehicles for collaboration at a catchment scale have been created by central government, they do not have significant decision making authority. Devolving more formal authority to local actors and giving them opportunities to directly participate in decision making are required to shift towards polycentric governance arrangements. Further attention could be given to the existing informal networks in the catchment and how they can be mobilised more effectively to help guide water quality decision making. Alongside changes to the distribution of power in the network, trust needs to be repaired, particularly by state and private actors, such as the Environment Agency and water industry. This finding is particularly important as trust is a key factor shaping the effectiveness of the collaborative processes that underpin adaptive governance. The decision to conduct this research in a way that facilitates social learning and relationship building makes a small contribution to improving trust in the network and demonstrates part of the value of transdisciplinary research.

The findings in this study have implications for UK policy surrounding water quality, particularly for chalk streams, and could be integrated into current strategies, such as the Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021). Although this study focuses on water quality, as oppose to water quantity or habitat quality, many of the governance challenges are likely to be similar as many of the actors in the networks likely overlap. Without addressing some of the governance issues found in our study, such as the lack of trust in environmental regulators, there is a risk that other interventions to improve water quality may fail. Additionally, the findings are locally relevant and have been used as a catalyst for self-reflection about roles, influence and effectiveness by some actors in the network.

While the recommendations we make are context specific, this study demonstrates how place-based, participatory SNA can be used as a tool to recognise structural problems in a governance network and identify opportunities to improve outcomes. In addition, the approach can be applied to other catchments and other important habitats. Combining quantitative network data and qualitative narrative data enabled deeper insights into the relationships and roles of actors. While creating opportunities for collective analysis by participants enabled social learning and further refined our understanding of the issues and potential remedies.

Chapter 6 Overall discussion and conclusions

Chalk streams are unique and globally important freshwater ecosystems. The chemical and physical characteristics of chalk streams, nutrient rich and alkaline water, with stable temperature and limited hydraulic energy, support high biological diversity, including many rare or endangered species. However, there has been a significant decline in the ecological health of chalk streams that threatens their biodiversity (Dolman, Vowles and Kemp, 2024). The aim of my thesis was to develop a holistic understanding of the relationships between chalk streams and people to expand the evidence base for decision making and ultimately lead to the sustainable management of these systems. The ecosystem services concept provided a lens through which to examine the relationships between chalk streams and humans. I applied this concept to two archetypal chalk stream catchments, the River Test and the River Itchen, Hampshire, UK. I used the concept of ecosystem services to articulate the value of chalk streams to society, and to explore the governance of ecosystem services as a route to improve the quality of ecosystem service provision.

In Chapter 3, the results of a freelisting questionnaire completed by stakeholders, established that there is a wide range of provisioning, regulating, and cultural ecosystem services provided by the River Test and River Itchen, with cultural ecosystem services being particularly important to stakeholders. However, the provision of ecosystem services is threatened by many drivers of change. Using the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES) framework to categorise these drivers into 'indirect', 'indirect to direct', and 'direct' drivers highlighted the connections between the drivers of change. Climate change and pollution were identified as particularly important direct drivers of change. However, indirect drivers of change, particularly population growth, governance and policy, and societal values and attitudes, underpin and propel the direct drivers.

In Chapter 4, I developed a spatially explicit understanding of the value of ecosystem services using a public participatory geographical information system (PPGIS) survey. I used the results from Chapter 3 to inform the ecosystem service values included in the survey. Three distinct bundles of ecosystem services were identified: 'ecosystem service coldspots', 'multifunctional landscapes' and 'cultural landscape hotspots'. Access and landcover type influence the distribution of these bundles.

Based on the finding in Chapter 3 that governance is a key driver of change, I described and analysed the social network for governance in Chapter 5 to understand how it could be altered to improve water quality outcomes. Water quality is a key ecosystem function underpinning the provision of ecosystem services, and pollution was identified as a key driver of change in Chapter 3. I identified a mixture of state, civil society, and private actors involved in the governance of water quality. Despite appearing to be well connected, decision making was very centralised, and trust in the main state actors and private actors in the network was perceived to be low, undermining collaboration and co-ordinating action.

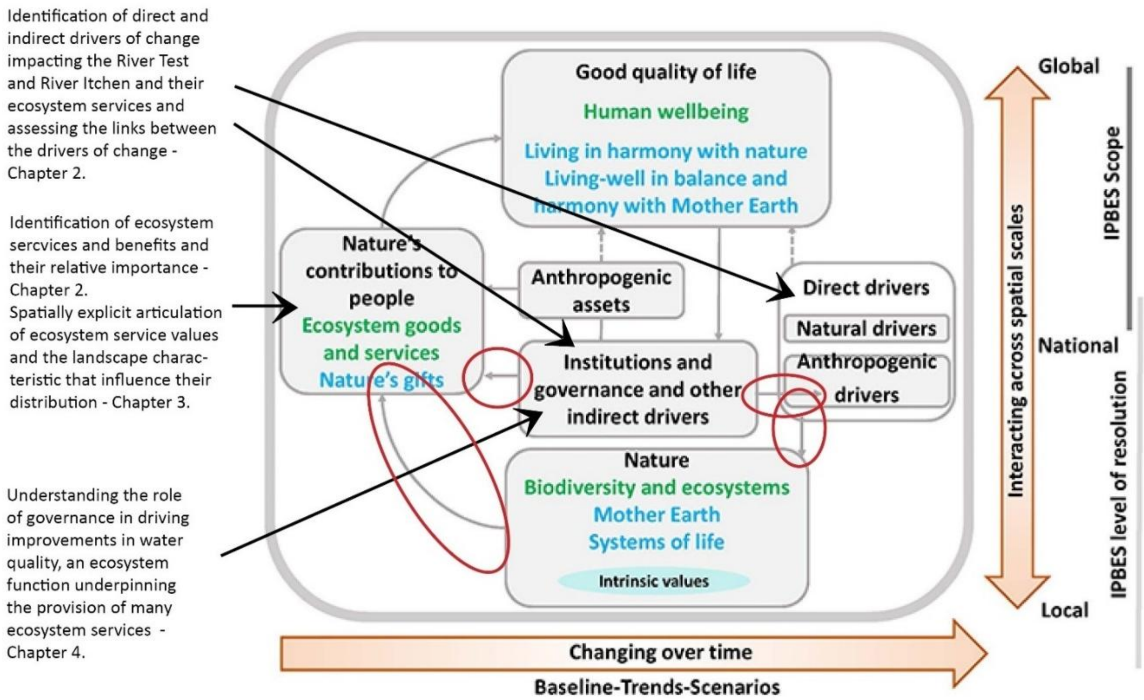


Figure 6.1 The IPBES framework (Díaz et al., 2015) with the chapters of the thesis mapped onto the components and connections within the framework. The red circles indicate connections that are considered in the thesis.

6.1 Novelty and significance of my research

This thesis is centred around the ecosystem services concept, specifically the IPBES framework (Díaz et al., 2015). The ecosystem service concept is a holistic and versatile tool to structure knowledge about how people and nature are connected, both how nature underpins human wellbeing and how human activities impact nature (as demonstrated by the ecosystem service analyses described in Chapter 3 and Chapter 4). The chapters focus on different components and connections within the IPBES framework, as detailed in Figure 6.1. Together, the chapters address the overarching aim of my thesis, to develop a holistic understanding of the relationships between people and chalk streams.

Combined, Chapters 3 and 4 establish a spatially explicit socio-cultural valuation of the River Test and River Itchen. To my knowledge, this is the first study to explicitly apply a socio-cultural ecosystem services approach to chalk streams at a catchment scale. The focal chalk streams provide a wide range of ecosystem services but are particularly valued by stakeholders for their cultural services. However, the relative importance of ecosystem services differed between stakeholder groups, demonstrating the need to disaggregate findings by beneficiary. There are distinct spatial patterns of ecosystem service bundles throughout the river corridors.

The ecological condition of the River Test and River Itchen, and the ecosystem services they provide, are threatened by a multitude of direct and indirect drivers (as shown in Chapter 3). Direct drivers of change identified were climate change, diffuse and point-source pollution, hydrological change, and the non-native invasive species such as the signal crayfish (*Pacifastacus leniusculus)*. The direct drivers are the result of a series of human activities to satisfy needs and aspirations, for example, food production in the form of watercress growing and other agriculture, infrastructure and housing development, and water abstraction for drinking and agriculture. Notably there are many sources of pollution in the focal catchments, including from agriculture, sewage discharge, pharmaceuticals, and watercress growing. How these different human needs and aspirations are met is important and key to whether human activities are carried out with more or less impact on chalk streams, i.e., more or less sustainably. Indirect drivers propel and define how society meets these different human needs and aspirations. The key indirect drivers in the focal catchments were population growth, societal values and attitudes, and governance and policy.

While many of the drivers of change identified are not necessarily surprising and reflect broad patterns of threat to freshwater systems in general (Davis et al., 2015; Reid et al., 2018; Vörösmarty et al., 2010), the holistic overview of drivers for the River Test and River Itchen and the analysis of the connections between the drivers is novel. Understanding the context of a specific catchment is crucial as the breadth and relative importance of drivers of change differ between catchments (Itzkin et al., 2021). For example, as demonstrated in Chapter 3, the groundwater driven baseflow of the rivers can be an important pathway for the transmission of pollutants (Robinson et al., 2024) and one that introduces a significant lag time between a pollutant being discharged, accumulating in the chalk aquifer, and then entering a chalk stream. As chalk streams are relatively low energy freshwater systems (Kemp et al., 2017), the dispersal of pollutants can be slow and the effects of the pollutants therefore more damaging. So, although the drivers of change are common to many freshwater systems, the specific set of drivers that affect a catchment, how they impact the provision of ecosystem services, and the implication for society are context-dependent. By understanding the connections between drivers, particularly between the indirect drivers and direct drivers, it allows the root causes of river degradation to be addressed or appropriate mitigating actions to be put in place. For example, societal values towards nature drive the social paradigms that frame environmental policy and the importance that society places on the environment relative to other concerns (Bogert et al., 2022). In turn environmental policy affects the way that human activities such as agriculture are undertaken. For example, the extent to which farming practice is expected to support nature through actions, such as creating riparian buffer strips to mitigate the impact of pollution from agriculture on chalk streams.

Structuring the drivers using the IPBES framework provided a means through which to understand the connections and causality between drivers, as shown in Chapter 3. There are many connections between the drivers of change, but of interest is a feedback loop between outdoor recreation and societal values and attitudes. Developing a connection to chalk streams through outdoor recreation was recognised by stakeholders as an important way of positively influencing societal values and attitudes of care and protection towards chalk streams (Lumber, Richardson and Sheffield, 2017; Richardson et al., 2020). This finding is supported by the results of the spatial mapping in Chapter 4. The co-occurrence of recreation, biodiversity appreciation, and health and therapy values in the ‘cultural landscape’ bundle reflect the role of outdoor recreation as an intermediate between the rivers and health and wellbeing. Through outdoor recreational activities, such as walking by the rivers, people have the opportunity to observe and experience the biodiversity supported by chalk streams and the aesthetics of the landscape. In turn, this can enhance an individual’s wellbeing, their sense of connection towards chalk streams, and their pro-conservation values. As physical access to the river corridors significantly influenced the distribution of the ‘cultural landscapes’ bundle, expanding access to the rivers could increase the provision of cultural services, including recreation, and enhance the connection between people and chalk streams. Increasing the provision of opportunities for recreation is also important considering the anticipated population growth within the catchments.

In Chapter 3 some stakeholders raised the issue of trade-offs between the benefits of expanding public access to chalk streams and the potential harm to these sensitive habitats. While the trade-off is recognised in the literature (e.g. Komossa, Wartmann and Verburg, 2021), recreation was not considered to be one of the most significant drivers of degradation of chalk streams by stakeholders for the River Test and River Itchen. Additionally, there are actions that can be taken to limit the negative effects of recreation, for example zoning off areas of the rivers at particularly sensitive times of the year (e.g. during salmon spawning), providing infrastructure such as paths and bins to guide people around sites and limit littering, and educating people about the Countryside Code and responsible dog ownership (British Ecological Society, 2023). Expanding access to the River Test and River Itchen along some stretches of the river, while adopting some of the actions that can limit the negative impacts to the rivers, could yield benefits to wellbeing and pro-conservation values and attitudes. Areas of the river near to towns, which are suitable for public footpaths, would be most appropriate for access expansion. The approach taken in Winnall Moors Nature Reserve, on the River Itchen in Winchester (Hampshire and Isle of Wight Wildlife Trust, n.d.), is an example of how public access can be combined with effective nature conservation. The reserve uses board walks to weave public footpaths through the reed beds, wetlands and streams and employs information boards to educate people about the wildlife and responsible use of the reserve. However, dog walking and swimming are not permitted at the reserve, demonstrating that some restrictions to the type of recreation may need to be in place in sensitive habitats. Although, the results in Chapter 4 demonstrate that fishing and walking frequently take place in different areas of the river, there can be conflict between different recreational users e.g. anglers, swimmers and walkers, as their activities can interfere, or are perceived to interfere, with each other (Dudley, 2017; Brockington et al., 2023). Expanding public access would need to be mindful of the different types of recreational use, and how to manage the needs of different recreational users, alongside minimising impacts on the chalk streams.

Governance was identified as an important indirect driver of change in Chapter 3 and so in Chapter 5, chalk stream water quality governance was examined using social network analysis, the first application of this method to chalk stream governance. Adaptive and integrated governance are two alternative approaches to water governance that have emerged in response to the complexity and uncertainty inherent in freshwater systems. By describing and analysing the social network for water quality, with reference to the characteristics of adaptive and integrated governance, such as polycentricity, adaptive capacity, trust, and collaboration (Bodin, Crona and Ernstson., 2006), it was established that the current governance structures could be improved to achieve better outcomes for chalk streams. Specific recommendations included devolving power to civil society actors, fostering trust between actors to facilitate collaboration, and improving connections to important but peripheral actors in the network.

Civil society actors adopted many important roles within the network, facilitating collaboration, generating new knowledge, and building trust. These roles address important components of adaptive and integrated governance, but often the actors who have taken on these roles have limited influence on water quality decision making. For example, the Test & Itchen Catchment Partnership, the formal mechanism for collaborative management, was not perceived to have a significant influence. Since I conducted the study, some of the civil society actors, such as Vitacress Conservation Trust (VCT), are no longer present in the network, partly due to funding pressures. The loss of influential civil society actors weakens governance structures as civil society actors such as VCT typically bring local, on-the-ground knowledge and experience that diversifies the knowledge informing decision making. Without long-term support, funding, and formal decision-making power for civil society actors, governance will continue to be primarily centralised and hierarchical and less collaborative.

Enhancing the adaptive capacity of the governance network was also a recommendation in Chapter 5. Ensuring that new knowledge can inform and be incorporated into decision making is a key part of increasing adaptive capacity (Pahl-Wostl, 2009). The ecosystem services concept can provide a foundation for adaptive governance, providing a way of monitoring changes, generating new knowledge, and as a means of communicating information to stakeholders (Schultz et al., 2015). So, the findings from this thesis themselves expand the evidence base available for chalk stream adaptive governance. Additionally, the involvement of stakeholders, including those who hold decision-making power, such as the Environment Agency, in the participatory research processes in this thesis is one way of directly informing decision making. By participating in my research and engaging with other stakeholders, participants gained new knowledge and learned more about the concerns of others (as evidenced in Chapters 3 and 5), key elements of adaptive governance. Continued opportunities to co-create knowledge and bring together diverse stakeholder perspectives would enhance social learning and governance processes for the focal catchments.

6.1.1 Participatory research approaches

The ecosystem services concept has been recognised as both a 'bridging' concept (linking different disciplines and types of knowledge) and pedagogic tool (Malmborg, 2021) that can support the coproduction of knowledge with stakeholders. The findings in this thesis and the results of the participant surveys in Chapters 3 and 5, corroborate this assertion. Knowledge co-production can contribute significantly to addressing complex sustainability challenges, both by generating more credible, salient, and legitimate knowledge (Tengö et al., 2014), and by providing a means for deliberation and dialogue about contested issues where stakeholders have different perspectives and values (Tengö et al., 2017; Norström et al., 2020).

Throughout the thesis, I used participatory processes and methods to incorporate stakeholder perspectives into the research and co-produce knowledge. The participatory process developed in Chapter 3 represents a novel attempt to develop an understanding of ecosystem services and their threats with stakeholders. In Chapter 4, I adapted previous PPGIS methods to the context of the River Test and River Itchen, and specifically included a method to measure and report on the accuracy and reliability of the survey data, which is not commonly found in PPGIS studies. In Chapter 5, I expanded upon the Net-Map approach (Schiffer and Hauck, 2010) and included collective analysis with participants in the form of a workshop, to enhance the opportunities for mutual learning, improve the quality of the analysis, and increase the legitimacy of the findings. I also used the perspectives of stakeholders to develop the overall research process, using the results reported in Chapter 3 to inform the development of the methods and ultimate research findings reported in Chapters 4 and 5. Survey feedback from participants involved in Chapters 3 and 5 indicate that the participatory processes helped them gain new knowledge (particularly a more holistic understanding of the issues affecting chalk streams), appreciate the concerns of other stakeholders, and develop shared actions.

As discussed in section 2.1, building trusted relationships is an important component of effective participatory research (Reed et al., 2009). As most of my PhD was conducted on a part-time basis, I have had a longer time period to develop working relationships with stakeholders and foster trust. I believe that the trusted relationships I developed with many of the stakeholders are, in part, responsible for the high levels of engagement with my research.

Longer term funding for research projects where academic researchers collaborate with stakeholders could help to develop trust and lead to better research outputs. Although this research project is drawing to a close, maintaining trust in academic research and demonstrating the value of participatory processes is important. Disseminating the findings of co-produced research is a crucial part of demonstrating the value of participatory research, maintaining trust with participants, and is an ethical responsibility of researchers (Blackstock, Kelly and Horsey, 2007; Chen et al., 2010). Throughout my PhD I have presented the results of my research to stakeholders, inputted to consultations, and published the findings in both academic journals (Ball et al., 2022) and relevant industry magazines (Ball, Holland and Peh, 2023). However, I recognise that there is more I can do to disseminate my findings to the people involved for example, by creating audience appropriate, actionable summaries of my findings, presenting at future Test and Itchen Catchment Partnership meetings, and by creating a practical toolkit so that the research methods can be implemented by stakeholders in the Test and Itchen catchments, and in other river catchments.

6.2 Recommendations for decision making

The findings in this thesis expand the evidence base for chalk stream decision makers. In this section, I set out the recommendations that I contributed to the consultation for the Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021). Following this I detail other national scale and then catchment scale recommendations.

After the publication of the draft Chalk Streams Restoration Strategy (2021), I inputted the following recommendations into the consultation for developing the final strategy.

1. The process for establishing the strategy should adopt adaptive management practices to ensure continual learning opportunities that can feed into the strategy and implementation plan. The strategy and implementation plan should be considered a 'live' document. The learning process should be transparent and involve stakeholders.
2. A clear stakeholder engagement strategy and process should be developed, ensuring that all stakeholders are identified including the general public and local communities to broaden the sources of knowledge that feed into this process. Consideration should also be given to the extent of stakeholder engagement and the process of engagement. For

example, stakeholders could co-produce the problem definition, strategy, and solutions, rather than just being consulted.

3. The strategy should apply an ecosystem services lens to avoid any unintended consequences when implementing this strategy and to help maximise the benefits of the project for people and nature. While water quality, water quantity and physical habitat underpin the provision of many ecosystem services, a focus on just biophysical characteristics can fail to spot trade-offs between the ecosystem services provided by chalk streams. For example, river restoration and conservation actions could have a trade-off with recreational activities.

In addition, there are other recommendations for national scale decision makers. My thesis demonstrates the value of using the IPBES conceptual framework and participatory processes to help make sense of the inherent complexity of socio-ecological systems. Although the IPBES framework represents a simplification of the complexity and connections between ecological and social systems, it provides a guide to the key components and relationships in the system. By considering several components with the IPBES framework (drivers of change, ecosystem services, and governance) I have generated a big-picture, holistic understanding of the River Test and River Itchen. Integrating diverse knowledge sources through participatory processes has enriched the findings of this research and provided benefits for participants. Although my work focuses on specific case study catchments, I recommend that the approach I have taken be applied to other freshwater systems and other areas of importance for biodiversity and people.

My findings suggest several recommendations for decision makers operating at a catchment or local scale. I recommend that the findings from my socio-cultural valuation be combined with existing biophysical data to provide a more comprehensive understanding of the relationships between people and chalk streams and that the spatially explicit assessment of ecosystem services developed in Chapter 3 is incorporated into local spatial planning. For example, the local plans developed by the each local planning authority that cover part of the catchment area as part of the analysis of local community priorities, and Local Nature Recovery Strategies (LNRS) to help establish where nature restoration actions can be carried out to best effect. Additionally, I recommend developing a series of indicators for the provision of key ecosystem services to provide additional metrics for monitoring the health of chalk streams alongside conventional measures such as biodiversity and water quality metrics. This would enable decision makers to evaluate the impacts of actions on ecosystem service provision and establish any trade-offs. Finally, as access influences the provision of cultural services, I recommend that access to the River Test and River Itchen is reviewed and trials for expanded public access take place. Increasing access could improve wellbeing and foster connection with the rivers. Implementing these recommendations would help to move more toward more sustainable management of the River Test and River Itchen.

6.2.1 Application of the research to river restoration process and implementation in other catchments

This section outlines how the research methods, and the outputs they generate, adopted in thesis can be adapted to facilitate river restoration processes. While the methods could also be adapted to inform other sustainable management approaches, I have focused on the river restoration due to the interest in the relatively new River Restoration Framework (RRF) (River Restoration Centre, 2021; Robins et al., 2024). The RRF (Figure 6.2) establishes 4 phases to river restoration 1) Understanding the catchment, 2) Prioritise and set objectives 3) Design and delivery and 4) Monitoring and appraisal. While there is guidance on how to undertake these phases, there is limited guidance on how to operationalise the participatory decision-making processes that the RRF advocates for. Integrating the research methods used in this thesis as part of the RRF would provide opportunities to bring stakeholder perspectives into the river restoration decision-making process and would deliver additional information and insights to deepen the social-ecological understanding of the catchment (enhancing the RRF phase ‘Understanding the catchment’) (Figure 6.2). The relevance of the thesis research methods are as follows:

1. Identifying and mapping the stakeholders who influence, or are impacted by, river restoration is an important initial step to ensure that there is a comprehensive understanding of all stakeholder groups, including potentially marginalised groups. This analysis would provide a foundation from which to build an understanding of the different perspectives on the outcomes for river restoration. The approach used in Chapter 3, using a combination of existing stakeholder networks, desk-based research, and interviews with stakeholders, allows rapid stakeholder mapping.

2. Identifying ecosystem services provided by the river and assessing the relative importance of ecosystem services to different stakeholder groups would facilitate analysis of who could

benefit or lose out from different river restoration options, particularly when combined with spatial mapping of ecosystem services (see bullet point 3). The freelisting method in Chapter 3 demonstrates a participatory approach to identifying and prioritising ecosystem services.

3. Participatory ecosystem services mapping, particularly when analysed alongside biophysical maps, would help to identify areas where ecosystem service provision could be enhanced through river restoration, where ecosystem service provision might hinder river restoration, or where river restoration may face opposition from stakeholders. The online participatory mapping approach in Chapter 4 demonstrates how spatial maps can identify hotspots of ecosystem service provision and illuminate the factors driving ecosystem service provision.

4. Enhancing the understanding of the indirect drivers of change and the causal pathways through to the impacts on rivers, develops an understanding of the root causes of pressures and opportunities to drive ‘deeper’ transformational change (Gittins, Picken and Dajka, 2025). As shown in Chapter 3, stakeholder knowledge can be elicited to understand the catchment scale drivers of change. This analysis could complement the desk-based research and field surveys, already advocated for in the River Restoration Framework.

5. Understanding which actors are involved in the governance of a river, who has influence over particular outcomes e.g. water quality, and governance structures, as shown in Chapter 5, can deepen understanding of what is considered to be a key indirect driver of change (Gittins, Picken and Dajka, 2025). Participatory social network analysis was used in Chapter 5 to identify the actors involved in governance and their relative influence, understand the governance network structure, and develop recommendations to improve the governance outcomes. While the study in this thesis focused on the governance of water quality, other aspects of governance could be explored using this approach for example, examining the governance of water flow in the river or groundwater levels, or the governance of river restoration.

Further information about the methods can be found in Table 6.1.

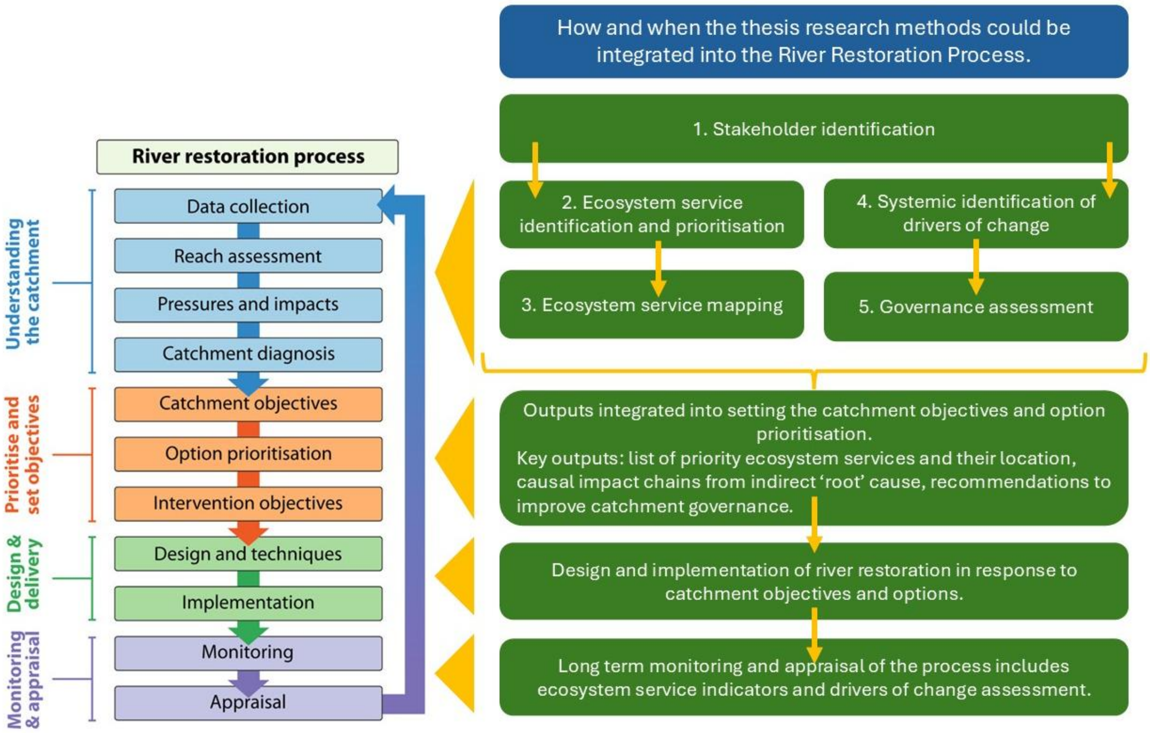


Figure 6.2 The River Restoration Framework (River Restoration Centre, 2021; Robins et al., 2024) depicting how and when the research methods used in the thesis could be integrated into the river restoration process.

Table 6.1 Toolkit of activities that can enhance the understanding of a catchment to facilitate sustainable management and river restoration

Activity (in order of execution)	**Example of a participatory approach**	**Methodological considerations**	**Practical considerations**
1. Stakeholder identification	Combining evidence from existing stakeholder networks, desk-based research and snowball sampled interviews.	• Explicitly consider potentially marginalised stakeholder groups.	• Stakeholder lists may be held by organisations such as the catchment partnership and could form the basis for stakeholder identification.
2. Ecosystem service identification and prioritisation	Freelisting questionnaire	• The sampling approach should ensure that a range of stakeholder views are elicited.	• In person sampling approaches can require more resource but may allow
3. Spatial mapping of ecosystem services	Online participatory mapping survey	• The outputs from activity 2 'Identifying ecosystem services' should inform the selection of ecosystem services for mapping.	• The time and money available may impact the specific participatory mapping approach taken e.g. is there funding for an online mapping platform.
4. Systemic identification of indirect and direct drivers of change	Stakeholder workshops using nominal group technique.	• Consider the extent and depth of secondary data available • See section 6.2.1.1 for more details	• Stakeholder workshops require time and resources to design and implement • See section 6.2.1.1 for more details
5. Governance assessment	Participatory social network analysis e.g. Net-map (Schiffer and Hauck, 2010).	• Consider whether governance has been identified as an important indirect driver of change in activity 4 'Systemic identification of indirect and direct drivers of change'.	• The time and resources available may influence the approach; individual interviews with stakeholders take time to compile whereas a single collective workshop may be more time efficient.

6.2.1.1 Specific recommendations for workshop design and facilitation

There are several recommendations, ascertained during the design and facilitation of the stakeholder workshops in Chapter 3, for running smooth and effective stakeholder workshops:

Workshop design

1. Ensure that there are an agreed set of objectives for the workshop before designing the workshop process, to ensure that there is a clear focus.

2. Design a mix of activities that maintain participants energy levels throughout the workshop. For example, include activities where participants are asked to stand or move around the room.

3. Many people like to have time to individually consider a question before discussing it with a group, so allow thinking time. Capturing this part of the process for example, on sticky notes, also allows all participant views to be captured.

4. Pre-assign a participants to breakout groups so that the groups contain a diverse mix of stakeholder groups and to ensure that participants do not just join a group with people they already know.

5. Pilot the workshop to ensure that the workshop questions and instructions are clear, the outputs of the workshop address the workshop objectives, and to highlight any logistical complexity.

Workshop facilitation

6. Ensure that participants have time at the beginning of the workshop to introduce themselves to the group so that everyone is aware of who is in the room with them.

7. Set ground rules and expectations for the workshop at the start. For example, that all viewpoints are welcome, and that differences of opinion should be discussed respectfully.

8. An icebreaker activity can be helpful to ease participants into discussion and to energise participants. For example, ask participants to find a person that they don't already know and share with each other their favourite breakfast food, or part of a river.

9. Have strategies in place to manage the power dynamics between participants. For example, inviting comments from participants that have not yet spoken.

10. If possible, have a facilitator for each break-out group to guide the activity and manage any power dynamics within the group.

6.3 Suggestions for improvement, and future directions

Bringing together diverse stakeholder perspectives is a key part of participatory studies. While engagement with my research was high, there was limited participation from representatives of some private sector organisations, i.e. from the water industry and fish farms. It is possible that these stakeholders were unwilling to engage in group workshops as they are often the target of criticism and perceived as causes of degradation for the rivers by other stakeholders (as shown in Chapter 5). Adapting the process and using alternative means to elicit knowledge and involve these stakeholders, for example by using individual interviews rather than group workshops, might ensure wider engagement with the research.

This thesis did not aim to explore the biophysical links between the chalk streams and the provision of ecosystem services. However, having demonstrated the importance of cultural services, understanding how the biophysical characteristics of chalk streams (such as water clarity, levels of biodiversity, riparian vegetation height) underpin the delivery of these ecosystem services would be of interest (Jones et al., 2022). This information could inform chalk stream management to enhance the provision of cultural services or to establish if there are synergies and trade-offs between managing chalk streams for biodiversity and managing chalk streams for the provision of cultural ecosystem services. For example, raising water levels in the Somerset Levels and Moors wetland system in south-west England to increase habitat for wetland birdlife was found to have potential synergies with recreational activities, particularly bird-watching and angling (Acreman et al., 2011).

One of the key recommendations from the Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021) is to give statutory protection to all chalk streams. As the River Test and River Itchen have protected area status (both rivers are designated as Sites of Special Scientific Interest (SSSI) and the River Itchen is designated as a Special Area of Conservation (SAC)), assessing the extent to which these designations enhance or change the provision of ecosystem services by comparing the findings with assessments for non-designated chalk streams would be of benefit and could expand the evidence base for this recommendation.

Biodiversity Net Gain (BNG), an approach to development in England that mandates that developers must ensure that nature habitats are left in a better state than before any development (by delivering a biodiversity net gain of 10%), offers a potential mechanism to drive investment in river restoration. Further work to understand how BNG, and other green finance mechanisms, such as voluntary markets for nature restoration or mitigation banks (Lave, 2018) can impact the sustainable management of chalk rivers, would be valuable. For example, examining how the geomorphological features, biodiversity, and ecosystem services provided by chalk streams contribute to society, could provide a lens to facilitate more effective spatial targeting of development and investment in chalk stream restoration.

The analysis in Chapter 4 indicated that access to the rivers is partly determined by financial resources i.e. those who can afford it can access the rivers via private fisheries, which generates unequal access to ecosystem services. Further work to disaggregate the 'general public' stakeholder category could improve our understanding of who can and does access the supply of ecosystem services and highlight issues of distributive justice (Loos et al., 2022). Additionally, exploring the values that underpin different stakeholder attitudes and perspectives could help decision makers understand other perspectives more clearly and navigate conflict.

Finally, the ecosystem services concept has limitations, perhaps most significantly the anthropocentric view and focus on instrumental values (Luck et al., 2012). Using the ecosystem services concept in combination with other perspectives of nature, for example, a biocentric lens, could facilitate the inclusion of intrinsic values of nature and may yield more nuanced decision making. A 'more than human' approach (acknowledging the presence, rights and ethics of non-human entities) is one example of how the rights and perspectives of 'nature' can be incorporated into sustainability assessments and planning (Fieuw, Foth and Caldwell, 2022).

6.4 Conclusions

Chalk streams are globally important freshwater ecosystems, often described as 'England's rainforests' due to their concentrated geographic distribution (approximately 80% of chalk streams are located in England) and the high biological diversity that they support. In light of the continued ecological decline of many chalk streams, my research explored how the ecosystem services concept can be used to understand the relationships between humans and two archetypal chalk streams, the River Test and River Itchen. By applying the ecosystem services concept, I have produced a spatially explicit understanding of the value that these rivers provide to society and revealed the social network that exists between actors that mediate both the supply and quality of ecosystem services, focusing on water quality.

My thesis demonstrates the value of recognising and embracing the complexity of socio-ecological systems. By using a broad ecosystem services framework to guide this research and by considering the connections between several of the key components within the framework (drivers of change, ecosystem services, and governance) I have generated a big-picture, holistic understanding of the relationships between chalk streams and people. Additionally, by integrating knowledge from a range of stakeholders I have articulated some of the complexity of chalk stream socio-ecological systems. In doing so I have expanded the knowledge base for chalk streams and generated recommendations for decision makers that can ultimately lead to more sustainable management of these rivers.

Appendix A Supplementary information for Chapter 2

A.1 Freelisting survey guide

Would you mind answering a short survey about the River Itchen? I'm interested in the ways that people benefit and interact with the River Itchen. The benefits that society obtains from rivers are wide and varied. This research aims to identify the different benefits or services that the River Itchen or River Test provides, and their relative importance.

Q1. Thinking about the River Itchen and /or River Test, could you list and describe all the ways that you individually benefit from the river.

Q2. Which of the benefits that you have just listed do you consider to be the most important to you individually? Could you rank the top five benefits by writing 1 to 5 (where 1 is the most important) in the second column of the table.

A.2 Workshop guides

A.2.1 Workshop 1

Thank you for participating in this workshop.

We'll be asking you to do a variety of activities designed to help us understand more about the River Test and River Itchen and the drivers of change affecting them. Some of these activities will be for you to be complete individually and some as part of a group.

Firstly, we'd appreciate it if you could fill in the 'Questions about you' on page 3 of your booklet. These questions help us to evaluate who is represented at this workshop and the implications for our findings.

Part 1. Individual activity

We'd like you to list and describe the activities or drivers that you think impact the River Itchen and/or River Test now or over the next 10 years. We're looking for anything that you think will bring about change - it could be something environmental, economic, political, social, or technological.

We would like you to consider the likelihood of the change occurring. How likely is it to happen? Please score each driver of change you have listed from 1 to 3, where:

1 - Unlikely to happen

2 - Somewhat likely to happen

3 - Very likely to happen / happening now

We would like you to consider the impact of the change occurring. Please score each driver of change you have listed from 1 to 3, where:

1 - Low impact

2 - Moderate impact

3 - High impact

Part 2. Group exercise

Q1. In your groups we'd like you to come to a consensus on the five most important drivers of change.

Q2. We would now like you to consider how each of the drivers of change you have just identified might impact the ecosystem services written along the top of table 3.

We'd like you to write a short explanation in the box detailing why you think the ecosystem services will change in this way and who you think will be affected by the change.

Wrap up

Thank you for your time today. Tea and coffee should be available outside. If you have any other comments or questions please feel free to come and talk to one of us. Thank you again for your time and insight today.

A.2.2 Workshop 2

Welcome to this afternoon's chalk stream workshop.

Firstly, we'd appreciate it if you could fill in the 'Questions about you' on page 3 of your booklet. These questions help us to evaluate who is represented at this workshop and the implications for our findings.

At the first workshop we explored the different drivers of change impacting chalk streams. We asked the people who attended this workshop to consider which drivers were impacting chalks rivers now and would do in the future.

We have collated and structured the knowledge produced in this workshop into one overall diagram that we'd like to share with you this afternoon. This is work-in-progress based on information collected in the last workshop.

Part 1

Exercise 1. We'd like you to take some time to look through the diagram. I'd like you to take the printed copies and annotate it with your thoughts - anything you think is missing, anything that you're unclear about, anything you disagree with, or anything you like and agree with.

If you have any questions – please do ask.

Exercise 2 Now in pairs or 3's, depending on where you're sitting, I'd like you to discuss What knowledge gaps does the model highlight? What can we learn from this model?

Plenary discussion

What are your overall thoughts on the model? Has it made you rethink the issues impacting chalk streams?

If you have any other thoughts following our discussion please note them down on your model. I'll give you a few minutes to do this.

I'd like to start with you discussing in groups any potential responses and then we'll come together in 15 minutes to collate these as a group. At this point please do note down any ideas however difficult to implement or unconventional. You might find is useful to refer to the drivers of change model that we've just been looking at.

If you have time, you can begin to prioritise some of your ideas.

Would anyone like to share any of their ideas, or their reflections on this activity?

Thank you for your time today. Tea and coffee should be available outside. If you have any other comments or questions please feel free to come and talk to one of us. Thank you again for your time and insight today.

A.3 Participant feedback form

Thank you for taking part in the workshop. Below are a few questions that will help us to evaluate the process. The survey should take no more than 5 minutes to complete.

During the workshop,

1) To what extent did you learn something new? Circle the most appropriate answer

Not at all	Slight	Moderate	Great	N/a

2) To what extent did you learn about the concerns of others?

Not at all	Slight	Moderate	Great	N/a

3) To what extent did problems or solutions arise that you were not previously aware of?

Not at all	Slight	Moderate	Great	N/a

4) To what extent did participating help you to see areas in which you agree or disagree with others?

Not at all	Slight	Moderate	Great	N/a

5) To what extent did participating help you to perceive chalk streams and /or their issues in a different way?

Not at all	Slight	Moderate	Great	N/a

6) To what extent were actions identified to address problems or build on opportunities?

Not at all	Slight	Moderate	Great	N/a

Overall, did you find the exercises in the workshop useful?

What were the strengths of the process?

How could the process have been improved?

What would you like to see happen next?

Any other comments?

A.4 Smith's salience index

It provides an index value on a scale from zero to one, using the formula:

$$S=(\Sigma((L-R_j + 1)/L))/N$$

"where S is the average rank of an item across all lists in the sample, weighted by the lengths of the lists in which the item actually occurs; L = the length of (number of items in) a list; Rj = the rank of an item in the list (first = 1); and N = the number of lists in the sample" (Smith & Borgatti, 1997, pp. 208–209). Where a participant identified the same service more than once we used the first instance in the calculation and ignored subsequent mentions.

A.5 Perceived impact scores by stakeholder group

Table A.5. Median perceived impact score for each stakeholder group as assigned by participants in the first workshop. A score of 6 indicated the largest impact and a score of 1 indicated the smallest impact.

	Median perceived impact score for stakeholder groups								
Driver of change	**Aquaculture**	**ENGOs**	**Farmers**	**Fisheries**	**Governance**	**Government**	**Local residents**	**Land owners**	**Researchers**
Climate change		5.0	4.0	4.5	5.0	5.0	5.0	5.0	5.0
Demographic change						5.0	5.0		4.5
Economy		4.5	4.5	4.5					3.0
Governance and policy		4.0		4.0	3.0	4.0		5.0	3.0
Hydrological change	4.5	4.0				5.0	5.0		
Knowledge and education		5.0	4.0	5.0		4.0			
Land use change		5.0				4.0		5.0	4.0
Needs of the population	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5
Non-native invasive species		5.0			5.0	5.0			
Pollution		5.0		4.5		5.0	5.0	5.0	4.0
River restoration		5.0	3.0			5.0			
Technology and innovation		2.5					5.0		2.0
Values and attitudes	5.0	2.0	4.0			5.0	4.0		3.0

Appendix B Supplementary information for Chapter 3

B.1 PPGIS survey questions

1) Information about you

1. How old are you? Please tick the relevant box.

18-24	25-34	35-44	45-54	55-64	65+	Prefer not to say

2. What is your gender? Please tick one of the options below.

Male	Female	Other	Prefer not to say

2) Where do you live? Please zoom in and mark the location on the map

What is your postcode?

Open text box

3) Ecosystem services mapping

Below are a list of ways that you may use, enjoy or appreciate this landscape. We would like you to mark on the map the places where each statement is true for you. You can mark as many places are you like. Click on the statement to generate a marker which you can then add to the map.

Statements
I feel better in this place because it benefits my physical health and / or mental health
I appreciate the food that I can harvest or is produced in this place
I value this place as it provides me with work or a source of income
I enjoy spending time with other people in this place
I appreciate the local cultural, cultural heritage, or history in this place
I spend time outside walking, cycling, swimming, fishing, boating or watching wildlife in this place. Which activity do you take part in here?
I appreciate the plants, animals and ecosystems in this place
I enjoy the beautiful scenery, sights and sounds in this place
This place is important to me for a reason not previously mentioned.

Drop down questions included with the statement I spend time outside walking, cycling, swimming, fishing, boating or watching wildlife in this place.

Which activity do you take part in here? Select all the relevant options

Walking or hiking	
Fishing	
Swimming	
Canoeing or kayaking	
Watching wildlife	
Other	

How frequently do you visit this place? Please select one option

Frequently (more than once a week)	
Often (more than once a month)	
Occasionally (more than once a year)	
Rarely (less than once a year	

4) Socio- demographic and other questions

1. What is the highest level of education you have completed? Please tick the relevant box.

No formal education	GCSE/Equivalent	A' Level/Equivalent	Undergraduate degree	Postgraduate degree

2. What is your relationship with the mapping area? Please mark the relevant box

I live in this area all the time	
I live in this area some of the time or seasonally	
I work in this area but live somewhere else	
I visit this area for leisure	

3. How well do you feel you know this area? Please mark the relevant box

Very well	Quite well	To some extent	Quite poorly	Extremely poorly

4. How often have you visited either the River Itchen or River Test in the past year? Please select one option

Regularly (more than once a week)	
Often (more than once a month)	
Occasionally (more than once this year)	
Not visited either river in the past year	

5. How do you regularly use or interact with the rivers? Please select a maximum of two options

I own, manage or work for a business which is dependent on the River Itchen or River Test
I am a member of an organisation that protects, or campaigns to protect, the River Itchen or River Test, e.g. The Campaign to Protect Rural England (CPRE), WWF-UK, Hampshire and Isle of Wight Wildlife Trust
I am involved in conservation or management of the River Itchen or River Test through my work
I farm land within the River Itchen or River Test catchments
I have riparian rights to part of the River Itchen or River Test
I am involved in research or education activities related to the River Itchen or River Test
None of the statements above apply to me

6. What is your employment status / occupation?

Employed full time	
Employed part time	
Self employed	
Student	
Retired	
Carer	
Domestic work	
Unemployed	

B.2 Data sources used in the multinomial logit model

Table B.2. Data sources used in the multinomial logit model

Data	Description	Available from
Agriculture	Land cover class numbers 3 & 4	Land cover map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Built-up areas	Land cover class numbers 20 & 21	Land cover map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Freshwater	Land cover class numbers 14	Land cover map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Grassland	Land cover class numbers 5, 6 & 7	Land cover map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Woodland	Land cover class numbers 1 & 2	Land cover map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Access	Length of path (in km) Open street maps	https://www.openstreetmap.org/

B.3 Mapped points for each ecosystem service value

Table B.3.1. Number of points mapped for each ecosystem service value

Ecosystem service value	No. of points mapped
Recreation	584
Aesthetics	522
Biodiversity and wildlife	467
Health and therapy	388
Connection to others	333
Culture and heritage	241
Food provision	108
Economic	57
Other	32
Total	**2732**

Table B.3.2. Mapped points for recreation value broken down by recreation type (note that more than one type of recreation could be assigned to a mapped point)

Activity	Count
Walking or hiking	423
Watching wildlife	246
Cycling	132
Fishing	106
Swimming	65
Other	35
Canoeing or kayaking	16
Total	**1023**

Table B.3.3. Breakdown of participants by stakeholder group

Stakeholder	Count
Business owner	6
Farmer	8
General public	206
Member of conservation org	42
Riparian owner	15
Unknown	3
Work in conservation	12
Total	**292**

Appendix C Supplementary information for Chapter 4

C.1 Interviewee descriptions and the extent of their involvement

#	Interviewee description	Attended Workshop?
1	National government – Environment Agency	✓
2	Research and academia	
3	Environmental Non-governmental Organisations - local	✓
4	Membership organisation	
5	Citizens and community	✓
6	Aquaculture	✓
7	Water industry	
8	Environmental Non-governmental Organisations - local	
9	National government – Natural England	✓
10	Citizens and community / land and riparian owner	✓
11	Environmental Non-governmental Organisations - local	
12	National government – Defra	
13	Agriculture	✓
14	Environmental Non-governmental Organisations - national	
15	Environmental Non-governmental Organisations - national	

C.2 Interview protocol

Introduction and background

I'd like to thank you for agreeing to take part in our study. As I've mentioned previously, our conversation today will focus on the governance of water quality for the River Test and/or River Itchen. This interview will be a little different as we'll be creating a map / picture to look at who's involved in the governance of water quality and how they are linked.

As a reminder our discussion will remain confidential, and any results will be anonymised. As mentioned in the Participant Information Sheet, I'd like to record our discussion as it's difficult for me to simultaneously listen and write-down notes. Are you still OK with me recording our conversation today?

Questions

1. To begin, could you tell me briefly about your role / relationship to the river(s)?
2. a) Today we're going to be creating a visual map for the governance of water quality, so to kick off the process could you tell me who has been involved with or influenced the governance of water quality for the River Itchen and / or River Test over the last 2 years? This can include both formal and informal involvement. Could you name the most important organisations or people please?

   b) Why is [name of actor] important for the governance of water quality?

3. a) I'd like to look at the links between the different actors you've mentioned, focusing on financial links, information, and pressure.

   Does [name actor] have a financial links with [name actor] with respect to the governance of water quality?

   b) How have you observed this happening? And have you experienced this link flowing back the other way?

   [Repeat for information and pressure links]

4. Thanks for the information you've provided so far, we've been through the bulk of the interview.

   a) I've brought along these blocks and I'd like you to stack the blocks next to each of the names on the page with respect to how much actual influence you think they have over the governance of water quality. So, the higher the tower the more influence the organisation or person has. You do not need to use all the blocks.

b) What makes [actor name] influential / not influential?

5. Now we've completed the visual map, is there anything that you notice about it? Is there anything you'd like to comment on?

6. Is there anyone else you think we should speak to about the governance of water quality?

7. Do you have any questions for me / us?

8. Are you interested in seeing the results of the study?

Thanks again for your time and participation. We really appreciate your help.

The interview protocol was amended for virtual use due to the COVID-19 pandemic. The consent forms were signed prior to the interview and emailed to the lead researcher. The visual maps were drawn using Microsoft Powerpoint. Interviewees were not able to physically stack blocks but instead assigned influence scores to each actor.

C.3 Workshop protocol

Welcome, housekeeping and data confidentiality

Welcome to the workshop. Thank you for giving us your time today.

You've all been sent the participant information sheet for the workshop and emailed back a confirmation that you're happy to take part and for the session to be recorded. As a reminder the information you provide us will remain anonymised and we will ensure that no-one is identifiable in our reports. I would also ask you to not share what you see in this workshop with anyone outside of this group, particularly given the discussion in this workshop may alter the overall results of the project.

In the interviews and this workshop we are dealing with your perceptions of water quality governance, which means that there is no right or wrong, just perceptions. I'm going to start the recording now.

Introductions

I'd like to start with introductions so that you all know who's in the virtual room with you. Could you tell us your name, very briefly your role or relationship to the river, and your favourite breakfast food. I'll start and then nominate the next person and so on.

Background

In this workshop we'll be looking at the outcomes of the interviews you took part in and discussing the results, with the aim of brainstorming some tangible actions for improving the governance of water quality. We are fortunate to have people with different backgrounds and perspectives in this workshop and we hope by bringing you all together we can have a rich discussion around water quality.

For some of you it has been a little while since you were interviewed and so I will briefly remind you of what we did. Based on your perceptions, we created a visual map of the actors involved in water quality governance for the River Test and River Itchen, we then examined the connections between them – looking at financial connections, pressure, and information flows. Finally, you assigned a score to each actor to reflect the level of actual influence you felt they had over water quality governance.

We've combined all the individual maps from the interviews to produce one amalgamated map of perceptions for each type of connection. We translated the visual maps you drew into matrices, noting each actor and connection. And then we added these matrices together to produce an amalgamated map. Our discussion today will be based around these maps.

Overview of the results

I'd like to start by giving you an overview of the results. We interviewed 15 individuals from a range of organisations and backgrounds. Across the 15 interviews 74 actors i.e., different organisations or individuals, were named as having a role in governance. These include actors from the state, civil society, and private sector.

Are there any questions?

Part 1

This is the combined visual map of the perceptions of pressure. Each actor is represented as a circle, and the lines between the circles represent connections. So as an example, ACTOR 1 is thought to apply pressure to ACTOR 2, and this is reflected by an arrow from the ACTOR 1 to ACTOR 2. The size of the circles represents how influential that actor was perceived to be – so the larger the circle the ore influential, the smaller the less influential. The width and shade of the lines shows how often a connection was mentioned – so the wider and darker a line, the more times that link was mentioned across the 15 interviews. A connection can be mentioned a maximum of 15 times, as we interviewed 15 people. I'll give you a couple of minutes to look at the map, let me know if you have any questions?

Question 1: Is there anything that surprises you about the map?

Question 2: Is pressure directed from and to the right actors? Are there any actors who are missing? Are there any actors that could or should be brought into the network?

Question 3: Is the pressure applied appropriate?

Question 4: Is pressure the right tool in this context? Is there an alternative approach?

Question 5: What could be improved in this network?

Part 2

I'd like to also discuss the network map for information. Again, each actor is represented as a circle – the larger the circle the more influential that actor was perceived to be. The lines between the circles represent connections the width and colour of the line shows how often a connection was mentioned. I'll give you a few minutes to look at the map.

Question 6: You'll note that a lot of actors are very well connected. Are there any actors who are particularly central and important to information sharing? Do you think that Is there anything that could be done to improve information connections?

Part 3: Actions

I'd like to summarise the actions that we've talked about through the workshop.

Question 7: Can we pull out a list of actions to improve governance? Feel free to also jot down your thoughts in the chat function

Part 5: Survey

Before we finish the workshop, I'd appreciate it if you could complete a brief survey about the interview and workshop process.

I've just sent a link through in the chat and via email to the survey. Could you please click on the link and complete the survey. Do let me know if you have any questions.

C.4 Participant survey

Thank you for taking part in the water quality governance interviews and workshop. Below are a few questions that will help us to evaluate the process. The survey should take no more than 5 minutes to complete.

Q1) During the interviews and workshop:

1) To what extent did you learn new information? (Not at all, slight, moderate, great)
2) To what extent did you learn about the concerns of others? (Not at all, slight, moderate, great)
3) To what extent did problems or opportunities arise that you were not previously aware of? (Not at all, slight, moderate, great)
4) To what extent did participating help you to see areas in which you agree or disagree with others? (Not at all, slight, moderate, great)
5) To what extent did participating help you to see problems in a different way? (Not at all, slight, moderate, great)
6) To what extent were actions identified to address problems or build on opportunities? (Not at all, slight, moderate, great)

Q2) What would you like to see happen next in terms of the process of looking at governance? [Open text field]

Q3) What were the strengths of the process? [Open text field]

Q4) How could the process have been improved? [Open text field]

Q5) Any other comments? [Open text field]

C.5 Calculation of quantitative network and node metrics

To allow analysis of actor position and influence in the network we calculated two centrality measures for each actor, ingoing and outgoing degree centrality and betweenness centrality. Ingoing and outgoing degree centrality is the number of direct connections coming in or out of a node, standardised by dividing by the maximum potential number of direct connections, 2(n-1), where n is the number of nodes in the network. Betweenness centrality is the number of times a node acts a bridge for the shortest path between two other nodes (Freeman, 1978), standardised by dividing between the maximum number of pairs of nodes, (n-1)(n-2), where n is the number of nodes in the network.

To allow analysis of the network characteristics we calculated several network metrics. Density is the total number of ties in a network divided by the total number of possible ties in the network. A network where all actors are connected to every other actor would have a density of 1 (Scott, 2017). Centralisation is a measure of the degree of variance, expressed as a percentage, from a perfectly centralized or 'star-shaped' network of the same size (Freeman, 1979). We calculated centralisation by summing the differences between the highest degree centrality score of any one node and those of the other nodes, and then dividing this value by a theoretical maximum possible sums of differences. Centralisation therefore reflects the extent to which one actor is central in the network.

To aggregate these metrics for each actor category we averaged the influence values, degree centrality and betweenness centrality metrics, using the number of actors in the category as the denominator.

C.6 Node metrics by actor

Actor code	No. of times mentioned	Normalised influence	Degree centrality	Betweenness centrality
NATGOV1	15	1.00	1.45	0.222
NATGOV2	15	0.79	1.11	0.086
ENGO1	14	0.38	0.97	0.055
WATER1	13	0.51	0.93	0.066
AQUA1	13	0.27	0.82	0.051
ENGO2	13	0.28	0.78	0.034
ENGO3	11	0.45	0.93	0.048
MEM1	11	0.21	0.80	0.042
LAND1	10	0.16	0.58	0.017
AGRI1	9	0.49	0.70	0.053
FORUM1	9	0.30	0.62	0.025
ENGO4	8	0.10	0.67	0.042
FORUM2	8	0.13	0.49	0.013
RES1	8	0.09	0.42	0.004
FORUM3	7	0.12	0.64	0.024
AQUA2	7	0.11	0.22	0.000
COMM2	6	0.09	0.45	0.007
COMM1	6	0.05	0.38	0.022
NATGOV3	6	0.21	0.25	0.003
COMM4	5	0.16	0.50	0.014
FISH1	5	0.04	0.42	0.006
FISH2	5	0.04	0.38	0.001
NATGOV4	5	0.24	0.36	0.018
COMM3	5	0.13	0.34	0.014
COMM6	5	0.02	0.32	0.001
COMM5	5	0.10	0.32	0.006
NATGOV5	5	0.05	0.20	0.001
COMM7	4	0.02	0.29	0.018
ENGO5	4	0.03	0.26	0.002
NATGOV6	4	0.03	0.14	0.000
MEM2	4	0.02	0.14	0.000
OTHER1	4	0.03	0.07	0.000
WATER3	3	0.12	0.46	0.012
WATER2	3	0.10	0.33	0.003
LOCGOV1	3	0.13	0.25	0.001
NATGOV7	3	0.12	0.25	0.001
ENGO6	3	0.05	0.24	0.004
LOCGOV2	3	0.07	0.14	0.000
RES3	3	0.02	0.14	0.000
CONS1	3	0.06	0.13	0.000
RES2	3	0.02	0.13	0.000

OTHIND1	3	0.10	0.12	0.000
ENGO7	2	0.08	0.22	0.000
LOCGOV3	2	0.07	0.18	0.007
HOUS1	2	0.04	0.16	0.000
MEM3	2	0.08	0.14	0.000
NATGOV8	2	0.06	0.13	0.000
COMM8	2	0.01	0.11	0.000
CONS2	2	0.00	0.08	0.000
SUP1	2	0.02	0.05	0.000
LOCGOV4	2	0.00	0.04	0.000
MEM4	1	0.01	0.21	0.001
OTHER2	1	0.01	0.21	0.000
MEDIA1	1	0.02	0.20	0.000
MEM5	1	0.02	0.14	0.000
CONS3	1	0.04	0.13	0.000
CONS5	1	0.01	0.13	0.000
LOCGOV5	1	0.00	0.13	0.000
FISH3	1	0.00	0.12	0.000
COMM9	1	0.06	0.11	0.000
COMM12	1	0.00	0.11	0.000
WATER4	1	0.00	0.09	0.000
EU1	1	0.02	0.07	0.000
COMM10	1	0.01	0.07	0.000
FISH4	1	0.00	0.07	0.000
FISH5	1	0.00	0.07	0.000
WATER5	1	0.00	0.07	0.000
NATGOV9	1	0.03	0.05	0.000
RES4	1	0.02	0.05	0.000
COMM11	1	0.00	0.05	0.000
OTHER3	1	0.02	0.03	0.000
CONS4	1	0.02	0.01	0.000
RAIL	1	0.01	0.00	0.000
ENGO8	1	0.00	0.00	0.000

List of References

Abma, T., Banks, S., Cook, T., Dias, S., Madsen, W., Springett, J. and Wright, M.T., (2019). *Participatory Research for Health and Social Well-Being*. Springer International Publishing. Available from: https://doi.org/10.1007/978-3-319-93191-3/COVER [Accessed 1 September 2025].

Acornley, R.M. and Sear, D.A., (1999). Sediment transport and siltation of brown trout (Salmo trutta L.) spawning gravels in chalk streams. *Hydrological Processes*, 13(3), pp.447–458. Available from: https://doi.org/10.1002/(SICI)1099-1085(19990228)13:3<447::AID-HYP749>3.0.CO;2-G [Accessed 24 July 2025].

Acreman, M.C., Harding, R.J., Lloyd, C., McNamara, N.P., Mountford, J.O., Mould, D.J., Purse, B. V., Heard, M.S., Stratford, C.J. and Dury, S.J., (2011). Trade-off in ecosystem services of the Somerset Levels and Moors wetlands. *Hydrological Sciences Journal*, 56(8), pp.1543–1565. Available from: https://doi.org/10.1080/02626667.2011.629783 [Accessed 15 June 2025].

Acuña, V., Díez, J.R., Flores, L., Meleason, M. and Elosegi, A., (2013). Does it make economic sense to restore rivers for their ecosystem services? *Journal of Applied Ecology*, 50(4), pp.988–997. Available from: https://doi.org/10.1111/1365-2664.12107 [Accessed 18 July 2024].

Aerts, R., Honnay, O. and Van Nieuwenhuyse, A., (2018). Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*, 127(1), pp.5–22. Available from: https://doi.org/10.1093/BMB/LDY021 [Accessed 27 November 2023].

Akpor, O.B., Ohiobor, G.O. and Olaolu, T.D., (2014). Heavy metal pollutants in wastewater effluents: Sources, effects and remediation. *Advances in Bioscience and Bioengineering*, 2(4), pp.37–43. Available from: https://doi.org/10.11648/j.abb.20140204.11.

Albert, J.S., Destouni, G., Duke-Sylvester, S.M., Magurran, A.E., Oberdorff, T., Reis, R.E., Winemiller, K.O. and Ripple, W.J., (2021). Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio*, 50(1), pp.85–94. Available from: https://doi.org/10.1007/S13280-020-01318-8/FIGURES/2 [Accessed 12 September 2025].

Albertson, L.K., Sklar, L.S., Pontau, P., Dow, M. and Cardinale, B.J.,(2014). A mechanistic model linking insect (Hydropsychidae) silk nets to incipient sediment motion in gravel-bedded streams. *Journal of Geophysical Research: Earth Surface*, 119(9), pp.1833–1852. Available from: https://doi.org/10.1002/2013JF003024 [Accessed 12 September 2025].

Aldridge, D.C., (2000). The impacts of dredging and weed cutting on a population of freshwater mussels (Bivalvia: Unionidae). *Biological Conservation*, 95(3), pp.247–257. Available from: https://doi.org/10.1016/S0006-3207(00)00045-8.

Ali, H., Khan, E. and Sajad, Muhannad.J., (2013). Phytoremediation of heavy metals- Concepts and applications. *Chemosphere*, 91, pp.869–881.

Ansell, C. and Gash, A., (2008). Collaborative Governance in Theory and Practice. *Journal of Public Administration Research and Theory*, 18(4), pp.543–571. Available from: https://doi.org/10.1093/JOPART/MUM032 [Accessed 23 March 2022].

Armitage, D., De Loë, R. and Plummer, R., (2012). Environmental governance and its implications for conservation practice. *Conservation Letters*, 5(4), pp.245–255. Available from: https://doi.org/10.1111/J.1755-263X.2012.00238.X;JOURNAL:JOURNAL:1755263X;WGROUP:STRING:PUBLICATION [Accessed 24 August 2025].

Armstrong, J.D., Kemp, P.S., Kennedy, G.J.A., Ladle, M. and Milner, N.J., (2003). Habitat requirements of Atlantic salmon and brown trout in rivers and streams. *Fisheries Research*, 62(2), pp.143–170. Available from: https://doi.org/10.1016/S0165-7836(02)00160-1 [Accessed 14 July 2025].

Arnell, N.W., (2003). Relative effects of multi-decadal climatic variability and changes in the mean and variability of climate due to global warming: future streamflows in Britain. *Journal of Hydrology*, 270(3–4), pp.195–213. Available from: https://doi.org/10.1016/S0022-1694(02)00288-3.

Babai, D., Jánó, B. and Molnár, Z., (2021). In the trap of interacting indirect and direct drivers: the disintegration of extensive, traditional grassland management in Central and Eastern Europe. *Ecology and Society*, 26(4), p.art6. Available from: https://doi.org/10.5751/ES-12679-260406 [Accessed 27 April 2023].

Bagstad, K.J., Semmens, D.J., Ancona, Z.H. and Sherrouse, B.C., (2017). Evaluating alternative methods for biophysical and cultural ecosystem services hotspot mapping in natural resource planning. *Landscape Ecology*, 32(1), pp.77–97. Available from: https://doi.org/10.1007/S10980-016-0430-6/FIGURES/6 [Accessed 21 March 2023].

Baland, J.-M. and Platteau, J.-P., (2005). Halting Degradation of Natural Resources. *Halting Degradation of Natural Resources*. Available from: https://doi.org/10.1093/0198290616.001.0001 [Accessed 18 September 2021].

Ball, J., Hauck, J., Holland, R.A., Lovegrove, A., Snaddon, J., Taylor, G. and Peh, K.S.H., (2022). Improving governance outcomes for water quality: Insights from participatory social network analysis for chalk stream catchments in England. *People and Nature*, 4(5), pp.1352–1368. Available from: https://doi.org/10.1002/PAN3.10390 [Accessed 19 January 2023].

Ball, J., Holland, R.A. and Peh, K.S.-H., (2023). Chalk streams: crystal-clear governance is critical. *The Environment*. Available from: https://www.researchgate.net/publication/374504554_Chalk_streams_crystal-clear_governance_is_critical [Accessed 8 August 2024].

Ballantine, D.J., Walling, D.E., Collins, A.L. and Leeks, G.J.L., (2009). The content and storage of phosphorus in fine-grained channel bed sediment in contrasting lowland agricultural catchments in the UK. *Geoderma*, 151(3–4), pp.141–149. Available from: https://doi.org/10.1016/J.GEODERMA.2009.03.021 [Accessed 16 July 2025].

Balvanera, P., Pfaff, A., Viña, A., Garcia Frapolli, E., Hussain, S.A., Merino, L., Minang, P.A., Nagabhatla, N. and Sidorovich, A., (2019). Chapter 2.1. Status and Trends –Drivers of Change. In: E.S. Brondízio, J. Settele, S. Díaz and H.T. Ngo, eds. *Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES secretaria. Available from: https://doi.org/10.5281/ZENODO.5517423 [Accessed 26 January 2023].

Barnaud, C, Corbera, E, Muradian, R, Salliou, N, Sirami, C, Vialatte, A, Choisis, J.-P, Dendoncker, N, Mathevet, R, Moreau, C, Reyes-García, V, Boada, M, Deconchat, M, Cibien, C, Garnier, S, Maneja, R., Barnaud, Cecile, Corbera, Esteve, Muradian, Roldan, Salliou, Nicolas, Sirami, Clélia, Vialatte, Aude, Choisis, Jean-Philippe, Dendoncker, Nicolas, Mathevet, Raphael, Moreau, Clémence, Reyes-García, Victoria, Boada, Martí, Deconchat, Marc, Cibien, Catherine, Garnier, Stephan and Antona, M., (2018). Ecosystem services, social interdependencies, and collective action: a conceptual framework. *Ecology and Society,* 23(1). Available from: https://doi.org/10.5751/ES-09848-230115 [Accessed 31 August 2025].

Barnaud, C., De Longueville, F., Gonella, G., Antona, M., Dendoncker, N. and Waylen, K.A., (2023). Participatory research on ecosystem services in the face of disputed values and other uncertainties: A review. *Ecosystem Services*, 63, p.101551. Available from: https://doi.org/10.1016/J.ECOSER.2023.101551 [Accessed 31 August 2025].

Barnes, C., van Laerhoven, F. and Driessen, P.P.J., (2016). Advocating for Change? How a Civil Society-led Coalition Influences the Implementation of the Forest Rights Act in India. *World Development*, 84, pp.162–175. Available from: https://doi.org/10.1016/J.WORLDDEV.2016.03.013 [Accessed 29 April 2024].

Baumeister, C.F., Gerstenberg, T., Plieninger, T. and Schraml, U., (2020). Exploring cultural ecosystem service hotspots: Linking multiple urban forest features with public participation mapping data. *Urban Forestry & Urban Greening*, 48, p.126. Available from: https://doi.org/10.1016/J.UFUG.2019.126561 [Accessed 8 April 2022].

BBC, (2011). *Thames Water accused over dry River Kennet in Wiltshire - BBC News*. Available from: http://www.bbc.co.uk/news/uk-england-wiltshire-15076406 [Accessed 12 September 2025].

BBC, (2014). *Winchester residents battle against rising flood water - BBC News*. Available from: http://www.bbc.co.uk/news/uk-england-hampshire-26169796 [Accessed 12 September 2025].

Bennett, N.J., Roth, R., Klain, S.C., Chan, K., Christie, P., Clark, D.A., Cullman, G., Curran, D., Durbin, T.J., Epstein, G., Greenberg, A., Nelson, M.P., Sandlos, J., Stedman, R., Teel, T.L., Thomas, R., Veríssimo, D. and Wyborn, C., (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation*, 205, pp.93–108. Available from: https://doi.org/10.1016/j.biocon.2016.10.006 [Accessed 1 November 2019].

Bennett, N.J. and Satterfield, T., (2018). Environmental governance: A practical framework to guide design, evaluation, and analysis. *Conservation Letters*, 11(6), p.e12600. Available from: https://doi.org/10.1111/CONL.12600 [Accessed 24 August 2025].

Berrie, A.D., (1992). The chalk-stream environment. *Hydrobiologia*, 248(1), pp.3–9. Available from: https://doi.org/10.1007/BF00008881.

Bettey, J., (2007). The Floated Water Meadows of Wessex: A Triumph of English Agriculture. In: H. Cook and T. Williamson, eds. *Water Meadows: History, Ecology and Conservation*. Macclesfield: Windgather Press, pp.8–21.

Bidegain, I., Cerda, C., Catalán, E., Tironi, A. and López-Santiago, C., (2019). Social preferences for ecosystem services in a biodiversity hotspot in South America. *PLOS ONE*, 14(4), p.e0215715. Available from: https://doi.org/10.1371/JOURNAL.PONE.0215715 [Accessed 31 August 2025].

Blackstock, K.L., Kelly, G.J. and Horsey, B.L., (2007). Developing and applying a framework to evaluate participatory research for sustainability. *Ecological Economics*, 60(4), pp.726–742. Available from: https://doi.org/10.1016/J.ECOLECON.2006.05.014 [Accessed 9 January 2023].

Bodin, Ö., Crona, B. and Ernstson, H., (2006). Social Networks in Natural Resource Management: What Is There to Learn from a Structural Perspective? *Ecology and Society*, 11(2). Available from: https://doi.org/10.5751/ES-01808-1102r02.

Bodin, Ö. and Crona, B.I., (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change*, 19(3), pp.366–374. Available from: https://doi.org/10.1016/j.gloenvcha.2009.05.002.

Bodin, O. and Prell, C., (2011). *Social Networks and Natural Resource Management: Uncovering the Social Fabric of Environmental Governance*. Ed. by O. Bodin and C. Prell. Cambridge: Cambridge University Press.

Boeraeve, F., Dufrene, M., De Vreese, R., Jacobs, S., Pipart, N., Turkelboom, F., Verheyden, W. and Dendoncker, N., (2018). Participatory identification and selection of ecosystem services: building on field experiences. *Ecology and Society,* 23(2). Available from: https://doi.org/10.5751/ES-10087-230227 [Accessed 30 May 2023].

Bogert, J. M., Ellers, J., Lewandowsky, S., Balgopal, M., Harvey, J. A., Bogert, J. M., Ellers, J., Lewandowsky, S., Balgopal, M. M., and Harvey, J. A., (2022). Reviewing the relationship between neoliberal societies and nature: implications of the industrialized dominant social paradigm for a sustainable future. *Ecology and Society,* 27(2). Available from: https://doi.org/10.5751/ES-13134-270207 [Accessed 11 June 2025].

Borgwardt, F., Robinson, L., Trauner, D., Teixeira, H., Nogueira, A.J.A., Lillebø, A.I., Piet, G., Kuemmerlen, M., O'Higgins, T., McDonald, H., Arevalo-Torres, J., Barbosa, A.L., Iglesias-Campos, A., Hein, T. and Culhane, F., (2019). Exploring variability in environmental impact risk from human activities across aquatic ecosystems. *Science of The Total Environment*, 652, pp.1396–1408. Available from: https://doi.org/10.1016/J.SCITOTENV.2018.10.339 [Accessed 12 September 2025].

Bowes, M.J., Smith, J.T., Hilton, J., Sturt, M.M. and Armitage, P.D., (2007). Periphyton biomass response to changing phosphorus concentrations in a nutrient-impacted river: A new methodology for phosphorus target setting. *Canadian Journal of Fisheries and Aquatic Sciences* [Online], 64(2), pp.227–238. Available from: https://doi.org/10.1139/F06-180;WEBSITE:WEBSITE:NRC-SITE;WGROUP:STRING:CSP [Accessed 16 July 2025].

Brandes, U. and Wagner, D., (2004). Analysis and Visualization of Social Networks. *Graph Drawing Software* [Online]. Springer, Berlin, Heidelberg, pp.321–340. Available from: https://doi.org/10.1007/978-3-642-18638-7_15 [Accessed 26 May 2021].

Brauman, K.A., Daily, G.C., Duarte, T.K. and Mooney, H.A., (2007). The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. *Annual Review of Environment and Resources*, 32(1), pp.67–98. Available from: https://doi.org/10.1146/annurev.energy.32.031306.102758 [Accessed 4 October 2016].

Brenchley, P.J. and Rawson, P.F., (2006). *The Geology of England and Wales*. Ed. by P.J. Brenchley and P.F. Rawson. London: The Geological Society.

Briones, M.J.I., (2024). Special feature on ecosystem engineers: Cross-scale and cross-system perspectives. *Functional Ecology*, 38(1), pp.4–7. Available from: https://doi.org/10.1111/1365-2435.14418;WGROUP:STRING:PUBLICATION [Accessed 12 July 2025].

British Ecological Society, (2023). *How can we balance wildlife conservation with public access to nature?*. Available from: https://www.britishecologicalsociety.org/how-can-we-balance-wildlife-conservation-with-public-access-to-nature/ [Accessed 16 June 2024].

Britton, E., Kindermann, G., Domegan, C. and Carlin, C., (2020). Blue care: a systematic review of blue space interventions for health and wellbeing. *Health Promotion International*, 35(1), pp.50–69. Available from: https://doi.org/10.1093/HEAPRO/DAY103 [Accessed 29 November 2023].

Brockington, C.I.M., Murray, T., Buttrey, F., Charlesworth, D., Consuegra, S. and Garcia de Leaniz, C., (2023). Understanding and Reducing Conflict over the Recreational Use of Rivers. *Leisure Sciences*. Available from: https://doi.org/10.1080/01490400.2023.2267529;WGROUP:STRING:PUBLICATION [Accessed 11 June 2025].

Brondizio, E., Diaz, S., Settele, Josef, Ngo, Hien T., Gueze, M., Aumeeruddy-Thomas, Y., Bai, X., Geschke, A., Molnár, Z., Niamir, A., Pascual, U., Simcock, A. and Jaureguiberry, P., (2019).

Chapter 1: Assessing a planet in transformation: Rationale and approach of the IPBES Global Assessment on Biodiversity and Ecosystem Services. In: E.S. Brondízio, J. Settele, S. Díaz and H. T Ngo, eds. *Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES secretaria. Available from: https://doi.org/10.5281/ZENODO.5517203 [Accessed 26 January 2023].

Brooks, J., McCluskey, S., Turley, E. and King, N., (2015). The Utility of Template Analysis in Qualitative Psychology Research. *Qualitative Research in Psychology*, 12(2), p.202. Available from: https://doi.org/10.1080/14780887.2014.955224 [Accessed 30 November 2022].

Brown, G. and Fagerholm, N., (2015). Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. *Ecosystem Services*, 13, pp.119–133. Available from: https://doi.org/10.1016/J.ECOSER.2014.10.007 [Accessed 10 July 2019].

Brown, G., Helene Hausner, V. and Lægreid, E., (2015). Physical landscape associations with mapped ecosystem values with implications for spatial value transfer: An empirical study from Norway. *Ecosystem Services*, 15, pp.19–34. Available from: https://doi.org/10.1016/j.ecoser.2015.07.005 [Accessed 28 January 2022].

Brunn, H., Arnold, G., Körner, W., Rippen, G., Steinhäuser, K.G. and Valentin, I., (2023). PFAS: forever chemicals—persistent, bioaccumulative and mobile. Reviewing the status and the need for their phase out and remediation of contaminated sites. *Environmental Sciences Europe*, 35(1), pp.1–50. Available from: https://doi.org/10.1186/S12302-023-00721-8 [Accessed 22 April 2024].

Brunsdon, C. and Comber, L., (2019). *An introduction to R for spatial analysis & mapping*. 2nd edition. SAGE Publications Ltd. Available from: [Accessed 30 May 2024].

Bullock, J.M., Fuentes-Montemayor, E., McCarthy, B., Park, K., Hails, R.S., Woodcock, B.A., Watts, K., Corstanje, R. and Harris, J., (2022). Future restoration should enhance ecological complexity and emergent properties at multiple scales. *Ecography*, 2022(4). Available from: https://doi.org/10.1111/ECOG.05780;WGROUP:STRING:PUBLICATION [Accessed 7 September 2025].

Bunting, G., England, J., Gething, K., Sykes, T., Webb, J. and Stubbington, R., (2021). Aquatic and terrestrial invertebrate community responses to drying in chalk streams. *Water and Environment Journal* [Online], 35(1), pp.229–241. Available from: https://doi.org/10.1111/WEJ.12621;WGROUP:STRING:PUBLICATION [Accessed 14 July 2025].

Bürgi, M., Silbernagel, J., Wu, J. and Kienast, F., (2015). Linking ecosystem services with landscape history. *Landscape Ecology*, 30(1), pp.11–20. Available from: https://doi.org/10.1007/S10980-014-0102-3/TABLES/2 [Accessed 18 July 2025].

Burgman, M.A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., Rumpff, L. and Twardy, C., (2011). Expert Status and Performance. *PLoS ONE*, 6(7), p.e22998. Available from: https://doi.org/10.1371/journal.pone.0022998 [Accessed 2 April 2019].

Burkhard, B. and Maes, J., (2017). *Mapping Ecosystem Services*. *Advanced Books*, 1. Pensoft Publishers. Available from: https://doi.org/10.3897/AB.E12837 [Accessed 24 August 2025].

Burt, R.S., (1992). *Structural holes: The social structure of competition*. *Structural Holes: the social structure of competition*. Havard University Press. Available from: [Accessed 18 September 2021].

Burt, R.S., (2004). Structural Holes and Good Ideas. *American Journal of Sociology* [Online], 110(2), pp.349–399. Available from: https://doi.org/10.1086/421787 [Accessed 18 September 2021].

Butler, J.R.A., Skewes, T., Mitchell, D., Pontio, M. and Hills, T., (2014). Stakeholder perceptions of ecosystem service declines in Milne Bay, Papua New Guinea: Is human population a more critical driver than climate change? *Marine Policy*, 46. Available from: https://doi.org/10.1016/j.marpol.2013.12.011.

Buxton, T.H., (2018). Flume simulations of salmon bioturbation effects on critical shear stress and bedload transport in rivers. *River Research and Applications*, 34(4), pp.357–371. Available from: https://doi.org/10.1002/RRA.3250 [Accessed 12 September 2025].

Cargo, M. and Mercer, S.L., (2008). The value and challenges of participatory research: Strengthening its practice. *Annual Review of Public Health*, 29(Volume 29, 2008), pp.325–350. Available from: https://doi.org/10.1146/ANNUREV.PUBLHEALTH.29.091307.083824/CITE/REFWORKS [Accessed 24 July 2025].

Carlsson, L., (2016). Nonhierarchical Implementation Analysis: An Alternative to the Methodological Mismatch in Policy Analysis. *Journal of Theoretical Politics*, 8(4), pp.527–546. Available from: https://doi.org/10.1177/0951692896008004005 [Accessed 18 September 2021].

Carlsson, L. and Berkes, F., (2005). Co-management: concepts and methodological implications. *Journal of Environmental Management*, 75(1), pp.65–76. Available from: https://doi.org/10.1016/J.JENVMAN.2004.11.008 [Accessed 11 August 2021].

Chaffin, B.C., Floyd, T.M. and Anzollitto, P., (2024). Environmental Governance Networks and Geography: A Research Agenda at the Confluence of Critical Concepts for Navigating Rapid Environmental Change. *Annals of the American Association of Geographers*, 114(8), pp.1718–1730. Available from: https://doi.org/10.1080/24694452.2024.2343493;CTYPE:STRING:JOURNAL [Accessed 3 August 2025].

Chaffin, B.C., Garmestani, A.S., Gosnell, H. and Craig, R.K., (2016). Institutional networks and adaptive water governance in the Klamath River Basin, USA. *Environmental Science & Policy*, 57, pp.112–121. Available from: https://doi.org/10.1016/J.ENVSCI.2015.11.008 [Accessed 5 August 2021].

Chalmers, N. and Fabricius, C., (2007). Expert and generalist local knowledge about land-cover change on South Africa's Wild Coast: can local ecological knowledge add value to science? *Ecology and society*, 12(1). Available from: http://www.ecologyandsociety.org/vol12/iss1/art10/ [Accessed 27 April 2023].

Chan, K.M.A., Boyd, D.R., Gould, R.K., Jetzkowitz, J., Liu, J., Muraca, B., Naidoo, R., Olmsted, P., Satterfield, T., Selomane, O., Singh, G.G., Sumaila, R., Ngo, H.T., Boedhihartono, A.K., Agard, J., de Aguiar, A.P.D., Armenteras, D., Balint, L., Barrington-Leigh, C., Cheung, W.W.L., Díaz, S., Driscoll, J., Esler, K., Eyster, H., Gregr, E.J., Hashimoto, S., Hernández Pedraza, G.C., Hickler, T., Kok, M., Lazarova, T., Mohamed, A.A.A., Murray-Hudson, M., O'Farrell, P., Palomo, I., Saysel, A.K., Seppelt, R., Settele, J., Strassburg, B., Xue, D. and Brondízio, E.S., (2020). Levers and leverage points for pathways to sustainability. *People and Nature*, 2(3), pp.693–717. Available from: https://doi.org/10.1002/PAN3.10124/SUPPINFO [Accessed 2 November 2022].

Chan, K.M.A., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J. and Woodside, U., (2012). Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. *BioScience*, 62(8), pp.744–756. Available from: https://doi.org/10.1525/bio.2012.62.8.7 [Accessed 13 July 2018].

Chan, K.M.A., Olmsted, P., Bennett, N., Klain, S.C. and Williams, E.A., (2017). Can Ecosystem Services Make Conservation Normal and Commonplace? *Conservation for the Anthropocene*

Ocean, pp.225–252. Available from: https://doi.org/10.1016/B978-0-12-805375-1.00011-8 [Accessed 27 April 2023].

Chan, Kai M A, Satterfield, T. and Goldstein, J., (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics*, 74, pp.8–18. Available from: https://doi.org/10.1016/j.ecolecon.2011.11.011 [Accessed 1 March 2017].

Chan, Kai M.A., Satterfield, T. and Goldstein, J., (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics*, 74, pp.8–18. Available from: https://doi.org/10.1016/j.ecolecon.2011.11.011 [Accessed 1 March 2017].

Chen, P.G., Diaz, N., Lucas, G. and Rosenthal, M.S., (2010). Dissemination of Results in Community-Based Participatory Research. *American Journal of Preventive Medicine*, 39(4), pp.372–378. Available from: https://doi.org/10.1016/J.AMEPRE.2010.05.021 [Accessed 8 August 2024].

Church, A., Gilchrist, P. and Ravenscroft, N., (2007). Negotiating Recreational Access Under Asymmetrical Power Relations: The Case of Inland Waterways in England. *Society & Natural Resources*, 20(3), pp.213–227. Available from: https://doi.org/10.1080/08941920601117298 [Accessed 16 June 2024].

Clary, Warren.P., (1999). Stream channel and vegetation responses to late spring cattle grazing. *Journal of Range Management*, 52, pp.218–227.

Coleman, J.S., (1990). *Foundations of Social Theory*, (2). Harvard University Press. Available from: https://doi.org/10.1093/SF/69.2.625 [Accessed 18 September 2021].

Coleman, K. and Stern, M.J., (2017). Exploring the Functions of Different Forms of Trust in Collaborative Natural Resource Management, *Society & Natural Resources*, 31(1), pp.21–38. Available from: https://doi.org/10.1080/08941920.2017.1364452 [Accessed 23 November 2021].

Collins, A.L. and Zhang, Y., (2016). Exceedance of modern ‘background’ fine-grained sediment delivery to rivers due to current agricultural land use and uptake of water pollution mitigation options across England and Wales. *Environmental Science & Policy*, 61, pp.61–73. Available from: https://doi.org/10.1016/J.ENVSCI.2016.03.017 [Accessed 16 July 2025].

Collins, R., Johnson, D., Crilly, D., Rickard, A., Neal, L., Morse, A., Walker, M., Lear, R., Deasy, C., Paling, N., Anderton, S., Ryder, C., Bide, P. and Holt, A., (2020). Collaborative water management across England – An overview of the Catchment Based Approach. *Environmental*

Science & Policy, 112, pp.117–125. Available from: https://doi.org/10.1016/J.ENVSCI.2020.06.001 [Accessed 28 July 2025].

Communities European Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora *Official Journal of the European Union* 7–50.

Cook, H., Stearne, K. and Williamson, T., (2003). The Origins of Water Meadows in England. *The Agricultural History Review*, 51, pp.155–162. Available from: https://doi.org/10.2307/40275966.

Cook, H. and Williamson, T., (2007). *Water Meadows: History, Ecology and Conservation*. Macclesfield: Windgather Press.

Cook, H.F., Cutting, R.L. and Valsami-Jones, E., (2017). Flooding with constraints: water meadow irrigation impacts on temperature, oxygen, phosphorus and sediment in water returned to a river. *Journal of Flood Risk Management*, 10(4), pp.463–473. Available from: https://doi.org/10.1111/JFR3.12142 [Accessed 3 August 2024].

Cooper, D., Naden, P., Old, G., Laize, C. and Mainstone, C., (2008). *Development of guideline sediment targets to support management of sediment inputs into aquatic systems* [Online]. Centre for Ecology and Hydrology. Available from: https://publications.naturalengland.org.uk/file/63027 [Accessed 24 July 2025].

Cordner, A., Brown, P., Cousins, I.T., Scheringer, M., Martinon, L., Dagorn, G., Aubert, R., Hosea, L., Salvidge, R., Felke, C., Tausche, N., Drepper, D., Liva, G., Tudela, A., Delgado, A., Salvatore, D., Pilz, S. and Horel, S., (2024). PFAS Contamination in Europe: Generating Knowledge and Mapping Known and Likely Contamination with “Expert-Reviewed” Journalism. *Environmental Science & Technology* [Online], 58(15), pp.6616–6627. Available from: https://doi.org/10.1021/ACS.EST.3C09746 [Accessed 12 September 2025].

Cornacchia, L., Wharton, G., Davies, G., Grabowski, R.C., Temmerman, S., Van Der Wal, D., Bouma, T.J. and Van De Koppel, J., (2020). Self-organization of river vegetation leads to emergent buffering of river flows and water levels. *Proceedings of the Royal Society B: Biological Sciences* [Online], 287(1931). Available from: https://doi.org/10.1098/RSPB.2020.1147;JOURNAL:JOURNAL:RSPB1905 [Accessed 16 July 2025].

Cortés-Calderón, S.V., López-Rodríguez, M.D., Jiménez-Aceituno, A., Castro, A.J. and Mancilla-García, M., (2025). Contributions of Net-Map to sustainability action research. *Current Opinion* *in Environmental Sustainability*, 75, p.101542. Available from: https://doi.org/10.1016/J.COSUST.2025.101542 [Accessed 24 August 2025].

Costanza, R., (2016). Ecosystem services in theory and practice. In: M. Potschin, R. Haines-Young, R. Fish and R.K. Turner, eds. *Routledge Handbook of Ecosystem Services*. Oxford: Routledge, pp.15–24.

Crisp, D.T., Matthews, A.M., Westlake, D.F. and Association, F.B., (1982). The temperatures of nine flowing waters in southern England. *Hydrobiologia*, 89(3), pp.193–204. Available from: https://doi.org/10.1007/BF00005705.

Crona, B. and Bodin, O., (2010). Power asymmetries in small-scale fisheries: a barrier to governance transformability? *Ecology & Society*, 15(4). Available from: http://www.ecologyandsociety.org/vol15/iss4/art32/.

Crouzat, E., Mouchet, M., Turkelboom, F., Byczek, C., Meersmans, J., Berger, F., Verkerk, P.J. and Lavorel, S., (2015). Assessing bundles of ecosystem services from regional to landscape scale: insights from the French Alps. *Journal of Applied Ecology*, 52(5), pp.1145–1155. Available from: https://doi.org/10.1111/1365-2664.12502 [Accessed 15 June 2024].

CTSA Community Engagement Key Function Committee, (2011). *Principles of Community Engagement, 2nd edition* [Online]. Available from: https://scholar.google.com/scholar_lookup?title=Principles+of+Community+Engagement%2C+2nd+edition&publication_year=2011&author=CTSA+Community+Engagement+Key+Function+Committee+Task+Force+on+the+Principles+of+Community+Engagement [Accessed 24 July 2025].

Culhane, F., Teixeira, H., Nogueira, A.J.A., Borgwardt, F., Trauner, D., Lillebø, A., Piet, G., Kuemmerlen, M., McDonald, H., O'Higgins, T., Barbosa, A.L., van der Wal, J.T., Iglesias-Campos, A., Arevalo-Torres, J., Barbière, J. and Robinson, L.A., (2019). Risk to the supply of ecosystem services across aquatic ecosystems. *Science of The Total Environment* [Online], 660, pp.611–621. Available from: https://doi.org/10.1016/J.SCITOTENV.2018.12.346 [Accessed 15 May 2019].

Cusens, J., Barraclough, A.M.D. and Måren, I.E., (2021). Participatory mapping reveals biocultural and nature values in the shared landscape of a Nordic UNESCO Biosphere Reserve. *People and Nature*, 00, pp.1–17. Available from: https://doi.org/10.1002/PAN3.10287 [Accessed 3 December 2021].

Cvitanovic, C., Shellock, R.J., Mackay, M., van Putten, E.I., Karcher, D.B., Dickey-Collas, M. and Ballesteros, M., (2021). Strategies for building and managing 'trust' to enable knowledge exchange at the interface of environmental science and policy. *Environmental Science & Policy,* 123, pp.179–189. Available from: https://doi.org/10.1016/J.ENVSCI.2021.05.020 [Accessed 23 November 2021].

Davis, J., O'Grady, A.P., Dale, A., Arthington, A.H., Gell, P.A., Driver, P.D., Bond, N., Casanova, M., Finlayson, M., Watts, R.J., Capon, S.J., Nagelkerken, I., Tingley, R., Fry, B., Page, T.J. and Specht, A., (2015). When trends intersect: The challenge of protecting freshwater ecosystems under multiple land use and hydrological intensification scenarios. *Science of The Total Environment*, 534, pp.65–78. Available from: https://doi.org/10.1016/J.SCITOTENV.2015.03.127 [Accessed 16 January 2023].

Daw, T M, Hicks, C., Brown, K, Chaigneau, T, Januchowski-Hartley, F., Cheung, W., Rosendo, S, Crona, B, Coulthard, S, Sandbrook, C, Perry, C, Bandeira, S, Muthiga, N A, Schulte-Herbrüggen, B, Bosire, J, Mcclanahan, T R, Daw, Tim M, Hicks, C.C., Brown, Katrina, Chaigneau, Tomas, Januchowski-Hartley, F.A., Cheung, W.W.L., Rosendo, Sérgio, Crona, Beatrice, Coulthard, Sarah, Sandbrook, Chris, Perry, Chris, Bandeira, Salomão, Muthiga, Nyawira A, Schulte-Herbrüggen, Björn, Bosire, Jared and Mcclanahan, Tim R, (2016). Elasticity in ecosystem services: exploring the variable relationship between ecosystems and human well-being. *Ecology and Society*, 21(2). Available from: https://doi.org/10.5751/ES-08173-210211 [Accessed 2 November 2022].

Dawson, N.M., Grogan, K., Martin, A., Mertz, O., Pasgaard, M. and Rasmussen, L.V., (2017). Environmental justice research shows the importance of social feedbacks in ecosystem service trade-offs. *Ecology and Society*, 22(3), p.art12. Available from: https://doi.org/10.5751/ES-09481-220312 [Accessed 18 July 2024].

Defra, (2003). *Strategic review of diffuse water pollution from agriculture. Discussion document* [Online]. Available from: https://webarchive.nationalarchives.gov.uk/ukgwa/20130822074033/http://www.defra.gov.uk/environment/water/dwpa/reports/pdf/dwpa07-b.pdf [Accessed 14 July 2025].

Defra, (2013). *Catchment Based Approach: Improving the quality of our water environment.* [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/204231/pb13934-water-environment-catchment-based-approach.pdf [Accessed 28 July 2025].

Defra, (2020). *Latest water classifications results published - Defra in the media* [Online]. Available from: https://deframedia.blog.gov.uk/2020/09/18/latest-water-classifications-results-published/ [Accessed 18 September 2021].

Defra, (2023). *Future of farming in England* [Online]. Available from: https://www.gov.uk/government/collections/future-of-farming-in-england [Accessed 12 September 2025].

Defra, (2025). *Land Use Consultation* [Online]. Available from: https://consult.defra.gov.uk/land-use-framework/land-use-consultation/ [Accessed 12 September 2025].

Defra, (2025). *List of current bathing waters* [Online]. Available from: https://www.gov.uk/government/publications/bathing-waters-list-of-designated-waters-in-england/list-of-current-bathing-waters [Accessed 8 September 2025].

Defra and Environment Agency, (2016). *Thames river basin district river basin management plan*.

Degenne, A. and Forse, M., (1999). *Introducing Social Networks*. *Introducing Social Networks* [Online]. SAGE Publications, Ltd. Available from: https://doi.org/10.4135/9781849209373 [Accessed 18 September 2021].

Dempsey, J. and Robertson, M.M., (2012). Ecosystem services: Tensions, impurities, and points of engagement within neoliberalism. *Progress in Human Geography* [Online], 36(6), pp.758–779. Available from: https://doi.org/10.1177/0309132512437076 [Accessed 18 July 2024].

Devente, J., Reed, M.S., Stringer, L.C., Valente, S. and Newig, J., (2016). How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society,* 21(2). Available from: https://doi.org/10.5751/ES-08053-210224 [Accessed 9 March 2023].

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, T.S., Asfaw, Z., Bartus, G., Brooks, A.L., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D., (2015). The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*, 14, pp.1–16. Available from: https://doi.org/10.1016/J.COSUST.2014.11.002 [Accessed 28 February 2023].

Dodds, W.K., Perkin, J.S. and Gerken, J.E., (2013). Human Impact on Freshwater Ecosystem Services: A Global Perspective. *Environmental Science & Technology*, 47(16), pp.9061–9068. Available from: https://doi.org/10.1021/es4021052 [Accessed 26 April 2019].

Dolman, L.A., Vowles, A.S. and Kemp, P.S., (2024). Chalk stream restoration: Physical and ecological responses to gravel augmentation. *PLOS ONE* [Online], 19(11), p.e0313876. Available from: https://doi.org/10.1371/JOURNAL.PONE.0313876 [Accessed 11 June 2025].

Drescher, M., Perera, A.H., Johnson, C.J., Buse, L.J., Drew, C.A. and Burgman, M.A., (2013). Toward rigorous use of expert knowledge in ecological research. *Ecosphere*, 4(7), p.art83. Available from: https://doi.org/10.1890/ES12-00415.1 [Accessed 30 January 2019].

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A., (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81(02), p.163. Available from: https://doi.org/10.1017/S1464793105006950 [Accessed 10 April 2017].

Dudley, M., (2017). “Muddying the waters: recreational conflict and rights of use of British rivers”. *Water History,* 9(3), pp.259–277. Available from: https://doi.org/10.1007/S12685-017-0193-2 [Accessed 11 June 2025].

Duea, S.R., Zimmerman, E.B., Vaughn, L.M., Dias, S. and Harris, J., (2022). A Guide to Selecting Participatory Research Methods Based on Project and Partnership Goals. *Journal of participatory research methods*, 3(1), p.10.35844/001c.32605. Available from: https://doi.org/10.35844/001C.32605 [Accessed 1 September 2025].

Durham Community Research Team, (2011). *Community-based Participatory Research: Ethical Challenges Researchers and Project Partners* [Online]. Durham. Available from: [Accessed 13 April 2024].

Ebner, M., Fontana, V., Schirpke, U. and Tappeiner, U., (2022). Stakeholder perspectives on ecosystem services of mountain lakes in the European Alps. *Ecosystem Services*, 53, p.101386. Available from: https://doi.org/10.1016/J.ECOSER.2021.101386 [Accessed 30 August 2025].

Ebner, M., Schirpke, U. and Tappeiner, U., (2022). Combining multiple socio-cultural approaches – Deeper insights into cultural ecosystem services of mountain lakes? *Landscape and Urban Planning*, 228, p.104. Available from: https://doi.org/10.1016/J.LANDURBPLAN.2022.104549 [Accessed 16 January 2023].

Ehrlich, P. and Ehrlich, A., (1981). *Extinction: The Causes and Consequences of the Disappearance of Species*. New York: Random House. Available from: [Accessed 17 July 2025].

Ehrlich, P.R. and Mooney, H.A., (1983). Extinction, Substitution, and Ecosystem Services. *BioScience*, 33(4), pp.248–254. Available from: https://doi.org/10.2307/1309037 [Accessed 3 February 2024].

Ehrlich, P.R. and Pringle, R.M., (2008). Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. *Proceedings of the National Academy of Sciences*, 105(1), pp.11579–11586. Available from: https://doi.org/10.1073/PNAS.0801911105 [Accessed 6 March 2023].

Eigenbrod, F., Armsworth, P.R., Anderson, B.J., Heinemeyer, A., Gillings, S., Roy, D.B., Thomas, C.D. and Gaston, K.J., (2010). The impact of proxy-based methods on mapping the distribution of ecosystem services. *Journal of Applied Ecology*, 47(2), pp.377–385. Available from: https://doi.org/10.1111/J.1365-2664.2010.01777.X [Accessed 4 February 2024].

Emerson, K., Nabatchi, T. and Balogh, S., (2012). An Integrative Framework for Collaborative Governance. *Journal of Public Administration Research and Theory*, 22(1), pp.1–29. Available from: https://doi.org/10.1093/JOPART/MUR011 [Accessed 23 March 2022].

English Nature, (2002). *Defining reference conditions for chalk stream and Fenland natural channels*. Available from: https://publications.naturalengland.org.uk/file/77057#:~:text=Chalk%20streams%20have%20a%20high,(Whiting%20and%20Moog%202001) [Accessed 23 March 2022].

Environment Act (2021). Available from: https://www.legislation.gov.uk/ukpga/2021/30/contents [Accessed 29 July 2025].

Environment Agency, (2004). *The State of Englands Chalk Rivers*. Available from: http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.19CK86CYZNA2H3D [Accessed 13 July 2025].

Environment Agency, (2013). *Test & Itchen River Restoration Strategy, Technical Report*. Available from: https://www.therrc.co.uk/assets/files/Designated_Rivers/Test_Itchen/technical_report_issue_5_final.pdf [Accessed 29 July 2025].

Environment Agency, (2019). *Test and Itchen Abstraction licensing Strategy version 3*. Bristol. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/793438/Test_and_Itchen_Abstraction_Licence_Strategy.pdf [Accessed 29 July 2025].

Environment Agency, (2021a). *Reasons for not achieving good status dataset*. Available from: https://environment.data.gov.uk/ [Accessed 29 July 2025].

Environment Agency, (2021b). *The Water Framework Directive 2000/60/EC (WFD) Classification Status Cycle 2*. Available from: https://data.gov.uk/dataset [Accessed 14 July 2025].

Environment Agency, (2022). *Test and Itchen Management Catchment*. Available from: https://environment.data.gov.uk/catchment-planning/ManagementCatchment/3097 [Accessed 25 August 2025].

Environment Agency and Natural England, (2021). *Chalk stream strategy launched to protect 'England's rainforests'*. Available from: https://www.gov.uk/government/news/chalk-stream-strategy-launched-to-protect-englands-rainforests [Accessed 25 March 2024].

Environment Agency and Natural Resources Wales, (2013). *Water stressed areas – final classification*. Available from: https://assets.publishing.service.gov.uk/media/5a7c33a6ed915d7d70d1d409/water-stressed-classification-2013.pdf [Accessed 12 September 2025].

Environmental Audit Committee, (2022). *Water quality in rivers Fourth Report of Session 2021-22*. Available from: www.parliament.uk. [Accessed 7 March 2023].

Ernoul, L., Wardell-Johnson, A., Willm, L., Béchet, A., Boutron, O., Mathevet, R., Arnassant, S. and Sandoz, A., (2018). Participatory mapping: Exploring landscape values associated with an iconic species. *Applied Geography*, 95, pp.71–78. Available from: https://doi.org/10.1016/J.APGEOG.2018.04.013 [Accessed 8 September 2025].

Everall, N.C., Johnson, M.F., Wood, P. and Mattingley, L., (2018). Sensitivity of the early life stages of a mayfly to fine sediment and orthophosphate levels. *Environmental Pollution*, 237, pp.792–802. Available from: https://doi.org/10.1016/J.ENVPOL.2017.10.131 [Accessed 14 July 2025].

Fagerholm, N., García-Martín, M., Torralba, M., Bieling, C. and Plieninger, T., (2022). Public participation geographical information systems (PPGIS): Participatory research methods for sustainability - toolkit #1. *GAIA - Ecological Perspectives for Science and Society*, 31(1), pp.46–48. Available from: https://doi.org/10.14512/GAIA.31.1.10 [Accessed 4 April 2022].

Fagerholm, N., Oteros-Rozas, E., Raymond, C.M., Torralba, M., Moreno, G. and Plieninger, T., (2016). Assessing linkages between ecosystem services, land-use and well-being in an agroforestry landscape using public participation GIS. *Applied Geography*, 74, pp.30–46. Available from: https://doi.org/10.1016/J.APGEOG.2016.06.007 [Accessed 3 July 2019].

Fagerholm, N., Raymond, C.M., Olafsson, A.S., Brown, G., Rinne, T., Hasanzadeh, K., Broberg, A. and Kyttä, M., (2021). A methodological framework for analysis of participatory mapping data in research, planning, and management. *International Journal of Geographical Information Science*, 35(9), pp.1848–1875. Available from: https://doi.org/10.1080/13658816.2020.1869747 [Accessed 14 April 2022].

Felipe-Lucia, M.R., Comín, F.A. and Bennett, E.M., (2014a). Interactions among ecosystem services across land uses in a floodplain agroecosystem. *Ecology and Society* [Online], 19(1). Available from: https://doi.org/10.5751/ES-06249-190120 [Accessed 18 July 2024].

Fieuw, W., Foth, M. and Caldwell, G.A., (2022). Towards a More-than-Human Approach to Smart and Sustainable Urban Development: Designing for Multispecies Justice. *Sustainability 2022,* 14(2), p.948. Available from: https://doi.org/10.3390/SU14020948 [Accessed 7 August 2024].

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., Groot, R. de, Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D. and Balmford, A., (2008). Ecosystem services and economic theory: Integration for policy-relevant research. *Ecological Applications*, 18(8), pp.2050–2067. Available from: https://doi.org/10.1890/07-1537.1 [Accessed 26 June 2017].

Fliervoet, J.M., Geerling, G.W., Mostert, E. and Smits, A.J.M., (2015). Analyzing Collaborative Governance Through Social Network Analysis: A Case Study of River Management Along the

Waal River in The Netherlands. *Environmental Management*, 57(2), pp.355–367. Available from: https://doi.org/10.1007/S00267-015-0606-X [Accessed 11 August 2021].

FlyFish Circle, (2024). *Chalkstreams in Hampshire* [Online]. Available from: https://flyfishcircle.com/country/united-kingdom/location-group/chalkstreams-in-hampshire [Accessed 4 August 2024].

Folke, C., Hahn, T., Olsson, P. and Norberg, J., (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* [Online], 30, pp.441–473. Available from: https://doi.org/10.1146/annurev.energy.30.050504.144511 [Accessed 29 October 2020].

Fones, G.R., Bakir, A., Gray, J., Mattingley, L., Measham, N., Knight, P., Bowes, M.J., Greenwood, R. and Mills, G.A., (2020). Using high-frequency phosphorus monitoring for water quality management: a case study of the upper River Itchen, UK. *Environmental Monitoring and Assessment*, 192(3), pp.1–15. Available from: https://doi.org/10.1007/S10661-020-8138-0/FIGURES/3 [Accessed 29 July 2025].

Ford, A.T. and Ginley, F., (2024). Insights into PFAS contaminants before and after sewage discharges into a marine protected harbour. *Chemosphere* [Online], 366, p.143. Available from: https://doi.org/10.1016/J.CHEMOSPHERE.2024.143526 [Accessed 12 September 2025].

Förster, J., Barkmann, J., Fricke, R., Hotes, S., Kleyer, M., Kobbe, S., Kübler, D., Rumbaur, C., Siegmund-Schultze, M., Seppelt, R., Settele, J., Spangenberg, J.H., Tekken, V., Václavík, T. and Wittmer, H., (2015). Assessing ecosystem services for informing land-use decisions: a problem-oriented approach. *Ecology and Society*, 20(3), p.art31. Available from: https://doi.org/10.5751/ES-07804-200331 [Accessed 29 August 2019].

Freeman, L.C., (1978). Centrality in social networks conceptual clarification. *Social Networks* [Online], 1(3), pp.215–239. Available from: https://doi.org/10.1016/0378-8733(78)90021-7 [Accessed 18 September 2021].

Freeman, R.E., (1984). *Strategic management: a stakeholder approach*. Boston, Massachusetts, USA. Pitman. Available from: https://www.worldcat.org/title/strategic-management-a-stakeholder-approach/oclc/9685996 [Accessed 14 December 2022].

Friedkin, N.E., (1981). The Development of Structure in Random Networks: an analysis of the effects of increasing network density on five measures of structure. *Social Networks*, 3, pp.41–52. Available from: https://www.sciencedirect.com/science/article/pii/0378873381900046 [Accessed 18 September 2021].

Gardner, C.J. and Bullock, J.M., (2021). In the Climate Emergency, Conservation Must Become Survival Ecology. *Frontiers in Conservation Science*, 2. Available from: https://doi.org/10.3389/FCOSC.2021.659912/BIBTEX [Accessed 7 September 2025].

Gerrits, L. and Edelenbos, J., (2004). Management of sediments through stakeholder involvement: The risks and value of engaging stakeholders when looking for solutions for sediment-related problems. *Journal of Soils and Sediments*, 4(4), pp.239–246. Available from: https://doi.org/10.1007/BF02991120/METRICS [Accessed 1 September 2025].

Giakoumis, T. and Voulvoulis, N., (2018). A participatory ecosystems services approach for pressure prioritisation in support of the Water Framework Directive. *Ecosystem Services*, 34, pp.126–135. Available from: https://doi.org/10.1016/J.ECOSER.2018.10.007 [Accessed 15 May 2019].

Gibbons, M., Limoges, C., Nowotny, H., Scott, P. and Trow, M., (1994). *The New Production of Knowledge, The Dynamics of Science and Research in Contemporary Societies*. *The new production of knowledge: The dynamics of science and research in contemporary societies* [Online]. Sage Publications. Available from: https://uk.sagepub.com/en-gb/eur/the-new-production-of-knowledge/book204307 [Accessed 1 September 2025].

Gifford, R., (2011). The Dragons of Inaction: Psychological Barriers That Limit Climate Change Mitigation and Adaptation. *American Psychologist*, 66(4), pp.290–302. Available from: https://doi.org/10.1037/A0023566 [Accessed 7 March 2023].

Gittins, J.R., Picken, J. and Dajka, J.C., (2025). A Leverage Points Framework To Manage Changes in River Health. *River Research and Applications*, 41(1), pp.177–189. Available from: https://doi.org/10.1002/RRA.4391 [Accessed 12 May 2025].

Glasspool, J., (2007). *Chalk streams: A Guide to their Natural History and River Keeping*. Ed. by J. Glasspool. Test and Itchen Association Ltd.

Gottwald, S., Albert, C. and Fagerholm, N., (2021). Combining sense of place theory with the ecosystem services concept: empirical insights and reflections from a participatory mapping study. *Landscape Ecology*, pp.1–23. Available from: https://doi.org/10.1007/S10980-021-01362-Z/TABLES/9 [Accessed 10 January 2022].

Gozlan, R.E., Karimov, B.K., Zadereev, E., Kuznetsova, D. and Brucet, S., (2019). Status, trends, and future dynamics of freshwater ecosystems in Europe and Central Asia. *Inland Waters*, 9(1), pp.78–94. Available from: https://doi.org/10.1080/20442041.2018.1510271 [Accessed 12 September 2025].

Grabowski, R.C. and Gurnell, A.M., (2016). Diagnosing problems of fine sediment delivery and transfer in a lowland catchment. *Aquatic Sciences*, 78(1), pp.95–106. Available from: https://doi.org/10.1007/S00027-015-0426-3/FIGURES/6 [Accessed 16 July 2025].

Granovetter, M.S., (1973). The Strength of Weak Ties. *American Journal of Sociology*, 78(6), pp.1360–1380. Available from: https://www.jstor.org/stable/2776392?seq=1#metadata_info_tab_contents [Accessed 18 September 2021].

Graziano, M., Giorgi, A. and Feijoó, C., (2021). Multiple stressors and social-ecological traps in Pampean streams (Argentina): A conceptual model. *Science of The Total Environment*, 765. Available from: https://doi.org/10.1016/j.scitotenv.2020.142785 [Accessed 27 February 2023].

Greig, S., Sear, D. and Carling, P., (2007). A field-based assessment of oxygen supply to incubating Atlantic salmon (Salmo salar) embryos. *Hydrological Processes* [Online], 21(22), pp.3087–3100. Available from: https://doi.org/10.1002/hyp.6635.

Greig, S.M., Sear, D.A. and Carling, P.A., (2005). The impact of fine sediment accumulation on the survival of incubating salmon progeny: Implications for sediment management. *Science of The Total Environment*, 344(1–3), pp.241–258. Available from: https://doi.org/10.1016/j.scitotenv.2005.02.010.

Grêt-Regamey, A., Weibel, B., Kienast, F., Rabe, S.E. and Zulian, G., (2015). A tiered approach for mapping ecosystem services. *Ecosystem Services* [Online], 13, pp.16–27. Available from: https://doi.org/10.1016/J.ECOSER.2014.10.008 [Accessed 6 September 2025].

Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M.E., Meng, J., Mulligan, M., Nilsson, C., Olden, J.D., Opperman, J.J., Petry, P., Reidy Liermann, C., Sáenz, L., Salinas-Rodríguez, S., Schelle, P., Schmitt, R.J.P., Snider, J., Tan, F., Tockner, K., Valdujo, P.H., van Soesbergen, A. and Zarfl, C., (2019). Mapping the world's free-flowing rivers. *Nature*, 569(7755), pp.215–221. Available from: https://doi.org/10.1038/s41586-019-1111-9 [Accessed 18 July 2024].

De Groot, R., Fisher, B., Christie, M., Aronson, J., Braat, L., Gowdy, J., Haines-Young, R., Maltby, E., Blignaut, J., Brondízio, E., Costanza, R., Jax, K., Kadekodi, G.K., May, P.H., Mcneely, J. and

Shmelev, S., (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In: P. Kumar, ed. *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. London: Earthscan, pp.9–40. Available from: http://www.teebweb.org/wp-content/uploads/2013/04/D0-Chapter-1-Integrating-the-ecological-and-economic-dimensions-in-biodiversity-and-ecosystem-service-valuation.pdf [Accessed 6 July 2017].

Gupta, J., Pahl-Wostl, C. and Zondervan, R., (2013). 'Glocal' water governance: a multi-level challenge in the anthropocene. *Current Opinion in Environmental Sustainability*, 5(6), pp.573–580. Available from: https://doi.org/10.1016/j.cosust.2013.09.003 [Accessed 3 August 2021].

Gurnell, A.M., Bertoldi, W., Tockner, K., Wharton, G. and Zolezzi, G., (2016). How large is a river? Conceptualizing river landscape signatures and envelopes in four dimensions. *Wiley Interdisciplinary Reviews: Water*, 3(3), pp.313–325. Available from: https://doi.org/10.1002/WAT2.1143 [Accessed 17 July 2025].

Gurnell, A.M. and Grabowski, R.C., (2016). Vegetation–Hydrogeomorphology Interactions in a Low-Energy, Human-Impacted River. *River Research and Applications*, 32(2), pp.202–215. Available from: https://doi.org/10.1002/RRA.2922 [Accessed 14 July 2025].

Gurnell, A.M., Van Oosterhout, M.P., De Vlieger, B. and Goodson, J.M., (2006). Reach-scale interactions between aquatic plants and physical habitat: River Frome, Dorset. *River Research and Applications*, 22(6), pp.667–680. Available from: https://doi.org/10.1002/RRA.929 [Accessed 12 September 2025].

Haines-Young, R. and Potschin, M., (2010). The links between biodiversity, ecosystem services and human well-being. In: David.G. Raffaelli and L.J. Frid, Christopher, eds. *Ecosystem Ecology: a new synthesis*. Cambridge: Cambridge University Press, pp.110–139. Available from: https://www.nottingham.ac.uk/cem/pdf/Haines-Young&Potschin_2010.pdf [Accessed 6 July 2017].

Haines-Young, R. and Potschin, M., (2018). *Common International Classification of Ecosystem Services (CICES) V5.1*. Available from: www.cices.eu [Accessed 13 June 2019].

Hampshire & Isle of Wight Wildlife Trust, (2017). *Southern Chalkstreams project*. Available from: http://www.hiwwt.org.uk/southern-chalkstreams [Accessed 20 June 2017].

Hampshire and Isle of Wight Wildlife Trust, (2009). *Crayfish and River Users Guidelines for Specific Interest Groups*.

Hampshire and Isle of Wight Wildlife Trust, (2023). *Watercress and Winterbournes*. Available from: https://www.hiwwt.org.uk/watercress-and-winterbournes [Accessed 7 March 2023].

Hampshire and Isle of Wight Wildlife Trust, (n.d). *Winnall Moors Nature Reserve*. Available from: https://www.hiwwt.org.uk/nature-reserves/winnall-moors-nature-reserve [Accessed 7 September 2025].

Hampshire County Council, (2003). *Water and Biodiversity Topic Action Plan*. Available from: http://www.hampshirebiodiversity.org.uk/pdf/PublishedPlans/Water_BAP.pdf [Accessed 12 October 2016].

Hanel, P.H.P., Foad, C. and Maio, G.R., (2021). Attitudes and Values. *Oxford Research Encyclopedia of Psychology*. Available from: https://doi.org/10.1093/ACREFORE/9780190236557.013.248 [Accessed 7 September 2025].

Hanna, D.E.L., Tomscha, S.A., Ouellet Dallaire, C. and Bennett, E.M., (2018). A review of riverine ecosystem service quantification: Research gaps and recommendations. *Journal of Applied Ecology*, 55(3), pp.1299–1311. Available from: https://doi.org/10.1111/1365-2664.13045 [Accessed 1 May 2018].

Hanrahan, G., Gledhill, M., House, W.A. and Worsfold, P.J., (2003). Evaluation of phosphorus concentrations in relation to annual and seasonal physico-chemical water quality parameters in a UK chalk stream. *Water Research*, 37(15), pp.3579–3589. Available from: https://doi.org/10.1016/S0043-1354(03)00265-3 [Accessed 24 July 2025].

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O. and Jax, K., (2013). Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives. *Environmental Science and Policy*, 25, pp.13–21. Available from: https://doi.org/10.1016/j.envsci.2012.08.001 [Accessed 9 December 2020].

Hauck, J., Saarikoski, H., Turkelboom, F. and Keune, H., (2016). Stakeholder involvement in ecosystem service decision-making and research. In: M. Potschin and K. Jax, eds. *OpenNESS Ecosystem Services Reference Book*. Available from: http://pubs.iied.org/pdfs/6021IIED.pdf [Accessed 31 August 2025].

Hauck, J., Stein, C., Schiffer, E. and Vandewalle, M., (2015). Seeing the forest and the trees: Facilitating participatory network planning in environmental governance. *Global Environmental Change*, 35, pp.400–410. Available from: https://doi.org/10.1016/J.GLOENVCHA.2015.09.022 [Accessed 30 July 2019].

Hearne, J.W. and Armitage, P.D., (1993). Implications of the annual macrophyte growth cycle on habitat in rivers. *Regulated Rivers: Research & Management*, 8(4), pp.313–322. Available from: https://doi.org/10.1002/RRR.3450080402;REQUESTEDJOURNAL:JOURNAL:10991646 [Accessed 14 July 2025].

Herz, A., Peters, L. and Truschkat, I., (2015). View of How to do Qualitative Structural Analysis: The Qualitative Interpretation of Network Maps and Narrative Interviews. *Forum: Qualitative Social Research*, 16(1). Available from: https://www.qualitative-research.net/index.php/fqs/article/view/2092/3904 [Accessed 28 May 2021].

Heywood, M.J.T. and Walling, D.E., (2003). Suspended sediment fluxes in chalk streams in the Hampshire Avon catchment, U.K. *Hydrobiologia*, 494(1), pp.111–117. Available from: https://doi.org/10.1023/A:1025445711343/METRICS [Accessed 24 July 2025].

Heywood, M.J.T. and Walling, D.E., (2007). The sedimentation of salmonid spawning gravels in the Hampshire Avon catchment, UK: Implications for the dissolved oxygen content of intragravel water and embryo survival. *Hydrological Processes*, 21(6), pp.770–788. Available from: https://doi.org/10.1002/HYP.6266 [Accessed 16 July 2025].

Hoffmann, C., García Márquez, J.R. and Krueger, T., (2018). A local perspective on drivers and measures to slow deforestation in the Andean-Amazonian foothills of Colombia. *Land Use Policy*, 77, pp.379–391. Available from: https://doi.org/10.1016/J.LANDUSEPOL.2018.04.043 [Accessed 31 January 2023].

Hohenthal, J., Owidi, E., Minoia, P. and Pellikka, P., (2015). Local assessment of changes in water-related ecosystem services and their management: DPASER conceptual model and its application in Taita Hills, Kenya. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 11(3), pp.225–238. Available from: https://doi.org/10.1080/21513732.2014.985256 [Accessed 15 May 2019].

Holdich, D.M., James, J., Jackson, C. and Peay, S., (2014). The North American signal crayfish, with particular reference to its success as an invasive species in Great Britain. *Ethology Ecology and Evolution*, 26(2–3), pp.232–262. Available from: https://doi.org/10.1080/03949370.2014.903380;JOURNAL:JOURNAL:TEEE19;WGROUP:STRING:PUBLICATION [Accessed 16 July 2025].

Honey-Rosés, J., Canessa, M., Daitch, S., Gomes, B., Muñoz-Blanco García, J., Xavier, A. and Zapata, O., (2020). Comparing Structured and Unstructured Facilitation Approaches in Consultation Workshops: A Field Experiment. *Group Decision and Negotiation*, 29(5), pp.949–

967. Available from: https://doi.org/10.1007/S10726-020-09688-W/TABLES/5 [Accessed 25 August 2025].

Hu, A., 2024. 7. The workshop as a research methodology: Lessons learned from workshops utilized as a participatory research method. *Metodetilnærminger og prosessuelle design i barnehageforskning*, pp.120–133. Available from: https://doi.org/10.18261/9788215064697-24-07 [Accessed 25 August 2025].

Hubbard, R.K., Newton, G.L. and Hill, G.M., (2004). Water Quality and the Grazing Animal Water quality and the grazing animal 1. *J. Anim. Sci*, 82, pp.255–263.

Hugé, J. and Mukherjee, N., (2018). The nominal group technique in ecology and conservation: Application and challenges. *Methods in Ecology and Evolution*, 9(1), pp.33–41. Available from: https://doi.org/10.1111/2041-210X.12831 [Accessed 3 May 2019].

Huitema, D., Mostert, W., Egas, S., Moellenkamp, Pahl-Wostl and Yalcin, (2009). Adaptive Water Governance: Assessing the Institutional Prescriptions of Adaptive (Co-)Management from a Governance Perspective and Defining a Research Agenda. *Ecology and Society*, 14(1). Available from: https://www.ecologyandsociety.org/vol14/iss1/art26/.

Iniesta-Arandia, I., García-Llorente, M., Aguilera, P.A., Montes, C. and Martín-López, B., (2014). Socio-cultural valuation of ecosystem services: uncovering the links between values, drivers of change, and human well-being. *Ecological Economics*, 108, pp.36–48. Available from: https://doi.org/10.1016/J.ECOLECON.2014.09.028 [Accessed 18 July 2019].

International Association of Public Participation (IAP2), (2018). *IAP2 Spectrum of Public Participation* [Online]. Available from: https://cdn.ymaws.com/www.iap2.org/resource/resmgr/pillars/Spectrum_8.5x11_Print.pdf [Accessed 1 September 2025].

Isbell, F., Balvanera, P., Mori, A.S., He, J.S., Bullock, J.M., Regmi, G.R., Seabloom, E.W., Ferrier, S., Sala, O.E., Guerrero-Ramírez, N.R., Tavella, J., Larkin, D.J., Schmid, B., Outhwaite, C.L., Pramual, P., Borer, E.T., Loreau, M., Omotoriogun, T.C., Obura, D.O., Anderson, M., Portales-Reyes, C., Kirkman, K., Vergara, P.M., Clark, A.T., Komatsu, K.J., Petchey, O.L., Weiskopf, S.R., Williams, L.J., Collins, S.L., Eisenhauer, N., Trisos, C.H., Renard, D., Wright, A.J., Tripathi, P., Cowles, J., Byrnes, J.E.K., Reich, P.B., Purvis, A., Sharip, Z., O'Connor, M.I., Kazanski, C.E., Haddad, N.M., Soto, E.H., Dee, L.E., Díaz, S., Zirbel, C.R., Avolio, M.L., Wang, S., Ma, Z., Liang, J., Farah, H.C., Johnson, J.A., Miller, B.W., Hautier, Y., Smith, M.D., Knops, J.M.H., Myers, B.J.E., Harmáčková, Z. V., Cortés, J., Harfoot, M.B.J., Gonzalez, A., Newbold, T., Oehri, J., Mazón, M., Dobbs, C. and Palmer, M.S., (2022). Expert perspectives on global biodiversity loss and its drivers and impacts on people. *Frontiers in Ecology and the Environment*. Available from: https://doi.org/10.1002/FEE.2536 [Accessed 1 March 2023].

Itzkin, A., Scholes, M.C., Clifford-Holmes, J.K., Rowntree, K., van der Waal, B. and Coetzer, K., (2021). A Social-Ecological Systems Understanding of Drivers of Degradation in the Tsitsa River Catchment to Inform Sustainable Land Management. *Sustainability,* 13(2), p.516. Available from: https://doi.org/10.3390/SU13020516 [Accessed 2 August 2024].

Jackson, C.R., Meister, R. and Prudhomme, C., (2011). Modelling the effects of climate change and its uncertainty on UK Chalk groundwater resources from an ensemble of global climate model projections. *Journal of Hydrology*, 399(1–2), pp.12–28. Available from: https://doi.org/10.1016/J.JHYDROL.2010.12.028 [Accessed 24 July 2025].

Jagadananda and Brown, L.D., (2020). Civil Society Legitimacy and Accountability: Issues and Challenges. *NGO Management*, pp.115–135. Available from: https://doi.org/10.4324/9781849775427-12 [Accessed 29 April 2024].

Jamshidi, E., Morasae, E.K., Shahandeh, K., Majdzadeh, R., Seydali, E., Aramesh, K. and Abknar, N.L., (2014). Ethical Considerations of Community-based Participatory Research: Contextual Underpinnings for Developing Countries. *International Journal of Preventive Medicine*, 5(10), p.1328. Available from: /pmc/articles/PMC4223954/ [Accessed 12 December 2023].

Jarvie, H.P., Neal, C. and Williams, R.J., (2004). Assessing changes in phosphorus concentrations in relation to in-stream plant ecology in lowland permeable catchments: Bringing ecosystem functioning into water quality monitoring. *Water, Air, and Soil Pollution: Focus*, 4(2–3), pp.641–655. Available from: https://doi.org/10.1023/B:WAFO.0000028384.30561.36/METRICS [Accessed 14 July 2025].

Jiménez-Segura, L., Restrepo-Ángel, J.D. and Hernandez-Serna, A., (2022). Drivers for the artisanal fisheries production in the Magdalena River. *Frontiers in Environmental Science*, 10, p.1619. Available from: https://doi.org/10.3389/FENVS.2022.866575/BIBTEX [Accessed 28 March 2023].

Joint Nature Conservation Committee, (n.d). *River Itchen - Special Areas of Conservation*. Available from: https://sac.jncc.gov.uk/site/UK0012599 [Accessed 14 July 2025].

Joint Nature Conservation Committee, (2024). *UK BAP Priority Habitats* [Online]. Available from: https://jncc.gov.uk/our-work/uk-bap-priority-habitats/ [Accessed 18 July 2025].

Jones, J.I., Murphy, J.F., Collins, A.L., Sear, D.A., Naden, P.S. and Armitage, P.D., (2012). The Impact Of Fine Sediment On Macro-Invertebrates. *River Research and Applications*, 28(8), pp.1055–1071. Available from: https://doi.org/10.1002/RRA.1516;JOURNAL:JOURNAL:10991646;PAGE:STRING:ARTICLE/CHAPTER [Accessed 16 July 2025].

Jones, L., Boeri, M., Christie, M., Durance, I., Evans, K.L., Fletcher, D., Harrison, L., Jorgensen, A., Masante, D., McGinlay, J., Paterson, D.M., Schmucki, R., Short, C., Small, N., Southon, G., Stojanovic, T. and Waters, R., (2022). Can we model cultural ecosystem services, and are we measuring the right things? *People and Nature*, 4(1), pp.166–179. Available from: https://doi.org/10.1002/PAN3.10271/SUPPINFO [Accessed 6 August 2024].

Jones, L., Holland, R.A., Ball, J., Sykes, T., Taylor, G., Ingwall-King, L., Snaddon, J.L. and S.-H. Peh, K., (2020). A place-based participatory mapping approach for assessing cultural ecosystem services in urban green space. *People and Nature*, 2(1), pp.123–137. Available from: https://doi.org/10.1002/PAN3.10057/SUPPINFO [Accessed 19 January 2023].

Jonsson, B. and Jonsson, N., (2009). A review of the likely effects of climate change on anadromous Atlantic salmon Salmo salar and brown trout Salmo trutta, with particular reference to water temperature and flow. *Journal of Fish Biology*, 75(10), pp.2381–2447. Available from: https://doi.org/10.1111/J.1095-8649.2009.02380.X;JOURNAL:JOURNAL:10958649;PAGEGROUP:STRING:PUBLICATION [Accessed 15 July 2025].

Keeler, B.L., Polasky, S., Brauman, K.A., Johnson, K.A., Finlay, J.C., O'Neille, A., Kovacs, K. and Dalzell, B., (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proceedings of the National Academy of Sciences of the United States of America*, 109(45), pp.18619–18624. Available from: https://doi.org/10.1073/PNAS.1215991109/-/DCSUPPLEMENTAL [Accessed 10 January 2022].

Kemp, P.S., Vowles, A.S., Sotherton, N., Roberts, D., Acreman, M.C. and Karageorgopoulos, P., (2017). Challenging convention: the winter ecology of brown trout (Salmo trutta) in a productive and stable environment. *Freshwater Biology*, 62(1), pp.146–160. Available from: https://doi.org/10.1111/FWB.12858;WGROUP:STRING:PUBLICATION [Accessed 11 June 2025].

Kochskämper, E., Challies, E., Newig, J. and Jager, N.W., (2016). Participation for effective environmental governance? Evidence from Water Framework Directive implementation in

Germany, Spain and the United Kingdom. *Journal of Environmental Management*, 181, pp.737–748. Available from: https://doi.org/10.1016/J.JENVMAN.2016.08.007 [Accessed 28 July 2025].

Komossa, F., Wartmann, F.M. and Verburg, P.H., (2021). Expanding the toolbox: Assessing methods for local outdoor recreation planning. *Landscape and Urban Planning*, 212, p.104105. Available from: https://doi.org/10.1016/J.LANDURBPLAN.2021.104105 [Accessed 2 August 2024].

Kremen, C. and Merenlender, A.M., (2018). Landscapes that work for biodiversity and people. *Science*, 362(6412). Available from: https://doi.org/10.1126/SCIENCE.AAU6020/SUPPL_FILE/AAU6020-KREMEN-SM.PDF [Accessed 22 January 2024].

Langemeyer, J., Palomo, I., Baraibar, S. and Gómez-Baggethun, E., (2018). Participatory multi-criteria decision aid: Operationalizing an integrated assessment of ecosystem services. *Ecosystem Services*, 30, pp.49–60. Available from: https://doi.org/10.1016/J.ECOSER.2018.01.012 [Accessed 31 August 2025].

Larson, S., Alexander, K.S., Djalante, R. and Kirono, D.G.C., (2013). The Added Value of Understanding Informal Social Networks in an Adaptive Capacity Assessment: Explorations of an Urban Water Management System in Indonesia. *Water Resources Management 2013 27:13*, 27(13), pp.4425–4441. Available from: https://doi.org/10.1007/S11269-013-0412-2 [Accessed 5 August 2021].

Lau, J.D., Hicks, C.C., Gurney, G.G. and Cinner, J.E., (2019). What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosystem Services*, 35, pp.219–230. Available from: https://doi.org/10.1016/J.ECOSER.2018.12.012 [Accessed 17 July 2025].

Lave, R.,(2018). Stream Mitigation Banking. *WIREs Water*, 5e1279, Available from: https://doi.org/10.1002/wat2.1279 [Accessed 5 October 2025].

Leiserowitz, A., (2019). Building Public and Political Will for Climate Change Action. In: Daniel.C. Esty, ed. *A Better Planet: Forty Big Ideas for a Sustainable Future* [Online]. Yale University Press, pp.155–162. Available from: https://doi.org/10.2307/J.CTVQC6GCQ.21 [Accessed 29 November 2021].

Lemos, M.C. and Agrawal, A., (2006). Environmental Governance. *Annual Review of Environment and Resources*, 31(1), pp.297–325. Available from: https://doi.org/10.1146/annurev.energy.31.042605.135621 [Accessed 5 December 2019].

Levine, J., Muthukrishna, M., Chan, K.M.A. and Satterfield, T., (2017). Sea otters, social justice, and ecosystem-service perceptions in Clayoquot Sound, Canada. *Conservation Biology*, 31(2), pp.343–352. Available from: https://doi.org/10.1111/cobi.12795 [Accessed 15 May 2018].

Liberating Structures, (n.d.). *1-2-4-All,* Available from: https://www.liberatingstructures.com/1-1-2-4-all/ [Accessed 27 January 2025].

Linke, S., Norris, R.H. and Pressey, R.L., (2008). Irreplaceability of river networks: towards catchment-based conservation planning. *Journal of Applied Ecology*, 45(5), pp.1486–1495. Available from: https://doi.org/10.1111/J.1365-2664.2008.01520.X [Accessed 18 July 2024].

Loc, H.H., Park, E., Thu, T.N., Diep, N.T.H. and Can, N.T., (2021). An enhanced analytical framework of participatory GIS for ecosystem services assessment applied to a Ramsar wetland site in the Vietnam Mekong Delta. *Ecosystem Services* , 48, p.101245. Available from: https://doi.org/10.1016/J.ECOSER.2021.101245 [Accessed 6 April 2022].

Locatelli, B., Benra, F., Geneletti, D., Loft, L., Loos, J., Schröter, B., Winkler, K. and Zoderer, B.M., (2025). Framing the relationship between justice and ecosystem services: A systematic review. *Ecosystem Services*, 74, p.101755. Available from: https://doi.org/10.1016/J.ECOSER.2025.101755 [Accessed 12 September 2025].

Lockwood, M., Davidson, J., Curtis, A., Stratford, E. and Griffith, R., (2010). Governance principles for natural resource management. *Society and Natural Resources*, 23(10), pp.986–1001. Available from: https://doi.org/10.1080/08941920802178214;REQUESTEDJOURNAL:JOURNAL:USNR20;WGROUP:STRING:PUBLICATION [Accessed 24 August 2025].

Longato, D., Cortinovis, C., Albert, C. and Geneletti, D., (2021). Practical applications of ecosystem services in spatial planning: Lessons learned from a systematic literature review. *Environmental Science & Policy*, 119, pp.72–84. Available from: https://doi.org/10.1016/J.ENVSCI.2021.02.001 [Accessed 22 January 2024].

Loos, J., Benra, F., Berbés-Blázquez, M., Bremer, L.L., Chan, K.M.A., Egoh, B., Felipe-Lucia, M., Geneletti, D., Keeler, B., Locatelli, B., Loft, L., Schröter, B., Schröter, M. and Winkler, K.J., (2022).

An environmental justice perspective on ecosystem services. *Ambio 2022 52:3*, 52(3), pp.477–488. Available from: https://doi.org/10.1007/S13280-022-01812-1 [Accessed 6 August 2024].

Lopes, R. and Videira, N., (2016). A Collaborative Approach for Scoping Ecosystem Services with Stakeholders: The Case of Arrábida Natural Park. *Environmental Management*, 58(2), pp.323–342. Available from: https://doi.org/10.1007/S00267-016-0711-5/FIGURES/5 [Accessed 31 August 2025].

Lopes, R. and Videira, N., (2019). How to articulate the multiple value dimensions of ecosystem services? Insights from implementing the PArticulatES framework in a coastal social-ecological system in Portugal. *Ecosystem Services*, 38, p.100955. Available from: https://doi.org/10.1016/J.ECOSER.2019.100955 [Accessed 17 July 2025].

Luck, G.W., Chan, K.M.A., Eser, U., Gómez-Baggethun, E., Matzdorf, B., Norton, B. and Potschin, M.B., (2012). Ethical Considerations in On-Ground Applications of the Ecosystem Services Concept. *BioScience*, 62(12), pp.1020–1029. Available from: https://doi.org/10.1525/BIO.2012.62.12.4 [Accessed 18 July 2024].

Lumber, R., Richardson, M. and Sheffield, D., (2017). Beyond knowing nature: Contact, emotion, compassion, meaning, and beauty are pathways to nature connection. *PLOS ONE*, 12(5), p.e0177186. Available from: https://doi.org/10.1371/JOURNAL.PONE.0177186 [Accessed 11 June 2025].

Macadam, C., Stubbington, R. and Wallace, I., (2021). The specialist insects that rely on the wet: dry habitats of temporary streams. *The Freshwater Biological Association Newsletter*, (81), pp.28–33.

MacDonald, A.M. and Allen, D.J., (2001). Aquifer properties of the chalk of England. *Quarterly Journal of Engineering Geology and Hydrogeology*, 34(4), pp.371–384. Available from: https://doi.org/10.1144/QJEGH.34.4.371;SUBPAGE:STRING:ABSTRACT;WEBSITE:WEBSITE:WWW.LYELLCOLLECTION.ORG;JOURNAL:JOURNAL:QJEGH-1;WGROUP:STRING:PUBLICATION [Accessed 24 July 2025].

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J.P., Grizzetti, B., Drakou, E.G., Notte, A. La, Zulian, G., Bouraoui, F., Luisa Paracchini, M., Braat, L. and Bidoglio, G., (2012). Mapping ecosystem services for policy support and decision making in the European Union. *Ecosystem Services*, 1(1), pp.31–39. Available from: https://doi.org/10.1016/j.ecoser.2012.06.004 [Accessed 11 February 2022].

Magner, J.A., Vondracek, B. and Brooks, K.N., (2008). Grazed Riparian Management and Stream Channel Response in Southeastern Minnesota (USA) Streams. *Environmental Management*, 42(3), pp.377–390. Available from: https://doi.org/10.1007/s00267-008-9132-4.

Mainstone, C. (1999). *Chalk rivers - nature conservation and management*. Available from: publications.naturalengland.org.uk/file/6236206.

Mainstone, C.P. and Parr, W., (2002). Phosphorus in rivers — ecology and management. *Science of The Total Environment*, 282, pp.25–47. Available from: https://doi.org/10.1016/S0048-9697(01)00937-8.

Malinga, R., Gordon, L.J., Lindborg, R. and Jewitt, G., (2013). Using Participatory Scenario Planning to Identify Ecosystem Services in Changing Landscapes. *Ecology and Society,* 18(4). Available from: https://doi.org/10.5751/ES-05494-180410 [Accessed 31 August 2025].

Malmborg, K., (2021). *How on Earth? : Operationalizing the ecosystem service concept for sustainability,* Ph.D Thesis. Stockholm University . Available from: [Accessed 13 July 2024].

Mapita Oy, (2019). *Maptionnaire*. Helsinki.

Martín-López, B., Leister, I., Cruz, P.L., Palomo, I., Grêt-Regamey, A., Harrison, P.A., Lavorel, S., Locatelli, B., Luque, S. and Walz, A., (2019). Nature's contributions to people in mountains: A review. *PLOS ONE*, 14(6), p.e0217847. Available from: https://doi.org/10.1371/JOURNAL.PONE.0217847 [Accessed 31 August 2025].

Martin-Ortega, J., Mesa-Jurado, M.A., Pineda-Vazquez, M. and Novo, P., (2019). Nature commodification: 'a necessary evil'? An analysis of the views of environmental professionals on ecosystem services-based approaches. *Ecosystem Services*, 37, p.100926. Available from: https://doi.org/10.1016/J.ECOSER.2019.100926 [Accessed 18 July 2024].

Martnez-Harms, M.J. and Balvanera, P., (2012). Methods for mapping ecosystem service supply: A review. *International Journal of Biodiversity Science, Ecosystem Services and Management*, 8(1–2), pp.17–25. Available from: https://doi.org/10.1080/21513732.2012.663792;JOURNAL:JOURNAL:TBSM20 [Accessed 24 August 2025].

Masao, C.A., Prescott, G.W., Snethlage, M.A., Urbach, D., Torre-Marin Rando, A., Molina-Venegas, R., Mollel, N.P., Hemp, C., Hemp, A. and Fischer, M., (2022). Stakeholder perspectives on nature, people and sustainability at Mount Kilimanjaro. *People and Nature*, 4(3), pp.711–729. Available from: https://doi.org/10.1002/PAN3.10310 [Accessed 5 October 2022].

Mascarenhas, A., Ramos, T.B., Haase, D. and Santos, R., (2016). Participatory selection of ecosystem services for spatial planning: Insights from the Lisbon Metropolitan Area, Portugal. *Ecosystem Services*, 18, pp.87–99. Available from: https://doi.org/10.1016/J.ECOSER.2016.02.011 [Accessed 30 August 2025].

Mathieu, L., Tinch, R. and Provins, A., (2018). Catchment management in England and Wales: the role of arguments for ecosystems and their services. *Biodiversity and Conservation*, 27(7), pp.1639–1658. Available from: https://doi.org/10.1007/S10531-016-1176-9/TABLES/2 [Accessed 28 July 2025].

Mendoza, G.A. and Prabhu, R., (2006). Participatory modelling and analysis for sustainable forest management: Overview of soft system dynamics models and applications. *Forest Policy and Economics*, 9(2), pp.179–196. Available from: https://doi.org/10.1016/j.forpol.2005.06.006 [Accessed 17 January 2023].

Menzel, S. and Teng, J., (2010). Ecosystem services as a stakeholder-driven concept for conservation science. *Conservation Biology*, 24(3), pp.907–909. Available from: https://doi.org/10.1111/J.1523-1739.2009.01347.X [Accessed 30 August 2025].

Meyerson, L.A. and Mooney, H.A., (2007). Invasive alien species in an era of globalization. *Frontiers in Ecology and the Environment*, 5(4), pp.199–208. Available from: https://doi.org/10.1890/1540-9295(2007)5[199:IASIAE]2.0.CO;2.

Millennium Ecosystem Assessment, (2005). *Introduction and Conceptual Framework*. Available from: http://www.millenniumassessment.org/documents/document.299.aspx.pdf [Accessed 17 July 2017].

Miller, C.A. and Wyborn, C., (2020). Co-production in global sustainability: Histories and theories. *Environmental Science & Policy*, 113, pp.88–95. Available from: https://doi.org/10.1016/J.ENVSCI.2018.01.016 [Accessed 10 November 2021].

Mondon, B., Sear, D.A., Collins, A.L., Shaw, P.J. and Sykes, T., (2021). The scope for a system-based approach to determine fine sediment targets for chalk streams. *CATENA*, 206, p.105541. Available from: https://doi.org/10.1016/J.CATENA.2021.105541 [Accessed 24 November 2021].

Montgomery, D.R., Buffington, J.M., Peterson, N.P., Schuett-Hames, D. and Quinn, T.P., (1996). Stream-bed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. *Canadian Journal of Fisheries and Aquatic Sciences*, 53(5), pp.1061–1070. Available from: https://doi.org/10.1139/F96-028 [Accessed 12 September 2025].

Muñoz, L., Hausner, V.H., Runge, C., Brown, G. and Daigle, R., (2020). Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway. *People and Nature*, 2(2), pp.437–449. Available from: https://doi.org/10.1002/PAN3.10083/SUPPINFO [Accessed 26 June 2023].

Murrin, E., Taylor, N., Peralta, L., Dudley, D., Cotton, W. and White, R.L., (2023). Does physical activity mediate the associations between blue space and mental health? A cross-sectional study in Australia. *BMC Public Health*, 23(1), pp.1–9. Available from: https://doi.org/10.1186/S12889-023-15101-3/FIGURES/1 [Accessed 27 November 2023].

Naiman, R.J. and Dudgeon, D., (2011). Global alteration of freshwaters: Influences on human and environmental well-being. *Ecological Research* [Online], 26(5), pp.865–873. Available from: https://doi.org/10.1007/s11284-010-0693-3 [Accessed 13 November 2020].

Natural England, (1996). *River Test SSSI*. Available from: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S2000170&SiteName=test&countyCode=19&responsiblePerson=&SeaArea=&IFCAArea= [Accessed 29 July 2025].

Natural England, (2000). *River Itchen SSSI*. Available from: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S2000227&SiteName=itchen&countyCode=19&responsiblePerson=&SeaArea=&IFCAArea= [Accessed 29 July 2025].

Natural England, (2022). *River Itchen Special Area of Conservation - Evidence Pack*. Available from: https://publications.naturalengland.org.uk/publication/6005400246943744 [Accessed 14 July 2025].

Natural England, (2023). *Adults' Year 3 Annual Report (April 2022 - March 2023)*. Available from: https://www.gov.uk/government/statistics/the-people-and-nature-survey-for-england-data-tables-and-publications-from-adults-survey-year-3-april-2022-march-2023-official-statistics/adults-year-3-annual-report-april-2022-march-2023-official-statistics [Accessed 28 November 2023].

Neumann, M., (2021). *MNLpred - Simulated Predicted Probabilities for Multinomial Logit Models*. https://CRAN.R-project.org/package=MNLpred. Available from: https://doi.org/10.5281/zenodo.4525342 [Accessed 30 May 2024].

Nightingale, A., (2009). Triangulation. *International Encyclopedia of Human Geography*, pp.489–492. Available from: https://doi.org/10.1016/B978-008044910-4.00552-6 [Accessed 30 March 2022].

Norström, A. V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J.B., Leach, M., Le Tissier, M., Martín-López, B., Louder, E., Loutre, M.F., Meadow, A.M., Nagendra, H., Payne, D., Peterson, G.D., Reyers, B., Scholes, R., Speranza, C.I., Spierenburg, M., Stafford-Smith, M., Tengö, M., van der Hel, S., van Putten, I. and Österblom, H., (2020). Principles for knowledge co-production in sustainability research. *Nature Sustainability*, 3(3), pp.182–190. Available from: https://doi.org/10.1038/s41893-019-0448-2 [Accessed 12 November 2021].

Nussbaum, M., Sen, A. and Sen, M.A., 1993. *The Quality of Life*. Oxford University Press. Available from: https://philpapers.org/rec/NUSTQO [Accessed 13 July 2024].

Office for National Statistics, (2022). *Overview of the UK population: 2020*. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/population estimates/articles/overviewoftheukpopulation/2020 [Accessed 7 March 2023].

Oh, H., Chung, M.-H. and Labianca, G., (2004). Group Social Capital and Group Effectiveness: The Role of Informal Socializing Ties. *Academy of Management Journal*, 47(6), pp.860–875. Available from: https://doi.org/10.5465/20159627 [Accessed 18 September 2021].

Old, G.H., Naden, P.S., Rameshwaran, P., Acreman, M.C., Baker, S., Edwards, F.K., Sorensen, J.P.R., Mountford, O., Gooddy, D.C., Stratford, C.J., Scarlett, P.M., Newman, J.R. and Neal, M., (2014). Instream and riparian implications of weed cutting in a chalk river. *Ecological Engineering*, 71, pp.290–300. Available from: https://doi.org/10.1016/j.ecoleng.2014.07.006.

Olsson, P., Folke, C. and Berkes, F., (2004). Adaptive Comanagement for Building Resilience in Social–Ecological Systems. *Environmental Management*, 34(1), pp.75–90. Available from: https://doi.org/10.1007/S00267-003-0101-7 [Accessed 18 September 2021].

O'Neil, R. and Hughes, K., (2014). *The State of England's Chalk Streams*. Available from: https://www.cokecce.co.uk/system/file_resources/328/wwf_chalkstreamreport_final_lr.pdf [Accessed 10 October 2016].

Ostrom, E., (2015). Governing the Commons: The Evolution of Institutions for Collective Action. *Governing the Commons: The Evolution of Institutions for Collective Action*, pp.1–280. Available from: https://doi.org/10.1017/CBO9781316423936 [Accessed 18 September 2021].

Pacioglu, O. and Moldovan, O.T., (2016). Response of invertebrates from the hyporheic zone of chalk rivers to eutrophication and land use. *Environmental Science and Pollution Research*, 23(5), pp.4729–4740. Available from: https://doi.org/10.1007/S11356-015-5703-0/TABLES/5 [Accessed 14 July 2025].

Pahl-Wostl, C., (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, 19(3), pp.354–365. Available from: https://doi.org/10.1016/J.GLOENVCHA.2009.06.001 [Accessed 11 August 2021].

Pahl-Wostl, C., (2015). *Water Governance in the Face of Global Change*. *Water Governance in the Face of Global Change: From Understanding to Transformation*. Water Governance - Concepts, Methods, and Practice. Cham: Springer International Publishing. Available from: https://doi.org/10.1007/978-3-319-21855-7 [Accessed 6 May 2021].

Pahl-Wostl, C., (2019). The role of governance modes and meta-governance in the transformation towards sustainable water governance. *Environmental Science & Policy*, 91, pp.6–16. Available from: https://doi.org/10.1016/j.envsci.2018.10.008 [Accessed 11 August 2021].

Pahl-Wostl, C., Jeffrey, P. and Sendzimir, J., (2011). Adaptive and integrated management of water resources. In: R.Q. Quentin and K. Hussey, eds. *Water Resources Planning and Management.* Cambridge, UK: Cambridge University Press, pp.292–310. Available from: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/0B0E8C1C59B298E5E7A78B88EF58AE30/9780511974304c13_p292-310_CBO.pdf/adaptive_and_integrated_management_of_water_resources.pdf [Accessed 3 August 2021].

Pahl-Wostl, C., Knieper, C., Lukat, E., Meergans, F., Schoderer, M., Schütze, N., Schweigatz, D., Dombrowsky, I., Lenschow, A., Stein, U., Thiel, A., Tröltzsch, J. and Vidaurre, R., (2020). Enhancing the capacity of water governance to deal with complex management challenges: A framework of analysis. *Environmental Science & Policy*, 107, pp.23–35. Available from: https://doi.org/10.1016/j.envsci.2020.02.011 [Accessed 11 August 2021].

Palomo, I., Martín-López, B., Zorrilla-Miras, P., García Del Amo, D. and Montes, C., (2014). Deliberative mapping of ecosystem services within and around Doñana National Park (SW Spain) in relation to land use change. *Regional Environmental Change*, 14(1), pp.237–251. Available from: https://doi.org/10.1007/S10113-013-0488-5/FIGURES/5 [Accessed 5 February 2024].

Paracchini, M.L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J.P., Termansen, M., Zandersen, M., Perez-Soba, M., Scholefield, P.A. and Bidoglio, G., (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. *Ecological Indicators*, 45, pp.371–385. Available from: https://doi.org/10.1016/J.ECOLIND.2014.04.018 [Accessed 8 June 2024].

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S.M., Wittmer, H., Adlan, A., Ahn, S.E., Al-Hafedh, Y.S., Amankwah, E., Asah, S.T., Berry, P., Bilgin, A., Breslow, S.J., Bullock, C., Cáceres, D., Daly-Hassen, H., Figueroa, E., Golden, C.D., Gómez-Baggethun, E., González-Jiménez, D., Houdet, J., Keune, H., Kumar, R., Ma, K., May, P.H., Mead, A., O'Farrell, P., Pandit, R., Pengue, W., Pichis-Madruga, R., Popa, F., Preston, S., Pacheco-Balanza, D., Saarikoski, H., Strassburg, B.B., van den Belt, M., Verma, M., Wickson, F. and Yagi, N., (2017). Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, 26–27, pp.7–16. Available from: https://doi.org/10.1016/J.COSUST.2016.12.006 [Accessed 1 June 2024].

Paudyal, K., Baral, H., Bhandari, S.P. and Keenan, R.J., (2015). Participatory assessment and mapping of ecosystem services in a data-poor region: Case study of community-managed forests in central Nepal. *Ecosystem Services*, 13, pp.81–92. Available from: https://doi.org/10.1016/J.ECOSER.2015.01.007 [Accessed 24 September 2019].

Paulus, P.B., Dzindolet, M.T., Poletes, G. and Camacho, L.M., (1993). Perception of Performance in Group Brainstorming: The Illusion of Group Productivity. *Personality and Social Psychology Bulletin*, 19(1), pp.78–89. Available from: https://doi.org/10.1177/0146167293191009 [Accessed 25 August 2025].

Plieninger, T., Dijks, S., Oteros-Rozas, E. and Bieling, C., (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy*, 33, pp.118–129. Available from: https://doi.org/10.1016/j.landusepol.2012.12.013 [Accessed 5 February 2024].

Plieninger, T., Torralba, M., Hartel, T. and Fagerholm, N., (2019). Perceived ecosystem services synergies, trade-offs, and bundles in European high nature value farming landscapes. *Landscape Ecology*, 34(7), pp.1565–1581. Available from: https://doi.org/10.1007/S10980-019-00775-1/FIGURES/3 [Accessed 14 April 2022].

Potschin, M. and Haines-Young, R., (2011). Introduction to the Special Issue. *Progress in Physical Geography: Earth and Environment*, 35(5), pp.571–574. Available from: https://doi.org/10.1177/0309133311422976 [Accessed 4 August 2024].

Potschin, M., Haines-Young, R., Fish, R. and Turner, R.K., (2016a). Ecosystem Services in the Twenty-first Century. In: M. Potschin, R. Haines-Young, R. Fish and R.K. Turner, eds. *Routledge Handbook of Ecosystem Services*. Routledge, pp.1–14.

Potschin, M., Haines-Young, R., Fish, R. and Turner, R.K., (2016b). *Routledge Handbook of Ecosystem Services*. Ed. by M. Potschin, R. Haines-Young, R. Fish and R.K. Turner. Oxford: Routledge.

Potschin, M.B. and Haines-Young, R.H., (2011). Ecosystem services: Exploring a geographical perspective. *Progress in Physical Geography*, 35(5), pp.575–594. Available from: https://doi.org/10.1177/0309133311423172.

Prenda, J., Armitage, P.D. and Grayston, A., (1997). Habitat use by the fish assemblages of two chalk streams. *Journal of Fish Biology*, 51(1), pp.64–79. Available from: https://doi.org/10.1111/J.1095-8649.1997.TB02514.X [Accessed 14 July 2025].

Pretty, J. and Ward, H., (2001). Social Capital and the Environment. *World Development*, 29(2), pp.209–227. Available from: https://doi.org/10.1016/S0305-750X(00)00098-X [Accessed 11 August 2021].

Purzycki, B.G. and Jamieson-Lane, A., (2017). AnthroTools: An R Package for Cross- Cultural Ethnographic Data Analysis. *Cross-Cultural Research*, 51(511), pp.51–74. Available from: https://doi.org/10.1177/1069397116680352 [Accessed 1 June 2018].

QSR International Pty Ltd, 2020. *NVivo*.

Queiroz, C., Meacham, M., Richter, K., Norström, A. V., Andersson, E., Norberg, J. and Peterson, G., (2015). Mapping bundles of ecosystem services reveals distinct types of multifunctionality within a Swedish landscape. *Ambio*, 44(1), pp.89–101. Available from: https://doi.org/10.1007/S13280-014-0601-0/FIGURES/6 [Accessed 15 June 2024].

Quinlan, M., (2005). Considerations for Collecting Freelists in the Field: Examples from Ethobotany. *Field Methods*, 17(3), pp.219–234. Available from: https://doi.org/10.1177/1525822X05277460 [Accessed 12 May 2025].

Quinlan, M.B., (2017). The Freelisting Method. *Handbook of Research Methods in Health Social Sciences*. Springer Singapore, pp.1–16. Available from: https://doi.org/10.1007/978-981-10-2779-6_12-1 [Accessed 11 December 2019].

R Core Team, (2016). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria. Available from: https://www.r-project.org/.

Ramirez Aranda, N., De Waegemaeker, J. and Van de Weghe, N., (2023). Cultural ecosystem services along the Woluwe River: mapping the potential for a cross-regional green-blue network during the COVID-19 pandemic. *Journal of Environmental Planning and Management*. Available from: https://doi.org/10.1080/09640568.2023.2177141 [Accessed 11 October 2023].

Rangeley-Wilson, C., (2021). *Chalk stream restoration strategy*. Available from: https://catchmentbasedapproach.org/wp-content/uploads/2021/10/CaBA-CSRG-Strategy-MAIN-REPORT-FINAL-12.10.21-Low-Res.pdf [Accessed 2 November 2021].

Raudsepp-Hearne, C., Peterson, G.D. and Bennett, E.M., (2010). Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences of the United States of America*, 107(11), pp.5242–5247. Available from: https://doi.org/10.1073/PNAS.0907284107/SUPPL_FILE/PNAS.200907284SI.PDF [Accessed 9 January 2024].

Raven, P.J., Holmes, N.T.H., Dawson, F.H., Fox, P.J.A., Everard, M., Fozzard, I. and Rouen, K.J., (1998). *River Habitat Quality: the Physical Character of Rivers and Streams in the UK and the Isle of Man*. Bristol.

Reed, M.S., (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, 141(10), pp.2417–2431. Available from: https://doi.org/10.1016/J.BIOCON.2008.07.014 [Accessed 26 July 2019].

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C., (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, 90(5), pp.1933–1949. Available from: https://doi.org/10.1016/J.JENVMAN.2009.01.001 [Accessed 19 March 2019].

Reed, M.S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T., Neumann, R.K., Oughton, E.A., Sidoli del Ceno, J. and van Delden, H., (2018). A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26(1), pp.S7–S17. Available from: https://doi.org/10.1111/rec.12541 [Accessed 8 June 2021].

Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J., Smol, J.P., Taylor, W.W., Tockner, K., Vermaire, J.C., Dudgeon, D. and Cooke, S.J., (2018). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*. Available from: https://doi.org/10.1111/brv.12480 [Accessed 27 November 2018].

Reyers, B., Roux, D.J., Cowling, R.M., Ginsburg, A.E., Nel, J.L. and Farrell, P.O., (2010). Conservation planning as a transdisciplinary process. *Conservation Biology*, 24(4), pp.957–965. Available from: https://doi.org/10.1111/J.1523-1739.2010.01497.X;REQUESTEDJOURNAL:JOURNAL:15231739;WGROUP:STRING:PUBLICATION [Accessed 1 September 2025].

Reynaud, A. and Lanzanova, D., (2017). A Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes. *Ecological Economics*, 137, pp.184–194. Available from: https://doi.org/10.1016/J.ECOLECON.2017.03.001 [Accessed 31 August 2025].

Ricaurte, L.F., Olaya-Rodríguez, M.H., Cepeda-Valencia, J., Lara, D., Arroyave-Suárez, J., Max Finlayson, C. and Palomo, I., (2017). Future impacts of drivers of change on wetland ecosystem services in Colombia. *Global Environmental Change*, 44, pp.158–169. Available from: https://doi.org/10.1016/J.GLOENVCHA.2017.04.001 [Accessed 28 March 2023].

Richardson, M., Passmore, H.A., Barbett, L., Lumber, R., Thomas, R. and Hunt, A., (2020). The green care code: How nature connectedness and simple activities help explain pro-nature conservation behaviours. *People and Nature*, 2(3), pp.821–839. Available from: https://doi.org/10.1002/PAN3.10117/SUPPINFO [Accessed 11 June 2025].

Riley, W.D., Ives, M.J., Pawson, M.G. and Maxwell, D.L., (2006). Seasonal variation in habitat use by salmon, Salmo salar, trout, Salmo trutta and grayling, Thymallus thymallus, in a chalk stream. *Fisheries Management and Ecology*, 13(4), pp.221–236. Available from: https://doi.org/10.1111/j.1365-2400.2006.00496.x [Accessed 16 July 2017].

Riley, W.D., Pawson, M.G., Quayle, V. and Ives, M.J., (2009). The effects of stream canopy management on macroinvertebrate communities and juvenile salmonid production in a chalk stream. *Fisheries Management and Ecology*, 16(2), pp.100–111. Available from: https://doi.org/10.1111/j.1365-2400.2008.00649.x.

River Restoration Centre, (2021). *Manual of River Restoration Techniques*. Available from: https://www.therrc.co.uk/manual-river-restoration-techniques [Accessed 10 June 2025].

Robins, J.E., Naura, M., Austin, S., Bryden, A., Cullis, J., Prady, J., Shi, F. and Treves, R., (2024). A New Framework for River Restoration Planning at Catchment Scale in the UK. *River Research and Applications*, 41(1), pp.82–107. Available from: https://doi.org/10.1002/RRA.4408;JOURNAL:JOURNAL:10991646;CSUBTYPE:STRING:SPECIAL;PAGE:STRING:ARTICLE/CHAPTER [Accessed 2 June 2025].

Robinson, R.F.A., Mills, G.A., Grabic, R., Bořík, A. and Fones, G.R., (2024). Quantification and risk assessment of polar organic contaminants in two chalk streams in Hampshire, UK using the Chemcatcher passive sampler. *Science of The Total Environment*, 939, p.173316. Available from: https://doi.org/10.1016/J.SCITOTENV.2024.173316 [Accessed 16 June 2025].

Robinson, R.F.A., Mills, G.A., Gravell, A., Schumacher, M. and Fones, G.R., (2022). Occurrence of organic pollutants in the River Itchen and River Test—two chalk streams in Southern England, UK. *Environmental Science and Pollution Research*, 1, pp.1–19. Available from: https://doi.org/10.1007/S11356-022-23476-W/FIGURES/4 [Accessed 18 October 2022].

Rojas, R., Bennison, G., Gálvez, V., Claro, E. and Castelblanco, G., (2020). Advancing Collaborative Water Governance: Unravelling Stakeholders' Relationships and Influences in Contentious River Basins. *Water*, 12(12), p.3316. Available from: https://doi.org/10.3390/W12123316 [Accessed 18 September 2021].

Ruggerio, C.A., (2021). Sustainability and sustainable development: A review of principles and definitions. *Science of The Total Environment*, 786, p.147481. Available from: https://doi.org/10.1016/J.SCITOTENV.2021.147481 [Accessed 8 July 2024].

Ruiz-Frau, A., Krause, T. and Marbà, N., (2018). The use of sociocultural valuation in sustainable environmental management. *Ecosystem Services*, 29, pp.158–167. Available from: https://doi.org/10.1016/J.ECOSER.2017.12.013 [Accessed 31 August 2025].

Sabater, S., Elosegi, A. and Ludwig, R., (2021). Framing biophysical and societal implications of multiple stressor effects on river networks. *Science of The Total Environment*, 753, p.141973. Available from: https://doi.org/10.1016/J.SCITOTENV.2020.141973 [Accessed 27 February 2023].

Sabatier, P.A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A. and Matlock, M., (2005). *Swimming upstream: Collaborative approaches to watershed management, American and* *comparative environmental policy series*. MIT Press, p.327. Available from: [Accessed 18 September 2021].

Sandström, A. and Carlsson, L., (2008a). Network governance of the commons. *International Journal of the Commons*, 2(1), pp.33–54.

Sandström, A. and Carlsson, L., (2008b). The Performance of Policy Networks: The Relation between Network Structure and Network Performance. *Policy Studies Journal*, 36(4), pp.497–524. Available from: https://doi.org/10.1111/J.1541-0072.2008.00281.X [Accessed 18 September 2021].

Sandström, A. and Rova, C., (2010). Adaptive Co-management Networks: a Comparative Analysis of Two Fishery Conservation Areas in Sweden. *Ecology and Society*, 15(3). Available from: https://www.ecologyandsociety.org/vol15/iss3/art14/.

Scher, B.D., Scott-Barrett, J., Hickman, M. and Chrisinger, B.W., (2023). Participatory Research Emergent Recommendations for Researchers and Academic Institutions: A Rapid Scoping Review. *Journal of Participatory Research Methods*, 4(2), p.2023. Available from: https://doi.org/10.35844/001C.74807 [Accessed 1 September 2025].

Schiffer, E. and Hauck, J., (2010). Net-map: Collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods*, 22(3), pp.231–249. Available from: https://doi.org/10.1177/1525822X10374798 [Accessed 30 July 2019].

Schleyer, C., Lux, A., Mehring, M. and Görg, C., (2017). Ecosystem Services as a Boundary Concept: Arguments from Social Ecology. *Sustainability*, 9(7), p.1107. Available from: https://doi.org/10.3390/SU9071107 [Accessed 22 January 2024].

Scholte, S.S.K., van Teeffelen, A.J.A. and Verburg, P.H., (2015). Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. *Ecological Economics*, 114, pp.67–78. Available from: https://doi.org/10.1016/J.ECOLECON.2015.03.007 [Accessed 11 July 2019].

Schoonover, H A, Grêt-Regamey, A, Metzger, M J, Ruiz-Frau, A, Santos-Reis, M, Scholte, S S K, Walz, A, Nicholas, K A, Schoonover, Heather A, Grêt-Regamey, Adrienne, Metzger, Marc J, Ruiz-Frau, Ana, Santos-Reis, Margarida, Scholte, Samantha S K, Walz, Ariane and Nicholas, Kimberly A, (2019). Creating space, aligning motivations, and building trust: a practical framework for stakeholder engagement based on experience in 12 ecosystem services case studies. *Ecology* *and Society*, 24(1). Available from: https://doi.org/10.5751/ES-10061-240111 [Accessed 31 August 2025].

Schröter, B., Sattler, C., Graef, F., Chen, C., Delgadillo, E., Hackenberg, I., Halle, E.M., Hirt, A., Kubatzki, A. and Matzdorf, B., (2018). Strengths and weaknesses of the Net-Map tool for participatory social network analysis in resource management: Experience from case studies conducted on four continents. *Methodological Innovations*, 11(2), p.205979911878775. Available from: https://doi.org/10.1177/2059799118787754 [Accessed 30 July 2019].

Schröter, M., Kraemer, R., Mantel, M., Kabisch, N., Hecker, S., Richter, A., Neumeier, V. and Bonn, A., (2017). Citizen science for assessing ecosystem services: Status, challenges and opportunities. *Ecosystem Services*, 28, pp.80–94. Available from: https://doi.org/10.1016/J.ECOSER.2017.09.017 [Accessed 17 March 2024].

Schröter, M., Stumpf, K.H., Loos, J., van Oudenhoven, A.P.E., Böhnke-Henrichs, A. and Abson, D.J., (2017). Refocusing ecosystem services towards sustainability. *Ecosystem Services*, 25, pp.35–43. Available from: https://doi.org/10.1016/J.ECOSER.2017.03.019 [Accessed 13 July 2024].

Schröter, M., van der Zanden, E.H., van Oudenhoven, A.P.E., Remme, R.P., Serna-Chavez, H.M., de Groot, R.S. and Opdam, P., (2014). Ecosystem Services as a Contested Concept: a Synthesis of Critique and Counter-Arguments. *Conservation Letters*, 7(6), pp.514–523. Available from: https://doi.org/10.1111/CONL.12091 [Accessed 18 July 2024].

Schultz, L., Folke, C., Österblom, H. and Olsson, P., (2015). Adaptive governance, ecosystem management, and natural capital. *Proceedings of the National Academy of Sciences of the United States of America*, 112(24), pp.7369–7374. Available from: https://doi.org/10.1073/PNAS.1406493112/SUPPL_FILE/PNAS.201406493SI.PDF [Accessed 29 July 2024].

Schwartz, C., Shaaban, M., Bellingrath-Kimura, S.D. and Piorr, A., (2021). Participatory Mapping of Demand for Ecosystem Services in Agricultural Landscapes. *Agriculture*, 11(12), p.1193. Available from: https://doi.org/10.3390/AGRICULTURE11121193 [Accessed 21 March 2023].

Scott, J., (2012). *What is Social Network Analysis? What is Social Network Analysis?*. London: Bloomsbury Academic. Available from: https://doi.org/10.5040/9781849668187 [Accessed 24 August 2025].

Scott, J., (2017). *Social network analysis*. 4th ed. London: Sage Publications.

Sear, D., Newson, M., Old, J. and Hill, C., (2005). *Geomorphological appraisal of the River Nar Site of Special Scientific Interest. English Nature Research Reports*. Available from: https://publications.naturalengland.org.uk/publication/59058 [Accessed 24 July 2025].

Sear, D.A., Armitage, P.D. and Dawson, F.H., (1999). Groundwater dominated rivers. *Hydrological Processes*, 13(3), pp.255–276. Available from: https://doi.org/10.1002/(SICI)1099-1085(19990228)13:3<255::AID-HYP737>3.0.CO;2-Y [Accessed 13 June 2017].

Sear, D.A., Jones, J.I., Collins, A.L., Hulin, A., Burke, N., Bateman, S., Pattison, I. and Naden, P.S., (2016). Does fine sediment source as well as quantity affect salmonid embryo mortality and development? *Science of The Total Environment*, 541, pp.957–968. Available from: https://doi.org/10.1016/J.SCITOTENV.2015.09.155 [Accessed 14 July 2025].

Seekamp, E., McCreary, A., Mayer, J., Zack, S., Charlebois, P. and Pasternak, L., (2016). Exploring the efficacy of an aquatic invasive species prevention campaign among water recreationists. *Biological Invasions*, 18(6), pp.1745–1758. Available from: https://doi.org/10.1007/S10530-016-1117-2/TABLES/7 [Accessed 8 September 2025].

Sen, A., (1999). *Development as Freedom*. New York: Anchor Books. Available from: [Accessed 13 July 2024].

Shaw, P.J., Leung, K.C. and Clarke, D., (2021). The fractionation of phosphorus in UK chalk stream surface waters and its relevance to the regulation and management of water quality. *Journal of Environmental Management*, 289, p.112555. Available from: https://doi.org/10.1016/J.JENVMAN.2021.112555 [Accessed 15 July 2025].

Simmons, O.M., Gregory, S.D., Gillingham, P.K., Riley, W.D., Scott, L.J. and Britton, J.R., (2021). Biological and environmental influences on the migration phenology of Atlantic salmon Salmo salar smolts in a chalk stream in southern England. *Freshwater Biology*, 66(8), pp.1581–1594. Available from: https://doi.org/10.1111/FWB.13776;PAGEGROUP:STRING:PUBLICATION [Accessed 15 July 2025].

Simon, A. and Collison, A.J.C., (2002). Quantifying the mechanical and hydrologic effects of riparian vegetation on streambank stability. *Earth Surface Processes and Landforms*, 27(5), pp.527–546. Available from: https://doi.org/10.1002/ESP.325 [Accessed 12 September 2025].

Smith, J.J. and Borgatti, S.P., (1997). Salience Counts And So Does Accuracy: Correcting and Updating a Measure for Free-List-Item Salience. *Journal of Linguistic Anthropology*, 7(2), pp.208–209. Available from: https://doi.org/10.1525/jlin.1997.7.2.208.

Smith, P.A., Dosser, J., Tero, C. and Kite, N., (2003). A method to identify chalk rivers and assess their nature-conservation value. *Water and Environment Journal*, 17(3), pp.140–144. Available from: https://doi.org/10.1111/j.1747-6593.2003.tb00450.x.

Smith, S.D.P., Bunnell, D.B., Burton, G.A., Ciborowski, J.J.H., Davidson, A.D., Dickinson, C.E., Eaton, L.A., Esselman, P.C., Evans, M.A., Kashian, D.R., Manning, N.F., McIntyre, P.B., Nalepa, T.F., Pérez-Fuentetaja, A., Steinman, A.D., Uzarski, D.G. and Allan, J.D., (2019). Evidence for interactions among environmental stressors in the Laurentian Great Lakes. *Ecological Indicators*, 101, pp.203–211. Available from: https://doi.org/10.1016/J.ECOLIND.2019.01.010 [Accessed 30 January 2019].

Quintas-Soriano, C., Brandt, J., Running, K., Baxter, C.V., Gibson, D.M., Narducci, J., and Castro, A.J., (2018). Social-ecological systems influence ecosystem service perception: a Programme on Ecosystem Change and Society (PECS) analysis. *Ecology and Society,* 23(3). Available from: https://doi.org/10.5751/ES-10226-230303 [Accessed 31 August 2025].

Staddon, S.C., Nightingale, A. and Shrestha, S.K., (2015). Exploring participation in ecological monitoring in Nepal's community forests. *Environmental Conservation*, 42(3), pp.268–277. Available from: https://doi.org/10.1017/S037689291500003X [Accessed 1 September 2025].

Stearne, K., (2007). The Management of Water Meadows: Four Hundred Years of Intesive Integrated Agriculture. In: H. Cook and T. Williamson, eds. *Water Meadows: History, Ecology and Conservation*. Macclesfield: Windgather Press, pp.107–121.

Stein, C., Ernstson, H. and Barron, J., (2011). A social network approach to analyzing water governance: The case of the Mkindo catchment, Tanzania. *Physics and Chemistry of the Earth*, 36(14–15), pp.1085–1092. Available from: https://doi.org/10.1016/j.pce.2011.07.083 [Accessed 6 May 2021].

Stosch, K.C., Quilliam, R.S., Bunnefeld, N. and Oliver, D.M., (2022). Catchment-Scale Participatory Mapping Identifies Stakeholder Perceptions of Land and Water Management Conflicts. *Land*, 11(2), p.300. Available from: https://doi.org/10.3390/LAND11020300/S1 [Accessed 14 April 2022].

Stubbington, R., Dimon, J., England, J. and Watts, G., (2022). *Chalk streams of the future: The effects of climate change on biodiversity in England's iconic river ecosystems*. Available from: https://dynamicstreams.wixsite.com/website/publications [Accessed 28 November 2022].

Su, G., Logez, M., Xu, J., Tao, S., Villéger, S. and Brosse, S., (2021). Human impacts on global freshwater fish biodiversity. *Science*, 371(6531), pp.835–838. Available from: https://doi.org/10.1126/SCIENCE.ABD3369 [Accessed 12 September 2025].

Summers, J.K., Smith, L.M., Case, J.L. and Linthurst, R.A., (2012). A review of the elements of human well-being with an emphasis on the contribution of ecosystem services. *Ambio*, 41(4), pp.327–340. Available from: https://doi.org/10.1007/S13280-012-0256-7/TABLES/1 [Accessed 17 July 2025].

Svoboda, J., Mrugała, A., Kozubíková-Balcarová, E. and Petrusek, A., (2017). Hosts and transmission of the crayfish plague pathogen Aphanomyces astaci: a review. *Journal of Fish Diseases*, 40(1), pp.127–140. Available from: https://doi.org/10.1111/JFD.12472 [Accessed 16 July 2025].

Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P. and Spierenburg, M., (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio*, 43(5), pp.579–591. Available from: https://doi.org/10.1007/S13280-014-0501-3/FIGURES/2 [Accessed 6 February 2023].

Tengö, M., Hill, R., Malmer, P., Raymond, C.M., Spierenburg, M., Danielsen, F., Elmqvist, T. and Folke, C., (2017). Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. *Current Opinion in Environmental Sustainability*, 26–27, pp.17–25. Available from: https://doi.org/10.1016/J.COSUST.2016.12.005 [Accessed 18 July 2024].

Test & Itchen Catchment Partnership, (2021). *Welcome to the Test & Itchen Catchment Partnership*. Available from: https://wessexrt.maps.arcgis.com/apps/MapSeries/index.html?appid=0a34efb4503c47f5965302685e9a2582 [Accessed 29 November 2021].

Test & Itchen Catchment Partnership, (2023). *The Test & Itchen Catchment*. Available from: https://wessexrt.maps.arcgis.com/apps/MapSeries/index.html?appid=0a34efb4503c47f5965302685e9a2582 [Accessed 6 March 2023].

The Rivers Trust, (2024). *State of our Rivers Report*. Available from: https://theriverstrust.org/rivers-report-2024 [Accessed 8 September 2025].

The Royal Commission on Environmental Pollution, (2011). *Demographic change and the environment*. Available from:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228980/8001.pdf [Accessed 7 March 2023].

The Wildlife Trusts, (2017). *Chalk streams*. Available from: http://www.wildlifetrusts.org/wildlife/habitats/chalk-streams [Accessed 15 July 2017].

Thompson, M.S.A., Brooks, S.J., Sayer, C.D., Woodward, G., Axmacher, J.C., Perkins, D.M. and Gray, C., (2018). Large woody debris "rewilding" rapidly restores biodiversity in riverine food webs. *Journal of Applied Ecology*, 55(2), pp.895–904. Available from: https://doi.org/10.1111/1365-2664.13013 [Accessed 12 September 2025].

Thorley, A., (1981). Pollen Analytical Evidence Relating to the Vegetation History of the Chalk. *Journal of Biogeography*, 8(2), p.93. Available from: https://doi.org/10.2307/2844552.

Tomscha, S.A., Gergel, S.E. and Tomlinson, M.J., (2017). The spatial organization of ecosystem services in river-floodplains. *Ecosphere*, 8(3), p.e01728. Available from: https://doi.org/10.1002/ECS2.1728 [Accessed 12 September 2025].

Trabucchi, M., O'Farrell, P.J., Notivol, E. and Comín, F.A., (2014). Mapping ecological processes and ecosystem services for prioritizing restoration efforts in a semi-arid Mediterranean river basin. *Environmental Management*, 53(6), pp.1132–1145. Available from: https://doi.org/10.1007/S00267-014-0264-4/TABLES/2 [Accessed 18 July 2024].

Tuda, A.O., Kark, S. and Newton, A., (2021). Polycentricity and adaptive governance of transboundary marine socio-ecological systems. *Ocean & Coastal Management*, 200, p.105412. Available from: https://doi.org/10.1016/J.OCECOAMAN.2020.105412 [Accessed 6 January 2022].

Met Office Hadley Centre, (2018). UK Climate Projections Available from: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp [Accessed 10 September 2025]

UK National Ecosystem Assessment, (2011). *UK National Ecosystem Assessment: Synthesis of the Key Findings*. Cambridge.

UK Parliament (*2021) Environment Act*. Queen's Printer of Acts of Parliament. Available from: https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted [Accessed 6 April 2023].

United Nations Department of Economic and Social Affairs, (n.d). *Sustainable Development*. Available from: https://sdgs.un.org/ [Accessed 17 July 2025].

Varga-Atkins, T., Bunyan, N., Fewtrell, R. and McIsaac, J., (2011). *The Nominal Group Technique-a practical guide for facilitators*. Available from: [Accessed 25 August 2025].

Vári, Á., Podschun, S.A., Erős, T., Hein, T., Pataki, B., Iojă, I.C., Adamescu, C.M., Gerhardt, A., Gruber, T., Dedić, A., Ćirić, M., Gavrilović, B. and Báldi, A., (2022). Freshwater systems and ecosystem services: Challenges and chances for cross-fertilization of disciplines. *Ambio*, 51(1), pp.135–151. Available from: https://doi.org/10.1007/S13280-021-01556-4/FIGURES/1 [Accessed 12 September 2025].

Vaughn, L.M. and Jacquez, F., (2020). Participatory Research Methods – Choice Points in the Research Process. *Journal of Participatory Research Methods*, 1(1), p.2020. Available from: https://doi.org/10.35844/001C.13244 [Accessed 6 December 2023].

Vella, S., Reed, M., Sidoli Del Ceno, J., Attlee, A. and Maya, P., (2015). SIA, Participation and Mediation on the ground. *IAIA 2015 Conference Proceedings Publication*. Florence, Italy. Available from: www.iaia.org [Accessed 1 September 2025].

Venables, W.N. and Ripley, B.D., (2002). *Modern Applied Statistics*. Fourth. New York: Springer. Available from: https://www.stats.ox.ac.uk/pub/MASS4/ [Accessed 30 May 2024].

Vidal-Abarca Gutiérrez, M.R. and Suárez Alonso, M.L., (2013). Which are, what is their status and what can we expect from ecosystem services provided by Spanish rivers and riparian areas? *Biodiversity and Conservation*, 22(11), pp.2469–2503. Available from: https://doi.org/10.1007/S10531-013-0532-2/FIGURES/4 [Accessed 18 July 2024].

Vollmer, D., Prescott, M.F., Padawangi, R., Girot, C. and Grêt-Regamey, A., (2015. Understanding the value of urban riparian corridors: Considerations in planning for cultural services along an Indonesian river. *Landscape and Urban Planning*, 138, pp.144–154. Available from: https://doi.org/10.1016/J.LANDURBPLAN.2015.02.011 [Accessed 13 July 2018].

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M., (2010). Global threats to human water security and river biodiversity. *Nature*, 467(7315), pp.555–561. Available from: https://doi.org/10.1038/nature09440 [Accessed 17 November 2016].

Ward, S., Meng, F., Bunney, S., Diao, K. and Butler, D., (2020). Animating inter-organisational resilience communication: A participatory social network analysis of water governance in the UK. *Heliyon*, 6(10), p.e05069. Available from: https://doi.org/10.1016/j.heliyon.2020.e05069 [Accessed 16 March 2021].

Waton, P.V., (1983). *A palynological study of the impact of man on the landscape of central southern England with special reference to the chalklands*. University of Southampton.

Watson, N., (2015). Adaptation through Collaboration: Evaluating the Emergence of Institutional Arrangements for Catchment Management and Governance in England. *International Journal of Water Governance*, 3(3), pp.55–80. Available from: https://doi.org/10.7564/13-IJWG26 [Accessed 28 July 2025].

Watson, N., Deeming, H. and Treffny, R., (2009). Beyond Bureaucracy? Assessing Institutional Change in the Governance of Water in England. *Water Alternatives*, 2(3), pp.448–460. Available from: www.water-alternatives.org [Accessed 31 May 2019].

Westwood, C.G., England, J., Dunbar, M.J., Holmes, N.T.H., Leeming, D.J. and Hammond, D., (2017). An approach to setting ecological flow thresholds for southern English chalk streams. *Water and Environment Journal*, 31(4), pp.528–536. Available from: https://doi.org/10.1111/WEJ.12275 [Accessed 24 July 2025].

Wetherell, A., (2023). Rivers, streams and wetlands – the Chalk and its water-dependent ecosystems. In: R.P. Farrell, N. Massei, E. Foley, P.R. Howlett and L.J. West, eds. *The Chalk Aquifers of Northern Europe*. London: Geological Society of London, pp.275–289. Available from: https://doi.org/10.1144/SP517-2020-140 [Accessed 12 September 2025].

Wharton, G., Cotton, J.A., Wotton, R.S., Bass, J.A.B., Heppell, C.M., Trimmer, M., Sanders, I.A. and Warren, L.L., (2006). Macrophytes and suspension-feeding invertebrates modify flows and fine sediments in the Frome and Piddle catchments, Dorset (UK). *Journal of Hydrology*, 330(1–2), pp.171–184. Available from: https://doi.org/10.1016/J.JHYDROL.2006.04.034 [Accessed 14 July 2025].

Wharton, G., Mohajeri, S.H. and Righetti, M., (2017). The pernicious problem of streambed colmation: a multi-disciplinary reflection on the mechanisms, causes, impacts, and management challenges. *Wiley Interdisciplinary Reviews: Water*, 4(5), p.e1231. Available from: https://doi.org/10.1002/WAT2.1231 [Accessed 16 July 2025].

White, G.F., (1998). Reflections on the 50-year international search for integrated water management. *Water Policy*, 1(1), pp.21–27. Available from: https://doi.org/10.1016/S1366-7017(98)00003-8 [Accessed 11 August 2021].

Whitehead, P.G., Wilby, R.L., Butterfield, D. and Wade, A.J., (2006). Impacts of climate change on in-stream nitrogen in a lowland chalk stream: An appraisal of adaptation strategies. *Science* *of The Total Environment*, 365(1–3), pp.260–273. Available from: https://doi.org/10.1016/j.scitotenv.2006.02.040.

Wickham, H., (2016). *ggplot2: Elegant Graphics for Data Analysis*. *ggplot2*. New York, NY: Springer New York. Available from: https://ggplot2.tidyverse.org [Accessed 1 August 2018].

Wiek, A., Talwar, S., O'Shea, M. and Robinson, J., (2014). Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation*, 23(2), pp.117–132. Available from: https://doi.org/10.1093/RESEVAL/RVT031 [Accessed 1 September 2025].

Winkler, K.J. and Hauck, J., (2019). Landscape stewardship for a German UNESCO Biosphere Reserve: a network approach to establishing stewardship governance. *Ecology and Society*, 24(3), p.art12. Available from: https://doi.org/10.5751/ES-10982-240312 [Accessed 20 August 2019].

Wotton, R.S. and Malmqvist, B., (2001). Feces in Aquatic Ecosystems: Feeding animals transform organic matter into fecal pellets, which sink or are transported horizontally by currents; these fluxes relocate organic matter in aquatic ecosystems. *BioScience*, 51(7), pp.537–544. Available from: https://doi.org/10.1641/0006-3568(2001)051[0537:FIAE]2.0.CO;2 [Accessed 14 July 2025].

Wright, J.F., (1992). Spatial and temporal occurrence of invertebrates in a chalk stream, Berkshire, England. *Hydrobiologia*, 248(1), pp.11–30. Available from: https://doi.org/10.1007/BF00008882/METRICS [Accessed 12 September 2025].

WWF, (2020). *Living Planet Report 2020 - Bending the curve of biodiversity loss*. Gland, Switzerland. Available from: https://f.hubspotusercontent20.net/hubfs/4783129/LPR/PDFs/ENGLISH-FULL.pdf [Accessed 21 October 2020].

WWF, (2022). *Living Planet Report 2022 - Building a nature positive society*. Ed. by R.E.A. Almond, M. Grooten, D. Juffe Bignoli and T. Petersen. Gland, Switzerland: WWF. Available from: https://www.wwf.org.uk/sites/default/files/2022-10/lpr_2022_full_report.pdf [Accessed 14 February 2023].

Yoward, T. and Yoward, M., (2011). *Mills and Millers of Hampshire*. Ed. by A. Vaidya. 1st ed. Hampshire Mills Group.

Zambrana, N.Y.P., Bussmann, R.W., Hart, R.E., Huanca, A.L.M., Soria, G.O., Vaca, M.O., Álvarez, D.O., Morán, J.S., Morán, M.S., Chávez, S., Moreno, B.C., Moreno, G.C., Roca, O. and Siripi, E., (2018). To list or not to list? The value and detriment of freelisting in ethnobotanical studies. *Nature Plants*, 4(4), pp.201–204. Available from: https://doi.org/10.1038/s41477-018-0128-7 [Accessed 15 May 2018].

Zhang, Y., Collins, A.L., McMillan, S., Dixon, E.R., Cancer-Berroya, E., Poiret, C. and Stringfellow, A., (2017). Fingerprinting source contributions to bed sediment-associated organic matter in the headwater subcatchments of the River Itchen SAC, Hampshire, UK. *River Research and Applications*, 33(10), pp.1515–1526. Available from: https://doi.org/10.1002/RRA.3172;REQUESTEDJOURNAL:JOURNAL:15351467;JOURNAL:JOURNAL:10991646;CSUBTYPE:STRING:SPECIAL;PAGE:STRING:ARTICLE/CHAPTER [Accessed 29 July 2025].

Zoderer, B.M., Tasser, E., Carver, S. and Tappeiner, U., (2019). Stakeholder perspectives on ecosystem service supply and ecosystem service demand bundles. *Ecosystem Services*, 37, p.100938. Available from: https://doi.org/10.1016/J.ECOSER.2019.100938 [Accessed 31 August 2025].