About Drought

Maximising the impact of UK research on drought & water scarcity

Wetlands

Report Card 2019

The drought and water scarcity programme consists of 5 integrated research projects funded by UK research councils. A series of synthesis report cards summarise current and future aspects of water scarcity in the main UK ecosystems. This synthesis focuses on freshwater wetland environments.

The report card covers impacts, ecosystem response, future scenarios and mitigation for the following topics:

- Physical
- Chemical
- Biological
- Societal

Background

Wetlands form fundamental parts of the UK's landscape embracing a diverse range of habitats including fens, bogs, marshes, peatlands, wet grasslands, wet woodlands and floodplains. Wildlife support is a particularly important aspect of UK wetlands. Over 3,500 species of invertebrates, 150 species of aquatic plant, 22 species of duck and 33 species of wader have been identified living in UK wetlands, whilst all six of our native species of amphibian depend on wetlands for breeding (Merritt, 1994). Wetlands occupy the transitional zones from permanently wet to generally drier areas. They share characteristics of both environments yet cannot be classified unambiguously as either aquatic or terrestrial. It is the presence of water for some significant period of time that creates the soils, its micro-organisms and the plant and animal communities, such that the land functions in a different way from either fully aquatic or dry habitats (Acreman & Jose, 2000). Hydrology is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. Furthermore, when hydrological conditions in wetlands change even slightly, the biota may respond with massive changes in species abundance and richness and ecosystem productivity (Mitsch & Gosselink, 1993). Drought conditions will alter wetland processes and the species dependent on them.

Wetlands have evolved and adapted to natural fluctuations in the hydrological cycle including droughts, floods and 'normal' conditions. Although wetland ecosystems may change during droughts, these should be seen as natural disturbances (Brock *et al.,* 2003) rather than adverse impacts. Wetlands normally recover to pre-drought conditions when re-wetted. Disturbance history plays a major role in determining the type and form of freshwater biological communities (Cattanéo *et al*., 2001). For example, under constant wet conditions, the productivity of wetlands gradually declines and plant communities shift from annual species that produce an abundance of seeds to perennials, such as bulrush (*typha*), reducing habitat quality for waterfowl and other wildlife. During droughts wetlands dry-out and bottom sediments are exposed to air, stimulating decomposition, releasing nutrients and allowing annual seeds to germinate, thus stimulating productivity (Brakhage, 2018). Some wetland species may rely on periodic drought conditions for part of their life histories or have life strategies suited to exploiting the habitat or changed environmental conditions that are created by droughts (Gordon *et al*. 1992). Thus conservation of biological and genetic diversity in freshwater ecosystems is best served by protecting natural hydrological variability (Horne *et al*., 2017), including droughts (Everard, 1996).

Mankind's influences during the anthropocene (Best, 2019) have altered the natural environment and it is likely that human-induced changes will continue to increase (Convention on Biological Diversity, 2014). Abstraction of water has intensify droughts, increasing disturbance. Climate change has or will make droughts more frequent, reducing recovery time. Habitat loss has isolated wetlands hampering re-colonisation after droughts. Consequently droughts may be more likely to result in long term or permanent changes in wetland ecosystems in the future.

In this scorecard we focus on the response of freshwater wetlands to direct alterations in wetness during droughts, due normally to reduced rainfall, river flow and groundwater discharge and increased evaporation plus indirect pressures such as abstraction of water.

	Effects of drought	Response	Future scenarios	Mitigation
Physical	The physical responses of wetlands to droughts are generated, mainly, by lower levels of rainfall and higher air temperatures. Lower levels of rainfall result both directly on wetlands and on surrounding catchments reducing runoff. Higher air temperatures are usually associated with lower levels of atmospheric humidity, leading to increased evaporation rates over the surface of the waterbody and greater transpiration from wetland plants.	During droughts, wetland surface water bodies, such as ponds, contract in area and volume, with rates depending on their morphology. Larger areas of open water become fragmented as they divide into small separate pools. Areas periodically inundated, such as floodplains, may remain dry for longer periods than normally. Soils usually saturated start to dry-out and crack. Groundwater levels fall during droughts and wetlands may switch from being supplied by aquifers to becoming a supplier as water infiltrates into aquifers. During droughts, surface outflow may cease from peatlands (Burke, 1968; Newson, 1981; Boeye & Verheyen, 1992). Because of the water storage effects in the landscape, river-fed wetland ecosystems are more resilient to drought than rain-fed wetlands (Acreman & Blake, 2016). By the same token, groundwater-fed wetlands are generally the most resilient in less severe droughts. Wetlands normally revert to their pre-drought physical state once re-wetted, but this may take time (Large et al., 2007), in some cases several years (Hudson, 1988). In extreme droughts, changes in soil structure may be irreversible in the short term and may mean that pre-drought soil-water storage capacities will never be regained (Hudson, 1988).	Reduced summer rainfall and increased summer evaporation predicted for Great Britain by 2050 will put stress on wetlands in late summer and autumn with greater impacts in the south and east of GB than in the north and west. In addition, impacts on rain-fed wetlands will be greater than on those dominated by river inflows. (Acreman *et al*., 2009).	Many managed wetlands, incorporate large water features that not only provide habitat but act as reservoirs during dry periods. Drainage of blanket peats has been shown to increase dry period flow to streams (Burke, 1975; Robinson *et al*., 1991) due to lower evaporation. Drain-blocking can result in higher and more stable water tables within peat wetlands, making them better able to resist drought periods (Wilson *et al*., 2011).

	Effects of drought	Response	Future scenarios	Mitigation
Chemical	As water depth and volume decline in wetlands during droughts and temperatures rise, so their chemistry changes including dissolved oxygen level, salinity, dissolved organic carbon, turbidity and nutrient levels, especially nitrogen and phosphorus (Lake, 2011).	Drought in wetlands results in increased peat temperature, lower dissolved oxygen and higher pH leading to greater oxidation of sulphur compounds (Freeman *et al.*, 1993) and lower concentrations of nitrate and ammonium (van Dam, 1988; Proctor, 2006) and iron (Hughes *et al.*, 1997). Short-term droughts do not affect the acid neutralizing capacity or nutrient availability in fens (Cusell *et al.*, 2015). Dissolved organic carbon can decrease due to drought-induced acidification (Scott *et al.*, 1998; Worrall *et al.*, 2006; Clark *et al.*, 2012), but increases again after droughts (Grand-Clement et al., 2014). Peat wetlands become CO_2 sources during drying (Estop-Aragnes *et al.*, 2016), which can stimulate microbial growth that causes the breakdown of organic matter (Fenner & Freeman, 2011). In contrast, CH_4 production is lower under drought conditions (Freeman *et al.*, 2002), which persists at least one month beyond the end of the drought. During extreme droughts, nitrous oxide (N_2O) emissions (which can deplete stratospheric ozone) can increase exponentially (Dowrick *et al.,* 1999) and the enzyme B-glucosidase can stimulate increases in the concentration of magnesium and calcium (Freeman *et al.*, 1997). Re-wetting of the peat after significant water table draw-down can produce elevated arsenic concentrations in receiving waters (Rothwell *et al.*, 2009).	Reduced summer rainfall and increased summer evaporation predicted for Great Britain by 2050 will increase the likelihood of droughts in late summer and autumn with greater impacts in the south and east of GB than in the north and west (Acreman *et al.*, 2009). Thus chemical changes associated with droughts will be more likely and more intense.	Many managed wetlands, incorporate large water features that not only provide habitat but act as reservoirs during dry periods. Drainage of blanket peats has been shown to increase dry period flow to streams (Burke, 1975; Robinson *et al.*, 1991) increasing dilution in receiving waters. Drain-blocking can result in higher and more stable water tables within peat wetlands, which can reduce chemical changes within the wetland (Wilson *et al.*, 2011).

	Effects of drought	Response	Future scenarios	Mitigation
Biological	Algae, macrophytes, invertebrates, fish and aquatic birds have variable spatial and temporal responses to abiotic changes that occur during droughts, depending on species resistance and resilience, competitive and predatory interactions and the timing and characteristics of the drought. Whereas some species may have life strategies suited to exploiting the habitat or changed environmental conditions that are created by drought, for other organisms it is a time of stress (Gordon *et al*., 1992).	Biological tolerance and response to drought depends on the unique characteristics and adaptions of species. During droughts wetlands dry-out and bottom sediments are exposed to air, stimulating decomposition, releasing nutrients and allowing annual seeds to germinate, thus stimulating productivity (Brakhage, 2018). The toiche zone, normally inundated but exposed during low-water conditions, is subject to waves of colonisation and subsequent extinction variously by terrestrial and aquatic macrophyte species (Palmer & Newbold, 1983). Droughts can be accompanied by the disappearance of characteristic black alder carr species and a dominant growth of more drought-resistant species such as *Rubus idaeus* L. and *Rubus fructicosus* L. (Stortelder, 1998). The number of wading birds successfully breeding often declines and chick mortality is higher (Royal Society for the Protection of Birds, 2006). Droughts may prevent invasive species from becoming established. Permanent wetlands may lose macroinvertebrate fauna during droughts but can acquire fauna typical of temporary ponds (Jeffries, 1994), which are more resilience to drought (Biggs *et al*., 1994); drying-out of temporary wetlands does not diminish their conservation value, species richness or the likely occurrence of rare species (Pond Action, 1994; Collinson *et al*., 1995). Some wetland species rely on periodic drought conditions for part of their life histories or have life strategies suited to exploiting the habitat or changed environmental conditions that are created by drought (Gordon *et al*. 1992). Amphibians benefit from droughts as the following year is safer for their tadpoles (Hawkins, 1995) because their predators, such as fish are reduced or eliminated (Oldham, 1996). The rhizosphere beneath *Calluna* is disproportionately affected by drought conditions due to its concentration of root growth in the upper layers of the peat, rather than the deeper roots of *Juncus* which are more resilient (Genney *et al.,* 2000). Droughts can bring shifts in dominant species (Breeuwer *et al*., 2009), such as *Sphagnum* species.	Predicted reduced summer rainfall and increased summer evaporation will put stress on wetland plant communities in late summer and autumn with greater impacts in the south and east of GB than in the north and west (Acreman *et al*., 2009). It may not be possible to conserve some wetland species that are already on the margin of their ranges.	Management of water abstractions during drought is important. Abstraction from aquifers feeding wetlands can threaten their biodiversity (Fojt, 1994), Increased groundwater abstraction during droughts has led to the conversion of *Schoeno-Junceta* communities into degraded types of *Cirsio-Molinietum*, *Juncus subnodulosus* fen meadow (Harding, 1993). Proximity and connectivity between wetlands is also key. Recovery after drought depends on the ability of organisms that are lost to recolonise. Isolated populations of rare heath reptiles including rare species, such as the smooth snake and sand lizard may be totally lost during droughts, with little chance of natural recolonization (Burston, 2006). Managing the land to reduce habitat fragmentation may reduce this risk (Lawton *et al.,* 2010).

	Effects of drought	Response	Future scenarios	Mitigation
Societal	Wetlands provide a wide range of ecosystem services to people including management of floods, reduction in water pollutants. storage of carbon, recreation and a sense of well-being and social history (Maltby, 1986). Such services will change as the character of the wetland changes (Maltby & Acreman, 2011). Whilst ecosystem condition during and after droughts can be assessed objectively from physical, chemical and biological data, assessment of ecosystem services requires knowledge of preferences of the service user in the form of aesthetic, social or economic data. This may be inconsistent between users. For example, one person may perceive a dried-up wetland during a drought as negative, another person may view it positively	Under moist conditions peat soils are hydrophilic and can absorb water during rainfall (if they are not already saturated), which can reduce flooding downstream (Bullock & Acreman, 2003). However, when dry peat soils become hydrophobic and repel water (Rezanezhad *et al*., 2007) meaning that rainfall moves rapidly to watercourses via overland flows (Goulsbra & Evans, 2011) and can increase flooding downstream. Reduced soil water storage capacity of peat soils after drought (Hudson, 1988) may diminish any flood reduction capacity of wetlands for many months, years or permanently. During droughts, reduced water volumes in wetlands, or in streams receiving water from wetlands, will diminish water resources (Newson, 1981; Burt, 1995) because evapotranspiration depletes surface outflow (Gilvear *et al*., 1993). Groundwater from upland peaty soil aquifers can provide baseflow during dry periods that dilute pollutant inputs from lowland areas at the large catchment scale (Capell *et al*., 2011) improving water quality. During droughts dissolved organic carbon decreases (Worrall *et al*., 2006; Clark *et al*., 2012) but during subsequent rainfall events as DOC (Grand-Clement, 2014) or arsenic (Rothwell *et al*., 2009) increases following intense dryness. During dry periods release of methane from peat soils in wetlands usually reduces, but emission of carbon dioxide tends to increase as the soil oxidises (Acreman *et al*., 2011), thus altering greenhouse gas fluxes to the atmosphere. Wetlands provide grazing for cattle and, in response, this grazing maintains certain wetland types, such as wet grasslands (Crofts & Jefferson, 1999). During droughts, loss or decline of wetland species will reduce grazing opportunity for cattle. Changes in appearance of wetlands during droughts and loss of species, such as birds and reptiles, will alter the social values of wetlands, including landscape aesthetics, recreation and cultural associations. Drying of wetland soils during droughts may lead degradation or loss of archaeological remains or scientifically important pollen sequences (Skinner *et al*., 2014).	Future increase in drought frequency in many areas across Europe, due to global climate changes, are likely to threaten the persistence of wetland ecosystems services, such as biomass production, nutrient removal, carbon storage and fish production (Okruszko *et al*., 2011).	Drainage of blanket peats has been shown to increase dry period flow to streams (Burke, 1975; Robinson *et al*., 1991) due to lower evaporation. This could increase water resources in receiving streams. However, drain-blocking can result in higher and more stable water tables within wetlands themselves, reducing disturbance during drought periods (Wilson *et al*., 2011).

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