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A framework for a joint hydro-meteorological-social analysis of drought

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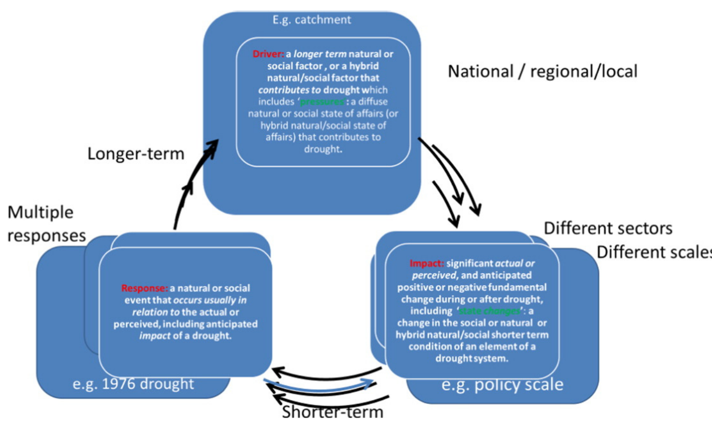
HIGHLIGHTS

- An innovative 'Drivers', 'Responses', 'Impacts' (DRI) framework is proposed.
- Drivers, Responses and Impacts, as well as Pressures and States are defined with reference to linked natural-social worlds.
- A temporal scale and various types of spatial scales are an integral aspect of the DRI framework.
- The framework is applied to the 1976 and 2003–6 drought episodes in the UK.

GRAPHICAL ABSTRACT



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ABSTRACT

This article presents an innovative framework for analysing environmental governance challenges by focusing on their Drivers, Responses and Impacts (DRI). It builds on and modifies the widely applied Drivers, Pressures, States, Impacts and Responses (DPSIR) model. It suggests, firstly and most importantly, that the various temporal and spatial scales at which Drivers, Responses and Impacts operate should be included in the DRI conceptual framework. Secondly, the framework focuses on Drivers, Impacts and Responses in order to provide a parsimonious account of a drought system that can be informed by a range of social science, humanities and science data. 'Pressures' are therefore considered as a sub-category of 'Drivers'. 'States' are a sub-category of 'Impacts'. Thirdly, and most fundamentally in order to facilitate cross-disciplinary research of droughts, the DRI framework defines each of its elements, 'Drivers', 'Pressures', 'States', 'Impacts' and 'Responses' as capable of being shaped by both linked natural and social factors. This is different from existing DPSIR models which often see 'Responses' and 'Impacts' as located mainly in the social world, while 'States' are considered to be states within the natural environment only. The article illustrates this argument through an application of the DRI framework to the 1976 and 2003–6 droughts. The article also starts to address how - in cross-disciplinary research that encompasses physical and social sciences – claims about relationships between Drivers as well as Impacts of and Responses to drought over time can be methodologically justified. While the DRI framework has been inductively developed out of research on droughts we argue that it can be applied to a range of environmental governance challenges.

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1. Introduction: cross-disciplinary research about historic droughts

Previous research about past and contemporary droughts, also in the UK, has focused on their hydro-meteorological characteristics, with limited consideration of their socio-economic Drivers, Impact and Responses. When droughts have been analysed with reference to their socio-economic dimensions this has often focused on specific drought events (e.g. Bakker, 2000) rather than a range of droughts over time. Taylor et al.'s (2009) work is an exception. It analyses seven key droughts between 1893 and 2006. The conceptual framework presented in this article seeks to further promote an understanding of the evolution of droughts over time. It also aims to facilitate cross-disciplinary analysis of the evolution of drought systems over time. This draws on data from a range of sectors in which droughts manifest. These are an agricultural, water resource management/legal regulation sector, as well as a meteorological and hydrological sector, including ground- and surface water hydrology. Moreover, the research[i] which gave rise to this framework includes data about how droughts affect ecosystems, and how droughts are perceived by those affected, as known through oral histories and media reporting. These 'sectors' capture different dimensions of drought across both a natural and social world, and therefore bring different disciplinary perspectives to bear on an understanding of drought.

The DRI framework presented here is a heuristic device. It builds deductively on existing Drivers, Pressures, States, Impacts and Responses (DPSIR) models discussed in the environmental governance literature. DPSIR models have been applied to water pollution and its regulation (Tscherning et al., 2012), such as most recently the implementation of the European Union Water Framework Directive (EU WFD, 2000, e.g. Borja et al., 2006). They have yet to be applied to the related challenge of drought. The DRI framework also draws on a preliminary collection and analysis of data from a research project on Historic Droughts.

Droughts are a distinct natural hazard. But we suggest that the DRI framework can also be applied to other environmental governance challenges. Droughts are distinct because they are a 'creeping phenomenon' (Wilhite, 2000: 4). In contrast to floods or storms they do not have a sudden beginning or a clear end. Hence, the impacts of drought often only accumulate over a considerable period of time, and, in contrast to other natural hazards, do not necessarily cause structural damage to infrastructure. Moreover, droughts, such as groundwater droughts, are not necessarily very visible, in contrast to floods or snowstorms, but they are still ranked as a very severe hazard in comparison to other natural hazards, such as earthquakes, bush fires or dust storms (Wilhite, 2000: 6). Finally, droughts can spread over a large geographical area, and in comparison to other natural hazard events, are not necessarily confined to a specific locality.

These distinct characteristics of droughts are reflected in the DRI framework since the framework enables to analyse droughts over longer time spans through the emphasis on temporal scales. The fact that droughts can be both large and small-scale is reflected in the DRI framework's emphasis on spatial scale of various magnitude. In light of the sometimes limited visibility of droughts, the DRI framework puts emphasis on combining both a natural and social science perspective in the definition of its key concepts. This ensures that various e.g. socio-economic impacts of drought are captured, even though its physical manifestation may not be very visible.

Hence, the DRI framework reflects distinct features of drought, but it is general and abstract enough to be relevant for the analysis also of other environmental governance challenges that may consist of more clearly defined specific events and vary less over different spatial scales. The DRI framework thus retains some of the principal features of the well-developed DPSIR model, which has been applied to a range of environmental governance challenges.

[i] We acknowledge financial support from the UK Natural Environment Research Council (NERC) Council [grant number: NE/L010356/1]. BGS staff publish with the Permission of the Director, British Geological Survey, NERC. Data relied upon for this research can be accessed in the public domain. We would like to acknowledge contributions from Lucy Barker, CEH, Rebecca Pearce, University of Exeter, and Carmen Dayrell, University of Lancaster to this article.

2. Key characteristics of the Drivers, Responses, Impacts (DRI) framework

2.1. Why integrate analysis of natural and social dimensions of drought?

The DRI framework presented here is different from existing DPSIR models because it defines its key elements - Drivers, Responses and Impacts - by integrating natural and social dimensions of these. Hence, we also no longer distinguish in this article between 'drought' as the event caused by natural factors, such as lack of rainfall, and 'water scarcity', i.e. water shortages caused by e.g. social factors, such as peaks in demand. Instead we consider drought as caused by both natural and social factors, being a state of too little water for human consumption and the natural environment.

This goes beyond perspectives that ask e.g. 'where does nature end and society begin?' (Kinzig, 2001: 715), and thus chimes with an approach that considers social and natural dimensions of the environment as closely interwoven (Swyngedouw, 2009: 56–60). This has also been explored through the concept of the Anthropocene, which suggests that human actions have given rise to a new geological epoch which starts with the Industrial Revolution, in England in 1800. It captures that human interactions with the natural environment have now become so significant that they shape earth systems, including the climate (Steffen et al., 2011). Such a shaping of the natural environment by human action can also be observed in the context of water quality. For instance, the Humber river[ii] and its coastal zone are considered to have been influenced by both the geology in the area that shaped soil type and climatic conditions, as well as past and present socio-economic factors that shaped human activity in the catchment, such as sediments from mining and current farming activity (Cave et al., 2003: 31,32). Linking natural and social dimensions of environmental governance challenges is thus now a crucial aspect of generating 'data' about them. The EU WFD, for instance, requires both socio-economic and natural science data to be considered when regulators assess the state of river basins and develop 'programs of measures' (Preamble 36 and Art. 4 (5) EU WFD).

Finally, understanding social and ecological systems as co-evolving provides the foundation for developing their resilience (Kinzig, 2001: 712). This matters also because resilience is no longer just a general aspiration of environmental management but a legal obligation, e.g. in English and Welsh water law. Achieving resilience of water companies' systems for the supply of water and sewerage services – in the light of environmental pressures, population growth and changes in consumer behaviour - is now a key objective of the regulatory framework (Section 2 (2A) (e) of the Water Industry Act 1991). Current DPSIR models are, however, limited in the extent to which they integrate the 'natural' and 'social' environment in their analysis.

2.2. DPSIR models define their key elements with reference to either 'the natural' or the 'social' environment

DPSIR models are often considered to be a tool for 'holistic' and 'integrated' (Kelble et al., 2013) natural resource management that seeks to incorporate both natural and social science accounts of the state and management of nature. But they frequently replicate in their definition of Drivers, Pressures, States, Impacts and Responses, distinctions between natural and social factors in the generation and mitigation of

[ii] The river Humber flows into the North Sea on the east coast of England. Its origin lies at the confluence of the Rivers Ouse and Trent. It separates the counties of Yorkshire and Lincolnshire at its widest point.

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