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Ecohydrology and Hydroecology: An Introduction

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1.1 Wider Context

Water is essential for life on our 'blue planet' but just 2.5% of all the Earth's water comprises freshwater. Of this precious freshwater resource, 0.3% is estimated to be surface water, held in rivers and streams (2%), wetlands (11%) and lakes (87%) (see, for example, Oki and Kanae, 2006). This tiny proportion of global water supports at least 6% (>100 000) of all described species (Dudgeon *et al.*, 2006). Water-dependent habitats are extremely diverse, located from poles to equator and low to high altitude, and comprise dynamic systems that vary in scale from individual plants to large complex vegetation communities, from the smallest headwater stream to the largest lowland river, complex floodplains, a myriad of wetland types, and lentic ecosystems ranging from ponds to vast lakes. Many of these habitats support communities and species of high conservation value, some of which are under threat from extinction (e.g., Grootjans *et al.*, 2006; Hannah *et al.*, 2007; Ricciardi and Rasmussen 1999; Sadler *et al.*, 2004; Wilcox and Thurow, 2006). Because of water's many uses, humans have fundamentally altered natural hydrological processes and conditions in many areas and, consequently, freshwater ecosystems have experienced reductions in biodiversity at least as great as the most impacted terrestrial ecosystems (Dudgeon *et al.*, 2006). When viewed against a backdrop of rapidly rising global population (predicted to reach about 8 billion by 2025; United Nations, 2000), it is clear that balancing the water needs of people against those of ecosystems (terrestrial and aquatic) is, and will increasingly become, a premier environmental issue (see, for example, Petts *et al.*, 2006a). This crucial, precarious 'balancing act'

involves some highly complex issues and, thus, it has compelled recent workers to identify the need, not only for new integrative science and new analytical approaches (e.g. Newman *et al.*, 2006; Petts *et al.*, 2006b), but for truly interdisciplinary research (e.g. Hannah *et al.*, 2004). In this context, it has been argued that the 'new' discipline(s) of hydroecology/ecohydrology has the potential not only to unlock elements of this complexity, but also to provide a foundation for the sustainable management of water resources (e.g. Zalewski, 2000; Zalewski *et al.*, 1997).

1.2 Hydroecology and Ecohydrology: A Brief Retrospective

The terms ecohydrology (eco-hydrology) and hydroecology (hydro-ecology), which include the subdiscipline of ecohydraulics, are being used increasingly by the international scientific community (see e.g. Janauer, 2000; Wilcox and Newman 2003, Wood *et al.*, 2001). Although there is a growing volume of research output at the interface between the hydrological and life (biological) sciences (e.g. Gurnell *et al.*, 2000; Zalewski, 2000), the terms hydroecology and ecohydrology and the scientific remit of the field are remarkably poorly defined, with limited consensus between many of the published definitions (e.g. Wassen and Grootjans, 1996; Zalewski *et al.*, 1997; Baird and Wilby, 1999; Dunbar and Acreman, 2001; Eagleson, 2002; Nuttle, 2002; Bond, 2003; Rodriguez-Iturbe, 2005). Furthermore, it has been suggested that while physical scientists, and hydrologists in particular, are embracing the new 'hot topic', ecologists and biologists are less aware or less inclined to engage in the debate regarding its status as a 'new paradigm' or subdiscipline (Bond, 2003). Bibliographic analysis (for details refer to Hannah *et al.*, 2004) has demonstrated the proliferation of the terms ecohydrology and hydroecology, and the breadth of subject matter; however, it has also identified a larger body of 'hidden' ecohydrological and hydroecological literature that does not flag itself as such (also see Bond, 2003; Bonell, 2002; Kundzewicz, 2002). Perhaps most significantly, the review of hydroecological/ecohydrological literature showed clearly that the majority of the research was undertaken within traditional subject boundaries (i.e., groups dominated by either physical or biological scientists) rather than interdisciplinary teams, uniting researchers from both traditions (Hannah *et al.*, 2004). Whether or not the terms are widely recognised or accepted as something 'new' (or as a subdiscipline) by scientists, the fact remains that the terms are increasingly making an impact within the hydrological and ecological literature. Indeed, the yearly citation rate of the terms has more than doubled since 2004 (Figure 1.1).

1.3 A Focus

It is apparent from our previous literature review and bibliographic analysis (Hannah *et al.*, 2004) that a definition identifying a theoretical core is needed before hydroecology and ecohydrology become established paradigms or disciplines. A definition including the discipline's aim and subject scope would serve as a focal point to help unite the research community. In this regard, a single definition that applies equally to hydroecology and ecohydrology is essential. At present, there is arguably no single accepted definition of either term, never mind a joint definition.

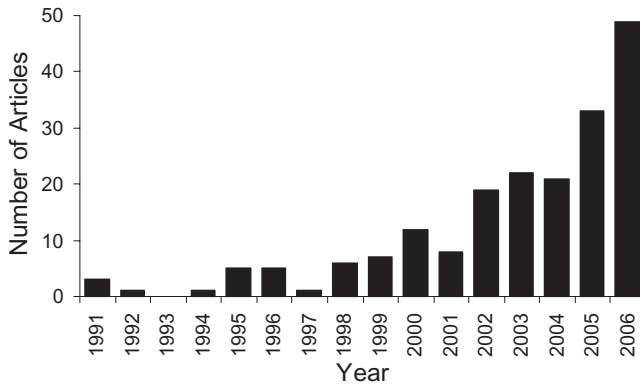


Figure 1.1 Number of peer-reviewed journal articles using the terms ecohydrology, ecohydrology, hydroecology and hydro-ecology (1991–2006)

There has been specific use of the term ecohydrology to refer to plant–water interactions both in the past (e.g., Baird and Wilby, 1999; Eagleson, 2002) and increasingly more recently, with special reference to semi-arid/dryland/rangeland environments (e.g. Newman *et al.*, 2006; Wilcox and Thurow, 2006). However, ecohydrology has also been employed to describe wider hydrology–ecology linkages (i.e. all biota and environments, e.g., Kundzewicz, 2002; Zalewski, 2002). Arguably, this specific versus generalist usage of ecohydrology could lead to confusion and misunderstanding. Therefore, we propose the use of the term hydroecology to refer to hydrology–ecology interactions in the broadest sense (cf. Dunbar and Acreman, 2001) and so provide an umbrella under which ecohydrology in its stricter form can be included.

We recognise the potential danger that definitions can become either too restrictive or nebulous to be effective and/or applicable. Like hydroecology, other ‘new’ scientific paradigms have begun life as ‘hot topics’ but they have faded away due to a problem of identity. If hydroecology is to avoid a similar fate, we must ensure that it is an identifiable and constructive discipline, and not a deconstructed version of existing paradigms or academic disciplines. A clear and inclusive definition of hydroecology should help to this end. Rather than debating and deliberating over the appropriate form of words in a revised definition, we suggest that it may be more instructive to provide a list of ‘target elements’ that outline the theoretical core and range of process interactions and scales that should encapsulate hydroecological research (Hannah *et al.*, 2004):

- (i) the bi-directional nature of hydrological–ecological interactions and importance of feedback mechanisms;
- (ii) the requirement for fundamental process understanding, rather than simply establishment of functional (statistical) links without a probable chain of causality;
- (iii) the subject scope to encompass: (a) the full range of (natural and human-impacted) water-dependent habitats/environments, and (b) flora, fauna and whole ecosystems;

- (iv) the need to consider process interactions operating at a range of spatial and temporal scales (including palaeohydrological and palaeoecological viewpoints); and
- (v) the interdisciplinary nature of the research philosophy (see Chapter 22).

1.4 This Book

Given the current upsurge in hydroecology and ecohydrology, we thought it important and timely to capture the current state-of-the art in one place as a research-level text. Our intention was to create a cutting-edge volume, which presents new results and methodological developments within the rapidly evolving field of hydroecology/ecohydrology. To achieve this goal, recognised international leaders in their subjects have written the individual chapters and have aimed to position their contributions at the research forefront. In terms of content, the book covers a range of hydrological and ecological processes, methodological approaches and hydroecologically sensitive habitats from an array of geographical locations (e.g., Australia, Europe, and North and South America). The book differs from others currently available not only in terms of its environmental breadth but it also covers a wide range of organisms (plants, invertebrates and fish) and their interactions with water.

The book is structured in three sections: Part 1 considers fundamental ecohydrological/hydroecological process understanding and how floral and faunal communities and ecosystem functions (e.g. nutrient cycling) are influenced and respond to water and its availability (Chapter 2 to Chapter 7). Part 2 of the book draws together up-to-date methodological approaches and critiques of how ecohydrological/hydroecological patterns and processes can (may) be monitored/modelled to maintain and protect the natural environment, and be managed to ensure the continued supply of water for human uses (Chapters 8–13). Part 3 comprises detailed ecohydrological and hydroecological case-studies of research undertaken on different floral and faunal groups in different environments across the globe (Chapter 14 to Chapter 21). The final chapter (Chapter 22) identifies some challenges and future prospects for hydroecology/ecohydrology.

We do not claim that this volume is all encompassing in its coverage of research that could be deemed to be hydroecology or ecohydrology. Indeed, we are conscious that this volume only begins to address palaeohydrology and palaeoecology. Palaeoecohydrology studies may provide valuable baseline information regarding pre-human influences on the environment and for climatic change/variability investigations (Lytle, 2005; Prebble *et al.*, 2005). In addition, the chapters almost exclusively deal with freshwater and do not consider marine/brackish water ecosystems or terrestrial environments subject to salinisation (e.g. Williams and Williams, 1998; Brown *et al.*, 2006). Saline water represents a challenging environment for floral and faunal communities and, as yet, these avenues of research have not been explored fully by ecohydrologists and hydroecologists.

1.5 Final Opening Remarks

It is clear that researchers actively involved in ecohydrological and hydroecological studies are increasingly aware of the need for a truly interdisciplinary philosophical

framework, as opposed to a multidisciplinary approach within clearly defined traditional subject boundaries (Hannah *et al.*, 2004; Newman *et al.*, 2006; Petts *et al.*, 2006a). We believe this volume indicates that while these barriers have not necessarily been removed, they may be overcome. The book addresses a range of methodological developments, habitats and floral/faunal groups, and illustrates the diversity of approaches to hydro-ecological/ecohydrological study. The chapters highlight significant advances in our knowledge, as well as providing thorough reviews of the subject matter, and crucially they identify the gaps in our knowledge that remain to be addressed. We hope that this book will provide a catalyst and starting point for others to become involved in dynamic interdisciplinary research at the hydrology–ecology interface. Perhaps, this volume may even provide a landmark in helping to set the foundation for the subdiscipline of hydro-ecology/ecohydrology to emerge from its larger ‘parent’ subjects and evolve into an accepted discipline in its own right.

References

- Baird AJ and Wilby RL. 1999. *Eco-Hydrology: Plants and Water in Terrestrial and Aquatic Environments*. Routledge: London.
- Bond B. 2003. Hydrology and ecology meet – and the meeting is good. *Hydrological Processes*, **17**, 2087–2089.
- Bonell M. 2002. Ecohydrology – a completely new idea? *Hydrological Sciences Journal*, **47**, 809–810.
- Brown CE, Pezeshki SR and DeLaune RD. 2006. The effects of salinity and soil drying on nutrient uptake and growth of *Spartina alterniflora* in a simulated tidal system. *Environmental and Experimental Botany*, **58**, 140–148.
- Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Leveque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ and Sullivan CA. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, **81**, 163–182.
- Dunbar MJ and Acreman MC. 2001. Applied hydro-ecological sciences for the twenty-first century. In Acreman, MC. (ed.) *Hydro-Ecology: Linking Hydrology and Aquatic Ecology*. Proceedings of Birmingham Workshop, July 1999. IAHS Publication No. 266, pp. 1–17.
- Eagleson PS. 2002. *Ecohydrology: Darwinian Expression of Vegetation Form and Function*. Cambridge University Press: Cambridge.
- Grootjans AP, Adema EB, Bleuten W, Joosten H, Madaras M and Janakova M. 2006. Hydrological landscape setting of base-rich fen mires and fen meadows: an overview. *Applied Vegetation Science*, **9**, 175–184.
- Gurnell AM, Hupp CR and Gregory SV. 2000. Preface. Linking hydrology and ecology. *Hydrological Processes*, **14**, 2813–2815.
- Hannah DM, Wood PJ and Sadler JP. 2004. Ecohydrology and hydroecology: A ‘new paradigm’? *Hydrological Processes*, **18**, 3439–3445.
- Hannah DM, Brown LE, Milner AM, Gurnell AM, McGregor GR, Petts GE, Smith BPG and Snook DL. 2007. Integrating climate-hydrology-ecology for alpine river systems, *Aquatic Conservation: Marine and Freshwater Ecosystems*, **17**, 636–656 doi: 10.1002/aqc.800.
- Janauer GA. 2000. Ecohydrology: fusing concepts and scales. *Ecological Engineering*, **16**, 9–16.
- Kundzewicz ZW. 2002. Ecohydrology – seeking consensus on interpretation of the notion. *Hydrological Sciences Journal*, **47**, 799–804.
- Lytle DE. 2005. Palaeoecological evidence of state shifts between forest and barrens on a Michigan sand plain, USA. *Holocene*, **15**, 821–836.
- Newman BD, Wilcox BP, Archer AR, Breshears DD, Dahm CN, Duffy CJ, McDowell NG, Phillips FM, Scanlon BR and Vivoni ER. 2006. Ecohydrology of water-limited environments: A scientific vision. *Water Resources Research*, **42**, W06302.

- Nuttle WK. 2002. Is ecohydrology one idea or many? *Hydrological Sciences Journal*, **47**, 805–807.
- Oki T and Kanae S. 2006. Global hydrological cycles and world water resources. *Science*, **313**, 1068–1072.
- Petts G, Morales Y and Sadler J. 2006a. Linking hydrology and biology to assess the water needs of river ecosystems. *Hydrological Processes*, **20**, 2247–2251.
- Petts GE, Nestler J and Kennedy R. 2006b. Advancing science for water resources management. *Hydrobiologia*, **565**, 277–288.
- Prebble M, Sim R, Finn J and Fink D. 2005. A holocene pollen and diatom record from Vanderlin Island, Gulf of Carpentaria, lowland tropical Australia. *Quaternary Research*, **64**, 357–371.
- Ricciardi A and Rasmussen JB. 1999. Extinction rates of North American freshwater fauna. *Conservation Biology*, **13**, 1220–1222.
- Rodriguez-Iturbe I. 2005. *Plants and Soil Moisture Dynamics: A Theoretical Approach to the Ecohydrology of Water-controlled Ecosystems*. Cambridge University Press: Cambridge.
- Sadler JP, Bell D and Fowles AP. 2004. The hydroecological controls and conservation value of beetles on exposed riverine sediments in England and Wales. *Biological Conservation*, **118**, 41–56.
- United Nations. 2000. *World Population Prospects: The 2000 Revision – Highlights*. UN Population Division, Department of Economic and Social Affairs, New York, USA.
- Wassen MJ and Grootjans AP. 1996. Ecohydrology: an interdisciplinary approach for wetland management and restoration. *Vegetatio*, **126**, 1–4.
- Wilcox BP and Newman DB. 2003. Ecohydrology of semiarid landscapes. *Ecology*, **86**, 275–276.
- Wilcox BP and Thurow TL. 2006. Emerging issues in rangeland ecohydrology. *Hydrological Processes*, **20**, 3159–3178.
- Williams DD and Williams NE. 1998. Aquatic insects in an estuarine environment: densities, distribution and salinity tolerance. *Freshwater Biology*, **39**, 411–421.
- Wood PJ, Hannah DM, Agnew MD and Petts GE. 2001. Scales of hydroecological variability within a groundwater-dominated chalk stream. *Regulated Rivers: Research and Management*, **17**, 347–367.
- Zalewski M, Janauer GA and Jolankaj G. 1997. Ecohydrology: a new paradigm for the sustainable use of aquatic resources. UNESCO IHP Technical Documents in Hydrology No. 7. IHP-V Projects 2.3/2.4, UNESCO, Paris, France.
- Zalewski M. 2000. Ecohydrology – the scientific background to use ecosystem properties as management tools toward sustainability of water resources. *Ecological Engineering*, **16**, 1–8.
- Zalewski M. 2002. Ecohydrology – the use of ecological and hydrological processes for sustainable management of water resources. *Hydrological Sciences Journal*, **47**, 823–832.