New policy directions for global pond conservation

Short running title: Global pond conservation

Matthew J Hill[1], Christopher Hassall[2], Beat Oertli[3], Lenore Fahrig[4], Belinda J Robson[5], Jeremy Biggs[6], Michael J Samways[7], Nisikawa Usio[8], Noriko Takamura[9], Jagdish Krishnaswamy[10] and Paul J Wood[11]

[1]Institute of Science and the Environment, University of Worcester, Henwick Grove, Worcester, WR2 6AJ, UK. Email: matthew.hill@worc.ac.uk

[2]School of Biology, Faculty of Biological Sciences, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK. Email: C.Hassall@leeds.ac.uk

[3]University of Applied Sciences and Arts Western Switzerland, Hepia Lullier, 1254 Jussy/Geneva, Switzerland. Email: beat.oertli@hesge.ch

[4]Geomatics and Landscape Ecology Laboratory, Biology Department, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada. Email: : lenore.fahrig@carleton.ca

[5]Environmental and Conservation Sciences, School of Veterinary & Life Sciences, Murdoch University, 90 South Street, Murdoch, WA 6150, Australia. Email: B.Robson@murdoch.edu.au

[6]Freshwater Habitats Trust, Bury Knowle House, Headington, Oxford, OX3 9HY. Email: jbiggs@freshwaterhabitats.org.uk

[7]Department of Conservation Ecology and Entomology, Stellenbosch University, 7602 South Africa. Email: samways@sun.ac.za

[8]Institute of Nature and Environmental Technology, Kanazawa University, Kanazawa 920-1192, Japan. Email: usio@se.kanazawa-u.ac.jp

[9]National Institute for Environmental Studies, Tsukuba 305-8506. Japan. Email: noriko-t@nies.go.jp

[10]Ashoka Trust for Research in Ecology and the Environment, Bengaluru, Karantaka, India. Email: jagdish@atree.org

[11]Centre for Hydrological and Ecosystem Science, Department of Geography, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK. Email: p.j.wood@lboro.ac.uk

Author for correspondence

Matthew J Hill

Institute of Science and the Environment

University of Worcester

Worcester

Worcestershire

WR2 6AJ

UK.

Tel: 00 44 (0) 1905 542707

Email: matthew.hill@worc.ac.uk

Abstract

Despite the existence of well-established international environmental and nature conservation policies (e.g., the Ramsar Convention and Convention on Biological Diversity) ponds are largely missing from national and international legislation and policy frameworks. Ponds are among the most biodiverse and ecologically important freshwater habitats, and their value lies not only in individual ponds, but more importantly, in networks of ponds (pondscapes). Ponds make an important contribution to society through the ecosystem services they provide, with effective conservation of pondscapes essential to ensuring that these services are maintained. Implementation of current pond conservation through individual site designations does not function at the landscape scale, where ponds contribute most to biodiversity. Conservation and management of pondscapes should complement current national and international nature conservation and water policy/legislation, as pondscapes can provide species protection in landscapes where large-scale traditional conservation areas cannot be established (e.g., urban or agricultural landscapes). We propose practical steps for the effective incorporation or enhancement of ponds within five policy areas: through open water sustainable urban drainage systems in urban planning, increased incentives in agri-environment schemes, curriculum inclusion in education, emphasis on ecological scale in mitigation measures following anthropogenic developments, and the inclusion of pondscapes in conservation policy.

Key words: biodiversity; ecosystem services; freshwater policy; international nature conservation; landscape-scale; pond networks; small waterbodies.

Introduction

Longstanding international environmental and nature conservation policies (such as the Ramsar Convention, the Convention on Biological Diversity, and the European Water Framework Directive) are important for protecting species and habitats, in the face of growing anthropogenic pressures (Dudgeon *et al.* 2006). Despite this, the number of threatened species listed on the IUCN Red List continues to increase, human-dominated lands (urban, agricultural) continue to replace natural lands (Decker *et al.* 2016), and a number of key terrestrial and freshwater habitats continue to be overlooked by policy makers. Ponds, defined in the UK and most of Europe as lentic waterbodies <2 ha in area (Williams *et al.* 2010), and pondscapes, defined as a network of ponds and their surrounding terrestrial matrix (Fig. 1), are one such historically neglected habitat. Recently, there has been a significant increase in recognition of the importance of ponds and pondscapes to biodiversity and ecosystem services by scientific and non-scientific communities. Yet these small waterbodies remain largely outside the remit of international, and in many cases national, conservation and environment legislation.

Current conservation status of ponds

Ponds are abundant across the globe (c. 500 million ponds and lakes are estimated to exist worldwide; Holgerson & Raymond 2016) and are critically important for ecology and society. Recent evidence indicates that pondscapes support high biodiversity (see The Pond Manifesto: EPCN 2008), and contribute disproportionately more to catchment aquatic biodiversity than larger and more widely studied freshwater bodies such as lakes and rivers (Davies *et al.* 2008b). Furthermore, ponds provide essential habitat for many nationally and internationally rare and threatened species and are important refuges in urban and agricultural landscapes (Davies *et al.* 2008b; Chester & Robson 2013). The significant contribution of pondscapes to local and regional aquatic biodiversity can be attributed to (i) the small catchments of individual ponds, resulting in idiosyncratic environmental conditions and habitat complexity, leading to landscape scale habitat heterogeneity (Davies *et al.* 2008b), (ii) the value of anthropogenic ponds (e.g. farm ponds) for increasing the area of freshwater habitat available for wildlife, and (iii) the provision of refuge habitats for aquatic communities, especially where natural wetlands have been largely converted into farm ponds or paddy fields (Takamura 2012; Chester & Robson 2013). Ponds also play an important role in supporting semi-aquatic and terrestrial flora and fauna, for example, agricultural areas that contain ponds support higher richness and abundance of terrestrial species than agricultural areas without ponds (syrphids and bees: Stewart *et al.* 2017; birds*:* Davies *et al.* 2016).

Ponds are increasingly recognised for the important ecosystem services they provide to society including flood alleviation, storage of urban storm water, the supply of irrigation water (Takamura 2012), and nutrient or pesticides removal from water. Ponds have been estimated to sequester a similar amount of carbon to the world's oceans (Downing *et al.* 2008), and may help mitigate the effects of urban heat islands (Coutts *et al.* 2012). These small waterbodies also provide considerable amenity, providing social and cultural benefits including improved physical and mental wellbeing and increased awareness of biodiversity and nature conservation (Lundy & Wade 2011).

Despite these benefits, current national and international environmental legislation and management strategies are almost exclusively focussed on large waterbodies, with ponds being harder to characterise, evaluate, monitor, and protect (see Table S1). In Europe, the EU Water Framework Directive (WFD) was implemented to protect and improve the water quality of all freshwaters and shallow coastal water. Yet in practice the WFD only covers rivers and standing waterbodies ≥50 ha, while excluding the vast majority of small wetlands and lentic waterbodies (Hassall *et al.* 2016). It has been suggested that the broad catchment-scale measures implemented under the WFD for larger waterbodies should also protect smaller waterbodies, but there is little evidence for this (Biggs *et al.* 2016). Nature conservation organisations have been quicker to identify the value of ponds for biodiversity, and as a result, nature conservation legislation at a European scale is currently the most important tool for protecting pond habitats and their biota (Hassall *et al.* 2016). The Habitats Directive provides protection as priority habitat to only a few pond types (e.g., Mediterranean temporary ponds, natural dystrophic lakes and ponds) and some pond associated species (e.g. Great Crested Newt, *Triturus cristatus*) (EC 1992). However, the scale at which pond conservation is applied currently (i.e. individual site designation) is not the scale at which ponds contribute most to biodiversity (pondscape scale; Hill *et al.* 2016). Furthermore, as significant advances in knowledge of pondscapes occurred after the implementation of the Habitats Directive and WFD, there remain significant gaps in the protection that these directives provide to pondscapes and their biota (Biggs *et al.* 2016).

Similarly, in North America and Australia, pond habitats in general do not receive direct legislative protection despite the Clean Water Rule 2015 of the Clean Water Act in the USA (Department of Army, Corps of Engineers and US Environmental Protection Agency 2015*)* and the national-scale Environment Protection and Biodiversity Conservation Act 1999 in Australia (Act 1999). The latter includes an inventory of > 900 'nationally-important' wetlands that are protected based on meeting ≥ 1 of 6 criteria. However, these criteria focus on attributes of single wetlands, ignoring their landscape contexts, and few small waterbodies are specifically designated.

In Asia, international legislation specifically targeted for conservation of pond habitats is largely lacking. A possible reason for this is a lack of holistic biodiversity or water quality surveys of ponds in international or national monitoring programmes. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (1990-) conducts nation-wide and long-term censuses of water quality and biodiversity in rivers and impounded reservoirs, local governments (1970-) monitor water quality of lakes, and the Ministry of the Environment (monitoring site 1000 programme; 2009-) evaluates biodiversity of some 20 wetlands or lakes. Although action plans for wetland/pond conservation exist in conjunction with The National Biodiversity Strategy of Japan 2012-2020, comprehensive or long-term water quality and biodiversity monitoring data are lacking. In India, almost all ponds and pondscapes are excluded from environmental and nature conservation legislation. Some large wetlands in India receive legislative consideration from the Wetlands (Conservation and Management) Rules under the Environment Protection Act 1986 and the National Environment Policy

2006, which regulates the activities that can be undertaken within these wetlands (Sundar & Kittur 2013). A few ponds within protected areas also receive some protection under the Wildlife Protection Act 1972. However, there have been heated debates between civil society and central governments because of restrictions on activities in these wetlands (although in Sept 2017, wetland conservation and management legislation in India was amended, potentially excluding certain categories of human-made water bodies). Legislation for the sustainable management of ponds in India is difficult as irrigation departments, fisheries departments and district councils often manage them jointly.

Ponds may receive indirect protection through other legislation. For example, South Africa's National Biodiversity Strategy and Action Plan (2005; NBSAP) and Namibia's National Biodiversity Strategy and Action Plan (2013; NNBSAP) aim to integrate terrestrial and aquatic management to minimise the impacts of processes that threaten biodiversity, to enhance ecosystem services and, to improve social and economic security. In such water scarce countries, pond security is thereby embedded in policies aimed at water security, biodiversity conservation and resilience without specifically referring to the thousands of water retention ponds throughout these nations. Importantly, both these southern African NBSAPs emphasise not only hydrology, resilience and sustainability, but also the importance of conserving the rich heritage of endemic species.

At the international level, the Ramsar Convention, signed by 169 countries, ensures that key wetland (Ramsar) sites of international importance are protected (Ramsar 2016), with many encompassing large numbers of ponds. Other international initiatives, particularly the Convention on Biological Diversity, have stimulated development of the international partnership for 'Satoyama Initiatives' to promote the sustainable management and use of natural resources that benefit society and biodiversity, partially incorporating pondscapes (Bélair *et al*. 2010). In addition, there are a few national-scale policies that provide protection for ponds, such as the UK's recognition of 'Priority Habitats' and 'Priority Species' for site-specific and species-specific conservation and management (JNCC & Defra 2012). However, most ponds and pondscapes fall outside of contemporary nature conservation policy. This has arisen largely from a lack of recognition and poor understanding of the importance of pondscapes for sustaining local and regional biodiversity at a policy/management level. In arid and semi-arid countries like Namibia and South Africa, where ponds are included in regional plans, the focus is to protect water resources and promote hydrological cycles rather than pond biodiversity *per se*. The reality of global freshwater conservation is nuanced and complex, incorporating a range of political issues (e.g., definitions of different freshwater habitats, top-down vs. bottom-up management), social issues (property and societal rights), and economic issues (economic development vs environmental conservation, and cost effectiveness of management) (Calhoun *et al.* 2014). However, there remain significant opportunities for the inclusion of ponds and pondscapes in international and national conservation and policy frameworks.

Opportunities for pond conservation, supported by science

Patch-network conservation

Knowledge regarding the value of pondscapes, even in human-dominated environments (Hill *et al.* 2016), now provides clear empirical evidence and support for their inclusion in environment and nature policy frameworks. Conceptual advances in ecological research from ‘corridors’ to ‘connectivity’ has provided critical scientific evidence to underpin the development of practical conservation strategies across landscapes. Groups of small habitats generally provide as high (or higher) conservation value than a single large habitat of equal area (Fahrig 2017). Several studies have shown that networks of smaller ponds support higher taxonomic richness and conservation value than one large pond (Martinez-Sanz *et al.* 2012; Oertli *et al.* 2002). In addition, higher pond density is associated with greater species richness in UK urban ponds (Gledhill *et al.* 2008). This suggests that the current legislative focus on large, contiguous habitats at the exclusion of small habitats is potentially misguided (e.g. EU Natura 2000 network: European Commission 2008). Further, applying patch-network conservation exclusively at large spatial scales can be ecologically ineffective, missing local scale biodiversity hotspots, particularly in human-dominated landscapes. One way to improve the effectiveness of landscape conservation is to incorporate networks of smaller freshwater habitats

(≈ pondscapes), alongside large-scale habitat networks. For example, in the context of widespread agro-forestry in South Africa, large-scale ecological networks (ENs) of remnant land within agroforestry landscapes have been set aside to mitigate the effects of agro-forestry. These ENs are rich in natural and artificial pondscapes and are similar in biodiversity value to those in neighbouring protected areas (Pryke *et al.* 2015). However, urban and agricultural landscapes often represent barriers (e.g., roads) for the dispersal and colonisation of pond biota. Managing pondscapes would increase focus on management actions that increase connectivity between ponds, especially for native species migration between ponds (e.g. culverts beneath roads, restoring drains as streamlines with fringing vegetation). Consideration of pondscapes favours landscape complementation because they encompass a variety of habitat types (proximal terrestrial and aquatic habitat) for many species to complete their life histories (Pope *et al.* 2000). Furthermore, conservation of pondscapes facilitates connectivity and dispersal, particularly in agricultural landscapes, acting as stepping stones between larger protected freshwater habitats, thereby increasing the effectiveness of conservation measures at larger spatial scales (Kukkala *et al.* 2016; Pryke *et al.* 2015).

In human-dominated landscapes, many ponds and pondscapes are located on private land and if faced with the prospect of mandatory conservation initiatives, it may be financially and logistically easier for landowners to remove (i.e. drain or infill and build over) ponds given their small size (Calhoun *et al.* 2014). In some agricultural and urban landscapes where private ownership of ponds is high, environment and conservation legislation may need to be flexible and designed to allow environmentally friendly farming, forestry, fisheries, ecotourism and/or urban development to ensure the persistence and protection of ponds, while not overly restricting local economic activities (Usio & Miyashita 2014). For example, most pondscapes in Japan are used for irrigation for rice farming and form a part of Satoyama, a landscape mosaic of paddy fields, dry cropland, farm ponds, grassland, secondary forests, streams and villages. Given that the biodiversity of Satoyama is maintained through traditional farming, forestry and fishing activities, moderate levels of human activities are encouraged to maintain indigenous biodiversity as well as to sustain the local economy (Takeuchi 2010). Furthermore, to raise public awareness of the value of multifunctionality in agricultural areas, the

FAO (Food and Agriculture Organization of the United Nations) designates regions with traditional agriculture, indigenous culture, scenic landscape and sustainable use of natural resources as Globally-Important Agricultural Heritage Systems (GIAHS 2017). Biodiversity conservation in urban areas presents a number of challenges associated with development. However, ponds are increasingly recognised for the ecosystem services they provide in cities. In some new urban developments, stormwater / groundwater recharge ponds have been created. These provide some 'natural' habitat, offsetting pond loss, and maintaining biodiversity in new developments (Hassall & Anderson 2015).

Monitoring ecological condition

Ponds and pondscapes are rarely monitored in a systematic manner because of the resource and logistical implications for protecting these abundant waterbodies. Other monitoring options are possible, such as the use of sentinel sites that can be monitored over long time-periods, citizen-science based monitoring projects, or environmental DNA techniques that may facilitate rapid and effective assessment of pond biodiversity and presence of protected species (Biggs *et al.* 2016). Monitoring approaches need to be further refined to provide rapid, low cost assessments of the environmental and biological quality of ponds to guide conservation management (Rosset *et al.* 2013). This is currently being implemented in South Africa using a Dragonfly Biotic Index, which can be applied to small pond environments as well as other freshwater systems (Samways & Simaika 2016). Monitoring a charismatic taxon like dragonflies, which may also act as an umbrella for many other taxa, makes data collection more feasible, especially as citizen scientists can be readily engaged. In India, the identification of ponds and wetlands through the development of the Wetland Atlas (Bassi *et al.* 2014) provides significant opportunities for the periodic monitoring of pondscapes using remotely sensed data and citizen scientists.

Ponds provide frequent opportunities for citizens to engage in conservation and habitat management activities, especially when linked to education or enjoyment of wildlife through dedicated trails

(Willis & Samways 2013). Given the inadequate funding levels for global biodiversity conservation (Waldron *et al.* 2013), there is increasing reliance on agencies such as environmental charities to act as intermediaries among government policy makers, stakeholders and the public to realise the aspirations of conservation initiatives. The development of a forum which connects stakeholders such as scientists, landholders, citizens, environmental groups/agencies and policy makers may facilitate pond conservation. Such a forum should provide digital and/or physical space for dialogue among groups, make scientific findings accessible to resource managers, stakeholders and citizens, provide training in pond monitoring, and facilitate the development of conservation initiatives that are robust, innovative and accessible for all groups (Calhoun *et al.* 2014).

Policy-based recommendations

Sufficient research now exists to underpin policy recommendations for ponds. There is an ecological need for the Ramsar Convention, the Convention on Biological Diversity and other international environmental legislation (e.g., the WFD in Europe) to now explicitly recognise pondscapes. Below, we provide recommendations on how ponds, pondscapes, and their ecosystem services should be incorporated into policy:

(1) Environmental context – Given that ponds often occur in networks linked by important terrestrial habitats, identifying groups of important sites as management units (recommended by the WFD; EC 2003) will be logistically easier and more cost effective than monitoring/protecting individual ponds. Defining pondscapes as management units increases opportunities to monitor ponds over wider areas and to identify objectives for each pondscape (Biggs *et al.* 2016). In addition, requiring permits for modifications (positive or negative) of ponds provides a policy tool that can consider the role of each pond within the pondscape, and would require applicants to maintain/enhance a pond’s capacity to sustain native biodiversity within the pondscape. Local government or non-government environmental organisations would be well-placed to implement pond management units and permits.

(2) Urban planning – Planning regulations can be adapted to prioritise open water sustainable urban drainage systems alongside other nature-based solutions (Dadson et al. 2017). Mitigation for pond loss during development should be based on pondscape-scale considerations rather than individual habitat creation. Also, during urban development, there should be a focus on zero ecological loss, as opposed to zero habitat loss, and ponds could form a key part of this strategy. Under some conditions, stormwater ponds can support significant biodiversity (Hassall & Anderson, 2015), especially where a treatment train of clean water ponds (e.g. receiving roof water) is initially separated from ponds receiving contaminated water (e.g. from roads or vehicle parks). Diverting runoff water that would otherwise flow directly to lakes or rivers, into such ponds, could increase pond density and biodiversity in urban areas as well as help mitigate flooding and retain pollutants.

(3) Flood management – The current trend towards natural flood management provides an opportunity for policies to incorporate pondscapes. Ponds can be easily integrated into open water flood storage strategies because small waterbodies may pose fewer logistical issues than larger ones, yet hold an equivalent volume of water. It may be also relatively easy to integrate numerous small ponds into urban or rural land management schemes, such as the "sponge city" concept currently being adopted in China (Liu *et al.* 2017).

(4) Agriculture – Financial incentives are sometimes provided (e.g., under the EU agri-environment schemes) for the maintenance of individual farmland ponds of significant biodiversity value (Attwood *et al.* 2009; Davies *et al.* 2008a). These incentives could be modified to ensure that the protection and creation/restoration of pond networks is rewarded at a rate greater than the sum of the individual ponds, provided collaborative agreements could be made between multiple landowners.

(5) Education - Opportunities may exist for "pond schools" which parallel "forest schools" in their focus on nature as a core of education (Austin *et al.* 2016). Many schools in urban or rural landscapes could make greater use of nearby ponds to provide enhanced pedagogical and health benefits. In addition, as part of the increased focus on nature play and kitchen gardens in schools, 'frog ponds' could be constructed to provide these benefits to students and their communities. In human-dominated

landscapes, public awareness of pondscapes can be increased by designating globally or nationally important pondscapes (through frameworks such as GIAHS 2017).

Conclusion

Current conservation policy is failing to preserve much of the aquatic biodiversity and ecosystem services supported by pondscapes. For policy to be consistent with current scientific understanding, pondscapes should be better integrated into national and international policy frameworks to maximise opportunities for conserving and protecting biodiversity and ecosystem services. Although the economic implications of new environmental policies will be contested in certain quarters, because of their small size pondscapes may be easier to conserve and maintain than larger waterbodies. Moving away from site-specific conservation to a strategy that conserves resilient landscapes, puts people at the heart of the environment, and grows natural capital will promote biodiversity conservation (Natural England 2016). An evidence-based conservation strategy that incorporates pondscapes into policy frameworks will significantly improve existing legislation by protecting a valuable, multifunctional habitat type that provides a solution to multiple complex societal challenges while supporting and enhancing biological diversity.

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Figure captions

Fig. 1 - Groups of small ponds and surrounding habitats ('pondscapes') provide important ecosystem services in human-dominated landscapes. A pondscape in (a) an agricultural landscape in the UK (Leicestershire) and (b) an urban setting in Australia (Perth; providing important habitat for amphibian metacommunities). Map data credit: Google Earth 2016.

(a)

(b)