Freshwater biodiversity and conservation planning: introduction to the virtual supplement

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The January 2011 Special Issue is the first major compilation of studies on systematic conservation planning in fresh waters (Turak & Linke, 2011). The papers in this Special Issue consolidate freshwater conservation planning as a field within both conservation science and freshwater ecology. This progress is largely a result of key advances in both disciplines (Linke, Turak & Nel, 2011). Many of the previous studies representing the advances in the discipline of freshwater ecology were published in Freshwater Biology as were three previous important papers on freshwater conservation planning. It was our aim to compile this virtual supplement containing all freshwater conservation planning papers published in this journal together with a selection of papers dealing with key concepts and techniques in freshwater ecology that made recent advances in freshwater conservation planning possible.

The virtual supplement includes papers on three themes: key concepts for biodiversity conservation in fresh waters, systematic planning studies and modelling.

Key concepts

The review by Ward & Tockner (2001) sets the scene for the entire Special Issue. The authors called for a holistic view of river biodiversity that includes linkages to all types of ecosystems (lentic, lotic, wetlands and groundwater) and argued that protection of riverine biodiversity should be conducted with more than just species in mind, a view that was translated into community, landscape and process based approaches in some of the papers in the Special Issue (see Nel et al., 2011; Turak et al., 2011). Importantly, Ward & Tockner also looked at connectivity gradients and how these can facilitate or hinder biodiversity protection. Concluding, this paper laid down the background for the four surrogate types discussed by Linke et al. (2011), as well as the thread of connectivity throughout the Special Issue.

Adding to the call of Ward & Tockner that groundwater/surface water interactions need to be considered, Deharveng et al. (2009) gave an excellent overview of the science and state of groundwater biodiversity science in Europe. This includes an inventory of European data, as well as an analysis of data gaps. Most importantly, especially for non-groundwater scientists, this paper, together with the study by Michel et al. discussed below, highlighted that sound science can provide valuable insights even if data are patchy and sparse and taxonomic knowledge is limited.

The paper by Johnson & Gage (1997) is slightly dated, but considering how few large-scale studies are actually performed, it is still extremely topical. Its authors described how the interaction of GIS systems, geostatistics, multivariate statistics and landscape models can be used to uncover complex relationships. While the paper was written before the age of systematic aquatic conservation planning, it stressed that insight gained from landscape-
scale analysis can be used in resource management and policy. In our view, this conclusion extends to conservation planning.

The last paper in this group is also already 12 years old, but it highlighted the major topic of restoration planning. At that time, and indeed even today, most systematic studies were focused on conservation, which can be limiting, considering how many of the earth’s waterways are already degraded (Vörösmarty et al., 2010). In this context, Wissmar & Beschta (1998) discussed restoration and management with a catchment perspective. Still highly topical, the authors set up a decision-theoretical framework to restoration. They also pointed out that societal considerations are crucial to the success of conservation and restoration success (see Barmuta, Linke & Turak, 2011; in the current Special Issue). Similar to most papers in the Special Issue, Wissmar & Beschta (1998) concluded that understanding processes and landscape connectivity is key to a successful restoration program. While not directly linked to systematic planning, these four papers provide vital background information for the advances documented in the Special Issue.

**Systematic planning studies**

Linke et al. (2007) included habitat condition, as well as future vulnerability in a comprehensive framework for biodiversity conservation. They concluded that high conservation value (irreplaceability), based on modelled macroinvertebrate distributions, is not the only key to a priority action. The present condition of a planning unit and the features it contains prescribe the type of action (conservation or restoration) and its vulnerability dictates urgency – with highly vulnerable planning units given priority. Together with Moilanen et al. (2008), Linke et al. were the first authors who included an a priori consideration of connectivity in their assessment. Moilanen et al. (2008), however, not only found an intuitive way to include upstream and downstream connectivity, but also included this in the existing software package Zonation (Moilanen, 2007). As documented by multiple papers in the Special Issue (Esselman & Allan, 2011; Hermoso et al., 2011) similar solutions have now been found for the package Marxan – operationalising freshwater conservation planning within two well-maintained software packages.

Marxan was also used by Michel et al. (2009), in the first application to groundwater biota. Using the PASCALIS dataset described by Deharveng et al. (2009), they compared hotspots strategies to a complementarity-based approach. Including spatial constraints in the reserve-design algorithm, their approach showed that using appropriate methods can yield efficient results – even if the background data are sparse. However, they demonstrated that alternative sampling strategies can reduce uncertainty. Furthermore, they concluded that aquifer complexes can be used as a spatial framework in which human influences and vulnerability should be included in a prioritisation approach, similar to riverine catchments in a lotic setting. The successful application of quantitative prioritizations for groundwater biodiversity by Michel et al. (2009) together with the applications in palustrine wetlands by Ausseil et al. (2011) and rivers across the world (Moilanen et al., 2008; Heiner et al., 2011; Rivers-Moore, Goodman & Nel, 2011) provide a solid foundation for integrated conservation planning across the freshwater realm although such approaches are yet to be implemented in lakes.

**Modelling techniques and landscape-scale data**

In the review paper of the Special Issue, Linke et al. (2011) concluded that common complaints about the data-hungry nature of systematic approaches are not relevant in times of large-scale environmental data and sophisticated GIS and modelling techniques
(discussed 13 years ago by Johnson & Gage, 1997). Olden & Jackson (2002) examined multiple modelling approaches to predict 27 fish species in temperate lakes. Based on predictive performance of real and simulated data, they recommended using neural networks and classification trees. However, they also pointed out that multiple evaluation metrics can be evaluated: sensitivity and specificity for example. Links of these modelling issues to systematic planning in a terrestrial setting were discussed by Wilson et al. (2005).

In a riverine context, Joy & Death (2004) were also successful in fitting artificial neural network models to fish and decapod assemblages in New Zealand. They used the resulting habitat suitability maps in monitoring frameworks, as well as conservation applications such as re-introductions of rare or endangered species. Another study from New Zealand (Leathwick et al., 2005) introduced a new method for species distribution modelling – multiple adaptive regression splines (MARS). This technique works on assemblage-level predictions and can therefore include community effects into the extrapolation. After its 2005 publication in *Freshwater Biology*, this modelling approach became the technique of choice for some freshwater conservation planners – as demonstrated by Moilanen et al. (2008) and Hermoso et al. (2011).

The three publications above all estimate hypothetical distributions of aquatic species. This is often unrealistic – we assume that the historical distributions are still valid while centuries of degrading landuse activities may have shifted distributions. While Linke et al. (2007) circumvented this by adding a condition metric to the planning stage, a more elegant approach is to include disturbance variables *a priori* as predictors. Fukushima et al. (2007) successfully included hydrological alteration in a model. They also concluded that there is an interaction between dams and other habitat attributes in predicting species persistence. The authors concluded that their models can be used to prioritise conservation and restoration measures such as dam removal. The second paper incorporating condition in distribution models is the European study by Lassalle et al. (2009), linking diadromous fish distribution to anthropogenic pressures. They identified movement barriers as some of the key variables explaining absence of migratory species.

The last paper in the virtual supplement deals with derivation of environmental datasets on a continental scale. While some very large-scale datasets already exist (for example HydroSHEDS (Lehner, Verdin & A. Jarvis, 2008)), Norris et al. (2007) managed to establish a detailed modelling framework for an entire continent. This included natural variables, but also comprehensive models of catchment disturbance, sedimentation, hydrological alteration, as well as modelled biotic indicators of river health. This database has been used to validate river condition in the decision framework by Linke et al. (2007). These comprehensive datasets can be used to infer landscape condition in systematic planning exercises and could for example be used in studies like Esselman & Allan (2011) in the Special Issue *in lieu* of their risk surfaces.

We believe that the articles in the virtual supplement will provide valuable background information to the Special Issue and foster understanding and use of the concepts of modern planning.


