Enhanced Diversity at Network Nodes: River Confluences Increase Vegetation-Patch Diversity

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Abstract: Although dendritic networks within ecosystems have typically been considered a special case of network topology, they have attracted a great deal of attention in recent years. These systems exhibit unique features in that both the nodes and branches provide distinct habitats. Within a river discontinuum context, river confluences, which are nodes of dendritic river networks, are hypothesised to have particular hydrodynamic traits that create heterogeneous habitats through a unique disturbance regime, although this hypothesis has not yet been tested. We tested this hypothesis using a vegetation data set collected from 14 river basin systems in Hyogo Prefecture, Japan. We compared vegetation-patch diversity between confluence and single-flow areas using hierarchical Bayesian models. Our results demonstrated greater vegetation-patch diversity in confluence areas compared to single-flow areas. Our findings support the hypothesis that confluences result in highly heterogeneous habitats. To the best of our knowledge, this is the first empirical report to demonstrate that river confluences have high vegetation-patch diversity. We conclude that network nodes play an important role in maintaining the biodiversity of river networks.

Keywords: Disturbance, geography, habitat heterogeneity, hierarchical Bayesian model, river channel network.

INTRODUCTION

Recent syntheses have used network theoretical analysis to understand the functioning of diverse sets of complex ecological systems (May 2006; Montoya et al. 2006). These analyses have suggested that emergent characteristics such as system-level responses to disturbance can be predicted from the structure of a network and the strength of interactions among network elements (Grant et al. 2007). Although dendritic networks within ecosystems are usually considered a special case of network topology (Grant et al. 2007), they have attracted a great deal of attention in recent years. Such systems exhibit the distinctive feature that both the nodes and branches provide unique habitats (Benda et al. 2004a; Benda et al. 2004b; Grant et al. 2007).

In dendritic networks, nodes provide high-quality habitats (Grant et al. 2007). River confluences, which correspond to the nodes of dendritic river networks, are known to exhibit particular hydrodynamic traits (Rhoads & Kenworthy 1995; De Serres et al. 1999; Benda et al. 2004a; Benda et al. 2004b; Rice et al. 2008) that result in many geomorphically diverse habitats (Benda et al. 2004b; Rice et al. 2008). In river ecosystems, flooding-induced disturbances, which provide the most dynamic and complex biophysical habitats (Naiman et al. 1993; Burkart 2001), occur more frequently at confluences (Benda et al. 2004b). Thus, confluences are considered to increase spatial and temporal habitat heterogeneity (Benda et al. 2004a; Benda et al. 2004b; Rice et al. 2008). Benda et al. (2004a, b) reviewed several cases of habitat creation by confluences, e.g., the formation of fans and erosion-resistant deposits, which may influence biodiversity (Benda et al. 2004a; Benda et al. 2004b). However, the roles of confluences in creating habitat heterogeneity (confluence effects) within river ecosystems have rarely been examined, but they should be investigated within a context of maintaining biodiversity in river ecosystems.

Habitats in river systems are characterised by differences in river streams and reaches, which join together to form larger networks (Lowe et al. 2006). Therefore, an effective analysis of the ecological importance of a river confluence as a component of the river channel network must incorporate the entire river channel network. Ideally, this kind of analysis applies data collected from many rivers that constitute various river channel networks (Benda et al. 2004b). This type of approach helps to minimise individual river system-specific “noise” when analysing confluence effects (Knick et al. 2008). However, few wide-area biodiversity data sets from many river systems are available, because data collection is often expensive and time-consuming (e.g., Svensson et al. 2007; Haddad et al. 2008). From 2002 to 2006, the Hyogo Prefecture government in Japan conducted the Research about the Natural Environment of Rivers (RNER)
program for all rivers within the prefecture. This program involved investigating riparian vegetation for 195 individual rivers in 14 river basin systems, over an area of 5105 ha. All data were digitised and then incorporated into a geographic information system (GIS) (Hyogo Prefecture 2007). We used the RNER riparian vegetation data to determine whether diversity in vegetation patches, which serve as potential habitat, increases around confluences of Hyogo Prefecture rivers. High physical heterogeneity may augment biological diversity via the well-established principle that biological diversity tends to increase with habitat variability (Benda et al. 2004b; Rice et al. 2008).

We analysed the RNER data set to determine how river confluences affect habitat heterogeneity using a hierarchical Bayesian model that included three hierarchical random effects (see “METHODS” section). In the RNER vegetation data set, different vegetation types were illustrated as patches on a vegetation map. The 17 vegetation types correspond to different habitat types in the RNER (Hyogo Prefecture 2009). We used Shannon and Simpson diversity indices of vegetation patches as indices of habitat diversity and compared these between confluence sites and non-confluence sites. The following sections present our findings and discuss the significance of river confluences in riparian ecosystems.

METHODS

Research About the Natural Environment of Rivers (RNER) Data Set

We used the RNER vegetation data set from surveys conducted between 2002 and 2006 (Fig. 1) to investigate riparian vegetation in alluvial river sections (total length, 680 km). The RNER vegetation data set was created using two steps. The first step involved identification of the edges of vegetation patches from aerial photographs and digitalisation of vegetation patches on a 1/2500 contour map. Color photographs (scale: 1/10,000) taken by the Hyogo Prefecture

Fig. (1). Watersheds and main streams of analyzed river basin systems in Hyogo Prefecture.
Table 1. Vegetation types in the RNER Data Set and Explanation of Indication Habitats. Definitions are Detailed in Hyogo Prefecture (2009)

<table>
<thead>
<tr>
<th>No.</th>
<th>Vegetation type</th>
<th>Habitat type as indicated by the vegetation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miscanthus sacchariflorus dominant vegetation</td>
<td>Sandy habitats frequently found in relatively gentle river inclination (1/1000-1/250) areas</td>
</tr>
<tr>
<td>2</td>
<td>Phragmites communis dominant vegetation</td>
<td>Muddy wetland habitats found in areas with low flow velocity</td>
</tr>
<tr>
<td>3</td>
<td>Phragmites japonica dominant vegetation</td>
<td>Frequently disturbed rudaceous habitats widely distributed in steeper river inclination (1/300-) areas</td>
</tr>
<tr>
<td>4</td>
<td>Salix gracilistyla dominant vegetation</td>
<td>Frequently flooded riverside habitats often found in steeper river inclination (1/200-) areas</td>
</tr>
<tr>
<td>5</td>
<td>Floating-leaved and submerged plant vegetation</td>
<td>Stagnant water and slow-current habitats</td>
</tr>
<tr>
<td>6</td>
<td>Halophytic plant vegetation</td>
<td>Habitats preferred by halophytic plants</td>
</tr>
<tr>
<td>7</td>
<td>Sand dune vegetation</td>
<td>Habitats similar to coastal sand dunes</td>
</tr>
<tr>
<td>8</td>
<td>Vegetation beside mountain stream</td>
<td>Stable wet habitats maintained by droplets of flow and/or bubbled-up water.</td>
</tr>
<tr>
<td>9</td>
<td>Riparian forest vegetation</td>
<td>Wet forest habitats elevated above the river water surface</td>
</tr>
<tr>
<td>10</td>
<td>Salix species (other than S. gracilistyla) dominant vegetation</td>
<td>Wet forest habitats near the river line in middle and lower stream areas</td>
</tr>
<tr>
<td>11</td>
<td>Annual plant vegetation just beside river channel</td>
<td>Frequently flooded and submerged habitats along the river line</td>
</tr>
<tr>
<td>12</td>
<td>Low-moor vegetation</td>
<td>Wetland habitats around indentations and swamps with low flow velocity</td>
</tr>
<tr>
<td>13</td>
<td>Rudaceous grassland vegetation</td>
<td>Typically dry but infrequently flooded habitats elevated above the river water surface</td>
</tr>
<tr>
<td>14</td>
<td>Floodplain grassland vegetation</td>
<td>Rarely flooded habitats far from and elevated above the river line</td>
</tr>
<tr>
<td>15</td>
<td>Floodplain woody plant vegetation</td>
<td>Floodplain habitats less frequently disturbed than low-moor vegetation</td>
</tr>
<tr>
<td>16</td>
<td>Hill forest vegetation</td>
<td>Rarely flooded hilly habitats</td>
</tr>
<tr>
<td>17</td>
<td>Roadside weed vegetation</td>
<td>Dry and treaded habitats</td>
</tr>
</tbody>
</table>

government were used for patch identification. After the creation of the vegetation patch map, extensive field surveys using the Braun–Blanquet approach (i.e., phytosociological surveys) were conducted to classify the types of vegetation within the patches (Hyogo Prefecture 2002, 2007). Because surveying all vegetation patches would be prohibitively time-consuming, the phytosociological surveys were conducted on arbitrarily selected patches for each vegetation type. The data set first classified vegetation patches into 17 types based on habitat types that were estimated from dominant species and their life form (Table 1). In addition, land use and unvegetated areas (e.g., natural bare ground, open water, and artificial areas) were also classified into five types, and the vegetation/land-use types were summarised as patches on a vegetation map (Fig. 2). Vegetation was mainly distributed within 50-m of the river line, and each vegetation patch was entered as digital polygon data into GIS (ArcGIS version 9.1; ESRI Co., Tokyo, Japan).

In this study, we used the 17 vegetation types to evaluate habitat heterogeneity, as this vegetation classification system was intended to categorise habitats for plants along river lines of Hyogo Prefecture (Hyogo Prefecture 2009; Table 1).

Data Preparation

We used GIS software (ArcGIS) to divide river lines into 500-m units along all rivers of Hyogo Prefecture; each 500-m unit was a 500-m long and approximately 400-m wide polygon (Fig. 2). The first 500-m unit was placed at the mouth of each river, and the other 500-m units were then set automatically along river lines starting from the first unit using GIS. When a single vegetation patch was encompassed by two 500-m units, the patch was divided into two 500-m units. We defined a 500-m unit adjacent to more than three other units and including a river confluence as a “confluence unit”, whereas a 500-m unit adjacent to two or fewer other units and not including a river confluence was considered a “single-flow unit” (Fig. 2). A total of 190 units were classified as confluence units, and 1293 units were classified as single-flow units. We also calculated the area of all patches of vegetation within each 500-m unit. We then calculated Shannon ($H'$) and Simpson ($D$) diversity indices of vegetation patches for each unit as follows:

$$H' = -\sum_{i=1}^{N} \left( \frac{a_i}{A_x} \right) \ln \left( \frac{a_i}{A_x} \right),$$

$$D = 1 - \sum_{i=1}^{N} \left( \frac{a_i}{A_x} \right)^2,$$

where $N$ is the number of vegetation types within the unit $x$, $A_x$ is the total vegetation area of the unit, and $a_i$ is the area of vegetation $i$. Finally, we calculated the total vegetation area and stream power index (SPI) per unit. SPI is the product of river-bed inclination and basin area and is generally used as an index of the erosive power of flowing water (Wilson & Gallant 2000). These two factors may affect vegetation diversity in riparian areas; therefore, we incorporated them into the models to control for their effects when determining confluence effects.
Pre-Specified Conditions

Data sets for river channel networks have a hierarchical construction: flows compose reaches, which link together to form larger stream networks (Lowe et al. 2006). Each of these components has unique traits. In addition, when a large-scale data set such as the RNER data set is analysed, the power of statistical analyses is often influenced by variation among data collectors, data sampling dates, and non-investigated site characteristics (Link 1999; Link & Sauer 2002; Clark et al. 2003; Thogmartin et al. 2004). Additionally, environmental factors are usually spatially auto-

Fig. (2). Example of the Research about the Natural Environment of Rivers (RNER) geographic information system (GIS) data. Square polygons represent individual units. Confluence and single-flow units are defined as units adjacent to more than three other units and two other units, respectively. The central white polygon represents open water, and the other small polygons represent classified vegetation patches.

Fig. (3). Conceptual diagram of nested random effect models. The central circle represents the vegetation diversity index (patch number, Shannon $H'$, or Simpson $D'$). The surrounding circle represents fix effects, and the wavy square represents random effects.
correlated (e.g., Keitt et al. 2002). To minimise these issues, multiple types of random effects should be incorporated into models (Link & Sauer 2002). The use of random effects is an effective method for data summarisation; i.e., the reduction of many parameters into simple summaries (Link 1999). The top-ranked random effect used in our analysis was river basin systems, which are related to variation in river length, catchment area, landform, and other traits. The second-ranked random effect is individual rivers, which are related to the diversity of types and scales of human land use and artificial constructions. The bottom-ranked random effect is individual 500-m units, which are related to unobserved micro-environmental factors such as observer error. Our models incorporated a nested structure of these three random effects, which were treated as mean zero normal random variables (Fig. 3).

Model Establishment

We established hierarchical Bayesian models that included three hierarchical random effects. Shannon $H'$ and Simpson $D$ were assumed to have normal distributions. Our models can be expressed as:

$$ Y_{ik} \sim \text{Normal}(\alpha_k, \sigma), $$

$$ \alpha_k = \text{Intercept} + \text{conf}_k + \text{SPI}_k + \text{area}_k + \text{Rf} + \text{Rg} + \text{Rr}, $$

and

$$ \sigma^2 = \text{Variance of all diversity index,} $$

where $Y_{ik}$ is Shannon $H'$ or Simpson $D'$ in a 500-m unit $k$ on river $i$ of river system $i$. We used the effects of three physical parameters as fixed effects: the presence of a river confluence ($\text{conf}_k$, 1, or 0); stream power index ($\text{SPI}_k$); and total vegetation area ($\text{area}_k$) of a unit. We also incorporated three random effects: river system, individual river, and individual unit ($\text{Rg}$, $\text{Rf}$, and $\text{Rr}$, respectively).

A necessary initial consideration in a Bayesian analysis is that prior distributions for each variable are informed (Link & Sauer 2002; Thogmartin et al. 2004). Because we had little empirical support for one distribution over another, our model was based on non-informative priors (Link & Sauer 2002; Thogmartin et al. 2004). All prior random and fixed effects were designed to have standard normal distributions (Fig. 3). Although we could not confirm normality of the two diversity indices in our data set using the Kolmogorov-Smirnov test (Shannon $H'$, p-value < 0.001; Simpson $D'$, p-value < 0.001), both indices did not have extreme dispersion (The means ± SD of $H'$ and $D$ were 1.09 ± 0.41 and 0.56 ± 0.19, respectively) and histograms of both indices had one peak around the mean values. Thus, the variance of each prior diversity index distribution ($\sigma^2$) was also designed to have a standard normal distribution.

Fitting the Hierarchical Model

To fit the hierarchical models, we used WinBUGS (The BUGS Project 2008) and R version 2.4.1 software (R Development Core Team 2008) with the R2WinBUGS package to conduct a Markov Chain Monte Carlo (MCMC) analysis using Gibbs sampling. To use the MCMC results, the Markov Chain must change from the initial values into a stationary distribution. We conducted MCMC sampling for 100,000 counts and discarded the initial 30,000 as burn-in. In addition, to minimise results affected by the initial values, we conducted an analysis of three sets of initial values during MCMC sampling. We used R to generate random-sampling initial values and evaluated the contribution of fixed effects using a posterior predictive check based on a 95% confidence interval.

RESULTS

The means (±SD) of Shannon $H'$ at confluence and single-flow units were 1.22 ± 0.32 and 1.07 ± 0.41, respectively, and the means of Simpson $D'$ at confluence and single-flow units were 0.62 ± 0.15 and 0.52 ± 0.20, respectively. The mean values of SPI at confluence and single-flow units were 931.57 ± 808.00 and 631.11 ± 705.49, respectively. The mean areas of vegetation in confluence and single-flow units were 103,106.8 ± 53,742.2 m² and 90,994.7 ± 62,312.0 m², respectively.

Our hierarchical Bayesian-model analysis revealed that all fixed effects had significant positive effects on Shannon $H'$ (the 95% confidence interval did not include 0; Table 2). Simpson $D'$ was positively affected by the presence of a confluence and area of vegetation but was not significantly affected by SPI (the 95% confidence interval included 0 for SPI; Table 3).

![Table 2. Quantiles (2.5%, 50%, and 97.5%) of Posterior Distributions of Shannon Diversity Index ($H'$)](https://example.com/table2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>S.D</th>
<th>Values for the Following Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5%</td>
</tr>
<tr>
<td>Confluence</td>
<td>7.59×10²</td>
<td>2.50×10²</td>
<td>2.65×10²</td>
</tr>
<tr>
<td>SPI</td>
<td>4.10×10⁴</td>
<td>1.39×10⁴</td>
<td>1.38×10⁴</td>
</tr>
<tr>
<td>Vegetation area</td>
<td>1.27×10⁶</td>
<td>2.96×10⁵</td>
<td>6.82×10⁶</td>
</tr>
<tr>
<td>Deviance</td>
<td>-4.12×1⁰</td>
<td>4.83×1⁰</td>
<td>1.53×1⁰</td>
</tr>
<tr>
<td>Intercept</td>
<td>2.24×1⁰</td>
<td>3.54×1⁰</td>
<td>4.24×1⁰</td>
</tr>
</tbody>
</table>

![Table 3. Quantiles (2.5%, 50%, and 97.5%) of Posterior Distributions of Simpson Diversity Index ($D'$)](https://example.com/table3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>S.D</th>
<th>Values for the following percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5%</td>
</tr>
<tr>
<td>Confluence</td>
<td>3.34×1⁰</td>
<td>1.27×1⁰</td>
<td>8.20×1⁰</td>
</tr>
<tr>
<td>SPI</td>
<td>1.32×1⁰</td>
<td>7.05×1⁰</td>
<td>-6.62×1⁰</td>
</tr>
<tr>
<td>Vegetation area</td>
<td>3.97×1⁰</td>
<td>1.53×1⁰</td>
<td>9.59×1⁰</td>
</tr>
<tr>
<td>Deviance</td>
<td>-2.38×1⁰</td>
<td>2.58×1⁰</td>
<td>-2.93×1⁰</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.15×1⁰</td>
<td>1.06×1⁰</td>
<td>2.55×1⁰</td>
</tr>
</tbody>
</table>

DISCUSSION

Our finding that confluence sites exhibited high vegetation-patch diversity in rivers in Hyogo Prefecture is the
first empirical support of the existence of confluence effects related to biological habitat diversity within riparian areas. Both the Shannon and Simpson diversity indices for vegetation patches were higher for confluence units than for single-flow units. Even though our results revealed a diversity pattern for roughly classified vegetation types, this type of pattern still provides a useful basis for investigating and understanding the process by which habitat diversity is maintained in riparian ecosystems.

Channel disturbances are amplified at confluences because these locations are points that accumulate water, sediments, and woody debris (Benda et al. 2004a; Benda et al. 2004b; Rice et al. 2006; Rice et al. 2008). Water movement can strongly affect the distribution of vegetation types throughout floodplains, as such forces alter the physical structure and stability of the habitat through erosion and sedimentation (Salo et al. 1986). Debris flows and sediment deposits result in topographic heterogeneity around river confluences (Benda et al. 2004b). Together with our results, these findings suggest that habitat diversity increases around river confluences because these areas have unique hydrodynamic features and subsequently amplify disturbance regimes. High habitat diversity generally corresponds to high diversity in plant species (Wagner et al. 2000). In fact, we found that plant species diversity was enhanced by the flooding-induced creation of bare ground around confluences of the river system in this study (Osawa et al. 2010). In turn, high plant diversity provides diverse habitats and food sources for animals (Qian & Ricklefs 2008). Thus, the highly diverse vegetation patches around river confluences may harbour many plant and animal species in river ecosystems. Future research should examine the detailed processes by which debris and sediment deposition and flooding disturbances enhance the establishment of diverse vegetation types and plant species.

In our analyses, we successfully regulated the effects of SPI and vegetation area in the models, and both factors affected vegetation diversity. For example, SPI positively affected the Shannon diversity index. SPI is conventionally used as an index of the erosive power of flowing water (Wilson & Gallant 2000) and can be used as a representation of disturbance intensity. Relatively strong disturbances likely occurred in high SPI areas, forming various types of vegetation patches, which points to the importance of disturbance for habitat diversity. Vegetation area positively affected both the Shannon and Simpson indices. The RNER program was conducted throughout alluvial (from mid to downstream) river areas that were surrounded by mainly urban and/or agricultural areas (Hyogo Prefecture 2007). One possible explanation for the positive relationship between diversity indices and vegetation area is that smaller vegetation areas are indicative of the intensification of artificial habitat alterations.

To the best of our knowledge, our study is the first to demonstrate that river confluences may generate habitat diversity for plants in riparian areas, although the results should be interpreted with a little caution because of the failure of our data to meet some assumptions concerning normality of the diversity indices in the analyses. A linear perspective on river networks (i.e., the river continuum concept; Vannote et al. 1980) has dominated much of river ecology over the last 20 years (Fisher 1997), despite the recognition that river networks are branched with tributaries that interrupt gradual downstream changes in channel and valley morphology (Benda et al. 2004a). Recently, the network dynamics hypothesis has articulated the relationships among key attributes of river networks and the patchy heterogeneity of the fluvial process and form (Benda et al. 2004a; Benda et al. 2004b). Our results present empirical evidence of this more recent discontinuum perspective in river ecology, in which river confluences are considered key elements within a dendritic river network. Future research should examine confluence effects in a diversity of freshwater riverine systems (e.g. Fernandes et al. 2004), with particular focus on the fact that confluences vary in geomorphic features, such as shape and scale, within and among watersheds. Such variation in geomorphic features may produce different confluence effects on biodiversity (Benda et al. 2004b).

ACKNOWLEDGEMENTS

We would like to thank the staff at the Ecology Division of the Museum of Nature and Human Activities Hyogo for their valuable support, and the staff at the Laboratory of River Environment LLP for supplying the Research about the Natural Environment of Rivers data set. We also thank Dr. M. Akasaka for commenting on an early version of this manuscript.

Appendix

Appendix 1. List of Communities that Belong to each Vegetation Type in the RNER Data Set. All Scientific Names are Referred to YList, (http://bean.bio.chiba-u.jp/bgplants/ylist_main.html)

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Community name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscanthus sacchariflorus dominant vegetation</td>
<td>Miscanthus sacchariflorus community</td>
</tr>
<tr>
<td>Phragmites communis dominant vegetation</td>
<td>Phragmites australis community</td>
</tr>
<tr>
<td>Phragmites japonica dominant vegetation</td>
<td>Phragmites japonica community</td>
</tr>
<tr>
<td>Salix gracilistyla dominant vegetation</td>
<td>Salix gracilistyla community</td>
</tr>
<tr>
<td>Vegetation type</td>
<td>Community name</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>Floating-leaved and submerged plant vegetation</td>
<td>Nymphoides peltata community</td>
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<tr>
<td></td>
<td>Nymphoides indica community</td>
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<tr>
<td></td>
<td>Potamogeton wrightii community</td>
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<tr>
<td></td>
<td>Trapana japonica community</td>
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<tr>
<td></td>
<td>Nuphar subintegerrima community</td>
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<tr>
<td></td>
<td>Potamogeton octandrus community</td>
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<tr>
<td></td>
<td>Potamogeton crispus community</td>
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<tr>
<td></td>
<td>Hydrilla verticillata community</td>
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<td></td>
<td>Vallisneria natans community</td>
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<tr>
<td></td>
<td>Potamogeton maackianus community</td>
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<tr>
<td></td>
<td>Ranunculus niponicus community</td>
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<td></td>
<td>Myriophyllum spicatum community</td>
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<tr>
<td></td>
<td>Potamogeton oxycyphus community</td>
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<td></td>
<td>Spirodela polyrhiza and Lemna aoukikusa community</td>
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<td></td>
<td>Egeria densa and Elodea nutallii community</td>
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<tr>
<td></td>
<td>Myriophyllum aquaticum community</td>
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<tr>
<td></td>
<td>Pistia stratiotes community</td>
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<td>Eichhornia crassipes community</td>
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<td>Azolla spp.(exotic) community</td>
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<td>Halophytic plant vegetation</td>
<td>Phacelurus latifolius community</td>
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<td>Aster tripolium community</td>
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<td>Carex scabridifolia community</td>
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<td>Limonium tetragonum community</td>
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<td>Suaeda australis and Atriplex gmelini community</td>
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<td>Artemisia fukudo community</td>
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<tr>
<td>Sand dune vegetation</td>
<td>Carex pumila community</td>
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<tr>
<td></td>
<td>Carex kobomugi and Wedelia prostrata community</td>
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<td>Scutellaria strigillosa community</td>
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<td></td>
<td>Calystegia soldanella and Lathyrus japonicus community</td>
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<td></td>
<td>Vitex rotundifolia community</td>
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<td>Hosta montana community</td>
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<td>Carex blepharicarpa and Osmunda lancea community</td>
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<td>Acorus graminens community</td>
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<td>Carex curvicolis and Sedum subtile community</td>
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<td>Carex teinogyna community</td>
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<td>Carex persistens community</td>
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<td>Carex forficula community</td>
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<td>Carex heterolepis community</td>
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<td>Vegetation beside mountain stream</td>
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(Appendix 1) Contd.....


The BUGS Project (2008) URL: http://www.mrc-bsu.cam.ac.uk/bugs/


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