Using Remote-Sensing Based River Typing to Predict Ecological Function and Ecosystem Services

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Functional Process Zones (FPZs)

The Riverine Ecosystem Synthesis (RES) (Thorp et al. 2008) emphasizes FPZs, which are distinct hydrogeomorphic patches that exist between the drainage basin and river reach scales (Fig 1). FPZs are large segments of river with similar hydrogeomorphic characteristics and can be identified using multivariate statistical analyses that take into account the hydrogeomorphic forces that shape riverine ecosystems. The variables used in the multivariate analyses span multiple spatial scales and include long term precipitation data, underlying geology, and both the composition and morphology of the river valley and river channel (Fig. 2, Table 1).

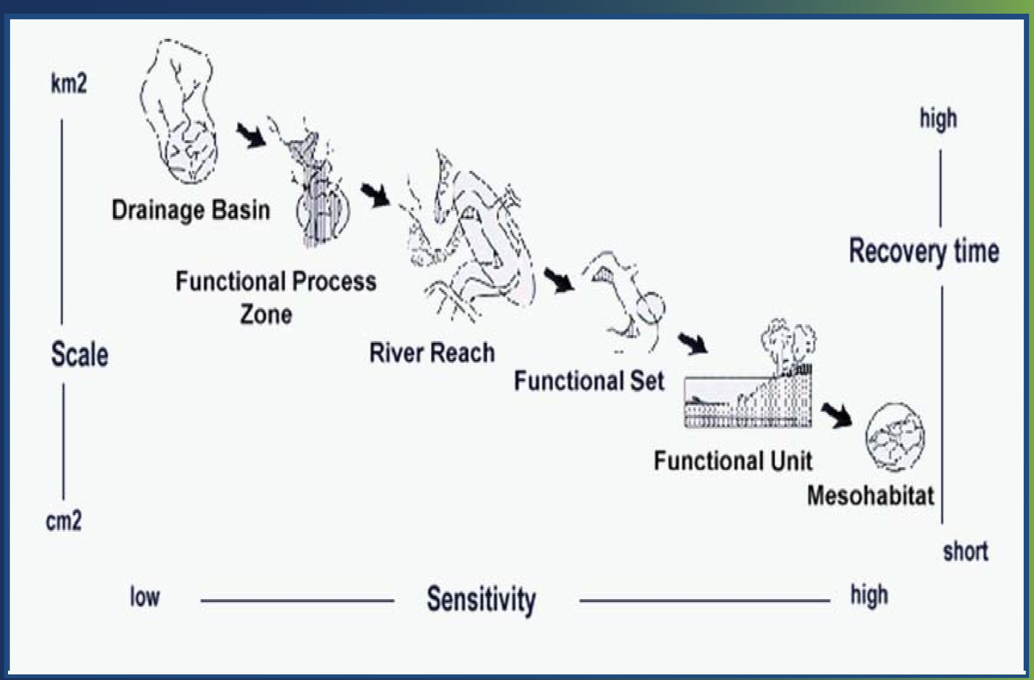

Figure 1. Hierarchically scaled patches in riverine ecosystems with FPZs nested between the drainage basin and reach scales (from Thorp et al. 2008).

Classification Procedure

The multivariate FPZ classification procedure outlined by Thorp et al. (2008) and Thoms et al. (in review) requires the measurement of 14 hydrogeomorphic variables (Table 1) in 5-km sample segments (Fig. 2) along the entire course of a river. The appropriate data layers are first projected in ArcGIS 9.3 (Fig 2) and measurements are made using a combination of standard tools in ArcMap and automated scripts. The scripts enable the rapid extraction of data from Digital Elevation Models (DEMs) or LIDAR and were written specifically for this classification procedure.

A sample segment by variable data base is then constructed in Microsoft Access. This serves as the data matrix used by the PATN 3.1 statistical software package for the UPGMA and Semi-Strong Hybrid multidimensional Scaling analyses.

UPGMA Analysis

The Flexible-Unweighted Pair-Groups with Arithmetic Averages (UPGMA) method employs the Gower association measure (Belbin and McDonald 1993) and is used to identify groups of sample segments with similar hydrogeomorphic characteristics (i.e., FPZs influenced by similar geomorphic processes) (Fig 3).

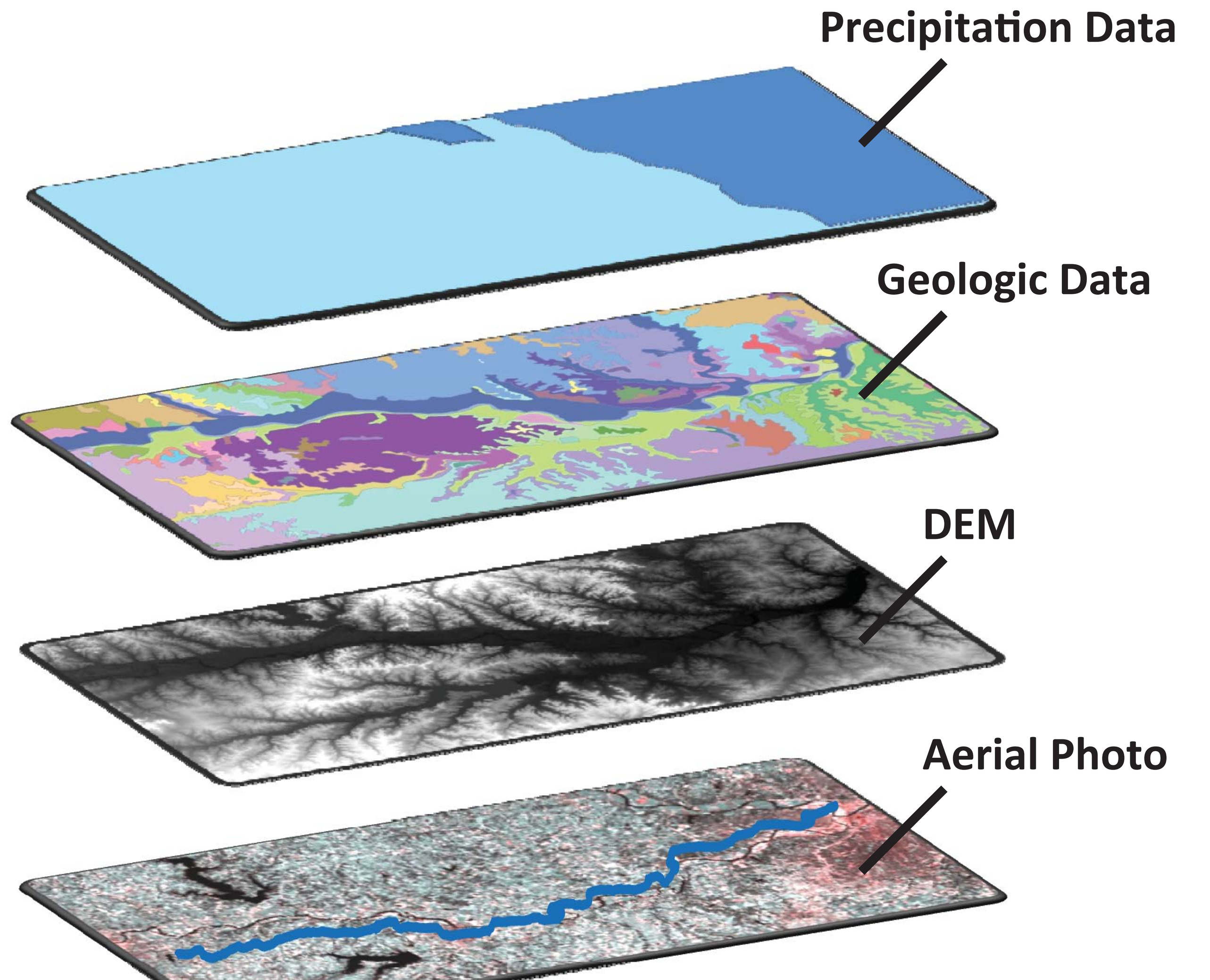

Figure 2. Example of data layers and 5-km river sample segments projected in ArcGIS 9.2

Table 1. Spatial scale, type, and data source for the 14 hydro-geomorphic variables used in the classification procedure

Scale	Variable	Data Source
Catchment	Mean Annual Precipitation	30 yr mean precipitation data (National Climatic Data Center)
Catchment	Geology	USGS State Geologic Maps 
River Valley	Valley Width	10m resolution DEMs from the National Elevation Dataset 
River Valley	Valley Floor Width	
River Valley	Valley Side Slopes	
River Valley	Down Valley Slope	
River Valley	Ratio of Valley Width to Valley Floor Width	
River Channel	Wavelength of the Channel Belt	0.3 m resolution ImageConnect Aerial Photographs (GlobeXplorer; ImageConnect)
River Channel	Sinuosity of the Channel Belt	
River Channel	Width of the Channel Belt	
River Channel	Sinuosity of the River Channel	
River Channel	Number of Channels	
River Channel	Channel Planform	

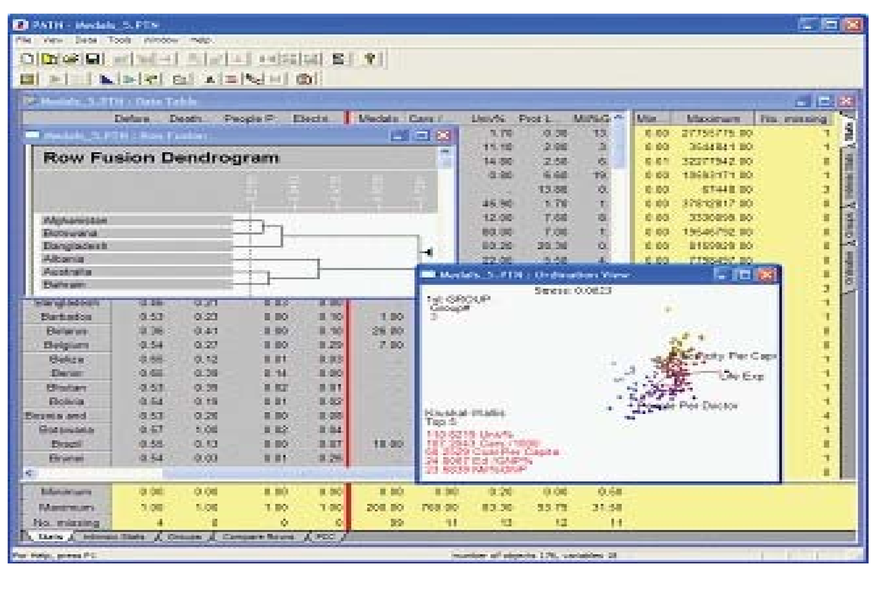

Figure 3. Example of a UPGMA analysis in PATN 3.1. The dendogram generated indicates the relationships between groups of 5-km sample segments with similar hydrogeomorphic characteristics .

Multidimensional Scaling, Interpretation, and Mapping

The validity of the groups identified by the UPGMA analysis is then assessed with the Semi-Strong Hybrid Multidimensional Scaling method of Belbin (1991). Sites are ordinated in a space generated by the hydrogeomorphic variables, and the ordination and grouping of sites are assessed to determine if they are significantly different from random. Once the groups are statistically validated, FPZs are interpreted based on their geomorphic character and FPZ maps are then generated for field use (Fig 4).

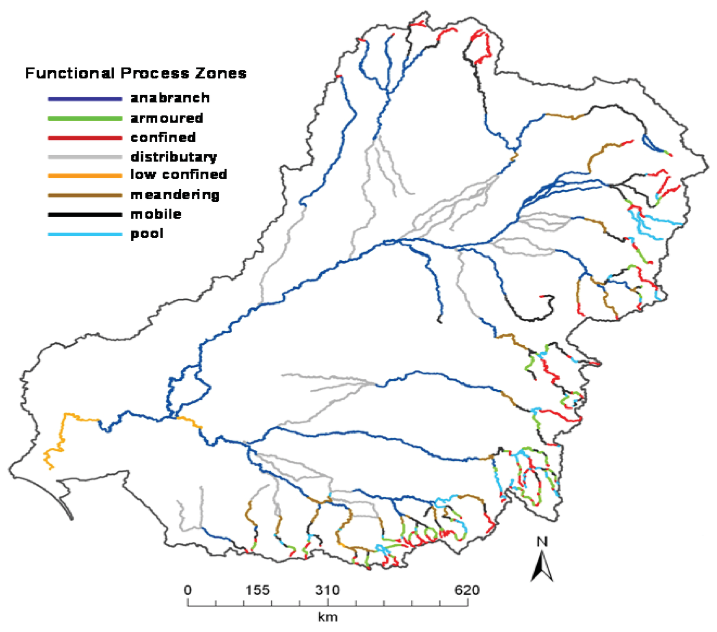

Figure 4. An example FPZ map from the Condamine River basins in Australia (courtesy of Martin Thoms of the University of Canberra, Australia)

Ecosystem Function and Ecosystem Services

An increasing trend in applied river science is to evaluate rivers by the ecosystem services and benefits they provide. Developing a stronger linkage between hydrologic and geomorphic attributes and ecosystem services improves the ability to restore, conserve, and manage vital and increasingly threatened riverine landscapes. Functional Process Zones (FPZs) occur at the valley-to-reach scale and represent a likely means to linking these systems across institutional, spatial, and temporal scales. Thus, FPZs hold strong potential as a management tool to characterize ecosystem services.

	Constricted	Meandering	Braided	Anastomosing	Leveed	Reservoir
Selected Hydrogeomorphic Attributes						
Shoreline complexity *	L	LM	H	H	L	M
Relative number of channels	L	L	H	MH	L	L
Functional habitats within channels	L	LM	M	H	L	LM
Channel/island permanence	M	M	L	H	M	H
Floodscape size and connectivity with main channel	L	MH	M	H	L	L
Ecosystem Benefits and Services						
Natural Ecosystem Benefits						
Biodiversity (species and trophic diversity)	L	M	L	H	L	M
Proportion of native biota (prior to any change in FPZ)	H	H	H	H	L	L
Primary and secondary productivity	L	M	M	H	L	H
Nutrient cycling and carbon sequestration	L	LM	LM	H	L	H
Water storage	L	LM	L	H	L	H
Sediment storage	L	M	M	H	L	H
Anthropogenic Services						
Food and fiber production **	L	M	L	H	L	M
Water withdrawal potential	MH	M	L	M	H	H
Recreational uses	LM	LM	L	H	L	H
Disturbance and natural hazard mitigation	L	M	L	H	H	H
Maintenance and catastrophic risk of failure	N/A	N/A	N/A	N/A	M	H
Transportation	H	M	L	M	H	H

* Ratio of shoreline length to downstream length
** Does not count agricultural crop production

L = Low
M = Medium
H = High

Table 1: Examples of relationships between hydrogeomorphic structure and ecosystem services for six contrasting types of natural and artificial FPZs. All predicted relationships are based on intra-basin comparisons only. This table is not meant to be definitive for services, and it was developed for generalized rivers.