# Chapter 53
# Exploring Non-Linear Relationships Between Landscape and Aquatic Ecological Condition in Southern Wisconsin:
## A GWR and ANN Approach

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## ABSTRACT

*Recent studies have implied the importance of incorporating configuration metrics into landscape-aquatic ecological integrity research; however few have addressed the needs of spatial data while exploring non-linear relationships. This study investigates spatial dependence of a measure of aquatic ecological condition at two basin scales, and the spatial and non-linear role of landscape in explaining that measure across 92 watersheds in Southern Wisconsin. It hypothesizes that: (1) indicators of ecological condition have different spatial needs at subwatershed and watershed scales; (2) land cover composition, urban configuration, and landscape diversity can explain aquatic ecological integrity differently; and (3) global non-linear analysis improve local spatial statistical techniques for explaining and interpreting landscape impacts on aquatic ecological integrity. Results revealed spatial autocorrelation in the measure of aquatic ecological condition at the HUC-12 subwatershed scale, and artificial neural networks (ANN) were an improvement over geographically weighted regression (GWR) for deciphering complex landscape-aquatic condition relationships.*

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## 1. INTRODUCTION

The current integrity of the planet is being stressed beyond its biological capacity, and understanding human created landscapes is more important than ever. Changes in land cover, through the appropriation of natural landscapes to provide for human needs, has been found to be one of the most pervasive alterations to native ecosystems resulting from human activity (Foley *et al*., 2005; Liu *et al*., 2007; Vitousek *et al.*, 1997). Landscape change influences natural systems by fragmenting landscape patches, isolating habitats, abridging ecosystem dynamics, introducing exotic species, controlling and modifying disturbances, escalating climate change, and disrupting energy flow and nutrient cycling (Alberti, 2005; Alberti, 2008; Foley *et al*., 2005; Liu *et al*., 2007; Milly *et al*., 2008; Picket *et al*., 2001). Continuing with the impacts of landscape change, terrestrial waters are often those ecosystems most affected by associated stressors (Foley *et al*., 2005; Liu *et al*., 2007; Naiman & Turner, 2000; Novotny *et al*., 2005; Milly *et al*., 2008).

Access and management of water resources is now considered a prerequisite for human development (Baron *et al*., 2002; Gleick, 2003). To support this, many nations throughout the world have adopted laws to protect or improve the integrity of hydrologic systems (Karr, 2006). A reoccurring theme throughout these regulations is to restore and maintain biological integrity of their respected waters. Monitoring programs for assessing human impacts on aquatic condition and water quality have existed for decades. Specifically, fish indicators of biological integrity have gained popularity for quantifying the impact of human activities on the biota and are in practice on six of the seven continents throughout the world (Roset *et al*., 2007). A variety of measuring techniques has been applied to fish as indicators of biological integrity; however, the Index of Biotic Integrity (IBI) has developed into the applied method of choice. The IBI (Karr, 1981) has been widely applied to fish assemblage data for assessing the environmental quality of aquatic habitats (Roset *et al*., 2007). Thus, the Fish Index of Biotic Integrity (F-IBI) has been welcomed as a robust method for investigating landscape-aquatic interactions (Karr & Yoder, 2004; Novotny *et al*., 2005), and has been found to help diagnose causes of ecological impacts and suggest appropriate management actions (Karr & Chu, 1999).

Previous studies between landscape-aquatic relationships have typically correlated changes in ecological integrity with simple aggregates of urbanization (e.g. percent urban) (Alberti *et al*., 2007). This paradigm has been reaffirmed since Klien's (1979) seminal work with dozens of regional investigations on how land cover composition relates to aquatic conditions (Alberti *et al*., 2007; Morley & Karr, 2002; Roth *et al*., 1996; Richards *et al*., 1996; Shandas & Alberti, 2009; Thorne *et al*., 2000). With that said, these relationships are typically non-linear (Novotny *et al*., 2005), and by no means can account for all the variability in aquatic ecological integrity. Recently, studies have implied the importance of incorporating configuration metrics into landscape-aquatic condition research (e.g. Alberti *et al*., 2007; Shandas & Alberti, 2009). These studies provide much needed information to planners, natural resource managers, and landscape design specialists that cannot be addressed with simple aggregates of land cover (Alberti *et al*., 2007). Configuration studies quantify landscape fragmentation through spatially explicit metrics, and their results can help diagnose distributional effects of land use or land cover on ecosystem services (Shandas & Alberti, 2009). With that said, few configuration studies have fully addressed the needs of spatial data (e.g., spatial autocorrelation) in species-environment spatial analysis (King *et al*., 2005; Wagner & Fortin, 2005), and fewer have attempted to do so while exploring non-linear relationships with measures of in-stream ecological condition.

When investigating species-environment relationships, it is important to take into account that many different processes influence natural systems over space. Two major quantitative shortcomings in spatial

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