Bioassessment of Stream Health in the Santa Ana Watershed Using Geographic Weighted Regression

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Introduction

The Santa Ana watershed located in southern California flows west from the San Bernardino Mountains through urban, industrial, commercial, and agricultural land use types before entering the Pacific Ocean. GIS-based GWR is useful for supporting with statistical methods and maintaining fresh water ecological systems using file geodatabases. Visually representing this data and associated spatial patterns reveals relationships that could aid scientists in determining areas of concern, focus monitoring (additional sampling), and better understand critical links between hydrology and biology. This analysis relied on aggregations of data to facilitate validation. This poster provides useful information about stream health in the Santa Ana watershed and its relationship to various factors.

Spatial Objective: *To explore and interpret the spatial patterns of water quality indicators in correlation with IBI score.*

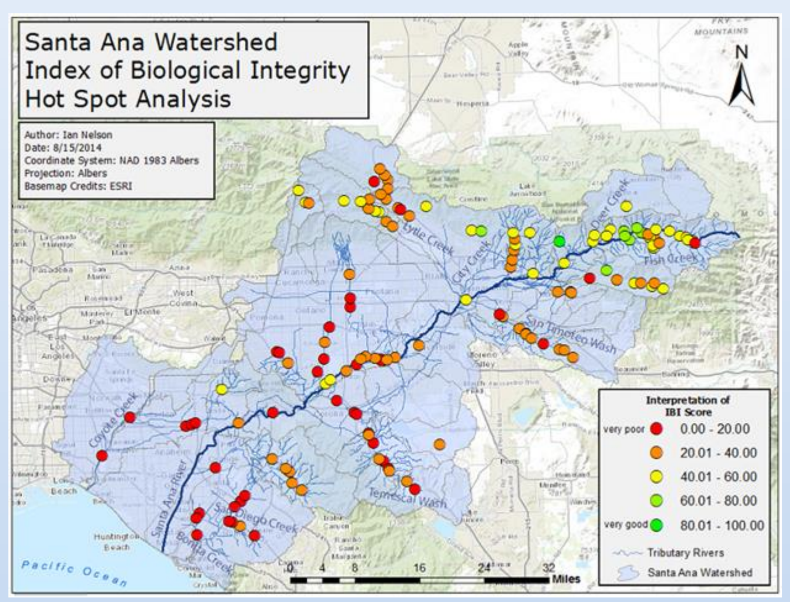


Figure 1. *Hot Spot Analysis of the Spatial Distribution of IBI score*

Data and Data Sources

The Index of Biological Integrity (IBI score), and corresponding water quality indicators dataset was provided by Dr. Dessie Underwood, director of Streams Ecological Assessment Laboratory at California State University Long Beach. All data were stored in three file geodatabases: (1) site locations for elevation strata 0-525 meters, (2) site locations for elevation strata over 525 meters, and (3) entire Santa Ana watershed.

Table 1. *List of data and data sources used in the project*

CALIFORNIA WATERSHEDS	CALWATER (WWW.CALWATER.ORG)
CALIFORNIA RIVERS	CALWATER (WWW.CALWATER.ORG)
BASE MAP	ESRI ARCGIS 10.1
INDEX OF BIOLOGICAL INTEGRITY (IBI)	DR. DESSIE L. A. UNDERWOOD

Table 2. *Interpretation of IBI Score*

Total Score	0-20	21-40	41-60	61-80	81-100
Rating	Very Poor	Poor	Fair	Good	Very Good

Methodology

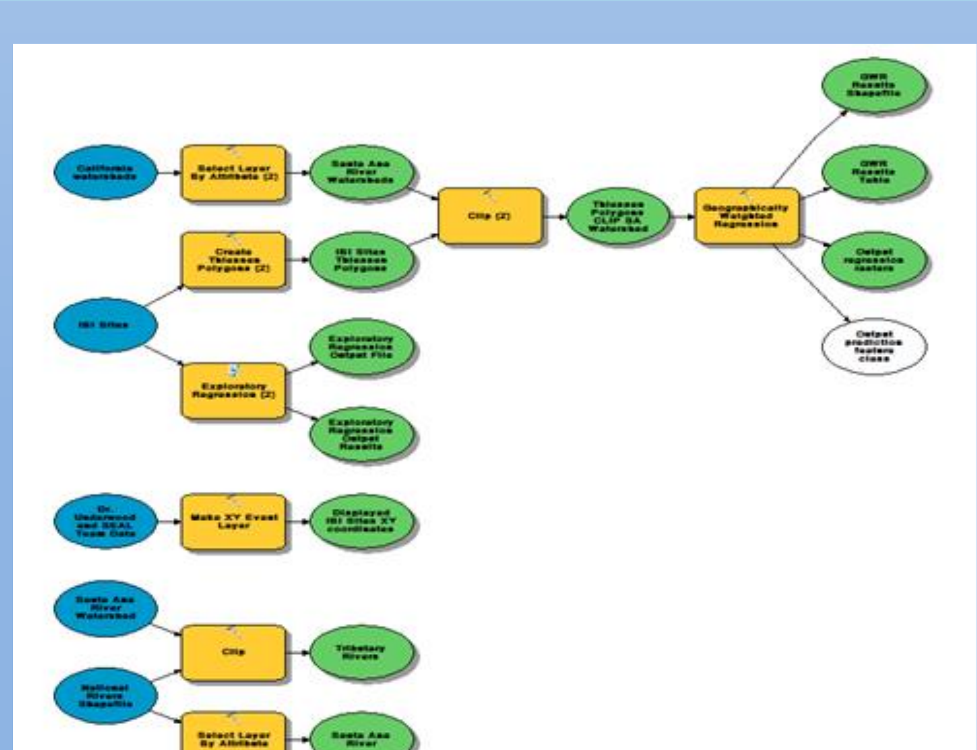


Figure 2. *Spatial Model of Methodology*

Results

Table 3. *Comparing revised elevation strata regression results with Dr. Underwood's original elevation.*

	Underwood's Original Elevation Strata Regression Results			Revised Elevation Strata Regression Results	
	SA 0-350	SA 350-700	SA 700+	SA 0-525	SA 525+
pH	-.416**	0.121	-.304*	(-)**	(-)***
Water Temp C	-0.099	-0.186	-.483**	(-)	
Conductivity	-0.246	-0.102	0.077	(-)**	(-)***
Turbidity	0.002	-0.102	0.077		(+)
Dissolved O2 (mg/L)	-0.059	0.15	0.156	(-)/(+)	(+)
Alkalinity	.345**	-.517**	-.412**	(+)**	(-)***
Dissolved Orthophosphates (mg/L)	.407**	-0.022	0.168	(+)**	
Nitrate-N (mg/L)	.294*	0.035	-.343** (few)	(+)**	(-)***
Nitrite-N (mg/L)	-.302*	-0.074	-0.235	(-)**	
Epifaunal Substrate	.332**	0.201	.460**	(+)*	
Sediment Deposition	-.276*	0.184	0.239	(-)	(+)***
Mean Width	.482**	0.093	-0.101		(-)
Variance Width	.359**	-0.031	0.055	(-)	
Variance of Densiometer	0.218	-0.02	-.365**		(-)***

Table 4. *OLS results for elevation strata under 525m*

Adj. R2	AICc	JB	K(BP)	VIF	SA
0.54	267.01	0.61	0.43	1.13	0.20

Table 5. *GWR results for elevation strata under 525m*

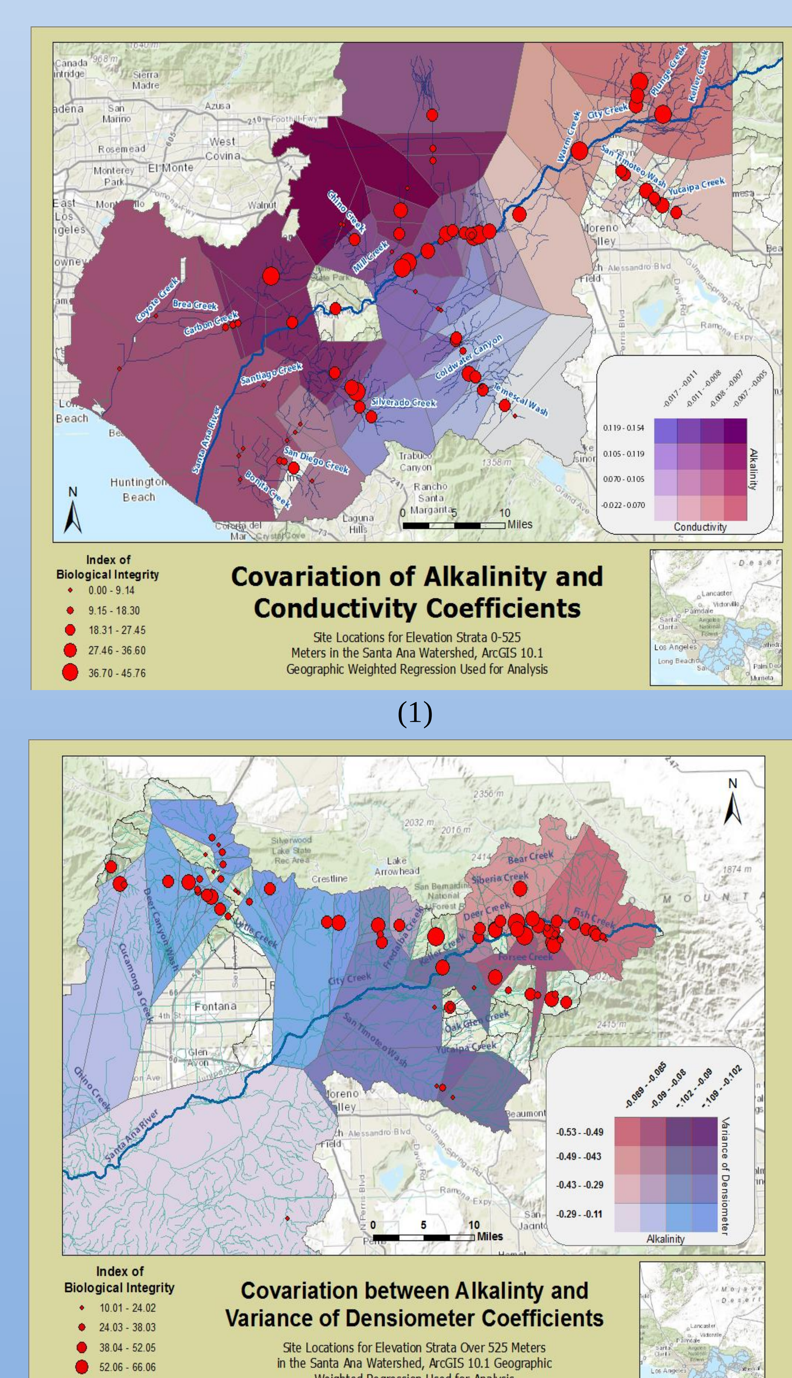
Adj. R2	AICc	JB	K(BP)	VIF	SA
0.34	368.12	0.73	0.27	1.42	0.82

Table 6. *OLS results for elevation strata over 525m*

Neighbors	Residual Squares	Effective Number	Sigma	AICc	R2	Adj. R2
42	4853.38	13.389	9.605	498.948	0.539	0.419

Table 7. *GWR results for elevation strata over 525m*

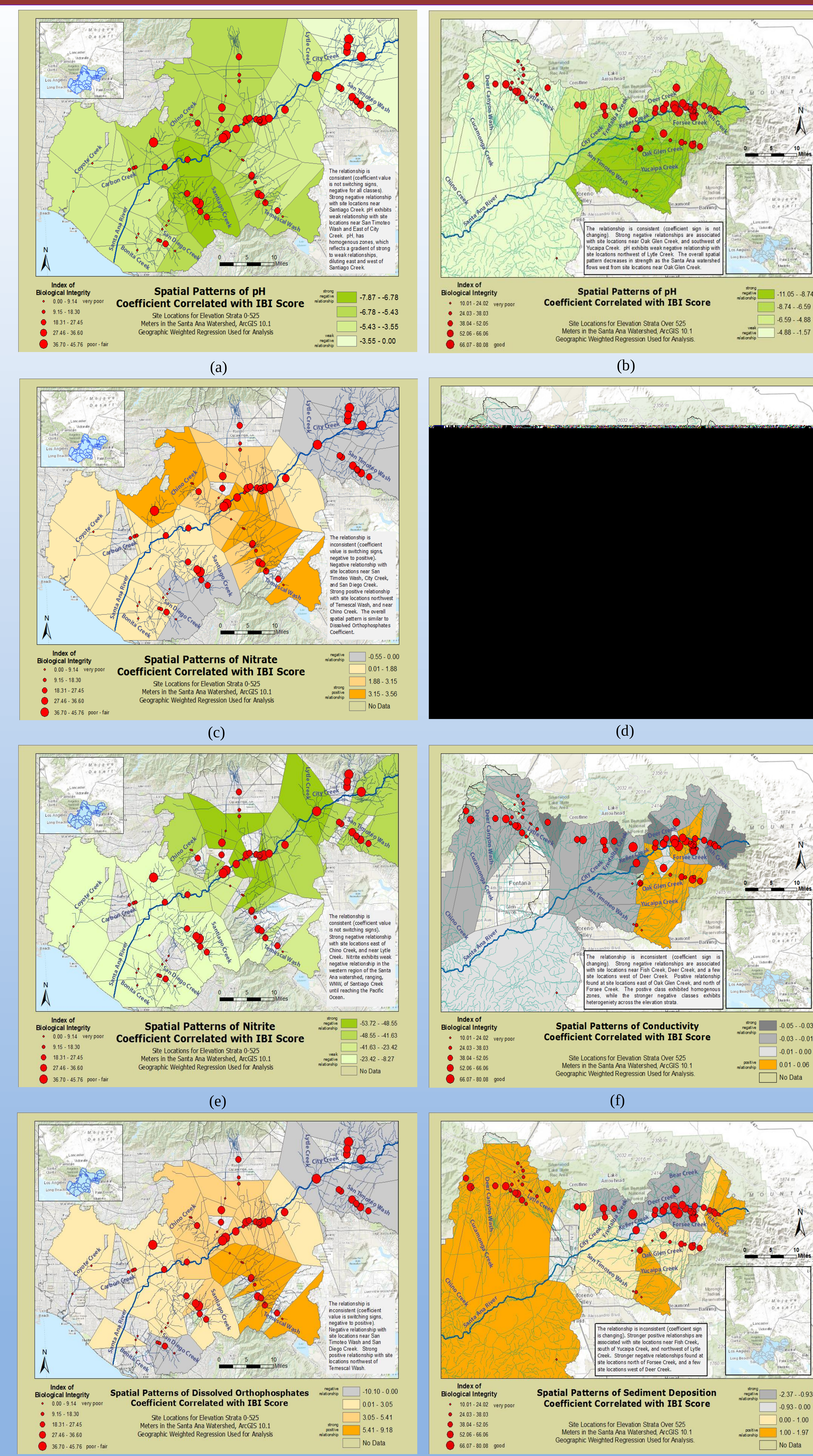
Neighbors	Residual Squares	Effective Number	Sigma	AICc	R2	Adj. R2
53	5536.793	7.485	10.795	426.332	0.550	0.488



(1)

(2)

Figure 3. *GWR spatial patterns of interrelatedness between water quality indicators that were uncovered in the best fit models: (1) elevation strata 0-525m,(2) elevation strata over 525m*



(a) (b)

(c) (d)

(e) (f)

(g) (h)

Figure 4. *Spatial patterns of significant water quality indicators correlated with IBI: (a) pH coefficient 0-525m, (b) pH coefficient over 525m, (c) nitrate coefficient 0-525m, (d) nitrate coefficient over 525m, (e) nitrite coefficient 0-525m, (f) conductivity coefficient over 525m, (g) dissolved orthophosphates coefficient, (h) sediment deposition coefficient.*

Discussion

The processes occurring in the Santa Ana watershed exhibit uncontrolled variation. The geographical extent of IBI scores in the western region contains site locations with very poor to poor IBI score, while the eastern region of the watershed exhibits a wide range of IBI score, **Figure 1,** from very poor to good, **Table 2**. The regression results and visual representation are scale-dependent, and some water quality indicators are inconsistent (changing from positive to negative). The OLS models and corresponding GWR models explained some variation in IBI score **Table 4 and 5** respectively for elevation strata 0-525 meters, and **Table 6 and 7** respectively for elevation strata over 525 meters. Several factors that may play an important role in the explainable variability that were not accounted for in this study are the dispersal abilities and evolution of BMI's, food resources, invasive species, and competition.

To understand the interrelatedness between variables modelled **Table 5 and 7**, bivariate choropleth maps **Figure 3**, were created using GWR. **Figure 3-1** shows regions in the Santa Ana watershed where alkalinity and conductivity coefficients are interrelated. Two site locations near Chino Creek are strongly positively correlated with alkalinity and strongly negatively correlated with conductivity. This might consequently be contributing to the very poor IBI score. Two site locations near Temescal Wash exhibit weak negative relationship with conductivity and a weak negative to positive relationship with alkalinity, however, no relation with IBI score was found. **Figure 3-2** shows the interrelatedness of alkalinity and variance of densiometer (vardens). Site locations northwest of Lytle Creek exhibit weak negative relationship with vardens, while alkalinity is strongly negatively correlated, and both are associated with poor – good IBI scores. Conversely, site locations near Fish Creek exhibit strong negative correlation with vardens, while alkalinity exhibits weak negative relationship and both are associated with good IBI score. Spatial patterns for significant water quality indicators **Table 3** were mapped to further explore the correlation between coefficient estimates of water quality indicators and IBI score **Figure 4 a-h**. The relationships between the IBI score and water quality indicators revealed strong evidence that these variables vary geographically **Figure 4, c, d, f, g, h**. A more detailed interpretation of the spatial patterns is provided in the text of each map.

Conclusion

The results from this project should not be viewed as an endpoint, but rather as the beginning to an exploratory data analysis that is improving through regression analyses and scatterplots of different aggregations of the same data. GWR is useful for visualizing the local variation among water quality indicators and IBI score. Another approach to creating bivariate choropleth maps should be investigated further. ESRI's ArcGIS 10.1 does not estimate a t-statistic for GWR, which is a disadvantage. The t-statistic is used to determine which areas are significant to the dependent variable. This approach detailed by (Mennis 2008), is an improvement over the approach of this analysis, which mapped the coefficient estimates. However, all explanatory variables were first analyzed using Exploratory Regression (OLS) to validate significance with IBI score. Lastly, future research should focus on creating zonal grids or schemes from point features. I used Thiessen Polygons tool to generate a zonal grid, but other alternatives may provide better results.

Acknowledgements

Dr. Dessie Underwood – IBI data, expertise, and interpretation with analysis
Members of Streams Ecological Assessment Laboratory (SEAL) – IBI Data
Michael Shensky and Dr. Ban -- Cartographic expertise

Submitted in partial fulfillment of the requirements of the Masters of Science in Geographic Information Science(MSGISci), August 16, 2014.

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