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Dr. Robert J. Varga, Editor
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Pomona College

Dr. Michelle Markley
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Carol Morgan
Keck Geology Consortium Administrative Assistant

Christina Kelly
Symposium Proceedings Layout & Design
Office of Communication & Marketing
Scripps College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

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Robert J. Varga
Editor and Keck Director
Pomona College

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Pomona College
185 E 6th St., Claremont, CA
91711

Christina Kelly
Proceedings Layout & Design
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2013-2014 PROJECTS

MAGNETIC AND GEOCHEMICAL CHARACTERIZATION OF IN SITU OBSIDIAN, NEW MEXICO*:*
Faculty: *ROB STERNBERG*, Franklin & Marshall College, *JOSHUA FEINBERG*, Univ. Minnesota, *STEVEN SHACKLEY,* Univ. California, Berkeley, *ANASTASIA STEFFEN*, Valles Caldera Trust, and Dept. of Anthropology, University of New Mexico
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TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
Students: *BRIAN FRETT*, Carleton College, *KATE KAMINSKI*, Union College, *BRIANNA RICK*, Carleton College, *MEGHAN RIEHL*, Union College, *CLAUDIA ROIG*, Univ. of Puerto Rico, Mayagüez Campus, *ADRIAN WACKETT*, Trinity University,

EVALUATING EXTREME WEATHER RESPONSE IN CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT*:*
Faculty: *ROBERT NEWTON*, Smith College, *ANNA MARTINI*, Amherst College, *JON WOODRUFF*, Univ. Massachusetts, Amherst, BRIAN YELLEN, University of Massachusetts
Students: *LUCY ANDREWS*, Macalester College, *AMY DELBECQ*, Beloit College, *SAMANTHA DOW*, Univ. Connecticut, *CATHERINE DUNN*, Oberlin College, *WESLEY JOHNSON*, Univ. Massachusetts, *RACHEL JOHNSON,* Carleton College, *SCOTT KUGEL*, The College of Wooster, *AIDA OROZCO*, Amherst College, *JULIA SEIDENSTEIN,* Lafayette College

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A GEOBIOLOGICAL APPROACH TO UNDERSTANDING DOLOMITE FORMATION AT DEEP SPRINGS LAKE, CA
Faculty: *DAVID JONES*, Amherst College, *JASON TOR*, Hampshire College,
Students: *KYRA BRISSON*, Hampshire College, *KYLE METCALFE*, Pomona College, *MICHELLE PARDIS*, Williams College, *CECILIA PESSOA*, Amherst College, *HANNAH PLON*, Wesleyan Univ., *KERRY STREIFF*, Whitman College

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Students: *RYAN EDGLEY*, California State Polytecnical University-Pomona, *EMILIE SINKLER*, Wesleyan University

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Faculty: *ANDREW DE WET*, Franklin & Marshall College, *CHRIS HAMILTON*. Univ. Maryland, *JACOB BLEACHER*, NASA, GSFC, *BRENT GARRY*, NASA-GSFC
Students: *SUSAN KONKOL*, Univ. Nevada-Reno, *JESSICA MCHALE*, Mt. Holyoke College, *RYAN SAMUELS,* Franklin & Marshall College, *MEGAN SWITZER*, Colgate University, *HESTER VON MEERSCHEIDT*, Boise State University, *CHARLES WISE*, Vassar College

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Faculty*: JEFF MARSHALL*, Cal Poly Pomona, *TOM GARDNER*, Trinity University, *MARINO PROTTI, OVSICORI-UNA, SHAWN MORRISH*, Cal Poly Pomona
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HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD NORWAY
Faculty: *AL WERNER*, Mt. Holyoke College, *STEVE ROOF,* Hampshire College, *MIKE RETELLE*, Bates College
Students: *JOHANNA EIDMANN*, Williams College, *DANA REUTER*, Mt. Holyoke College, *NATASHA SIMPSON*, Pomona (Pitzer) College, *JOSHUA SOLOMON*, Colgate University

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Keck Geology Consortium: Projects 2013-2014
Short Contributions— GIS Approach to Water-Level Change Project

POTENTIAL EFFECTS OF WATER-LEVEL CHANGES ON ISLAND ECOSYSTEMS: A GIS SPATIOTEMPORAL ANALYSIS OF SHORELINE CONFIGURATION
Faculty: KIM DIVER, Wesleyan University

GIS APPROACH TO WATER-LEVEL CHANGE: POTENTIAL EFFECTS OF WATER-LEVEL CHANGES ON ISLAND ECOSYSTEMS
RYAN EDGLEY, California State Polytechnic University, Pomona, CA
Research Advisor: Kim Diver

DECLINING WATER LEVEL IN LAKE MICHIGAN-HURON AND THE EFFECT ON ISLANDS IN THE MASSASAUGA PROVINCIAL PARK, ONTARIO
EMILIE SINKLER,Wesleyan University
Research Advisor: Kim Diver

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GIS APPROACH TO WATER-LEVEL CHANGE: POTENTIAL EFFECTS OF WATER-LEVEL CHANGES ON ISLAND ECOSYSTEMS

RYAN EDGLEY, California State Polytechnic University, Pomona, CA
Research Advisor: Kim Diver

ABSTRACT

The water levels of The Massasauga Provincial Park (Lake Huron, Canada) have a long history of fluctuation (Fig 1; Bishop, 1990). In 1998 the park began experiencing persistently lower than usual water levels, and because of environmental, climatic and geologic reasons the park's water levels are expected to continue to drop 1 meter by the year 2050 (Mortsch et al. 2000). The Provincial Park is home to a number of native and non-native tree, shrub and herbaceous species of vegetation. Studies in The Massasauga Provincial Park (MPP) show that island area, shape, and isolation are the main drivers of the diversity of plant species on islands within the archipelago (Diver 2004, 2008). With water levels encroaching upon historic lows, and projected to exceed that record in the coming decades, island areas will increase and coastlines will change. The aim of my portion of this project is to explore the role of feedbacks between island area, island isolation and island compactness on species richness patterns on islands. My results using the ordinary least square regression tool in ArcGIS indicate that only one of the three island compactness indices is a significant predictor of species richness (R2 values ~ 0.35). They also indicate that island area is also a moderate predictor of (R2 values ~ 0.45) which is consistent with the Theory of Island Biogeography TIB).

INTRODUCTION

Island area, shape, and isolation are the main drivers of the diversity of plant species on islands within The MPP archipelago (Diver 2004, 2008). However Diver's studies also show that the spatial variation of non-native plant species richness in The MPP is unexplained by area, isolation or habitat heterogeneity. My specific area of research within this project is to calculate differences in island shape and connectivity among the fieldwork years in order to discern if changing island shape or connectivity relate to differences in temporal variations in non-native species richness. This portion of the project will rely on the spatial analysis tools in ArcGIS.

Our hope is that a better understanding of what factors drive non-native species on island settings will illuminate the way we currently allocate land and boundaries of land for wildlife refuges and sanctuaries.

METHODS

In 2001, 2006 and 2011 Dr. Diver et al. conducted plant species inventories on the sample islands and offered relevant data towards this project. In each of those years, Dr. Diver recorded the number of native plant species, non-native plant species and total number of plant species on the islands, called "species richness". The species richness value does not always equal the sum of native and non-native plant species for two possible reasons: (1) the origin of some plants are unknown or (2) the classification of some specimens is still in process. So these species do not fall in either category of native or non-native but they are still counted in the total species richness metric. Also not all islands were inventoried for their species richness and they are left blank on Table 1. In conjunction with Dr. Diver's plant inventory we used several different years of satellite and aerial imagery of the MPP. Each year of the aerial images listed below corresponds to a year in which Dr. Diver and her team were on the islands inventorying the plants. Those photos were taken during:

2012, satellite imagery by DigitalGlobe acquired during the months of September and March, (95% and 5% coverage, respectively) with water levels at 175.86 m asl, which is -0.56 offset from Great Lakes Dashboard average of 176.42m asl. The water levels of this imagery correspond best with Dr. Diver's trip in 2011. Named "DigitalGlobe" here-on-out.

2005, by Canadian Hydrographic Service which is a digitized nautical map (not actual imagery) with water levels at an average annual level of 176.09, which is -0.33 different from the Great Lakes Dashboard average of 176.42 m asl. The water levels of this imagery correspond best with Dr. Diver's trip in 2001.

2004, aerial photos by The West Parry Sound Geography Network, (WPSGN) which had water levels at 176.11 m asl, which is -0.31 different from the Great Lakes Dashboard average of 176.42. The water levels of this imagery correspond best with Dr. Diver's trip in 2006.

Other Data Used

"SampleIsland": a vector data set compiled from a number of sources. The data originated from a parcel mapping project. The shoreline most likely came from 1984 Ontario Ministry of Natural Resources (MNR) Base Map, however the water was high that year in Georgian Bay (176.91 m asl) and some of the shorelines were altered using assessment sheets or surveys. The island names were linked from Municipal Property Assessment Corporation assessment sheets, MNR 1984 air photography, Canadian Hydrographic Service charts and registered surveys.

My portion of the project involved digitizing polygons along the shores of each of the 43 sample islands in ArcMap (ESRI ArcGIS 10.1) from each of the above listed years of imagery. From this digitization I was able to calculate perimeter length and area of the islands as they changed from each of the years of imagery. In my individual portion of the project I calculated two main independent variables to correlate with non-native plant species richness within the islands, island shape and island connectivity.

The shapes of the islands were calculated using compactness properties that assigned a normalized index to each island based on its shape. This task was completed in ArcGIS using a tool developed by researchers at the University of Connecticut, Center for Land Use Education and Research (Angel et al. 2010). This tool can analyze up to 10 compactness properties of 2-dimensional shapes and determine a compactness index for each property. Each of these compactness properties are described and mathematically defined in the paper *Ten compactness properties of circles: measuring shape in geography* (Angel et al., 2010). For this project we did not need to calculate all 10 indices, instead I chose the three that corresponded to our project most and they were Cohesion, Proximity and Perimeter. The cohesion index is described in the aforementioned paper as "the ratio of the average distance-squared among all points in an equal-area circle and the average distance-squared among all points in the shape" (Angel et al., 2010). A simple illustration (Fig. 1) is provided to help visualize what high and low cohesion can look like. The proximity index (Fig. 2) is described as "the ratio of the average distance from all points in the equal-area circle to its center and the average distance to the Proximate Center from all points in the shape" (Fig. 3). The 'Proximate Center' in this description is defined as the center of gravity for the shape. Lastly the Perimeter index is defined as "the ratio of the perimeter of the equal-area circle and the perimeter of the shape" (Fig. 4; Angel, 2010). Each of these indices was calculated for each island and individually assessed to correlate with non-native species richness.

The other metric used for my particular area of research was island connectivity. To effectively measure island connectivity (how much of an island was surrounded by other islands) we analyzed the island perimeter of each island and measured 250 meters away from the direction of the island. In effect we redrew the perimeter of the island except with 250 meters between the original shoreline and this new "stretched" shoreline. In creating this new 250 m buffer around each island, we calculated how much of the area within this buffer was water and how much of it was land. Upon calculating the area of land and the area of water in this buffer we divided the land area by the water area. This is known as the landscape measure of island isolation and it offers a numeric value that describes which islands are more or less isolated. Islands that are more isolated have smaller "land:water" ratios compared to the more "crowded" islands that have larger numbers.

Upon obtaining all of these metrics (Table 1), we used the spatial analysis tools in ArcGIS to determine if there was a statistically significant spatial relationship between the variables listed above (island shape [as described by their compactness indices] and connectivity,) and the non-native plant species richness within the islands. I used the ordinary least squares regression tool in ArcGIS to analyze the relationship between native and non-native plant species richness (dependent variables) and shape and connectivity (independent variables).

RESULTS

My specific area of research is to calculate differences in island shape and connectivity among the fieldwork years to discern if changing island shape or connectivity relates to differences in variations in non-native species richness. With the aid of the ordinary least square regression tool in ArcGIS we can offer answers to this query.

First, the island isolation variable (measured as land:water ratio) is not a strong predictor of species richness. However, the other variables (island area, island shape) do serve, in some role, as predictors for species richness. The island shape index that served as the only predictor of species richness is perimeter, this means that islands that had a lower island coastline to island area ratio (essentially islands that are more circle-like) would weakly predict (R^2 values ~ 0.35) greater non-native species richness and native species richness. The other two indices, cohesion and proximity did not adequately predict species richness. The last variable tested in these models was island area and it is a moderate predictor of both total and non-native species richness, which is consistent with the TIB (R^2 values ~ 0.45). Results are listed on table 2.

DISCUSSION

The Equilibrium Theory of Island Biogeography has long been the dominant paradigm explaining the relationship between area and isolation to species richness on islands. In general as islands become larger they can accommodate a larger diversity of species, while smaller islands have fewer resources and can provide for a smaller diversity of species. An island that is more isolated (further away from the mainland) would experience a smaller diversity of species, while one that is closer would experience more species richness because of the ease of migration to a closer island. Studies in The MPP show that island area, island shape, and island isolation are the main drivers of the diversity of plant species on islands within the archipelago (Diver 2004, 2008). However, the spatial variation of non-native plant species richness in The MPP is unexplained by area, habitat heterogeneity and isolation and this is my area of research within the project, to determine if there is an underlying correlation between island shape and connectivity with the spatial variation of non-native plant species richness.

To understand how to measure the shapes of the study islands we had to first understand that "the circle is the most compact of shapes. And, that there are [at least] ten distinct geometrical properties of the circle that make it the most compact of shapes" (Angel, 2010). In creating a way to measure the shapes of islands we calculated each of the island's normalized index from three of the ten distinct geometrical properties. This provided each island a number from 0 to 1.0 that measured its compactness. With the circle being the most compact shape it is the one and only shape that can be awarded the normalized index "1.0", all other shapes are given a number less than that, with the more circle-like islands receiving indices closer to 1.0.

Another metric within my area of research was to ascertain the level of connectivity each island had within its immediate surroundings. According to the Equilibrium Theory of Island Biogeography a more isolated island would have less species richness, while an island that is closer to the mainland will be richer. What's inherently challenging about studying levels of species richness within an archipelago is that islands farther from the mainland do not always have less species richness than an island of equal size closer to the mainland. The reason for this could be that the further islands, while more distant from the mainland have many islands between itself and the mainland; effectively using the closer islands as stepping stones and allowing species to migrate to the island with more ease. For this reason we would not be able to simply measure the distances of islands to the mainland "as the crow flies". Instead we created a 250m buffer around each island as described in the Methods section. From this we came to a land:water ratio for each island, which effectively informs us to how much connectivity each particular island has.

A key finding of this project is knowing the importance of accurate island areas for a region with dynamic water levels because it aids in understanding the degree of influence that island area has on plant species richness. Dr. Diver, who studied the area for her dissertation, used outdated island areas for her model and received results indicating a significant species-area relationship ($R^2 = 0.84$) (Diver, 2004). After reviewing the island areas from this project, Dr. Diver re-ran the model from her dissertation with more accurate island areas, and received a model that is less strong ($R^2 = 0.75$). These results reveals that anyone studying islands with dynamic water levels (e.g. the Great Lakes, the oceans with sea level rise) should obtain island areas for the year of their plant inventories. This is important because island area is a key variable in island biogeography.

CONCLUSION

A major goal of this project was to elucidate clearer distribution patterns and predictive models of non-native plant species in the MPP, this goal was not wholly realized. Our results tell us that only one island shape index we tested, perimeter, would weakly predict (R^2 values ~ 0.35) non-native species richness and total species richness in the park. However, even a weak relationship provides more of an explanation for the spatial distribution of non-native plant species in the region than past analyses. This leaves park managers in the area to continue to monitor their non-native populations and researchers in the area will have to continue to test possible influential variables. Perhaps the other shape indices in *Ten compactness properties of circles: measuring shape in geography* (Angel et al., 2010) would offer clearer indications of non-native species richness and total species richness in the park.

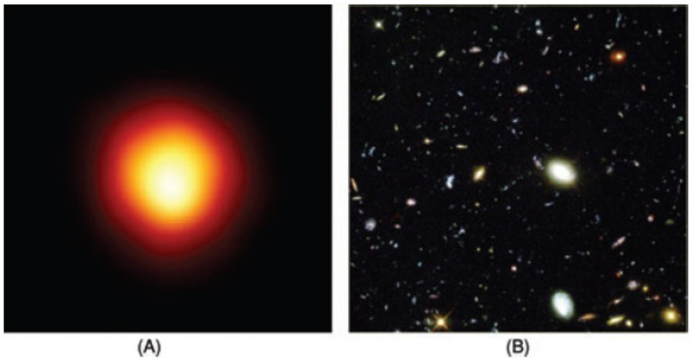

Figure 1. (A) Cohesion compactness in the Betelgeuse star (high). (B) Cohesion compactness in the distribution of matter in our expanding universe. (low)
Source of figure and caption: Angel et al. 2010.

Figure 2. (A) Proximity Compactness in the circus tent (high). (B) Roman Empire at its peak territorial extent - second century C.E. (low).
Source of figure and caption: Angel et al. 2010.

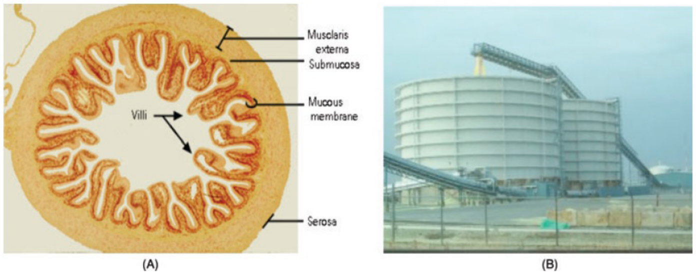

Figure 3. (A) Perimeter Compactness inside the small intestine (low). (B) Perimeter Compactness in a sulfur storage tank wall in Alberta (high).
Source of figure and caption: Angel et al. 2010.

Table 1. Range of values for independent and dependent variables for each sampled island for each year of imagery. Spatial relationships from ArcMap (ESRI ArcGIS 10.1), shape indices described by Angel et al. 2010 and species richness data from Diver, K.C. 2004.

					Shape Indices						Species Richness					
Imagery	**Area (Ha)**		**Land:Water**		**Cohesion**		**Proximity**		**Perimeter**		**Native**		**Non-Native**		**Total**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Nautical Chart	0.135	67.053	0.000	0.763	0.614	0.974	0.603	0.975	0.304	0.918	7	84	0	6	8	105
WPSGN	0.159	69.809	0.000	0.763	0.631	0.967	0.620	0.972	0.291	0.899	31	88	0	4	36	101
Digital Globe	0.151	69.940	0.001	0.671	0.627	0.970	0.618	0.973	0.282	0.919	0	2	19	100	20	101

Table 1. Results from the Ordinary Least Squares test completed in ArcMap (ESRI ArcGIS 10.1).
All refers to a multiple regression model including independent variables: land area, land:water ratio, perimeter index, cohesion index, and proximity index.*

Nautical Charts

Dependent Variable	Independent Variable	n	R^2	Probability Intercept	Probability Ind Variable	Model Significance
Total Species	Perimeter	34	0.317	<0.001	<0.001	<0.001
Total Species	Area	34	0.340	<0.001	<0.001	<0.001
Total Species	Cohesion	34	0.147	<0.001	0.025	0.025
Total Species	Proximity	34	0.076	0.003	0.114	0.114
Total Species	Land:Water	34	0.028	<0.001	0.343	0.343
Total Species	All*	34	0.576	0.083	<0.001	<0.001
	Perimeter				0.0272	
	Area				0.0339	
	Cohesion				0.0496	
	Proximity				0.1799	
	Land:Water				0.0819	
Non Native Species	Perimeter	34	0.377	<0.001	<0.001	<0.001
Non Native Species	Area	34	0.377	<0.001	<0.001	<0.001
Non Native Species	Cohesion	34	0.027	<0.001	0.352	0.352
Non Native Species	Proximity	34	0.139	0.007	0.030	0.030
Non Native Species	Land:Water	34	0.023	<0.001	0.389	0.389
Non Native Species	All*	34	0.470	0.312	0.002	0.002
	Land:Water				0.769	
	Area				0.061	
	Cohesion				0.549	
	Proximity				0.407	
	Perimeter				0.065	

WPSGN

Dependent Variable	Independent Variable	n	R^2	Probability Intercept	Probability Ind Variable	Model Significance
Total Species	Perimeter	19	0.412	<0.001	0.003	0.003
Total Species	Area	19	0.487	<0.001	<0.001	<0.001
Total Species	Cohesion	19	0.037	0.064	0.429	0.429
Total Species	Proximity	19	0.035	0.061	0.446	0.446
Total Species	Land:Water	19	0.014	<0.001	0.633	0.633
Total Species	All*	19	0.637	0.276	0.013	0.013
	Perimeter				0.113	
	Area				0.142	
	Cohesion				0.432	
	Proximity				0.493	
	Land:Water				0.113	
Non Native Species	Perimeter	19	0.287	0.004	0.018	0.018
Non Native Species	Area	19	0.587	0.079	<0.001	<0.001
Non Native Species	Cohesion	19	0.042	0.256	0.400	0.400
Non Native Species	Proximity	19	0.045	0.241	0.386	0.386
Non Native Species	Land:Water	19	0.033	0.037	0.460	0.460
Non Native Species	All*	19	0.801	0.894	0.000	0.000
	Perimeter				0.573	
	Area				0.000	
	Cohesion				0.021	
	Proximity				0.014	
	Land:Water				0.013	

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APPENDIX: GIS DATA SOURCES

PhotoImagery Bases from which islands were digitized

2004 data: WPSGN_Imagery, West Parry Sound GIS, Orthophoto, WMS server-based http://www.wpsgn.ca/datawarehouse.htm

2005 data: Nautical Chart 2202, Canadian Hydrographic Service

2012 data: MassasauagaProvincialPark-2012, DigitalGlobe, WVII satellite image