New Geospatial Approaches to the Anthropological Sciences

School for Advanced Research
Advanced Seminar Series
Michael F. Brown
General Editor

Since 1970 the School for Advanced Research (formerly the School of American Research) and SAR Press have published over one hundred volumes in the Advanced Seminar Series. These volumes arise from seminars held on SAR's Santa Fe campus that bring together small groups of experts to explore a single issue. Participants assess recent innovations in theory and methods, appraise ongoing research, and share data relevant to problems of significance in anthropology and related disciplines. The resulting volumes reflect SAR's commitment to the development of new ideas and to scholarship of the highest caliber. The complete Advanced Seminar Series can be found at www.sarweb.org.

Also available in the School for Advanced Research Advanced Seminar Series:

Seduced and Betrayed: Exposing the contemporary Microfinance Phenomenon
edited by Milford Bateman and Kate Maclean

Fat Planet: Obesity, Culture, and Symbolic Body Capital
edited by Eileen P. Anderson-Fye and Alexandra Brewis

Costly and Cute: Helpless Infants and Human Evolution
edited by Wenda R. Trevathan and Karen R. Rosenberg

Why Forage? Hunters and Gatherers in the Twenty-First Century
edited by Brian F. Codding and Karen L. Kramer

Muslim Youth and the 9/11 Generation
edited by Adeline Masquelier and Benjamin F. Soares

Childhood: Origins, Evolution, and Implications
edited by Alyssa N. Crittenden and Courtney L. Meehan

Artisans and Advocacy in the Global Market: Walking the Heart Path
edited by Jeanne Simonelli, Katherine O'Donnell, and June Nash

Disturbing Bodies: Perspectives on Forensic Anthropology
edited by Rosemary A. Joyce and Zoë Crossland

Linking the Histories of Slavery: North America and Its Borderlands
edited by Bonnie Martin and James F. Brooks

Things in Motion: Object Itineraries in Anthropological Practice
edited by Rosemary A. Joyce and Susan D. Gillespie

For additional titles in the School for Advanced Research Advanced Seminar Series, please visit unmpress.com.

New Geospatial Approaches to the Anthropological Sciences

Edited by Robert L. Anemone and Glenn C. Conroy

SCHOOL FOR ADVANCED RESEARCH PRESS • SANTA FE
UNIVERSITY OF NEW MEXICO PRESS • ALBUQUERQUE

Printed in the United States of America
21 20 19 18 17 16 1 2 3 4 5 6

Library of Congress Cataloging-in-Publication Data
<comment>[! CIP to come!]

Cover illustration: courtesy M. Frachetti and T. Burkowski
Designed by Lisa Tremaine
Composed in Minion Pro and Gill Sans fonts
The website developed in partnership with this volume can be found at geospatialsar.org. All figures have been created by the authors.

CONTENTS

ILLUSTRATIONS

FIGURES

TABLES

CHAPTER ONE

Geospatial Anthropology

Integrating Remote Sensing and Geographic Information Sciences into Anthropological Fieldwork and Analysis

ROBERT L. ANEMONE AND GLENN C. CONROY

INTRODUCTION

What are the common elements of the following hypothetical investigative scenarios? A cultural anthropologist seeks to trace the spread of certain distinctive cultural practices, beliefs, or objects; an archaeologist wishes to understand the organization of ancient irrigation systems or excavated ruins across an Incan landscape; a primatologist needs to quantify home range and core area size of an endangered primate species in the wild; a paleoanthropologist must prioritize areas to explore for fossils in a vast geospatial landscape that may encompass thousands of square kilometers. Each of these examples demonstrates (1) how anthropological data are often spatially distributed across landscapes that may vary tremendously in scale and (2) the analytical approaches made possible by modern spatial analysis techniques in anthropological research across all its subdisciplines.

This volume is the result of an Advanced Seminar held at the School for Advanced Research (SAR) in Santa Fe, New Mexico, during the spring of 2016 entitled "New Geospatial Approaches in Anthropology." This seminar brought together ten scholars who are currently applying state-of-the-art tools and techniques of geographical information science (GIScience) to diverse data sets of anthropological interest. While there are many alternative definitions of GIScience (see Mark 2003 for an excellent review), for our purposes (as discussed by Emerson and Anemone, chapter 2, this volume) GIScience includes technology (e.g., geographic information systems [GIS] software, global navigation satellite systems [GNSS]), data (e.g., remotely sensed imagery from satellites, airplanes, and many other sources), and, most importantly, a theoretical approach that seeks to understand patterns and relationships among spatial data all over the world.

The questions explored in the seminar in Santa Fe, and in this volume, crosscut the typical subdisciplinary, methodological, ideological, geographic, and chronological "silos" that so often limit scholarly communication among anthropologists. Our discussions forced us to recognize a deep, structural similarity between the kinds of questions we ask, the data we collect, and the analytical models and paradigms we use in our individual research programs. From this interchange of ideas came the realization that geospatial analysis in the broadest sense holds great promise for anthropological inquiry across all the subdisciplines. We hope this volume helps inform anthropologists as to how the powerful tools of GIScience, including GIS and remote sensing, can be used to benefit their own research programs.

A broad survey of the recent literature reveals that the use of sophisticated spatial analysis tools is unevenly distributed across anthropological subdisciplines (Conolly and Lake 2006; Anemone, Conroy, and Emerson 2011). In fact, one of our motives in organizing this seminar was to highlight how all subfields of anthropology can benefit from analyzing data in a geospatial context. Some of the earliest, and most sophisticated, users of GIScience were archaeologists (see Giardino 2011 for the history and Forte and Campana 2016 for a recent "snapshot"), and some notable applications include the development of predictive models for site location (Mehrer and Westcott 2006), the use of aerial remote-sensing approaches for visualizing hidden features on the ground (Sever and Wagner 1991; Chase et al. 2011), and the development of three-dimensional virtual reconstructions of excavated sites (Forte et al. 2012). Over the past decade or so, biological anthropologists have been studying the functional morphology of both living and fossil primates (and hominins) using various GIScience and three-dimensional visualization techniques at both the micro and macro levels (Boyer et al. 2011; Yapuncich and Boyer 2014; Harrington et al. 2016). It is quite fair to say that such studies, like the "virtual reconstruction" of fossils, have revolutionized the field of paleoanthropology (Conroy and Vannier 1984; Weber 2015). A paradigmatic example of this kind of work is Peter Ungar's chapter in this volume (chapter 6), in which he applies spatial thinking and GIScience methods to the study of microscopic surfaces of primate teeth to reveal surprising aspects of both diet and behavior.

But the application of GIScience technology is not limited to archaeology and biological anthropology. We can cite a number of innovative studies that illustrate the enormous potential of geospatial approaches in cultural anthropology, human biology, and primatology, as well.

For example, some of the very first papers to use satellite imagery to explore questions of anthropological relevance — and especially the interplay between cultural and biological anthropology — concerned human ecology, primate conservation, and the history of deforestation in Madagascar (Green and Sussman 1990; Sussman, Green, and Sussman 1994). These pioneering contributions demonstrated how a time series of remotely sensed satellite images could document long-term changes in forest cover and land use in extremely remote habitats. The satellite imagery documented a loss of about half of Madagascar's eastern rain forest (ca. 3.8 million ha) between 1950 and 1985, and a GIScience-based analysis indicated that the majority of remaining forests were on steep slopes and in areas of low human population density.

Subsequent ethnographic studies showed that forests are cleared in Madagascar for reasons that turn out to be more complex than initially imagined. The major drivers of forest destruction in Madagascar include "the need of an expanding population to clear land for subsistence agriculture (forest farming), and not large-scale timbering" (Sussman, Green, and Sussman 1994, 334). Once cleared, these tropical farmlands quickly lose their nutrients, leading to more forest clearing in a typical pattern of shifting agriculture that results all too often in rapid soil erosion and causes additional problems downstream as rivers tend to become laden with silt and thus more prone to flooding. In addition, ethnographic work by L. K. Sussman near the Beza Mahafaly Reserve in southern Madagascar suggested that complex cultural, political, and historical factors also influenced indigenous practices that lead to forest clearance (Sussman, Green, and Sussman 1994). Cattle rustling, the failure of wet-season crops, patterns of sexual division of labor, and government economic and subsistence policies are just a few of the factors that have influenced the rate of, and rationale for, forest destruction in this part of Madagascar.

The large-scale environmental changes revealed by remote sensing over recent decades in Madagascar can only be understood within a sophisticated anthropological, and geospatial, context. Our only hope for slowing the rate of this kind of environmental change, with its attendant risks to both the human and nonhuman components of the Madagascan biome, lies in tapping the synergy between anthropological and geospatial understandings. In this volume, the work of Serge Wich, Lian Pin Koh, and Zoltan Szantoi (chapter 7) is similarly concerned with monitoring environmental change in primate habitats of Southeast Asia.

Another study illustrating the interplay between cultural anthropology and spatial analysis is that of S. Aswani and M. Lauer (2006). Their research project sought to incorporate indigenous social and spatial knowledge concerning fishing grounds and other aspects of subsistence practice and local marine ecology into the process of creating marine protected areas in the Solomon Islands. The tools of GIScience and remote sensing were used to create spatial databases and maps that convey insider knowledge about the availability of marine resources and characteristic patterns of exploitation of these resources by local anglers. Indigenous and Western knowledge concerning the seascape, local subsistence behaviors, and resource-management practices was incorporated into what the authors call a “public participation GIS” to aid in the development of these protected areas. Aswani and Lauer (2006) suggest that the combination of marine science (to quantify habitats and their biological characteristics), ethnographic fieldwork (to reveal indigenous spatial-temporal ecological knowledge), and the tools of modern GIScience (to organize, visualize, and query the data) can enhance local participation in community decision-making about the management of resources held in common.

While the applied aspects of this study have been notable — leading to the creation of twenty-one marine protected areas in this region with the active participation of local anglers and villagers and a consequent reduction in unlawful poaching of marine resources — the researchers were also able to explore scientific questions and test hypotheses based on optimal-foraging theory concerning how individuals select which resource patches to exploit (Aswani and Lauer 2006). Beginning with digitized aerial photographs and topographic maps, the researchers documented (via direct, daily participation with anglers) fourteen major habitat types, six minor habitat types, and more than six hundred locally identified sites, including fishing sites, spawning grounds, lagoons and reefs, and other marine habitats (e.g., seagrass beds). By compiling these data into a GIS database, the investigators were able to create a series of maps that informed decisions about the location of proposed marine protection areas, which were based on the spatial and temporal distribution of marine resources. They were also able to test ecological hypotheses concerning the choices and behaviors of their informants by relating yields and nutritional quality, travel and extraction costs, and other parameters easily analyzed within the context of a GIScience model. The authors concluded that GIScience provides an "excellent spatial analytical tool for deepening our knowledge of the socio-ecological dimensions patterning a system . . . and can be integrated with a broader human ecological analysis to reveal the spatial and temporal patterning of Roviana fishermen's ecological knowledge and fishing behavior" (Aswani and Lauer 2006, 99).

Another example of a geospatial analysis of explicit anthropological interest concerns linkages between climate and the spread of infectious disease in humans. Lobitz and colleagues (2000) examined satellite imagery and other remotely sensed data in the context of recent (1992–1995) cholera outbreaks in Bangladesh. The remote-sensing data included sea surface temperature, established by thermal-imaging wavelengths from the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer sensor, and sea surface height, which was established using measurements taken with the Jet Propulsion Lab's TOPEX/Poseidon radar altimeter. Cholera case data indicated how many people in coastal regions of Bangladesh were treated (as both inpatients and outpatients) for cholera each week between 1980 and 1995, and they revealed two distinct seasonal peaks, one in the spring and another in the fall. Both annual peaks are significantly positively correlated with sea surface temperatures and with sea surface height because the cholera bacterium (*Vibrio cholerae*) is associated with zooplankton whose blooms are, to some extent, dependent upon water temperature. Sea surface temperature is thus a marker for plankton blooms, which allow *V. cholerae* to greatly increase in biomass, while sea surface height is a marker for increased human-plankton contact as plankton-laden tidal waters intrude into low-lying rivers where untreated water is drunk, bathed in, and used for washing by a majority of Bangladeshis.

This kind of work is critical for the development of improved predictive models (both locally and globally) for cholera outbreaks without the expensive and time-consuming shipboard collection of water and plankton samples in the field. With continued global climate change, medical anthropologists would be well advised to consider additional examples of human morbidity and mortality that are correlated with climatic or environmental variables that can be remotely monitored and spatially analyzed using the tools of GIScience (Campbell-Lendrum and Woodruff 2006).

Primatology is another research area within anthropology that could benefit enormously from sophisticated GIScience, including studies of both primate ecology and primate conservation. For example, R. A. Bergl and colleagues (2012) have demonstrated the power of remote sensing for quantifying forest loss and fragmentation, as well as the availability of suitable habitat for a critically endangered great ape, the Cross River gorilla (*Gorilla gorilla diehli*). Endemic to a small region along the border of Nigeria and Cameroon, the Cross River gorilla may be represented by as few as three hundred living individuals (Oates et al. 2003) due mainly to forest loss, habitat fragmentation, and hunting pressure. Previous research efforts to clarify the conservation status of these animals "have been hampered by a limited knowledge of the distribution of forest throughout the subspecies' range, the extent of habitat fragmentation, and of the patterns of movement of the gorillas across the landscape" (Bergl et al. 2012, 279).

Bergl and colleagues used Landsat imagery to create a land-cover classification that could identify suitable gorilla habitat, including corridors and linkages between known gorilla localities and other areas of unsurveyed and potentially suitable habitat that might contain gorilla populations. They performed a least-cost-path analysis to model if and how gorillas might disperse across the landscape between patches of suitable habitat while avoiding villages, farmland, and other areas of high human population density. Field surveys were used to ground-truth the predictive model, and gorillas were identified in ten of the twelve previously unsurveyed areas of predicted gorilla habitat. As a result of these surveys, the known range of the Cross River gorilla was increased by more than 50 percent. The results of the land-cover classification were also encouraging in that more than 2500 km^2 of suitable forest habitat were determined to exist near the 400 km^2 of known gorilla habitat, suggesting that the carrying capacity of this area for gorillas could potentially be much higher than it appears to be. In short, the use of satellite imagery and sophisticated geospatial analysis and modeling allowed the researchers to better understand the three critical gaps in their knowledge: distribution of forest, extent and fragmentation of gorilla habitat, and potential movement paths between these areas. While this kind of work can be done in a cost-effective and timely fashion with the tools of GIScience, comparable data would be expensive and difficult, if not impossible, to collect through fieldwork alone.

Another example of how GIScience facilitates the testing of primate socioecology hypotheses is C. A. Shaffer's (2013) work among bearded sakis (*Chiropotes sagulatus*) in Guyana. For decades primatologists have been attempting to operationalize aspects of feeding competition, group size and spacing, and resource quality for naturalistic primates. In particular, quantifying the quality and size of resource patches and their relationship to group size and spacing has been contentious (White and Wrangham 1988; Vogel and Janson 2011). Shaffer (2013) applied the tools of remote sensing and GIScience to the dual problems of operationalizing and quantifying group spacing or cohesiveness and food-patch size among bearded sakis in an innovative manner that allowed him to test hypotheses derived from optimal-foraging theory. Efficient foraging is selected for in nature since food-patch size is a major constraint on group size, allowing "feeding rates within a patch to be maximized" (Shaffer 2013, 235). The quality and size of available food patches suggest an optimal group size to ensure efficient foraging, and as resource patches are depleted, feeding competition increases until the best strategy is to move to another patch.

To determine if group size and cohesion among bearded sakis are shaped by patch quality and size, Shaffer (2013) used geospatial approaches to quantify these variables in a lowland rain-forest preserve in southern Guyana between January 2008 and January 2009. He used GPS to record the location of all feeding trees, and he scored tree phenology and crown volume to estimate the amount of fruit or flowers for each tree. He calculated patch quality at two different scales with grid sizes of 50 and 100 m — the choice of these two grid sizes was determined by the average and minimum daily group spread. Shaffer measured group spread at each five-minute scan interval with the aid of two field assistants, who positioned themselves at opposing sides of the group while the author positioned himself at the center. He measured group spread as the largest linear distance between any two of the three GPS points. Group size (at the beginning of each day) and the number of animals identified per scan made up two additional measures of group cohesion.

The resulting GIS model allowed Shaffer to test predictions relating group size and patch size, which were derived from optimal-foraging theory. Landsat imagery of the study site formed the base layer upon which Shaffer overlaid separate sheets of GIS data, such as feeding trees (scored for their food quality) and daily paths taken by the animals (including the polygons indicating group spread during the all-day follows). Unlike the animals in an earlier study by M. Norconk and W. Kinzey (1994), the sakis in Shaffer's study did not travel cohesively and disperse while feeding, but they did, as predicted, travel and feed in smaller groups during periods of low patch quality. Furthermore, between 40 percent and 60 percent of variation in group size was explained by patch quality, as predicted by optimal-foraging theory. As this paper amply demonstrated, "the development of powerful spatial analysis tools in the last decade has greatly improved our ability to test some of the fundamental questions in behavioral ecology" (Shaffer 2013, 243).

A final example of how geospatial tools and data sets can enrich anthropological analysis comes from the work of N. G. Jablonski and G. Chaplin (2000, 2010) on the evolution and adaptive significance of human skin color (Jablonski 2004). In seeking to test long-standing adaptive scenarios concerning the conditions under which skin color has evolved, these authors utilized available geospatial data in the form of satellite-measured worldwide levels of ultraviolet radiation. Prior to this work, essentially all anthropological research on the damaging photolytic effects of ultraviolet radiation on humans took for granted a latitudinal gradient in environmental conditions (e.g., temperature, ultraviolet radiation, humidity, etc.) that played a role in the distribution of skin colors around the globe. Using data collected between 1978 and 1993 by the NASA Total Ozone Mapping Spectrometer, which was carried by the Nimbus-7 satellite (Jablonski and Chaplin 2010), they presented a strongly supported model whereby human skin color shows the effects of two separate but correlated axes of clinal variation. One cline is the high ultraviolet radiation in the tropics and resulted in the evolution of darkly pigmented, photoprotective skin color. The other cline explains the evolution of light skin color as a result of the need for medium-wave ultraviolet radiation to penetrate the epidermis and stimulate the production of vitamin D_3. Their innovative use of available satellite data enabled Jablonski and Chaplin to successfully test a widely held hypothesis of human adaptation and thereby enrich our understanding of human evolution.