Advanced Spatial Analysis Training Program for Population Scientists

A. Specific Aims

Recent years have seen a rapid growth in interest in the addition of a spatial perspective to population research, and in part this growth has been driven by the ready availability of geo-referenced data, and the tools to analyze and visualize them: geographic information systems (GIS), spatial analysis, and spatial statistics (see Section B). Indeed spatial demography has been named a priority area of the Demographic and Behavioral Sciences Branch (DBSB) of NICHD, as evidenced by their most current *Goals and Opportunities Report (2002-2006)*. Similarly, Watcher (2005) writing in an introduction to a special issue in the *Proceedings of the National Academy of Sciences* noted that spatial demography "brings sciences together." More recently, Butz and Torrey (2006) writing in *Science* listed geographic information analysis tools as one of six innovation frontiers in the social sciences. For some time now the social sciences have begun to accept spatial analysis as a part of their various methodologies (Anselin, 2000; Goodchild et al., 2000; Goodchild and Janelle, 2004; 2004b (see **Appendix A** – sample publications)). The improved application of spatial data and methods to demographic research however is also identified as a critical methodological challenge facing population scientists today. The situation is not helped by the fact that the number of U.S. graduate level GIS and advanced spatial analysis courses with a significant social science or more specifically demographic content are limited (Brown, 2000, O'Kelly, 2000). Although the instructional environment for introductory GIS and spatial analysis courses is improving, the application and use of advanced spatial analysis methods in population science lags behind. Thus the next generation of population scientists may not be adequately prepared to take advantage of the recent methodological developments and new software products in spatial statistical analysis.

There are two aims of the "Advanced Spatial Analysis Training Program for Population Scientists" application.

Aim 1: To move beyond basic GIS training and set the highest standards for spatial analysis instruction in the population science by offering a series of *advanced spatial analysis* workshops on cutting-edge techniques. The four proposed workshops are:

- spatial regression modeling
- geographically weighted regression
- the integration of spatial and multi-level modeling
- spatial pattern analysis

The convention within the spatial analysis literature is to divide techniques into those developed for point patterns, spatially continuous data, and area (or lattice) data (see Unwin, 1981; Cressie, 1993; Bailey and Gatrell, 1995; Haining, 1990; O'Sullivan and Unwin, 2002). Briefly, the planned workshop series covers techniques associated with the different forms of spatial data. In Section B and C we justify the selection of these advanced spatial analysis topics and refer to additional workshop topics that *could* be included in the series such as agent-based modeling or Bayesian spatial modeling. The target audience for these advanced workshops is early-career population scientists (i.e., graduate students and junior faculty/researchers in demography-related disciplines) based at research institutions and population-related agencies in the United States. We will offer each workshop twice over a four-year period (subject to a review by the advisory board), reaching as many as 200 attendees (25 x 8 workshops). Specific workshop details, recruitment, and evaluation are described in full in Section D.

Aim 2: To supplement the workshop series with parallel development of *resource materials* on the four selected and other advanced spatial analysis methods; resource materials that will be made publicly available via an existing GIS and Population Science (GISPopSci) website (http://www.csiss.org/GISPopSci/). The current website will be enhanced with new learning materials, reference lists, and other advanced spatial analysis resources. These resources will be available to any one with access to a web browser. Though the instructional materials will not be able to fully reproduce the experience of an intense 5-day workshop they will provide access to a wealth of information including classic papers, sample data sets, and exercises. The development of these materials will be an ongoing activity throughout the five years of the training program, with an intensive effort in Year 5. It should be stressed that the website has several options that allow members of the population science community at large to register their own spatial demography-related projects and materials. We intend for the website to be developed for and to serve the wider population science field.

Our intent is that both the workshops *and* the website will help build a community of scholars within and across population science disciplines. Throughout the grant period we will be evaluating the impact of the workshops on the cohort of attendees (alumni). There will be an exit survey, a one year follow-up, and a later follow-up survey in Year 5 (for attendees of the first 3 years of workshops). We believe these workshops will facilitate the further development of spatially-informed demography, and will have trained 200 early-career scholars.

This advanced spatial analysis proposal brings together expertise from the Population Research Institute (PRI) at Penn State and the Center for Spatially Integrated Social Science (CSISS) at the University of California Santa Barbara. The Penn State and UC Santa Barbara partnership builds upon both shared expertise (GIS instruction, geography, workshop and conference management) and complementary expertise (demographic science, distance learning, and digital libraries). In Section C we include summary progress report materials on the GIS and Population Science workshops coordinated by the same instructional team (Matthews, Goodchild and Janelle).

In summary, this R25 application proposes that PRI and CSISS coordinate the development and offering of four 5-day advanced spatial analysis workshops and the development of web resources on these and other advanced spatial analysis topics for use by population scientists. We will offer workshops in both State College and Santa Barbara as this provides flexibility for applicants both in terms of timing and geographical accessibility. The proposed schedule of workshop covering four of the five years is:

Year	State College/PRI (May/June)	Santa Barbara/CSISS (June/July)
2008	Spatial & Multilevel Modeling *	Spatial Regression Modeling *
2009	Geographically Weighted Regression *	Spatial Pattern Analysis *
2010	Spatial Regression Modeling	Spatial & Multilevel Modeling
2011	Spatial Pattern Analysis	Geographically Weighted Regression

* = *workshop organization confirmed*

The workshops planned for 2008 and 2009 we regard as "confirmed" and this application is built around initial commitments from institutions and lead presenters (see letters of support). In a planned review at the end of 2009 Matthews, Goodchild, Janelle, and the training program's advisory board (Section D.1.) will critically review summary application pool data and the exit survey data collected from attendees during the first four workshops. They will specifically review whether the same workshops should be offered a second time (i.e., is there the demand?), whether the same lead presenters would be involved, and whether other workshop topics have emerged that we should focus on (e.g., the leading candidates at the time of writing this application are agent-based modeling and Bayesian spatial modeling – see Section C).

B. Background and Significance

Recognizing contributions that have been made "to the areas of neighborhood effects, stratification and segregation, population and the environment, and migration" (p. 16), the DBSB *Goals and Opportunities Report (2002-2006)* notes that spatial demographic research needs to address issues of theory, improving data accessibility and compatibility with spatial techniques, and fostering interdisciplinary research. Elsewhere (p. 20), the DBSB report identifies "improved application of spatial data and methods to demographic research" as a critical methodological challenge facing demographers today. Finally, the DBSB report cites macro-level population research as an important new area of emphasis, but recognizes that "accomplishing this goal will require attention to data needs and accessibility of data on population characteristics and change" (p. 27). We would include under this statement the need for a better understanding of data confidentiality and privacy issues such as the consequences of using geographic identifiers and strategies for masking data (Armstrong, Rushton and Zimmerman, 1999; Armstrong 2002; Rindfuss, 2002; VanWey et al., 2005). Ultimately, the goal is to promote high-quality research that bridges the micro-macro divide, an effort that DBSB places at the scientific frontier (see also recent calls for more integrated natural and behavioral sciences with a focus on the axes of time and nested levels/systems (Glass and McAtee, 2006)). The achievement of these goals will require that the next generation of demographers, and some of those already working in the field, be multi-disciplinary and well trained in state-of-the-art tools, techniques, and theories of advanced spatial analysis. This is precisely what we seek to achieve through this proposed training program for population scientists.

B. 1. Spatial is Special: the Bad and the Good News

Spatial data are special and must be treated differently if analysts are to avoid pitfalls (Cressie, 1993; O'Sullivan and Unwin 2002). Briefly, many of the standard techniques and methods documented in standard statistics texts have significant problems when we try to apply them to the analysis of spatial data. O'Sullivan and Unwin (2002) summarize the 'bad news' as the requirement that *samples are random* and observations independent (where the presence of *spatial autocorrelation* introduces redundancy affecting the calculation of confidence intervals and significance tests in regression-based techniques). Cressie (1993) argued that classical, non-spatial data analysis should be regarded as a special case of spatial data analysis. In synthesizing Cressie's framework, Weeks (2004, p. 383 (See **Appendix A** – sample publication)) writes "[I]n spatial data analysis, the researcher uses geostatistics to glean information from the *x* and *y* coordinates, whereas in classical statistical analysis the researcher ignores those coordinates (often not even realizing that they might exist)." Thus, in many instances locational attributes are considered to be a nuisance, rather than representing useful information on spatial autocorrelation. In contrast, in a formal spatial analysis, spatial autocorrelation becomes an object of investigation. If spatial autocorrelation exists, "then there may be spatial dependence, and thus, something of interest spatially that is occurring" (Weeks, 2004, p.383). It is worth noting that demographers were made aware of the need for special treatment of spatial data in linear regression modeling and the risks of ignoring spatial autocorrelation over 20 years ago (Doreian, 1980, 1981; Loftin and Ward, 1983) but until very recently few quantitative demographers regarded 'spatial is special.' (For additional information and examples of the use of spatial regression models, see the description of the workshop in Section D.2.a.).

Other areas of 'bad news' include the *modifiable areal unit problem* or MAUP (Openshaw, 1983). MAUP and the more general statistical problem of the *ecological fallacy* have been known of for some time. Gehlke and Biehl (1934, p. 170) in a study of the scale effect in census data noted that "a relatively high correlation might conceivably occur by census tracts when the traits so studied were completely dissociated in the individuals or families of those traits." Additional problems facing the spatial analyst include *scale*, the *nonuniformity of space* and *edge effects*. Goodchild and Janelle (2004, pp. 8-9) state "If a model fits imperfectly, then it is reasonable to expect that its residuals will show geographic patterns, and perhaps that the model will fit better (residual variation will be smaller) in some areas than others – in other words, it will exhibit spatial nonstationarity. If so, then the results obtained from an analysis over any limited study area will depend explicitly on the bounds of the study area, and it will be different if the study area is changed."

Progress is being made on the 'bad news' topics and there is much 'good news' for the spatial analyst. Important spatial concepts such as *distance*, *adjacency*, *interaction* and *neighborhood* appear in a variety of guises in most applications of statistical methods to spatial data; these are useful concepts for describing spatial distributions and specifically the relationships between spatial entities. Thus, spatial analysts can create distance-based, adjacency-based or interaction-based spatial weights matrices to generate Moran's I statistics and Local Indicators of Spatial Association (LISA) to measure global and local spatial autocorrelation of dependent and independent variables and errors (Anselin, 1995). Similarly, the spatial analyst can use methods such as variogram clouds and semivariograms to study the relationship between spatial locations of objects and data attributes of those objects.

Across the sciences there has been an emergence in the literature and developments of techniques for examining local relationships in aspatial data (e.g., LOWESS regression and Drift Analysis of Regression Parameters - DARP) and in the local analysis of spatial data such as LISA (Anselin, 1995) and geographically weighted regression (GWR) (Fotheringham, Charlton, and Brunsdon (2002). GWR and LISA are both methods used in what is known as place-based analysis (Goodchild and Janelle, 2004b). Goodchild and Janelle (2004b, p.9) provide an effective summary of the GWR approach in which one fits a model to data from geographically dispersed observations, weighing observations based on weights that are inversely related to distance from some chosen location: "[T]he fitted parameters of the model are now dependent on the location chosen and will vary as the regression is re-centered on different locations. By re-centering the regression many times, one can build up a complete map of the spatial variation of the parameter estimates, which can be interpreted based on spatial context and known characteristics of the study area." This modeling approach places an emphasis on differences across space, and the search for the exception or local 'hot spots.' (For additional information and examples of the use of geographically weighted regression, see the description of the workshop in Section D.2.b.).

With the availability of ever more geospatial data and the ability to integrate complex data from different sources and across time the interest in spatial pattern analysis has never been greater, and this appears especially so in spatial epidemiology, and crime analysis, fields which draw on point, spatially continuous (field) data or area (lattice) data and have specific interest not just in spatial clustering methods but in spatiotemporal analysis, spatial dynamics, and diffusion. Some of these spatial cluster methods and spatial diffusion modeling are very slowly filtering in to population science (e.g., Weeks (2004) study of fertility in Egypt). The main approaches to spatial pattern analysis include exploratory spatial data analysis (ESDA), spatial statistics, geostatistics, and spatial econometrics each with a range of techniques available to the researcher dependent on the type of data to be analyzed. A wide range of methods now exist for analyzing spatial clusters of point data such as disease or crime events (see Gatrell et al., 1996; Kulldorff, 1998) where the intent is to discover whether the observed events exhibit any systematic pattern as opposed be being distributed at random within a study area. Point-based cluster detection methods include those developed to detect overall clustering in a study area, those used to identify cluster locations (elevated rates), and those to assess clustering around point sources (e.g., a hazardous facility). The branch of statistical theory that deals with continuous field variables is geostatistics (Issaks and Srivastava, 1989; Cressie, 1993). Rather than focus on observations as the location of events, geostatistical methods aim to understand the spatial distribution of values of an attribute of interest over an entire study region, given values at fixed sampling points. Geostatistics assume at least some of the spatial variation in an attribute can be modeled by random processes with spatial autocorrelation and can be used to provide accurate and reliable estimations of attribute values at locations where no measurements are available. The developments in the materials and methods for geospatial data have facilitated adoption particularly in spatial epidemiology of advanced techniques for spatial pattern analysis, spatiotemporal analysis as well as Bayesian mapping and modeling (Gatrell et al., 1996; Elliott et al., 2001; Diggle, 2003; Lawson, Brown, and Rodeiro, 2003; Banajee, Carlin, and Gelfand, 2004; Lawson, 2006). (For additional information and examples of the use of spatial pattern analysis, see the description of the workshop in Section D.2.c.).

Section B.1.b includes a brief discussion of multilevel modeling within population research. While this integration of individual and contextual data is a well established methodological area within population science, we believe great unmet potential and some challenges exist for integrating multilevel analyses techniques and GIS/spatial analysis for exploring extra-local effects (Subramanian, Jones, and Duncan, 2003; Chaix, Merlo and Chauvin, 2005; Chaix et al., 2005; Macintyre and Ellaway, 2003; Diez Roux, 2003). There have been recent attempts to integrate spatial and multilevel models. For example, Chaix and his colleagues compare spatial and multilevel modeling approaches and specifically incorporate a continuous notion of space rather than relying on administrative boundary demarcations. Their spatial mixed models provide information not only on the magnitude but also on the scale of spatial variations, and provide more accurate standard errors for risk factor effects in studies of both mental disorders in Malmo, Sweden and health-care utilization in France. Their work suggests that in neighborhood studies, "a deeper understanding of the spatial variations in health outcomes may be gained by building notions of space into statistical models and measuring contextual factors across continuous space" (Chaix et al., 2005 p.179). (For additional information and examples of the use of multilevel and spatial models, see the description of the workshop in Section D.2.d.).

B.2. Spatial Perspectives in Population Research

Demographic projects are beginning to pay attention to the spatial characteristics of the phenomena being studied, and some are applying spatial statistical techniques that explicitly incorporate spatial relationships between geographic objects (for additional reviews see Weeks, 2004 and Castro, 2006). Voss et al. (2004) have described the growth in demographers' interest in social processes embedded within a spatial context as a re-emergence, noting that roughly until mid-20th century virtually all demography in the U.S. was spatial demography, where spatial demography is the formal demographic study of areal aggregates. That spatial demography waned in the second half of the 20th century is in part because of the attention afforded the individual in demographic research and the dominance of micro-demography. Spatial demography, however, did not disappear. The recent growth in the availability of geo-referenced data, and the tools to analyze and visualize them (GIS, spatial analysis, and spatial statistics) has generated new interest in spatial perspectives in several areas of population science. Consider the following research areas.

Although most studies of maternal and child health outcomes focus on individual-level data from large-scale surveys, population scientists have become particularly interested in contextual issues and multilevel modeling (Entwisle, Mason and Hermalin, 1986; Entwisle, Casterline, and Sayed, 1989; Entwisle et al., 1997; Hirschman and Guest, 1990; Pebley, Goldman, and Rodriguez 1996; Sastry, 1996; Degraff, Bilsborrow, and Guilkey 1997; Stephenson and Tsui, 2002). Similarly, multi-level modeling has been particularly evident in U.S. studies that focus on family and child wellbeing in the context of residential neighborhoods, typically urban, where researchers have begun to move beyond a limited set of census-derived variables; i.e., to seek out practical and innovative uses of alternative data sets (e.g., on crime, health, land-use, transportation, etc.) to create global rather than aggregated variables that describe and capture dimensions and characteristics of neighborhoods not previously contemplated (Coulton, 1997; Coulton, Korbin, Chan, and Su 2001; Sampson, Morenoff, and Earls 1999; Sampson et al., 2002). A methodological focus on multilevel or hierarchical modeling is relevant when examining the effects of contextual factors on social behavior played out at a lower level. It is also important to assess how much individual behavior is influenced by one's own characteristics as well as attributes of the larger community. Moreover, Sampson et al. (1999, p.645) argue, "[T]he emergence of intergenerational closure, reciprocal exchange, and child-centered social control in a neighborhood benefits not only residents of that area but also others who live nearby. Methodologically this leads to a model of spatial dependence in which neighborhood observations are interdependent and are characterized by a functional relationship between what happens at one place and what happens elsewhere." They conclude that "spatial externalities have been overlooked in prior research, but our analysis indicates that social capital and collective efficacy for children are relational in character at a higher level of analysis than the individual or the local neighborhood (1999, p. 567)."

Considerable research indicates that racial and socioeconomic segregation are persistent features of the U.S. metropolitan landscape (Farley and Frey, 1994; Jargowsky, 1997; Lewis Mumford Center for Comparative Urban and Regional Research, 2001; Logan et al., 2004; Massey and Denton, 1993) and that this segregation is associated with negative outcomes for families, youth, and children living in isolated poor and minority neighborhoods (Brooks-Gunn, Duncan, and Aber, 1997; Duncan and Brooks-Gunn, 1997; Wilson, 1987). Reliable and meaningful measurement of residential segregation is essential to the study of the causes, patterns, and consequences of racial and socioeconomic segregation. Nonetheless, prior work on residential segregation has been limited by a reliance on methodological tools that do not fully capture the spatial distributions of race and poverty. In brief, prior work has generally relied on measures of segregation that ignore the spatial proximity of neighborhoods and focus instead only on the racial composition within neighborhoods. A variety of *ad hoc* measures have been proposed to deal with these methodological limitations (Grannis, 2002; Massey and Denton, 1988; White, 1986; Wong, 1993, 2002, 2003, 2004 and 2005; Feitosa et al., 2006), but these have been rarely used in empirical research. In part, the proposed measures have been ignored because of their relatively *ad hoc* nature—most lack a conceptually and mathematically solid basis for measurement, and so they can produce results that are inconsistent with theoretically useful definitions of segregation. And in addition, these measures have been ignored because they are computationally intensive and no software tools exist to implement them, meaning that researchers must write their own programs if they want to use them. In a recent paper, Reardon and Firebaugh (2002) suggested a general approach to developing conceptually meaningful and mathematically tractable measures of spatial segregation. Methods developed by Reardon, Matthews, O'Sullivan, Lee, Firebaugh, and Farrell use geographic information analysis to operationalize this approach using Census data to generate a spatial segregation profile (Reardon et al., 2006) and the authors have used this methodology to explore the patterns and determinants of racial residential segregation at multiple scales (Lee at al., unpublished manuscript) and to look at spatial income inequality (Reardon et al., *unpublished manuscript*).

In the ethnographic component of the Three City Welfare Study and in a study of family and child wellbeing in small town North Carolina and Pennsylvania, Burton, Matthews, Skinner, and their colleagues have begun to explore how GIS can be used to study the geographies of families and to re-visit important conceptual and methodological issues regarding definitions of neighborhood or context (see Diez Roux, 2003; Macintyre, Ellaway, and Cummins 2002; Macintyre and Ellaway, 2003; Frumkin, 2006). In particular, Matthews and colleagues are interested in different forms of spatial behavior (Golledge and Stimson, 1997) expressed by individuals and families. Their application of GIS focuses on both building multi-scale contextual databases and the integration of GIS, quantitative, and qualitative data (i.e., geoethnography) on families and neighborhoods to help better understand the spatial and temporal rhythms of families and in doing so shed light on the complex and reciprocal relationship between families and neighborhoods (Burton et al., 2000; Matthews, Detwiler, and Burton, 2005; Skinner, Matthews, and Burton, 2005). Matthews' current geoethnography research focuses on the concept of 'jumping scale' and explores the degree to which families draw on non-local resources. He is working with geocoded activity log data to explore family's exposure to their neighborhood and the conceptual issues surrounding neighborhood effects.

Demographic researchers have also explored population and environment linkages (Pebley, 1998). Remote sensing, GIS, and spatial econometrics have already been used effectively to analyze the relationship between human activities and local environmental change, in particular in the area of deforestation and changing patterns of land use (Chomitz and Gray, 1996; Moran and Brondizio, 1998; Nelson and Hellerstein, 1997; and Wood and Skole, 1998). Empirical research on the reciprocal relations between population dynamics and the natural environment at the local level have been quite rare but, as shown in the edited collection by Fox, Rindfuss, Walsh, and Mishra (2003), the research environment is changing fast as population scientists begin to integrate GIS, remote sensing, and spatial analysis methods (see also Liverman, Moran, Rindfuss, and Stern, 1998). In recent work by Castro, Singer, and colleagues (Singer and Castro, 2001; Castro et al., 2006) spatial statistical analysis revealed that the early stages of frontier settlement are dominated by environmental risks, consequential to ecosystem transformations that promote larval habitats of *Anopheles darlingi*. With the advance of forest clearance and the establishment of agriculture, ranching, and urban development, malaria transmission is substantially reduced, and risks of new infection are largely driven by human behavioral factors. This type of research is significant in crafting policies for malaria mitigation.

There are other population and social science research areas where a spatial perspective is evident. The following listings of areas of research and the references are illustrative only. For example, the spatial perspective is evident in the areas of labor market research and explorations of the spatial mismatch hypothesis (see Mouw 2000, 2002), environmental justice, environmental pollution, and health outcomes (Anderton et al., 1994; McMaster, Leitner, and Sheppard, 1997; Daniels and Friedman, 1999; Davidson and

Anderton, 2000; Heitgerd and Lee, 2003), health inequality (Duncan, Jones, and Moon, 1993; LeClere, Rogers, and Peters 1997, 1998; Roberts, 1998; Yen and Kaplan, 1999; Browning, Cagney, and Wen, 2003; Morenoff 2003), welfare policy (DeJong et al., 2006), access to abortion and family planning services (Matthews, Ribar, Wilhelm, 1997; Lichter, McLaughlin, Ribar, 1998), access to health services (Rushton 1999; Jordan et al., 2004;), adolescent risk taking behaviors (Browning et al., 2004, 2005); crime (Block, Dabdoub, and Fregley 1995; Morenoff and Sampson, 1997; Sampson, Raudenbush, and Earls, 1997; Bowers and Hirchfield 1999; Messner et al., 1999; Anselin et al., 2000; Morenoff, Sampson, and Raudenbush, 2001; Baller et al., 2001), and alcohol research (Wieczorek and Hanson, 1997; Scribner, Cohen, and Farley, 1998; Gorman et al., 2001; Treno et al., 2001). A spatial perspective and the adoption of spatial analysis in public health and epidemiology grew rapidly during the 1990s (Clarke, McLafferty, and Tempalski, 1996; Rushton and Armstrong, 1998; Richards et al., 1999; Richards and Croner, 1999; Rushton, 2000, 2003; Albert, Gesler, and Levergood, 2000; Cromley and McLafferty, 2002; Richards, Pickle, and Rushton, 2006). Two areas of public health significance that have seen rapid growth in the use of GIS, geospatial databases and spatial analysis include physical activity (PA) research and studies of food environments. In the PA and food environments studies geospatial data sets have been used to create objective measures of the physical environment such as walkability (Sallis and Owen, 2002; Saelens et al., 2003) and built retail environments such as the density of fast food outlets and/or grocery stores (Morland et al., 2002; Block, Scribner, and DeSalvo 2004; Moore and Diez Roux, 2006; Austin et al., 2005; and, Zenk et al., 2005).

Many of the studies listed in the paragraphs above draw upon specific geospatial data sets, utilize non-census data/units of analysis (as well as census data/units), and adopt spatial analytical methods from overlay, buffering and spatial joins (for building databases and descriptive analysis) but only a relatively small number have adopted more advanced geostatistics and point pattern analysis (e.g., Austin et al., 2005) and spatial regression and related techniques (e.g., Morenoff, 2003; Browning et al., 2003, Voss et al., 2006). The unmet need for analysis in these substantive research areas (identified above), to be based on the kinds of advanced spatial analysis techniques such as the ones we propose, is very high indeed.

B.3. Existing Spatial Analysis Training Opportunities and Resources for Population Scientists

B.3.a. University Sector

Menken, Blanc, and Lloyd (2002) in a recent review of training and support for population scientists state "the broadening of the field has also necessitated the acquisition of additional skills and familiarity with the concepts and tools of related disciplines." Advanced spatial analysis is one such area. Despite the facts that there are approximately 70 U.S. academic institutions that are fee-paying members of the University Consortium for Geographic Information Science (UCGIS), that the number of GIS-related courses at the undergraduate and graduate level is growing, that the number of on-line GIS certificate and Masters programs has grown, and that model GIS curricula have been developed (by UCGIS in 2006), the actual number of formal training programs offering courses on advanced spatial analysis techniques - such as spatial regression modeling and spatial pattern analysis – that are tailored towards population science applications are very few; these include but are not limited to courses offered by Paul Voss at Wisconsin, Katherine White at Brown, and Stephen Matthews at Penn State. There is no question that GIS and spatial analysis capacity has emerged in the last decade at several member institutions of the Association of Population Centers; namely but not limited to the Carolina Population Center, Penn State's Population Research Institute, Wisconsin's Center for Demography and Ecology via the Applied Population Laboratory, the Minnesota Population Center, and Brown University's Population Studies and Training Center coupled with John Logan's Spatial Structures in the Social Sciences (S4) initiative. However, although research capacity can provide training opportunities for research assistants this does not always translate into advanced spatial analysis instruction tailored to demographers. The training environment facing graduate students at non-APC centers and in demography-related disciplines across all U.S. academic institutions is perhaps one that is less likely to focus on advanced spatial analysis methods. The latest edition of the American Sociological Association's *Syllabi and Instructional Material in Demography* edited by Nees and Bass (2003) does include a simple undergraduate exercise using GIS but does not include graduate-level courses that emphasize advanced spatial analysis techniques (though one graduate course includes a week on GIS and mapping).

B.3.b. Commercial Sector

The leading GIS/spatial analysis companies do offer regular workshops and even online resources based on their products (see for example ESRI (ArcGIS vendor) http://training.esri.com). These vendor courses vary widely in content, focus primarily on the product rather than necessarily the application, cover applications that are frequently tailored to the commercial use of the software, and also of importance to our target audience are not priced for the education market and can retail at around $500/day. Moreover, vendor training opportunities are rarely targeted towards population science research questions and applications. However, though GIS software packages increasingly include advanced spatial analysis tools (e.g., the recent development of ArcGIS Geostatistical Analyst and the integration of some spatial autocorrelation and hot-spot functions in ArcGIS 9.x) the salient methodological developments in advanced spatial statistics have been by individuals or teams of investigators that have developed their own code for specialized routines or their own packages (Rey and Anselin, 2006). Increasingly these packages are freely available for download and open source, or are very moderately priced for the academic. Examples are the continual development of analysis routines written for R (see Bivand, 2006), the GeoDa package developed by Luc Anselin (Anselin, 2006), STARS developed by Sergio Rey (Rey & Janikas, 2006) and packages such as Geographically Weighted Regression developed by Stewart Fotheringham, Chris Brunsdon, and Martin Charlton (Fotheringham et al, 2002). Although some open source packages are accompanied by good documentation (e.g., CrimeStat, GeoDa) this is not always the case providing barriers to use for beginnings. While GeoDa's support documentation demonstrates how ESDA and spatial regression models can be implemented, the workbook is somewhat limited in the technical aspects of spatial regression modeling. In defense of GeoDa, the package is supported by a team of experts led by Anselin and a diverse array of valuable resources can be found on the web, including an active discussion group. Some packages are supported by workshop opportunities (e.g., GeoDa) but these can often be prohibitively expensive for early-career scientists (the registration cost for two 4-day spatial econometric modeling related workshops being offered by Dr. Anselin in 2007 is $1,200 and $1,500).

B.3.c. Textbook Market

A final component of the current training opportunities is the textbook market. The best word to describe this market in terms of coverage of spatial analysis is bifurcated (see also the suggested reading sections of Geospatial Analysis by de Smith, Goodchild, and Longley (2007)). That is at one end of the spectrum there are numerous introductory textbooks on GIS (100+) and in recent years several workbooks have also emerged (e.g., Gorr and Kurland (2005) and Price (2005)) as well as the vendor workbooks such as that by Ormley et al. (2004) and guides such as those by Mitchell (1999 and 2005). In these GIS textbooks and workbooks the treatment of spatial analysis beyond cartography, spatial querying, overlay, and buffer analysis is either non-existent or minimal. That is, these workbooks provide limited coverage of advanced spatial analysis tools and spatial statistical methods, even for those functions/tools available within ArcGIS. It should be added that these textbooks typically offer up a sanitized GIS experience unlike the real world. At the other end of the spatial analysis textbook market there are several advanced spatial statistics texts; Cressie's (1991) classic text on *Statistics for Spatial Data* immediately comes to mind. In addition there are several spatial econometric texts (Anselin, 1988) or edited collections (Anselin and Florax 1995, Anselin et al., 2004, and Getis et al., 2004). Complete bifurcation would be an exaggeration as there are a few high-end/intermediate texts (Haining, 1990 and 2003) and primers (Fotheringham et al., 2002) as well as geographic/spatial analysis texts that provide more coverage of advanced techniques than the GIS-oriented texts; good examples of this latter group include the books on *Interactive Spatial Data Analysis* by Bailey and Gatrell (1996), *Geographic Information Analysis* by O'Sullivan and Unwin (2002), *Statistical Analysis of Geographic Information with ArcView GIS and ArcGIS* by Wong and Lee (2005), *Quantitative Geography* by Fotheringham, Brunsdon and Charlton (2000), and in a more focused application the book on *GIS and Public Health* by Cromley and McLafferty (2002). Within standard demography texts, the treatment afforded spatial analysis is scant to say the least with John Weeks' *Population* a rare exception providing several pages of coverage to GIS, geospatial data, and spatial analysis. Currently no specialist text on what one may regard as "spatial demography" exists; though note there have been publications on spatial population analysis (Rees and Wilson, 1977; Woods and Rees, 1986) and multiregional demography (Rogers 1975, 1995).

B.3.d. Journals: Special Issues and Specialist GIS Journals

In recent years a number of population science-related journals have carried special issues focusing on spatial perspectives and spatial analysis (*Social Science History* 2000, 24 (3); *Agricultural Economics* 2002, 27 (3); *Political Analysis* 2002, 10 (3); *Political Geography* 2002, 21 (2); *American Journal of Preventive Medicine* 2006, 30 (2); and *Proceedings of the National Academy of Sciences* 2005, 102 (43)). Similarly, in the near future *Population Research and Policy Review* will dedicate a special issue to “Spatial Demography” (Paul Voss guest editor). In addition, in related fields there have been recent calls for papers for a special issue of *Urban Geography* on spatial segregation (edited by David Wong, Casey Dawkins, and Michael Reibel) and *Children and Youth Services Review* will include a special issue examining how environment affects contributes to the well-being of children and youth that will introduce readers to new analytical approaches involving spatially referenced methods and theory (edited by Bridget Freisthler and David Crampton). These special issues are mostly, but not uniquely, focused on substantive applications rather than on advanced methods such as spatial regression modeling, geographically weighted regression, spatial/multilevel models or spatial pattern analysis. Note that this list above is selective and does not include special issues found in GIS and spatial analysis journals – e.g. *International Journal of Geographical Information Science*, *Journal of Geographical Systems*, *Transactions in GIS* and *Geographical Analysis* that are outlets where one might expect to encounter reports on methodological developments. For example, *Geographical Analysis* (2006, 38 (1)) carried a special issue on ‘Recent Advances in Software for Spatial Analysis in the Social Sciences’ edited by Sergio Rey and Luc Anselin.

B.4. Summary

Although it is possible to find training opportunities and resources to learn advanced spatial analysis methods in the university sector, the commercial sector, and from textbooks, the opportunities are limited, costly, and frequently not targeted towards population science research questions and applications. Thus we perceive a gap in the training of demography graduate students and other population scientists in the application of advanced spatial analysis methods. Our goal is to fill this training gap and to provide population scientists with exposure to advanced spatial analysis methods via a series of 5-day workshops. We have identified four advanced spatial analytic techniques for these workshops: spatial regression modeling, geographically weighted regression, the integration of spatial and multilevel models, and point pattern analysis. As described in Section D we have recruited leading scholars in the development and application of these techniques to be the lead instructors during the initial offering of these workshops (Voss and White on Spatial Regression; Fotheringham, Charlton, and Brunsdon on Geographically Weighted Regression; Jones and Subramanian on spatial and multilevel models; and, Getis, Weeks and Aldstadt on spatial pattern analysis).

One of the key cross-cutting issues identified by the Demographic and Behavioral Science Branch of NICHD is for improved theory, measurement and tools for studying socio-spatial aspects of population processes. The workshop series we propose will cover advanced statistical methods in spatial demography, including the conceptualization and measurement of neighborhood, methods for multi-level modeling and spatial regression, and the application of pattern analysis and spatial statistics to social epidemiology. The workshops will provide an important mechanism for both methodology and technology transfer to early-career population scientists.

C. Preliminary Studies/Progress Report

The advanced spatial analysis workshops extend the GIS training collaboration between Matthews at the Population Research Institute (PRI), Penn State and Goodchild and Janelle at the Center for Spatially Integrated Social Science (CSISS), University of California Santa Barbara. During the summers of 2005 and 2006 PRI and CSISS collaborated to provide standardized, intensive training opportunities on "GIS and Population Science (GISPopSci);" workshops where attendees could learn about spatial perspectives, data, methods, and applications via two-week workshops The primary goal of GISPopSci was to jump-start the adoption and use of spatial methods in population research among a current cohort of early-career population scientists, targeting graduate students at institutions that lacked relevant courses and/or support for GIS within the social sciences, particularly demography and related disciplines. We believe we were successful in our primary goal and provide supporting data on applicants, attendees, as well as workshop participant responses to the 2006 exit surveys (see below and **Appendix B**). The responses to exit survey are almost ubiquitously positive about the workshop experiences at both sites (State College and Santa Barbara), the commitment and availability of the workshop leaders and staff, the quality of the invited speakers, and the comprehensiveness of the supplemental resources that were provided to attendees (namely CDs produced by Stephen Matthews (Penn State) and Waldo Tobler (UCSB) as well as other CDs (e.g., copies of the special issue of *Geographical Analysis* (2006, 38 (1)) on 'Recent Advances in Software for Spatial Analysis in the Social Sciences' edited by Sergio Rey and Luc Anselin)).

In brief, we offered a total of four two-week GISPopSci workshops attended by approximately 100 predominantly early-career population scholars drawn from research institutes and population agencies across the United States. The agenda for the Penn State 2006 GISPopSci workshop is included in **Appendix C**. The agenda for all GISPopSci workshops are available at the project website (http://www.csiss.org/GISPopSci/); note that, while the workshops provided a standardized course, some flexibility was necessary as different in-house (local) and invited (external) speakers were used for each workshop. The GISPopSci workshops included a two-day ESRI-authorized instruction in an *Introduction to ArcGIS* as well as an opportunity to gain basic familiarity with additional selected programs such as Luc Anselin's GeoDa, R, GeoVista *Studio*, *ESTAT*, and *FlowMapper*. On the last day of each workshop the participants each made a presentation based on their own work. These final presentations were attended by the PI and co-PIs, several invited speakers, local faculty and members of the project advisory boards (external attendees at the various workshops including among others, Ernesto Brondizio (Indiana), John Logan (Brown), Linda Lobao (Ohio State), Narayan Sastry (RAND/Michigan), Paul Voss (Wisconsin), John Weeks (San Diego State University)). See **Appendix D** for a listing of all the last-day presentations in 2005 and 2006. At the end of each workshop participants received a certificate of completion for the two-day ESRI training as well as a certificate of completion from GISPopSci.

Several attendees at the GISPopSci 2005 workshops presented papers at the 2006 PAA conference in Los Angeles; there were 19 paper presentations made by the 2005 cohort (n = 47) of GIS and Population Science attendees, of which based on abstracts/papers at least 15 were presentations that used geospatial data and exploratory (ESDA, mapping) and/or confirmatory spatial analytical methods (spatial regression). At least three of the 2005 cohort of GIS and Population Science attendees made a spatial perspective/analysis presentation at the International Union for the Scientific Study of Population (IUSSP) in Tours, France, 2005 (and at least four other 2005 GISPopSci attendees presented non-spatial papers). Several of these conference presentations had their 'first viewing' as the wrap-up presentation on the final day of the 2-week workshops. Although we cannot take credit for individual achievements, we would like to think that the workshops contributed in some small way towards these presentations whether it was in the design of a map, the creative integration of spatial databases, or the use of one of the software packages such as GeoDa for ESDA and/or spatial regression modeling. It is also reassuring to find that our selection procedures identifing early-career population scientists mapped well with organizations such as PAA, IUSSP, and the Population Reference Bureau (PRB); two of the five awardees for the 2006 William and Flora Hewlett Foundation and the Population Reference Bureau two-year dissertation fellowships were attendees of the 2005 GIS Population Science workshops: Ernesto Amaral (UT-Austin) and Tony Ao (Harvard).

Although the GISPopSci training program was successful, it was evident from the 356 completed application forms (i.e., 134 in 2005 and 222 in 2006) that we received for these introductory two-week workshops that there is a significant and growing demand also for advanced spatial analysis training programs. [One of the unfortunate aspects of being a successful training program is that we had to waitlist and/or reject so many applications from deserving early-career scientist. In 2006 we rejected approximately four applications for every invitation to attend. Very few invitees declined and we rarely went more then 1 or 2 slots down on the waitlist for any workshop]. The demand for advanced workshops or short courses providing 3-5 days of focused instruction was echoed by attendees during the GISPopSci workshops (see exit survey Appendix B). In preparing this application we contacted all past GISPopSci attendees via e-mail asking for comments on an initial list of six advanced topics and other suggestions. While not a formal study we were left with little doubt there is high demand for opportunities to become exposed to and immersed in specialized software and programs such as GeoDa (Anselin, Syabri, and Kho, 2006), GWR (Fotheringham, Charlton, and Brunsdon, 2002), R (Bivand, 2006), PPA (Chen and Getis, 1998), and CrimeStat (Levine, 2006) and advanced spatial analysis methods such as spatial regression modeling (Voss, White, and Long, 2006), geographically weighted regression (Fotheringham, Charlton, and Brunsdon, 2002), spatial point pattern analysis (Gatrell et al., 1996), and the integration of spatial and multilevel models (Chaix, Merlo, and Chauvin, 2005). The demand for training opportunities in advanced analytical methods, particularly in methods emerging but not part of traditional demographic training such as advanced spatial analysis methods, is also echoed in the letters from our external advisory board members [Heuveline, Sanders, Voss, and Weeks].

While we selected four advanced methods other topics were referred to by 2005 and 2006 workshop attendees and in the self-statements from the wider applicant pool. These included, but were not limited to agent-based modeling (Epstein and Axtell, 1996; Gimblett 2002) and Bayesian spatial modeling (Banerjee, Carlin, and Gelfand, 2004). Agent-based modeling within demographic studies dates back to Schelling's tipping point and models of segregation (1969, 1971, and 1978), and developments in geovisualization and computation have led to recent attention to agent models in race/ethnic segregation (e.g., Macy and van de Rijt, 2006; Bruch and Mare, 2006). Bayesian spatial modeling is an area of feverish growth with Bayesian inference having a fundamental impact on virtually every statistical methodology (Davis Withers, 2002). The applications of Bayesian methods is perhaps most visible in spatial epidemiology but they are emerging in demographic applications too (see Assunção et al, 2005). CSISS has experience hosting workshops/events on hierarchical modeling including Bayesian methods (2001) and agent based modeling for land use/land cover change (2001) and will host a 3-day event in April 2007 on agent based modeling of complex spatial systems.

We are not proposing agent-based modeling or Bayesian modeling as part of our initial sequence of workshops but any one of these topics, or indeed others, could be recommended by our advisory board during our planned review at the end of the second year. We are starting out with the four advanced spatial analysis methods that are most commonly encountered in the academic literature in general – though not necessarily within population fields – and that we perceive the training need to be greatest (See Section D.2).

D. Research Education Program Plan
D.1. Program Directors
D.1.a. Training Program Coordinators

There are three key personnel: Matthews, Goodchild, and Janelle. Here we include a brief description of their research and instructional accomplishments as they relate to the proposed advanced spatial analysis training program for population scientists. All other faculty and personnel listed elsewhere in this application are instructors, invited presenters, or members of the training project's Advisory Board (i.e., PHS biosketches are not required unless they are classified as key personnel). Brief background sketches on all workshop instructors are included in the specific workshop descriptions in Section D.1.b.

Stephen A. Matthews is an Associate Professor of Sociology, Anthropology and Demography and for the past 11 years the Director of the Geographic Information Analysis Core within the Population Research Institute at Penn State. His interests focus on studies of health inequality and wellbeing among low-income families, race/ethnic segregation, and population and environment interactions. Matthews' current funding includes an NSF methodology grant on measuring spatial segregation (with Sean Reardon, Stanford), an R21 from NIEHS on neighborhood food environments, diet, and health (with Steve Cummins, London) and several collaborations with PRI demography faculty on their funded research and training grants. Matthews coordinated GIS, spatial analysis, and demography workshops at the Population Association of America (PAA) Conference between 1998 and 2003, a CSISS-sponsored workshop on Population Science and GIS in 2003, and served as PI on the R25 submission for the GIS and Population Science series offered in 2005 and 2006. Similarly, he has coordinated GIS workshop sessions and presentations at the Family Research Consortium IV (2004 and 2007) and as part of a capacity-building workshop for tobacco researchers held in Cape Town, South Africa (2004); the latter as part of Dr. Gary King's (Penn State) Fogarty grant. A GIS workshop on Dr. Airhihenbuwa's (PI) Fogarty grant on "Global health and georesource management in Africa" will likely take place in Nigeria before 2009. At Penn State, Matthews teaches a Spatial Demography course in the Dual-title Demography Training Program and has coordinated on-campus workshops developed for postdoctoral trainees attending the Summer Workshop for Minority Partners (1998) and the Family Research Consortium (1999, 2001), and for faculty affiliated with the Children, Youth and Families Consortium at Penn State (1999, 2000). Matthews serves on the advisory board for the on-line Masters in GIS launched at Penn State in 2004. He was the inaugural chair of Penn State's GIS Council (2001-2004), and remains as the College of Liberal Arts representative to the GIS Council. Matthews will be available throughout the Penn State workshops and will visit UCSB during each workshop (once per annum).

Michael F. Goodchild is Professor of Geography at the University of California, Santa Barbara; Director of the Center for Spatially Integrated Social Science; Chair of the Executive Committee of the National Center for Geographic Information and Analysis; and Associate Director of the Alexandria Digital Library. He holds a PhD from McMaster University in geography and a BA from Cambridge University in physics. He was PI for the UCSB subcontract under the R25 submission for the GIS and Population Science workshop series, and has coordinated a total of roughly 30 training workshops in this and other programs. He teaches a sequence of GIS courses at UCSB, and has offered over 30 one-day workshops at conferences. His research interests are in GIS and spatial analysis, with emphasis on uncertainty, interoperability, and data modeling, and with current funding from the National Geospatial-Intelligence Agency, the National Science Foundation, and the US Department of Transportation. He has published over 400 papers and books, including the textbooks *Geospatial Analysis* (2007) with Michael De Smith and Paul Longley, and *Geographic Information Systems and Science* (Second Edition, 2005) with Paul Longley, David Maguire, and David Rhind. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Foreign Fellow of the Royal Society of Canada, and has received honorary degrees from four universities. He will be available throughout the UCSB workshops.

Donald G. Janelle is a Research Professor at the University of California Santa Barbara. He holds Ph.D. and M.A. degrees in geography from Michigan State University and a B.A. in geography from the University of Southwestern Louisiana. He is the PI on an NSF-funded program titled Spatial Perspectives on Analysis for Curriculum Enhancement (SPACE) to encourage spatial analysis in undergraduate teaching in the social sciences. As co-PI on the UCSB subcontract for the GIS and Population Science R25 training program, he directed the development of the website (http://www.csiss.org/GISPopSci) and managed the recruitment of workshop participants. He previously served as Chair of the Geography Department and as Assistant Vice Provost at the University of Western Ontario. He is a former editor of *The Canadian Geographer* (the official journal of the Canadian Association of Geographers) and a recipient of the Edward L. Ullman Award for Career Contributions to Transportation Geography from the Association of American Geographers. His research focuses on the interrelated dynamics of human settlement systems with the human behavioral changes that take place in liaison with evolving technologies in transportation and communication. His publications build on the theme of human response to space-adjusting technologies: space-time analyses of individual behavior, the time-geography of cities, including research on the diurnal shifts in the demographic character of urban areas, the temporal-spatial ordering of social systems, and the role of space-adjusting technologies in structuring new patterns of social and economic organization. He co-edited *Spatially Integrated Social Science* (Oxford University Press, 2004) with Michael Goodchild.

This proposal extends the GIS and population science training collaboration between Matthews, Goodchild, and Janelle. The application is coordinated from the Population Research Institute at Penn State, with a subcontract to CSISS at UC Santa Barbara. The workshop conveners are Dr. Stephen Matthews (Penn State) and Dr. Michael Goodchild (UC Santa Barbara). Matthews and Goodchild are responsible for all aspects of workshop planning and implementation at their specific site. In addition to coordinating Penn State activities, Matthews will take the lead on workshop evaluation issues, coordinating the advisory board review as well as supervising the conversion of materials to web-based instruction. Dr. Don Janelle (Program Director, CSISS) and support staff at CSISS will be responsible for coordination of recruitment for both sites and for project website management. A GIS specialist working with Matthews will facilitate the creation of selected self-paced learning resources based on materials used during the workshops. They will work closely with CSISS staff to provide additional content material for the website. Matthews, Goodchild, and Janelle and their staffs will be proactive in helping advertise and generate materials for a project registry component of the website with a goal to create an important resource for the wider population science community.

D.1.b. Workshop Leaders

The workshops are led by the following individuals (letters of support from the workshop leaders are included)

Spatial Regression

Paul R. Voss is Professor Emeriti of Rural Sociology at the University of Wisconsin-Madison and a Demographic Specialist with the University of Wisconsin's Division of Cooperative Extension. He also holds a demographic research affiliation of the Wisconsin Applied Population Laboratory and is an affiliate of the Wisconsin Center for Demography and Ecology. He received his Ph.D. in sociology/demography from the University of Michigan in 1975 and has specialized for most of his professional career in modeling the processes of demographic change in small geographic areas, with particular emphasis on estimation and forecasting. Over the past decade, Dr. Voss has turned his attention to the proper specification and estimation of regression models when analyzing geographically referenced data. He teaches a graduate seminar in spatial data analysis for social scientists and is chair of the oversight committee of the Geographic Information and Analysis Core for the Wisconsin Center for Demography and Ecology. Together with Katherine White he has led 5-day workshops on spatial regression techniques in the U.S. and Europe. More information about Voss is available at: http://www.drs.wisc.edu/people/faculty/voss/voss.htm.

Katherine White is currently Assistant Professor of Sociology at Brown University and is affiliated with the Spatial Structures in the Social Sciences (S4) initiative and the Population Studies and Training Center. After earning a Ph.D. in sociology from the University of Washington, she pursued training in spatial methods of analysis at the University of Wisconsin Center for Demography and Ecology (where she was mentored by Dr. Paul Voss). Dr. White's research has focused on the divergent experiences of African American and white women and men who participated in the Great Migration of the early twentieth century. She has also examined the correlates of demographic changes in the U.S. Great Plains over the past century. Dr.

White's recent research addresses the population redistribution and inequality that resulted from the U.S.-led economic shift in early twentieth-century Puerto Rican agriculture, the emergence and persistence of the spatial distribution of U.S. child poverty, and the nature and consequences of the Return Migration of the later twentieth century. She pursues these areas of interest using advanced methods of spatial analysis. Dr. White teaches a graduate-level seminar on spatial data analysis techniques for the social sciences. Dr. White teaches courses in undergraduate research methods, and graduate level courses on Poverty as Social Inequality, as well as Spatial Data Analysis Techniques in the Social Sciences. Her teaching interests also include historical migration patterns in the U.S. and statistical methods of analysis. She has co-taught 5-day spatial regression workshops with Voss, including the summer statistical program at the ICSPR (2006 & 2007) and a scheduled workshop at the Odum Institute for Research in Social Science at the University of North Carolina, Chapel Hill (2007) and taught at the S4 GIS Winter Institute at Brown University (2007). More information about White is available at: http://www.brown.edu/Departments/Sociology/faculty/kwhite/.

Geographically Weighted Regression

A. Stewart Fotheringham is Science Foundation Ireland Research Professor and Director of the National Centre for Geocomputation at the National University of Ireland, Maynooth. He has previously held positions at the University of Newcastle (U.K.), SUNY Buffalo, the University of Florida, and Indiana University. He obtained his Ph.D. and MA degrees in Geography at McMaster University in Canada and his BSc in Geography at Aberdeen University in Scotland. Professor Fotheringham's research interests are in the analysis of spatial data and he has published eight books, including the classic text on geographically weighted regression (Fotheringham, Brunsdon, and Charlton, 2002), and 100+ articles. He is an editor of *Transactions in GIS* and has grants totaling over $5 million. He has conducted GWR workshops in 10 countries and on four continents. More information about Fotheringham is available at: *http://ncg.nuim.ie/ncg/people/staff/fotheringham/index.shtml.*

Martin Charlton is senior research associate at the National Center for Geocomputation at the National University of Ireland, Maynooth. He is an expert in the use of GIS and spatial statistics and has been a leading researcher in this area for over 20 years. He previously was a lecturer in GIS at the University of Newcastle, U.K. Charlton, together with Fotheringham and Brunsdon, is one of the originators of geographically weighted regression, for which he has written much of the software (including versions of the GWR software that run under UNIX and code for GWR in R). More information about Charlton is available at: http://ncg.nuim.ie/ncg/people/staff/charlton/index.shtml.

Chris Brunsdon is Professor and Chair of Geographic Information in the Department of Geography at the University of Leicester, U.K. Prior to his current appointment he was Reader in Spatial Analysis at the University of Newcastle, U.K., and Professor in the School of Computing at the University of Glamorgan, U.K.. His primary interests include the methodologies underlying spatial statistical analysis and geographical information systems, and their application in a number of subject areas; in particular the analysis of crime patterns, house prices and health-related data. He has published extensively in the areas of spatial analysis and visualization as well as co-authoring two books with Fotheringham and Charlton. He is one of the developers of geographically weighted regression, a technique of analysis that models geographical variations in the relationships between variables. Brunsdon has written code for GWR in R. He has co-presented in a number of workshops on GWR as well as R. He has successfully obtained a number of grants in the U.K. from the Economic and Social Research Council and the Home Office. As well as interests in the spatial analysis of social data, he has worked on GIS and spatial analysis of environmental data (the analysis of rainfall, hydrology and luminescence data). More information about Brunsdon is available at: *http://www.le.ac.uk/geography/staff/academic_brunsdon.html*.

Spatial Point Pattern Analysis

Arthur (Art) Getis is Distinguished Professor of Geography Emeritus at San Diego State University. He holds BS and MS degrees in Geography from The Pennsylvania State University and a Ph.D. in Geography from the

University of Washington. Getis has published widely in a range of geography, regional science, and epidemiology journals and his text (with J. Getis and J.D. Fellmann), *Introduction to Geography*, now in its 11th edition, is the best-selling text in the introductory field of geography. He has produced over 100 refereed papers and seven books. With the statistician, J.K.Ord, his work on local statistics is well known throughout the world. His research in spatial analysis and infectious diseases has been funded by the National Science Foundation and the National Institutes of Health. Dr. Getis' program of research develops new spatial analytic devices and applications in a number of fields chief among them is the transmission of infectious diseases and the spatial variability of health. He is editor-in-chief of the *Journal of Geographical Systems*. Dr. Getis has considerable experience with workshops, having been the leader of the five summer CSISS workshops entitled "An Introduction to Spatial Pattern Analysis in a GIS Environment." In addition, he has led workshops at the University of Massachusetts Medical Center, San Diego State University, and at the University of Costa Rica. More information about Getis is available at: http://geography.sdsu.edu/People/Faculty/getis.html.

John Weeks is Professor of Geography and Director of the International Population Center at San Diego State University. He is also Clinical Professor of Family and Preventive Medicine at the University of California, San Diego. He holds an AB degree in Sociology, an MA in Demography, and a Ph.D. in Demography, all from the University of California Berkeley. Weeks has published widely in a range of social science journals and his text on Population, now in its 9th edition, is the best-selling text in the field of demography. His research on geodemographics has been funded by the Andrew Mellon Foundation, the National Science Foundation and currently the National Institute of Child Health and Human Development. This program of research investigates the application of remote sensing, GIS, and spatial statistics to issues of spatial variability in health. He is also a Co-Principal Investigator on a NASA REASoN project titled A Border Security Decision Support System Driven by Remotely Sensed Data Inputs (Douglas Stow, PI), and Co-PI on an National Cancer Institute project, Multi-level Assessment of Indoor Tanning Practices (Joni Mayer, PI). Dr. Weeks has considerable experience with workshops, having been an instructor for five summers in the CSISS workshops on "An Introduction to Spatial Pattern Analysis in a GIS Environment," and for the past two years as a presenter in the GIS and Population Science workshops. Weeks also co-coordinated (with colleague Arthur Getis) a very successful SPACE (Spatial Perspectives on Analysis for Curriculum Enhancement) workshop, funded by NSF through UCGIS, at San Diego State University during the summer of 2004. More information about Weeks is available at: http://geography.sdsu.edu/People/Faculty/weeks.html.

Jared Aldstadt is Assistant Professor of Geography at the University at Buffalo. His research focus is spatial analysis applied to human health. Jared has received both NSF and NIH funding for his research on dengue fever transmission. He has been an instructor of previous CSISS workshops on spatial pattern analysis in a GIS environment and he developed laboratory materials for a Spatial Perspectives on Analysis for Curriculum Enhancement (SPACE) workshop. In 2004 Jared was a laboratory instructor at The Vespucci Initiative for the Advancement of Geographic Information Science's Summer Institute in Florence, Italy. More information about Aldstadt is available at: http://www.geog.buffalo.edu/people/.

Multilevel and Spatial Modeling

Kelvyn Jones is Professor of Geography, Head of School, and Director of the Learning Environment for Multilevel Methodology and Applications (LEMMA), the National Center for Research Methods (http://www.cmm.bristol.ac.uk/research/Lemma/index.shtml) based at the University of Bristol, U.K. He has held a Nuffield Social Science Fellowship for investigating multilevel modeling. He teaches research design, quantitative techniques, and the geography of health. His major substantial research interest is analyzing the geographies of morbidity and mortality with particular emphasis on applying and developing the methodology of multilevel models. In addition, he has studied multilevel perspectives on modeling census data and neighborhood effects in studies of income dynamics and voting behavior. His publications include *Health, Disease, and Society* (Jones and Moon, 1987), *Epidemiology: An Introduction* (Moon et al., 2000), and numerous articles in journals such as the *Journal of the Royal Statistical Society-Series A*, *Social Science and Medicine*, *American Journal of Epidemiology*, *British Medical Journal*, *Geographical Analysis*, *British Journal of Political Science*, *Environment and Planning*. He has taught multilevel workshops in both North America and Europe, including over a decade of involvement in the Essex summer school in the U.K. Jones and

Subramanian co-developed a training manual to assist researchers in the concept and application of multilevel models using the MLwiN program. More information about Jones is available at: http://www.ggy.bris.ac.uk/staff/staff_jones_kelvyn.html.

S.V. (Subu) Subramanian is Assistant Professor at the Department of Society, Human Development and Health, School of Public Health, Harvard University. He has a Ph.D. in geography with specialization in multilevel statistical methods and a Masters in development studies from the University of Delhi. In 1999-2000 Subu was the recipient of the 1999-2000 MacArthur Leadership Program in Population and Development Studies based at the Harvard Center for Population and Development Studies. The main focus of his research is on understanding how different contextual settings influence individual health outcomes and population disparities in health achievements. He has specifically investigated the impact of income inequality and social capital on individual health outcomes. His work has demonstrated the need to explicitly consider a multilevel methodological framework while conceptualizing and estimating contextual effects on public health issues. Currently, through a NIH/National Heart, Lung, Blood Institute Career Development Award, he is investigating the role of neighborhood-level factors (neighborhood structural disadvantage, collective psychosocial characteristics, and physical environmental conditions) in explaining the occurrence and distribution of asthma. Subu has published over 85 journal articles, book chapters, books, and working papers. He is an Assistant Editor for *Social Science and Medicine*, Editorial Consultant to *The Lancet*, Member of the Editorial Board for *Health and Place*, and BMC Public Health, and Book Review Editor for *Economics and Human Biology*. He has lectured and conducted workshops on the concept and practical applications of multilevel models in ten countries. More information about Subramanian is available at: http://www.hsph.harvard.edu/faculty/SVSubramanian.html.

D.1.c. Advisory Board

PRI, CSISS, and the GISPopSci training program have been well served by advisory boards. The GISPopSci advisory board included both demographers and GIScience faculty from the two institutions as well as external members. The composition of the advisory board helped ensure that the material included in the workshops was tailored to the application of GIS to demographic issues, theory, data, and methods. We have revised the membership of the advisory board to reflect changes in personnel and the new goals focusing on advanced methods. The advisory board will be used in several capacities, including but not limited to providing guidance and review of both the training resources (workshop and web-based) and workshop evaluation materials, and the advertising the workshops to help maximize our recruitment from underrepresented minorities and women.

Internal members at Penn State include Nancy Landale (Professor of Sociology and Demography, Director of the Population Research Institute), Gordon DeJong (Distinguished Professor of Sociology and Demography and Director of the Graduate Training Program in Demography), and Francis Dodoo (College of Liberal Arts Research Professor and Professor of Sociology and Demography at Penn State and Director of the Regional Institute for Population Studies (RIPS), University of Ghana). Drs. Landale, DeJong, and Dodoo are NIH grant-active faculty, have a strong commitment to training in demography, and serve on PRI's advisory board. Dr. DeJong served on the first GISPopSci advisory board. Dr. Landale replaces Dr. Leif Jensen (previous PRI Director) on the advisory board and Dr. Dodoo is a new addition to the board; he will provide an emphasis on international demography (More information about Landale, DeJong, and Dodoo is available at http://cairo.pop.psu.edu/CtrPRI/DirList.cfm).

Internal members at UCSB include Barbara Herr Harthorn (Research Anthropologist, Associate Professor of Women's Studies, and co- Director of the Center for Nanotechnology in Society), Helen Couclelis (Professor of Geography), and Peter Kuhn (Professor of Economics). Harthorn, Couclelis, and Kuhn all are members of the CSISS executive committee and they all served on the GISPopSci advisory board (More information about Harthorn, Couclelis, and Khun is available at http://www.csiss.org/aboutus/personnel/executive.htm).

External members. There are four external advisory board members: Patrick Heuveline, Professor of Sociology and Research Associate at the Population Research Center at NORC/University of Chicago, University of Chicago (http://sociology.uchicago.edu/faculty/heuveline.html), Seth Saunders, Professor of

Economics and Director of the Maryland Population Research Center, University of Maryland (http://www.popcenter.umd.edu/people/sanders_seth/), Paul Voss (Professor Emeriti Rural Sociology, Center for Demography and Ecology, University of Wisconsin), and John Weeks (Professor of Geography and Director, International Population Center, San Diego State University). Both Voss and Weeks were external advisors to the earlier GIS and Population Science Training Program. Although they are among the lead presenters in two of the proposed workshops we believe their continued involvement in an advisory capacity strengthens the 'demography' of the advisory board. Letters of support from the external advisory board members are included in the application.

D.2. Proposed Research Education Program

To address some of the issues raised in Section B, we propose to conduct a 5-year program aimed at reaching a substantial portion of the current cohort of early-career researchers in demography and population research. The program will consist of two residential workshops per annum for the first four years, 2008-2011 (typically held during the summer), augmented by extensive Web resources specific to the advanced spatial analysis methods to be covered. Over the first four years we anticipate offering eight workshops to a total of up to 50 researchers in each of the four specific advanced spatial analysis methods, up to 200 individuals in all. Given our past experience with GIS and spatial analysis workshops at both PRI and CSISS, we will offer high-quality workshops led by eminent researchers, include guest speakers, provide opportunities for participants to work with their own data, support the interaction of presenters and attendees, and foster peer-to-peer collaboration among attendees through small-group discussions and attendee presentations.

The workshops will typically combine morning lectures (theoretical and conceptual underpinnings) and afternoon computing-lab sessions (hands-on exercises/applications). Time will be set aside for individual consultations and group discussion. Workshop materials will include supplemental readings, data and exercises available on-line to workshop attendees. These resources will provide greater detail on the topics covered in the lecture/lab components and provide a point of return for review and deeper understanding of the topics covered as well as a source of references for further reading. The lab exercises will be guided by written, step-by-step tutorial instructions so that they can be repeated (and more fully absorbed) at a later time.

In all workshops GIS and mapping software will be used though the focus of these workshops is on spatial analysis, not geographic information systems (GIS). ArcGIS will be used as the standard GIS software but the workshops will include the use of GeoDa, R, GWR3, PPA, ClusterSeer, and MLwiN among other statistical packages. We expect applicants to have a solid grounding in standard multivariate regression techniques and be comfortable with matrix notation and algebra, and will assess their experience and abilities in these areas (and other skill sets and concept familiarities) as part of the application process.

The remainder of this section briefly describes each of the four workshops and the website development.

D.2.a. Spatial Regression Modeling

Lead presenters: Paul Voss (Wisconsin) and Katherine White (Brown)

The goal of this five-day workshop is to provide an overview of applied spatial regression analysis (spatial econometrics) that will enable participants to effectively incorporate these tools into their own empirical research. This course will introduce the broader field of spatial data analysis and the range of issues that generally must be dealt with when analyzing georeferenced data. Census-type data are among the most commonly encountered data that conform to this description, although the course acknowledges the wider range of data appropriate for spatial regression analysis.

This workshop will address the following questions: how does spatial autocorrelation arise; how is it measured and understood; how does it relate to issues of spatial heterogeneity and spatial dependence; and how should it inform the specification and estimation of regression models. The course is structured around a combined lecture format (mornings) and computing lab exercises (afternoons). Although we will use mapping software, the focus of the course is on spatial analysis, not geographic information systems (GIS). Software emphasis will be given to GeoDa and R for exploratory spatial data analysis (ESDA) and spatial regression modeling. Some acquaintance with this software is helpful but is not a prerequisite. Prerequisites for maximizing learning in this course are a solid grounding in standard multivariate regression techniques and a minimal level of comfort with matrix notation and algebra.

Exploratory spatial data analysis and spatial regression approaches are beginning to appear in population-related research (Voss, White and Hammer, 2006; Voss, White and Long, 2006). Recent methodological papers and applications of exploratory spatial data analysis include Frank (2003) that used spatial autocorrelation and ESDA to describe and compare socioeconomic and racial residential patterns in U.S. urban areas and looks at global and local spatial indices. Several papers by Sampson, Morenoff, and colleagues have all explored and documented the contribution of spatial regression applications in The Project on Human Development in Chicago Neighborhoods (PHDCN) (see Morenoff and Sampson, 1997; Sampson, Raudenbush, and Earls, 1997; Morenoff, Sampson, and Raudenbush, 2001; Morenoff, 2003). As Browning et al. (2003, p. 1227) observe, "An often-overlooked consideration in analyses of neighborhood or community phenomena is the spatial context of the study area … Moreover, neighborhoods with similar characteristics tend to cluster together—a phenomenon that may indicate spatially based dependencies. Among causes of spatial dependency are incorrect specification of the boundaries of areal units and, perhaps more importantly, the presence of spill-over effects or spatial externalities between jurisdictions (Anselin, 1988)." In macro-level crime research Messner et al. (1999) find evidence of strong positive spatial autocorrelation of homicide rates and that some of the relations between homicide and its covariates are not stable across space and, in a related paper, Baller et al. (2001) reexamine the impact of conventional structural covariates on homicide rates and explicitly model spatial effects.

In a recent paper, Voss, Long, Hammer, and Friedman (2006) provide a demonstration that should convince demographers and social scientists to examine spatial autocorrelation in their data and to explicitly correct for spatial externalities on variables that are spatially referenced. The authors apply ESDA and spatial regression analysis to examine inter-county variation in poverty rates based on an earlier study by Friedman and Lichter (1998). They find that explicit acknowledgement of spatial effects in an explanatory regression model improves considerably the earlier published results; including the shifting of "wrong sign" parameters, a reduction in the residual squared error, and the elimination of any substantive residual spatial autocorrelation. Substantively, the analysis improves estimates of the joint effects of place-influences and family-influences on child poverty. Other recent methodological papers and applications of spatial regression include Anselin and Le Gallo (2006) on the sensitivity of hedonic models of house price to the spatial interpolation of measures of air quality in Southern California. They observed a high degree of residual spatial autocorrelation warranting the inclusion of a spatially lagged dependent variable in their regression models. DeJong et al. (2006) used spatial regression models to look at spatial dependence and diffusion in state welfare policies. Beck et al. (2006) used spatial econometrics in a study of political economy, with the twist that they used alternative measures of distance based on trade and common dyad memberships between countries to look at the distribution of democracy across the globe.

D.2.b. Geographically Weighted Regression

Lead presenters: A. Stewart Fotheringham, Martin Charlton (both of the National University of Ireland, Maynooth, Ireland), and Chris Brunsdon (University of Leicester, U.K.).

The goal of this workshop is to introduce a new modeling technique for local spatial analysis; geographically weighted regression. This technique allows local, as opposed to global spatial models to be calibrated and interesting variations in relationships to be measured and mapped. Fotheringham, Charlton, and Brunsdon are the pioneers in this field (Fotheringham, Charlton, and Brunsdon, 2002) and developers of the package GWR (current release is Version 3) and they will be the lead presenters for the Geographically Weighted Regression Workshops. The GWR website (http://ncg.nuim.ie/ncg/GWR/) provides a brief primer on GWR, recent references, and details about acquiring the GWR software.

The standard procedure in the vast majority of empirical analyses of spatial data is either to calculate a global statistic or to calibrate a global model. The term ‘global’ implies that all the spatial data are used to compute a single statistic that is essentially an average of the conditions that exist throughout the study area in which the data have been measured. Such a procedure is flawed when the relationships being measured vary over space. Geographically Weighted Regression (GWR) is a statistical technique that allows variations in relationships over space to be measured within a single modeling framework. The output from GWR is a set of surfaces that can be mapped and measured, where each surface depicts the spatial variation of a relationship. The technique is based on regular regression modeling but can be extended in many different ways. It provides a great richness in the results obtained for any spatial data set and should be useful across all disciplines in which spatial data are used. This modeling approach challenges many of the global statements of spatial relationships that have been made in the academic literature.

Recent methodological papers and applications of GWR include studies of the analysis of health disparities (Goovaerts, 2005), environmental equity (Mennis and Jordan, 2005), housing markets (Fotheringham et al., 2002; Yu and Wei, forthcoming), population density and housing (Mennis, 2006), US poverty (Partridge and Rickman, 2005), poverty mapping in Malawi (Benson et al., 2005), urban poverty (Longley and Tobon, 2004), demography and religion (Jordan, 2006), regional industrialization and development (Huang and Leung, 2002; Yu, 2006), traffic models (Zhao and Park, 2004), the Irish famine (Gregory and Ell, 2005) and voting (Calvo and Escolar, 2003).

The workshop will be a mix of lectures and practical, computer-based sessions. Topics to be covered include local statistics and local models, the basics of GWR with examples, statistical inference and GWR, GWR and spatial autocorrelation, extensions to the basic GWR framework and concept, applications of specialized GWR software, and visualizing the output in ArcGIS. Exercises will be provided to participants but they will also be expected to bring their own spatial data set for experimentation with GWR. Participants will present the results of their GWR analyses on their own data sets at the conclusion of the course.

D.2.c. Spatial Pattern Analysis

Lead presenters: Art Getis, John Weeks (both at San Diego State University) and Jared Aldstadt (SUNY Buffalo)

This workshop focuses on applications of spatial pattern analysis in a geographic information systems environment. The workshop will feature a series of lectures on spatial pattern analysis, exercises demonstrating the principles outlined in the lectures, and data exploration based on current projects concerned with spatial patterns relating to various demographic, behavioral, and economic phenomena. Lectures will emphasize the fundamental principles and examples of the use of spatial pattern analysis for the help it gives toward the solution of important societal questions. Demonstrating concepts covered in the lectures, exercises will utilize a variety of software tools including ArcGIS 9.x, Point Pattern Analysis, and ClusterSeer software among others. The data exploration portion of the workshop will consist of GIS-based analyses of spatial data drawing on studies of crime within an urban environment (Getis), the spread of infectious diseases such as dengue fever in the tropics (Aldstadt), and the diffusion of fertility decline in a third-world setting (Weeks).

As noted in Section B.1, the main approaches to spatial pattern analysis include exploratory spatial data analysis (ESDA), spatial statistics, geostatistics, and spatial econometrics. This workshop will cover each of these four areas with an emphasis on spatial point pattern analysis and geostatistics. Recent applications of spatial pattern analysis techniques in the social sciences include the use of kriging and the use of local statistics of spatial association (the G* statistic (Getis and Ord, 1992; Ord and Getis, 1995)) to study malaria transmission in the Brazilian Amazon (Singer and Castro, 2001; Castro et al., 2006). The G* statistic has been used in a wide variety of fields particularly epidemiology (Burra et al, 2002; Jeffery et al. 2002, Wu et al. 2004) and crime (Craglia, Haining, and Wiles, 2000; Ratcliffe and McCullagh, 1999, 2001; Ceccato, Haining, and Signoretta, 2002). There have also been applications to labor markets (Ceccato and Persson, 2002). In a very different kind of study of food environments in Chicago, Austin et al. (2005) use bivariate K function statistical methods to quantify the degree of clustering (spatial dependence) of fast-food restaurants around school locations. They find fast-food restaurants cluster within a short-walking distance of schools, exposing children to poor-quality food environments in their school neighborhoods.

D.2.d. Multilevel and Spatial Modeling

Lead presenters: Kelvyn Jones (University of Bristol, U.K.) and S.V. (Subu) Subramanian (Harvard University)

This five-day workshop is designed to give participants a training experience in the concepts and applications of multilevel statistical modeling, particularly in a spatial and demographic context. More specifically the workshop has five major objectives: (1) the discussion of hierarchical & non- hierarchical structures in terms of unit diagrams and classification diagrams, participants are thereby introduced *conceptually* to a very broad range of designs (*e.g.*, panel, repeated cross-sectional, multivariate, multistage survey, and spatial designs); (2) a thorough consideration of normal theory two-level models; (3) an appreciation of more advanced topics (3-levels structures, multilevel logit models, estimation (including maximum likelihood estimators [(R)IGLS] as well as MCMC); properties of shrinkage estimates; (4) the use of specialist *MLwiN* software; and (5), the application of multilevel modeling to a social science research problem. Throughout there is a strong emphasis on interpretation, not technical facility *per se.* To gain the most from this workshop it is expected that participants would have prior experience of linear regression modeling, analysis of variance, statistical significance testing, and familiarity with a Windows environment.

On completion of the workshop students will be able to: recognize a research problem requiring multilevel modeling, outline the technical and substantive advantages of multilevel models in comparison to single-level models, distinguish between fixed and random effects, read and evaluate research papers that apply multilevel models, make the case for adopting an explicit modeling approach to heterogeneity and data dependencies whether these arise from population structures and/or multistage sampling, explain the concepts of: cross-level interactions, variance functions, impact heterogeneity, autocorrelation, design effect, and shrinkage estimates, specify, estimate and interpret 2 level normal-theory linear models which contain both categorical and continuous predictors and predictor variables at each level; interpret the results from a multilevel logit model in terms of odds and probabilities, including differences between subject specific and population average models, develop proficiency in the *MLwiN* software package so as to meaningfully estimate, evaluate and test a range of models, and apply multilevel models to a research problem according to a well-articulated research strategy.

For this workshop we envision at least one guest speaker to discuss the integration of spatial and multilevel modeling frameworks. We have approached Basil Chaix of the Research Unit in Epidemiology, Information Systems, and Modelisation (INSERM U707) at the National Institute for Health and Medical Research, Pierre & Marie Curie University, Paris, and he has agreed to participate in these workshops (see letter of support). Chaix has worked with Dr. Subramanian (Chaix et al. 2005).

D.2.e. Web Resources

The CSISS main webpage (http://www.csiss.org/), the GISPopSci webpage (http://www.csiss.org/GISPopSci/), and PRI's Geographic Information Analysis Core webpage (http://www.pop.psu.edu/gia-core/) all have a long standing commitment to provide access to materials and resources for social scientists and demographers who have an interest in spatial techniques, including GIS and spatial analysis. The CSISS site is one of the most comprehensive in the social sciences providing information on learning resources, spatial resources, spatial tools, events, and literature searches. GISPopSci and PRI-GIA Core websites are tailored more specifically to population scientists, the former containing sections on learning resources (including access to bibliographies, book listings, CSISS Classics, GIS Cookbook (introductory exercises), and selected readings) and research (including information on spatial analysis tools, population science-related tools, spatial demography links, and project and event registries). The PRI-GIA Core website contains additional spatial demography resources including but not limited to approximately 70 2-page 'resource documents' that provide short overviews of specific geospatial data resources, applications, methods, and software.

Throughout the timeframe of the grant, Matthews will work with all instructors and invited speakers to provide materials that can be posted on a public website and where relevant and permissible to develop complementary self-paced learning modules and/or short exercises that can be delivered through the Internet. Matthews will work with a GIS analyst and graduate students assigned to the GIA Core at PRI to develop web-pages containing key links to other resources specific to the content of each workshop. That is, we envision a set of on-line training resources that will be made available to the population science community at large.

Matthews and Janelle will encourage all workshop participants to generate materials that become part of the project website, specifically as part of the 'project registry' section. Examples of a project registry might range from a short narrative description of a workshop participant's research project to link to a PDF of a conference presentation or publication to a link to an off-site project webpage. Over time, the content of a participant's project registry will be updated as projects evolve/mature. We envision these project registries as being one way in which we can contribute to building up a core research community in the area of spatial demography. Moreover, we anticipate that many of the entries in the project registries will be generated by population scholars at large not just by attendees at the workshops. We have had some success in the past year generating entries from non-workshop attendees. These entries have typically originated in an e-mail explaining the purpose of the project registry sent to a population researcher(s) that has presented a paper at recent PAA meetings (and other meetings) where the project makes use of geospatial data and/or spatial analysis methods. Again, while web content will evolve over the timeframe of the grant in Year 5 we envision intense activities to develop instructional deliverables and build up other online resources. All materials will be posted to the GISPopSci website, a website that will continue to evolve. We will further develop this website rather create a parallel one as the success of the past workshops has generated visibility and product recognition. Matthews and his colleagues (at PRI and CSISS) are committed to maintaining access to web-based resources developed during the 5-year period after the proposed training program has been completed.

D.3. Program Participants and Recruitment Strategies
D.3.a. Participant Recruitment

The proposed workshops will be designed for early-career population researchers. We will use methods already pioneered by CSISS and used in the GIS and Population Science workshop series to reach potential participants, including:

- mailing fliers to contacts (e.g., directors, department heads, graduate chairs) at all population research centers, aging centers, and other institutions belonging to the association of population centers as well as population agencies throughout the U.S.;
- printing announcements in the newsletters of relevant learned societies, centers, etc.;
- acquiring mailing lists from the PAA, SDA, ASA, and other societies with substantial population research interests, including use of PRI's own mailing list, which is sent out to over 750 individuals;
- disseminating announcements on relevant list servers (e.g., specialty groups and sections within PAA, SDA, ASA, Family Research Consortium);
- posting announcements on the Websites of CSISS, the population research centers, relevant learned societies, etc.;
- distributing announcements at relevant professional conferences (PAA);
- distributing announcements to existing CSISS lists that have been compiled from previous workshop applicant lists, specialist meeting lists, etc. Not to be underestimated is the GISPopSci participant network of over 100 early-career scholars. These attendees are scattered across the U.S. in leading academic institutions and population agencies and can serve as both a conduit for reaching their immediate peers and colleagues and as advocates for the quality of our instructional program.

In the 2006 GIS and Population Science workshops, we received 222 applications for approximately 40 places. The number of potential applicants in the proposed workshops is hard to estimate, but we are confident that we will be able to reach a large proportion through these methods. We estimate the total size of the annual Ph.D. cohort in population research to be on the order of 100, suggesting a total of about 500 Ph.D. students currently enrolled (see DeJong, 2003), and others (up to 500) who will enter graduate programs over the next five years. We estimate that by including junior faculty, professional researchers, the staffs of agencies such as population agencies and state data centers, and the private sector we have a total target audience for our workshops well over 1000. We propose to enroll a total of up to 200 participants in the eight advanced spatial analysis workshops over the first four years of the program. We will emphasize the recruitment of current Ph.D. students and anticipate that they will make up 70-80 percent of the attendees. The target of 200 attendees, including approximately 150 Ph.D. students, seems a reasonable objective for a program to introduce advanced spatial methods to the field, and noting that spatial perspectives and methods will not appeal to everyone.

In selecting participants from the applicant pool we will pay attention to:

- *Home institution*. We will strive for a mix of representation, to take advantage of the potential for a residential workshop to produce lasting collaborations between institutions and across sub-disciplines. As in past GISPopSci workshops, all applications are treated individually and we will not use quotas to limit the number of invited applicants that can come from one department and/or institution. We will consider non-North American-based participants, but with a limit of 10% of the participant total (Please note that any reimbursements to non-U.S. participants will follow strictly Federal, funding agency, and university guidelines). As some North American-based demography graduate students come from developing countries, we will contribute to the promotion and diffusion of GIS methods and applications more broadly (Menken, Blanc, and Lloyd, 2002).

- *Gender and ethnicity*. We will strive for a mix of students that is as representative as possible of the general population, and give particular attention to participation by traditionally under-represented groups. In the 2005 GISPopSci workshops 50 percent of *applicants* were women and 40 percent minority. Among those invited as *participants*, 55 percent were women and 46 percent minority (12% African/African American, 21% Asian, 11% Hispanic, 2% Native American). For the 2006 GISPopSci workshops, 61 percent (30/49) of the successful applicants were women and 39 percent (19/49) were minority (Please note that 16 attendees did not provide race/ethnicity information and 3 reported 'other' but did not specify a race/ethnicity; of those 19 attendees that did provide information on race/ethnicity 12 were Asian, 3 African American, 1 African, and 3 Hispanic; all race/ethnicity data reported on here are taken from the application materials). We distributed announcements of the GISPopSci workshops to organizations and groups with traditionally under-represented groups such as ASA section on Racial and Ethnic Minorities and the Family Research Consortium IV as well as targeting fliers and e-mails to several leading African American and Hispanic scholars in demography and demography-related fields (not listed among PRI's mailing lists).

- *Background*. Applicants will complete an application form that will provide self-report data on educational attainment, academic field, and experience with a range of statistical methods, spatial analysis, ecological analysis, GIS, mapping and geospatial data as well as demographic research interests. Again, there is no quota on the number of applicants from a specific discipline though our intent is to select participants in order to create a representative mix of interests. In the interests of cross-fertilization and community building we will consider a limited number of participants with backgrounds in areas related to population research, such as geographical analysis and population biology, but will not actively recruit in these communities (e.g., CSISS while known among the academic geography community has tended to accept applicants from non-geographers over geographers). We will be especially vigilant in recruiting population scientists from specific fields such as economics and anthropology, where a spatial perspective is not as integrated in to the core discipline as other population-related sciences. As illustration of the disciplinary mix of a typical workshop, consider the disciplinary affiliation of 2005 and 2006 workshop attendees (**Appendix E**).

The Dual-degree Demography Training Program at Penn State is one of the largest demographic graduate training programs in the U.S. (n = 65 dual-degree demography students based on Fall 2006 registration data) and represents over 10 percent of the known demography student enrollment at APC Centers housing a formal training program in demography (DeJong, 2003). Special arrangements will be made for interested Penn State demography students who are unable to take advantage of other formal spatial analysis training opportunities (i.e., Spatial Demography course or other graduate GIS courses on campus such as those offered through the Department of Geography). During the GIS and Population Science workshops held at Penn State in 2005 and 2006 four Penn State Demography students and/or post-docs per workshop were invited to participate. If during the years 2008-2011 the Spatial Demography course is not offered for credit at Penn State we intend to permit 4-8 demography students to participate in the proposed workshops based at Penn State. The actual number will be determined by seat capacity within the instructional labs. Penn State graduate students will have to apply to attend the proposed workshop through a separate mechanism (i.e., not via the website) and the applications will be reviewed by Matthews and the internal advisory board members based at Penn State (i.e., Matthews, DeJong, Landale, and Dodoo). Penn State applicants will not be eligible for any student stipends. Based on past experience Penn State graduate students will contribute to group dynamics in a positive way both intellectually and as guides to resources on campus and in the local community. The latter is not trivial as it does contribute to a positive workshop experience. If Matthews is not teaching a spatial demography course in 2008-2011, then he and DeJong (Director, Graduate Training Program in Demography at Penn State) will seek to ensure that Penn State graduate students receive course credit from the University. In this paragraph we have emphasized Penn State because of the large number of demography students based there but we will pursue a similar strategy for facilitating local graduate student participation at UC Santa Barbara in the four workshops based there.

D.3.b. Participant Funding

We anticipate substantial variation among participants in their ability to cover the cost of a workshop. Full-time employees of non-governmental organizations, corporations, and the state data centers can usually obtain funding from their organizations; graduate students on the other hand will likely have limited access to funds. Based on our experience, the estimated cost of participation in a 5-day workshop would be approximately $1,200 (approximately $500 airfare/travel, $100/day for accommodation (x 5 minimum) and $40/day for meals (x 5)). We do not propose to cover all costs but rather we will offer stipends of $600 per invited and qualified applicant to help defray the costs of travel, accommodation, and participation. Qualifying applicants include graduate students, post-docs and others whose costs would not normally be covered by their employer (e.g., government agency). We will encourage and support successful applicants in their efforts to leverage additional source of funding from their home institution.

The average size of a workshop will be 25 attendees and we assume that on average 20 will qualify for a stipend. The other 5 attendees will include local graduate students (i.e., from Penn State or UCSB) and full-time employees of government and non-government organizations, corporations and agencies who would not qualify for a stipend. With 20 qualifying attendees we have budgeted $12,000 per workshop in stipends, for a total stipend cost across all eight workshops of $96,000.

Participants will be able to apply for multiple workshops, though admission to multiple workshops is not guaranteed. The 100 attendees at previous GIS and Population Science workshop would be eligible to apply for the advanced spatial analysis workshops but again admission is not guaranteed. Many of the 100 past attendees, when contacted about our plans for this application, expressed strong support and an interest in furthering their spatial analysis training.

D.4. Evaluation Plan

D.4.a. Workshop participant performance evaluation

We intend that all attendees will make a presentation of their own work on the final day of the workshops. In addition, we will encourage the creation of materials that can be shared via the project website. Typically, these would be documents linked to a section of the webpage titled “Project Registry.” We acknowledge that some participants may work on their own data, to be strongly encouraged, but that data access restrictions may prevent the sharing of material. We will remind attendees of appropriate data access and use issues prior to the workshop and encourage any attendees to make sure they have appropriate IRB documentation for any data they may bring to the workshops. For those not using their own data, we will make sample data available and/or facilitate access to public domain data sets for use in individual projects during the workshop.

D.4.b. Workshop evaluation

We will conduct an extensive program of evaluation of the workshop program and its support through the project website. We will conduct an entry survey of each participant to determine his or her background knowledge and expectations of the workshop. In addition, we will conduct an exit survey to gather initial opinions about the workshop and information on immediate plans following the workshop (This will be based on the exit surveys used for the GISPopSci workshops). For each cohort (Year 1-4 attendees) we will conduct a follow-up survey approximately twelve months after their workshop, gathering details on the longer-term impact of the workshop. We are particularly interested in whether the workshop experience led to modifications of research plans and approaches, modifications of teaching content and curriculum (if applicable), changes in collaborations, and other indicators of fundamental impact (presentations, publications, grants, fellowships with a formal spatial modeling component) . In Year 5 a second follow-up survey will be administered to all workshop attendees from Years 1-3. Tracking past workshop attendees should present few challenges, especially as the majority will be in academia, with many affiliated with the PAA and other professional associations. Similarly, past attendees of the GISPopSci workshops do contact PRI and CSISS for advice and workshop attendees as noted above have presented/attended PAA meetings. We anticipate meeting participants at future population conferences and events, and through the project website.

D.4.c. Follow-on activities

In our GISPopSci and CSISS–SPACE workshop experience, the success of a program depends very much on the extent to which the initial momentum created by workshops is sustained, through collaboration between participants, and continued interaction with faculty and instructors at the lead institutions. We propose several activities designed to foster continued interaction:

- *The Project Website.* We will use the Web site as the focus of a virtual community of alumni. We will maintain list servers, continually update the site with news of potential interest to the community, and add to its resources through contributions from alumni (particularly contributions resulting from participant contributions and research results in the form of project registries). As noted above, the website is not just for workshop attendees but rather is regard as a ‘community’ resource for population scientists.

- *Conference reunions.* We will encourage and facilitate gatherings at population research conferences, including the Population Association of America, the Southern Demography Association, and the American Sociological Association. We will structure these gatherings to provide opportunities for presentations on continuing research. For example, we will promote the submission of poster and/or paper sessions by workshop participants at future Population Association of America meetings and seek to work with the PAA board to organize special session on advanced spatial demography at least twice during the life time of the grant. We seek no funding support for these activities.

- *Consultation.* We will encourage and maintain access to the PI, co-PIs, and workshop leaders, for purposes of advice and consultation. We seek no funding support for these activities.

D.5. Timeline

The table below (next page) provides a detailed timeline for the workshop component of the project with a start date of October 1, 2007 assumed.

Year/Quarter(s)	**Tasks**
Year 1-4	
1st Q: Oct-Dec	Confirm dates, availability of presenters and sequence of workshops at each site. Advisory board and consultants to review proposed workshop offerings and structure. Develop materials (flyers/web materials) for advertising workshops.
2nd Q: Jan-Mar	Advertise workshops for following summer, explain selection criteria and eligibility for stipends, aggressively recruit applications from minorities and under-represented groups.
3rd Q: Apr-Jun	Select and inform invited applicants, wait-listed applicants, and those we cannot accommodate (March/April). Though this is an ongoing task, many logistical issues associated with a successful workshop will arise in the 1-2 months leading up to the workshops; these will include questions from attendees, instructors, and guest presenters and involve technical issues as well as the more mundane associated with travel and accommodation. Develop web resources (tutorials, literature searches, etc.); contact all presenters at the PAA using spatial analysis methods with a goal to create 'project profiles.'
4th Q: Jun-Sep	Host workshops; one in State College (typically in the early summer months; could be held as early as May) and one in Santa Barbara (typically held mid-summer, July). Evaluate exit surveys (Post workshop review). Work with presenters to develop web resources specific to the two advanced spatial analysis methods covered that year (revise and update each year).
Year 2-5	
3rd Q: Apr-Jun	12 month follow-up survey with previous year's attendees
Year 3	
1st Q: Oct-Dec	End of second year review. Receive feedback from Advisory Board members; make changes to workshop offerings as/if necessary.
Year 5	
Ongoing	Development of web-related instructional material will be an ongoing activity through all years, with an intensive effort in year 5 to convert workshop instructional resources for on-line delivery, adding value to the research community beyond the period of funding.
4th Q: Aug-Sep	Follow-up survey with attendees from Years 1-3. Overall program review and Final report.

D.6. Conclusions

There are many areas of demography where a spatial perspective has relevance and work is emerging in applications focusing on family/neighborhood research, race/ethnic segregation, poverty, labor market research, environmental justice, health inequality, epidemiology, food environments, physical activity research, crime analysis, and population and environment linkages. However, population scientists are not prepared for the geospatial data onslaught they are likely to face in the next decade, nor are they exposed to ongoing methodological developments and new software products in advanced spatial statistical analysis. Briefly, the current offering of formal advanced spatial analysis methods courses or workshops to population science professionals is limited.

Our goal is to address the advanced spatial analysis training shortfall head-on. We will offer exposure to four advanced spatial analytic methods in a series of tailored workshops. We envision intensive 5-day training workshops to be delivered on each topic twice (subject to an advisory board review) for a total of eight workshops. Approximately 200 early-career population scientists will attend these workshops, and among them will be a significant proportion of the current U.S. graduate student population with identifiable demographic research interests. In addition, we propose to create from the workshops, on-line materials for self-paced instruction that will be available to researchers in the field during the funding cycle and after it has concluded. Moreover, we envision a website that evolves with the cohort of scholars we train, where workshop participants and importantly non-participants help us build up a portfolio of resources surrounding the application of advanced spatial analysis methods in population science.

E. Human Subjects

First and foremost this is a training grant and exempt from human subjects regulations. That said, we are planning to collect data on workshop applicants and participants. Applicants will provide basic profile data and a justification statement identifying reasons why they would benefit from the workshop. Participants will provide entry and exit (i.e., evaluation) data on the workshop experience during and at the conclusion of the workshop. Finally, workshop participants will provide information in both a one-year follow-up and end-of-grant period survey (Year 5) that will be designed to capture information on the degree to which participants have used advanced spatial analysis methods in their own demographic research and teaching, and whether they have made administrative decisions that support the development of spatial analysis capacity at the institution in which they work. The various pieces of data listed above are to be collected primarily for workshop management and pedagogic purposes.

The surveys are currently covered by an "application for the use of human participants (for social science research)" submitted by Matthews to Penn State's Office of Research Protection as part of the GIS and Population Science training program for 2005 and 2006 (Penn State IRB #16853). Matthews submitted a "modified application" to extend the temporal coverage to 2012 and increase the participant number by 200. These data on workshop applicants and participants collected over the period 2008-2012 will be used to investigate the impact of our advanced spatial analysis training program should it be funded.

IRB #16853 covers an informed consent form that is distributed to all workshop attendees at the beginning of the workshop. The informed consent describes the purpose of the exit and follow-up surveys. Consent is given if the participant signs the form. We provide the participant with a photocopy of the signed consent form. The exit survey is a web-based survey and is voluntary. Participants will receive periodic reminders to complete the exit surveys; no more than five reminders. Confidentiality of responses to exit and follow-up surveys will be maintained to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties. These data are of limited value to anyone other than the PI, co-PI and advisory board who will use them for workshop management, review, and pedagogic purposes.

Gender and minority inclusion: We will strive for a mix of participants that is as representative as possible of the population of demography scholars and practitioners, and give particular attention to participation by traditionally under-represented groups. Gender and race/ethnicity data are self-reported by applicants to the GISPopSci workshops; over fifty percent of applicants and accepted participants in these workshops were women.

Participation of Children: Workshop participants will likely have a minimum of a Bachelors degree and/or be non-academic professionals in population-related employment. It is unlikely that any participants will be under age 21. None of the 356 applicants to GISPopSci were known to be under 21 and certainly none of the attendees were under 21.

F. Vertebrate Animals

Does not apply.

G: Literature Cited

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H: Consortium/Contractual Agreements

This application includes the hosting of workshops and instructional development at two sites: Penn State University in State College, PA and The University of California Santa Barbara in Santa Barbara, CA. The UCSB site is the sub-contract.

I: Consultants

Letters from workshop leaders and external advisory board members are included with this application.