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Salerno, JD
Mulder, MB
Kefauver, SC

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Human Migration, Protected Areas, and Conservation Outreach in Tanzania

JONATHAN D. SALERNO,* MONIQUE BORGERHOFF MULDER,† AND SHAWN C. KEFAUVER‡§**

*Graduate Group in Ecology, University of California, Davis, One Shields Avenue, Davis, CA 95616, U.S.A., email jdsalerno@ucdavis.edu

†Department of Anthropology, Graduate Group in Ecology and Center for Population Biology, University of California, Davis, One Shields Avenue, Davis, CA 95616, U.S.A.

‡Center for Spatial Technologies and Remote Sensing, University of California, Davis, Department LAWR, One Shields Avenue, Davis, CA 95616, U.S.A.

§CSIC, Global Ecology Unit, CREAF–CEAB-CSIC-UAB, Cerdanyola del Vallès, 08193 Barcelona, Catalonia, Spain

**CREAF, Cerdanyola del Vallès, 08193 Barcelona, Catalonia, Spain

Abstract: *A recent discussion debates the extent of human in-migration around protected areas (PAs) in the tropics. One proposed argument is that rural migrants move to bordering areas to access conservation outreach benefits. A counter proposal maintains that PAs have largely negative effects on local populations and that outreach initiatives even if successful present insufficient benefits to drive in-migration. Using data from Tanzania, we examined merits of statistical tests and spatial methods used previously to evaluate migration near PAs and applied hierarchical modeling with appropriate controls for demographic and geographic factors to advance the debate. Areas bordering national parks in Tanzania did not have elevated rates of in-migration. Low baseline population density and high vegetation productivity with low interannual variation rather than conservation outreach explained observed migration patterns. More generally we argue that to produce results of conservation policy significance, analyses must be conducted at appropriate scales, and we caution against use of demographic data without appropriate controls when drawing conclusions about migration dynamics.*

Keywords: community-based conservation, East Africa, national parks, population growth, rural migrants

La Migración Humana, Áreas Protegidas y el Alcance de la Conservación en Tanzania

Resumen: *Una discusión reciente debate la extensión de la inmigración humana en áreas protegidas en los trópicos. Un argumento propuesto es que los migrantes rurales se mudan a áreas fronterizas para acceder a los beneficios del alcance de la conservación. Una contrapropuesta mantiene que las áreas protegidas tienen un efecto negativo mayor sobre las poblaciones locales y que las iniciativas de alcance, aunque sean exitosas, presentan beneficios insuficientes para conducir la inmigración. Usando datos de Tanzania, examinamos los méritos de pruebas estadísticas y métodos espaciales usados previamente para evaluar la migración cerca de áreas protegidas y aplicamos un modelo jerárquico con controles apropiados para los factores demográficos y geográficos para avanzar el debate. Las áreas fronterizas en los parques nacionales en Tanzania no tuvieron tasas elevadas de inmigración. La baja densidad de población base y la alta productividad de vegetación con variación interanual baja más que explicar el alcance de la conservación, explicaron los patrones de migración. Más generalizado, discutimos que para producir resultados significativos de política de conservación, los análisis se deben hacer en escalas apropiadas y advertimos sobre el uso de datos demográficos sin un control apropiado al concluir sobre las dinámicas de migración.*

Palabras Clave: conservación basada en la comunidad, África Oriental, parques nacionales, crecimiento de la población, migrantes rurales

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Introduction

Human populations exist at greater densities and maintain higher rates of growth in areas of high biological diversity value than in all other inhabited areas (Cincotta et al. 2000; Williams 2011). A longstanding view holds that high human densities and persistent positive growth necessarily result in negative outcomes for tropical biological diversity both globally and locally (Meffe et al. 1993; Newmark et al. 1994). Accordingly, such anthropogenic threats are increasingly motivating biological diversity protection through the establishment of protected areas (PAs) and associated conservation outreach programs (Roe 2008; IUCN and UNEP 2010). Human in-migration to PA borders to access direct or indirect benefits provisioned by the PAs may increase existing anthropogenic pressures (de Sherbinin & Freudenberger 1998). However, though human migration represents a causal demographic process affecting population-environment dynamics in the tropics, it remains understudied (Bilsborrow 2002; de Sherbinin et al. 2008).

An emerging literature sheds light on in-migration to PAs (Wittemyer et al. 2008), yet questions persist concerning appropriate data sources and scales of investigation (Joppa et al. 2009) and the underlying mechanisms of migration processes (Scholte & de Groot 2010). In addition, the role of conservation outreach and development initiatives in PA-specific migration has not been adequately investigated, despite early concerns (Barrett & Arcese 1995; Noss 1997).

We examined rural population dynamics with respect to conservation outreach across the national parks network in Tanzania (Fig. 1). We sought to determine whether disproportionately high rates of in-migration to PA borders exist relative to overall levels of rural migration and whether in-migration disproportionately affects areas receiving funding from the nation's conservation outreach program. We also investigated the alternative explanation that rural people move to access available and productive land and that explanatory evidence varies across such a diverse system. We conducted our analyses at a scale relevant to conservation policy in Tanzania. We used existing techniques to investigate PA-migration dynamics—statistical tests and a spatially explicit method—and hierarchical modeling. Thus, we sought to move the discussion of PAs and migration forward to a policy-relevant context, as Wittemyer et al. (2008) recommend, and to redirect the focus of conservation science from simple measures of population to a more comprehensive analysis of demographic factors (Allendorf & Allendorf 2012).

Migration to PAs

Wittemyer et al. (2008) found that high rates of rural population growth—their proxy of in-migration—exist at PA borders across Africa and Latin America, and these findings were challenged on the grounds that their data sources were incongruous and their methods inadequate (Shoo 2008). Joppa et al. (2009) used an alternative approach to examine in-migration around the same PAs and found no consistent pattern of higher growth rates. In addition, any conclusions regarding migration based on population measures such as growth rates alone without considering underlying fertility (thereby controlling for intrinsic growth) are problematic (Bilsborrow 2002). These issues of conflicting results and inferences from simple measures of growth bring into question the utility of large-scaled assessments in identifying whether in-migration exists near PAs. Regarding migration mechanisms, the most pointed criticism of Wittemyer et al. (2008) centered on the authors' interpretation of the factors driving high growth rates: rural people migrated specifically to PA edges to access the benefits provided by the PA itself (Igoe et al. 2008; Davis 2011). This criticism reflected a decades-long debate over the impact of PAs on local populations and motivated a new framework for looking at how PAs affect migration behavior.

Scholte and De Groot (2010) summarized distinct mechanisms that could drive in-migration to areas near PAs as engulfment (people moving to access available land in low density areas where PAs are often established), attraction (people moving specifically to access PA benefits such as protected natural resources or employment from tourism), and incidental (PAs existing in areas of refugee resettlement or other displaced populations). In addition, demographers demonstrate that rural migration results from multiple factors at different scales acting on individuals and households (de Sherbinin et al. 2007; Barbieri et al. 2009), calling into question generalizations made at particularly large scales (Hoffman et al. 2011). For instance, results of site-based analyses of migration mechanisms near PAs largely refute that population growth is due to PAs simply attracting migrants. In Latin America and Africa, available and productive farming and grazing land, employment related and unrelated to PAs themselves, kin networks, and the development of adjacent urban areas drive a diversity of migration decisions for people settled near PA borders (Hoffman 2011; Estes et al. 2012; Zommers & MacDonald 2012). These mechanisms of migration represent the different models described by Scholte and de Groot (2010), each suggesting different approaches to alleviate further population increases and potential pressures on biological diversity.

Conservation Outreach, Migration, and Policy

Conservation outreach or integrated conservation and development programs, designed to mitigate the negative effects of PA establishment by provisioning benefit to local populations, were central to the attraction mechanism

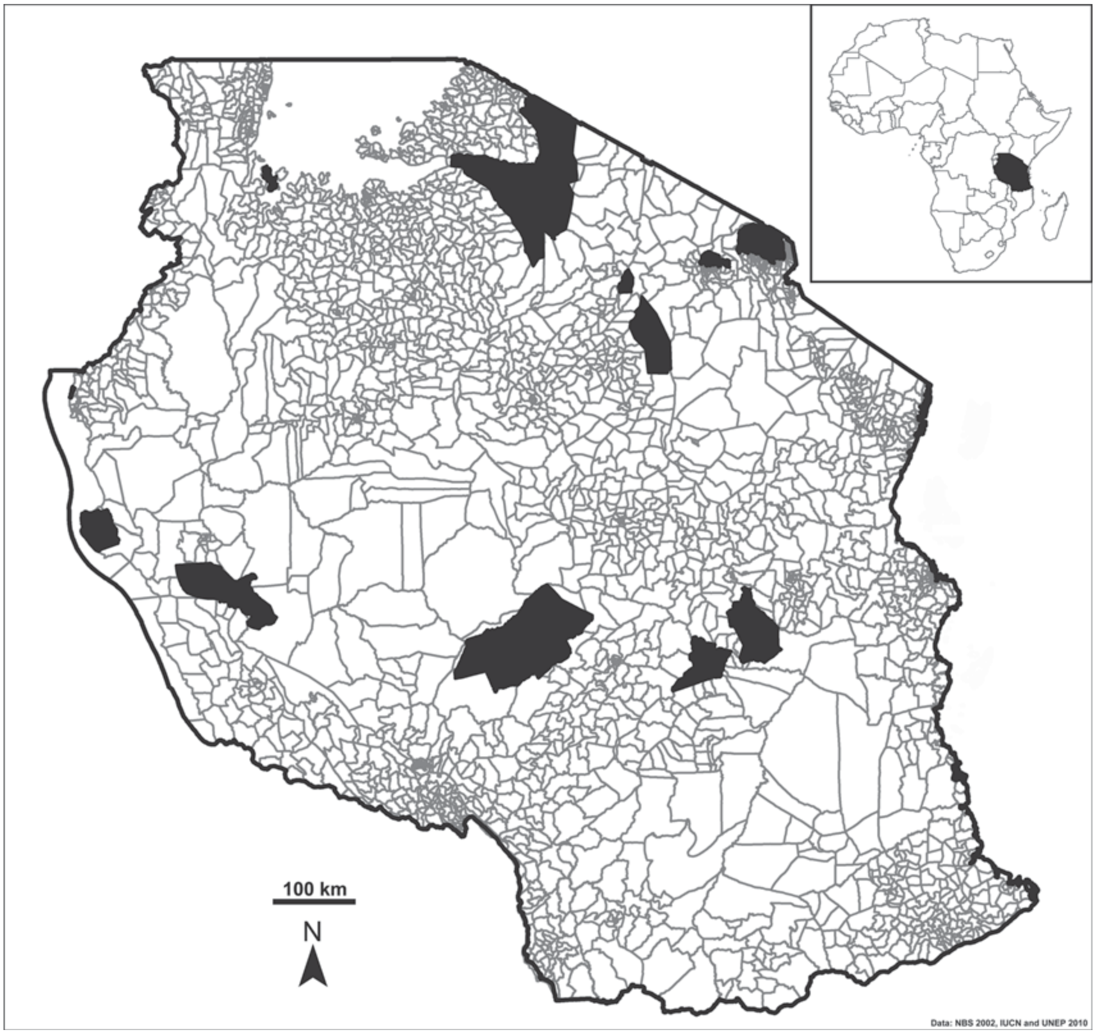

Figure 1. Mainland Tanzania's national parks network (black, national parks; white with gray outline, administrative wards). Boundaries are as they existed in 2002 (IUCN and UNEP 2010, National Bureau of Statistics 2002). Island areas not pictured were excluded from analyses.

discussed by Wittemyer et al. (2008). The authors inferred that increased population growth rates resulted in part from in-migration of rural people to PA borders to access health centers, schools, infrastructure, and other benefits provided as part of conservation strategies. Although outreach strategies designed to provide employment or market access may have distinct effects on migration from those provisioning health care or education, multiple approaches are typically combined (Brooks et al. 2006). Accordingly, for our analysis we define all such strategies together as outreach, recognizing that such initiatives can vary widely in the way they are integrated into conservation agendas (Borgerhoff Mulder & Coppolillo 2005).

In early studies of in-migration to PAs in Africa (Oates 1995; Noss 1997; Scholte 2003), researchers assumed outreach was successful in offsetting any costs incurred in living near the PA and that the net benefit to households would drive decisions to in-migrate. The conclusions of Wittemyer et al. (2008) relied on similar assumptions. Their findings are nevertheless puzzling—the suggestion of a global pattern of rural people moving to access benefits made available by PAs (e.g., outreach projects, employment, natural resources, infrastructure, security) is fundamentally contradicted by a large body of research detailing the significant costs of living near PAs (reviewed in West et al. 2006) even though it is clear that community services, such as hospitals and schools, may influence migration decisions in rural areas among some households (Barbieri et al. 2009; Massey et al. 2010; Lopez-Carr 2012). Moreover, the costs and benefits of living near a PA and reaping outreach benefits are not necessarily mutually exclusive, insofar as individuals, households, or communities may be differentially affected. Despite the widespread existence of outreach programs, the long running debate on the overall effectiveness of outreach and related community-based conservation strategies—whether or not they actually provide social benefit or protect biological diversity and among which groups (Naughton-Treves et al. 2005; Agrawal & Redford 2006)—indicates the need for caution when considering their impacts on migration.

In sum, there are many factors that influence migration, puzzling contradictions between being attracted to the borders of PAs and suffering the costs of restricted resource use or human-wildlife conflict, and dangers associated with drawing inferences from incorrectly scaled analyses, especially when different explanations are not considered as alternatives. We therefore argue that more informed approaches to the specific relationship between outreach and migration are needed before making conclusions that have direct relevance to how and where conservation and community development practices are conducted (Hoffman et al. 2011).

Methods

Data Sources and Processing

We compiled demographic variables from ward administrative areas as their boundaries existed in 2002 (i.e., our unit of analysis was the ward; wards are clustered in districts). Human population growth rate, our outcome variable, was calculated from 1988 and 2002 census data from Tanzania's National Bureau of Statistics (NBS) and geographically referenced (see also Estes et al. 2012). These data were further processed in collaboration with NBS to correct errors from the original censuses, including identification of refugee camps and other features causing anomalous growth rate calculations. Wards in the Indian Ocean island districts of Zanzibar, Pemba, and Mafia were excluded because they did not include strict PAs gazetted during our study period managed as part of mainland Tanzania's terrestrial PA network. The sample includes only rural wards containing populated areas. We also obtained coarse total fertility rates for 1988 from NBS. Finally, we estimated 1988 ward-level population density by resolving boundary changes with census documentation and maps from NBS and by accounting for unpopulated areas within PA boundaries. The resulting data set included 2439 wards clustered in 118 districts.

To the demographic data we added geographically referenced boundaries for all 12 national parks established before 1988 (including Udzungwa Mountains, reclassified as national park from national forest reserve in 1992) (IUCN and UNEP 2010) that corresponded to the census period. Following previous studies, we classified wards adjacent to PAs as those within 10 km of the PA boundary, based on the distance feasibly traveled for daily livelihood activities (e.g., Bruner et al. 2001). To obtain a measure of conservation outreach effort, we collected data from Tanzania National Parks (TANAPA) financial records detailing individual project activities and funds. These data represented 366 individual projects carried out in 137 wards adjacent to PAs from 1994, when activities officially began, through 2002; funding was aggregated within wards. TANAPA most commonly funded schools and health centers, but projects also included roads, water infrastructure, and income generation.

We modeled normalized difference vegetation index (NDVI) to produce measures of vegetation productivity across our period of interest from raw 8 km GIMMS NDVI measures (Tucker et al. 2005). The NDVI can be used as a proxy for ecosystem function and productivity (Pettorelli et al. 2005), and the GIMMS data set has been employed over large spatial and longitudinal scales, including in East Africa (Pelkey et al. 2003; Duffy & Pettorelli 2012). We processed these longitudinal NDVI raster data (1988–2002) with the STARSPAN spatial processing tool to estimate a time-series of measures for each ward boundary unit (Rueda et al. 2005). Using a similar approach as Azzali and Menenti (2000), we then fitted periodic linear models to each time-series to produce the most informative measures—mean, inter-, and subannual parameters—describing ward-level NDVI dynamics from 1988 to 2002. For further details see Supporting Information.

Analyses

We applied a hierarchical regression framework, hereafter referred to as the multivariate modeling approach. Using rural ward growth rate as our outcome variable, we defined an informed null model (M0) that included baseline population density, 4 NDVI covariates, and baseline fertility as predictors. Low population density and productive land describe geographic characteristics widely associated with rural migration, including in areas near PAs (Lopez-Carr 2012). In addition, including fertility rate so that in-migration was not confounded with intrinsic growth allowed for more informed inferences (Bilsborrow 2002). We evaluated hypotheses through interpretation of a series of increasingly complex models, along with their deviance information criterion (DIC) scores (model comparison strategy analogous to Akaike information criterion; see Spiegelhalter et al. 2002), through the successive addition of adjacency to PA (M1) and presence and funding of conservation outreach projects (M2) to the null model. The hierarchical structure of the models allows the level (intercept) and effects (slopes) of predictors to vary by district in order to account for unmeasured clustering effects; we refer to these as *varying effects*. Due to the non-Gaussian symmetric distribution of growth rate outcomes, we fitted models with the t distribution. Because we used this distribution in conjunction with a hierarchical structure, we applied a Bayesian approach (Gill 2008). In doing so, samples from the joint posterior distributions of the parameters were generated by Markov Chain Monte Carlo (Plummer 2011; R Development Core Team 2012).

To further assess rural population growth rates near PAs, we applied a spatially explicit method similar to that of Joppa et al.'s (2009) used to re-evaluate nonparametric findings. We compared rural ward growth rates (converted to 1 km gridded values) at distances of 0–10, 10–20, 0–20, and 20–40 km around individual national park boundaries (hereafter, buffers). If in-migration to PAs exists, higher growth rates would be observed in 0–10 km buffers than in 10–20 km buffers and in 0–20 km than in 20–40 km buffers, assuming fertility and mortality are constant across adjacent buffer areas. Analysis was conducted in ArcMap 10 (ESRI 2010) and R. We refer to this method as *buffer analysis*.

We applied nonparametric statistical tests similar to those used in previous studies to determine if rural growth rates were disproportionately higher around PA boundaries or in wards with outreach projects than in other areas (Wittemyer et al. 2008; Packer et al. 2011). We did so with a Wilcoxon rank-sum test (*wilcox.test* function as part of the *stats* package in R).

Results

Across Tanzania, baseline population density and NDVI were the only predictors that had consistent relationships with growth rate outcomes. PA adjacency and conservation outreach initiatives did little to explain growth after controlling for baseline fertility rates.

Comparing results from a series of 3 multivariate models provided the most precise test of whether higher rates of in-migration occurred adjacent to PAs and, more specifically, whether higher rates were associated with conservation outreach activities. The multivariate model including controls and PA adjacency (M1) provided the best fit to the growth rate data; the addition of outreach funding (M2 model) provided no improvement (Fig. 2). The M1 model indicated population density and NDVI measures were the only predictors that had consistent relationships with growth rate outcomes across Tanzania. Although PA adjacency was included in the best-competing model, its ward-level relationships with growth rate varied substantially in both positive and negative directions so as to indicate no consistent effect when aggregated across all districts. In other words, none of the conservation measures was reliably associated with growth rate outcomes. We found a negative association between growth rate and density, based on the posterior mean and credibility interval for the effect of density in model M1. Of the 4 NDVI measures, growth rates were positively associated with mean NDVI and negatively associated with interannual variation. Because of the coarse measures of fertility, which existed at a similar level to that of the model's district-level varying effects, the model produced imprecise estimates for the effect of this predictor.

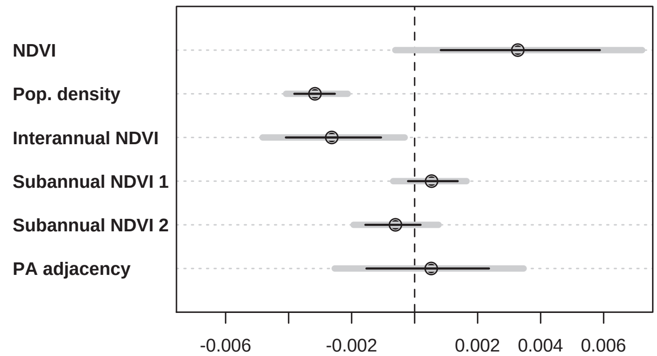

Figure 2. Hierarchical model results for predictors of human population growth rate in rural areas. Model results compared the null model (M0, population density, normalized difference vegetation index [NDVI] measures, and controls), M1 model (protected area adjacency and predictors in M0), and M2 model (conservation outreach projects and predictors in M1). Shown are coefficient estimates of focal predictors excluding controls from the highest ranked model, M1 (deviance information criterion score [DIC] = −4556). The M0 and M2 models are not displayed (DIC = −4548 and −4547, respectively). Estimates for the geographic predictors (population density and NDVI measures) in models M0 and M2 are analogous to those of M1 (Supporting Information). Posterior mean coefficients are plotted as points on the x-axis with 95% (gray bars) and 80% (black bars) credibility intervals.

Varying effects estimates from the M1 model showed that unmeasured district-level factors contributed much of the variation in growth rates. First, varying intercepts estimates for the informative predictors indicated mean growth rate differed between districts (Fig. 3). Second, although pooled coefficients for baseline population density and mean and interannual NDVI were still significant when averaged across all wards (Fig. 2), the district-level slopes provided by the hierarchical model varied greatly (Fig. 3a, c). In other words, the district-level adjustments made by the model to the coefficient estimates indicated significant variation between districts even though the coefficients themselves were significant across the country. Therefore, the hierarchical structure of the model allowed the strength of each of the effects on growth rate to change depending on district, and in some cases the direction was reversed. The variation in these district-level effects was most pronounced for baseline population density (Fig. 3a).

Mean population growth rates in the 0–10 km buffers of all national parks were lower than rates within 10–20 km buffers (Fig. 4a, all PAs). This relationship held

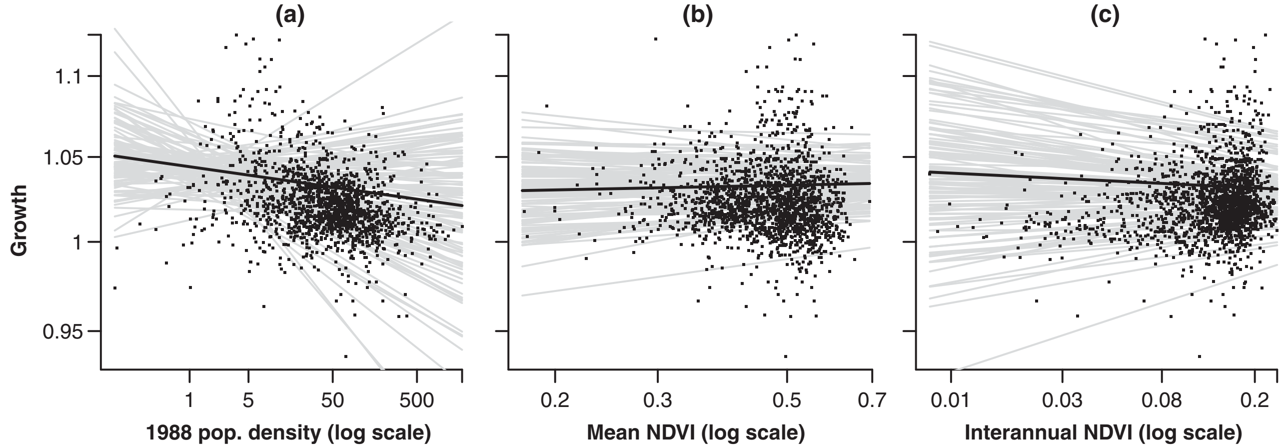

Figure 3. Variation in district-level effects of (a) baseline population density (people/km^2), (b) mean normalized difference vegetation index (NDVI), and (c) interannual variation in NDVI (point estimates of which are shown in Fig. 2) on human population growth from the best-fitting hierarchical model (M1) (black lines, mean effects pooled across the population; gray lines, slope and intercept estimates for each rural district).

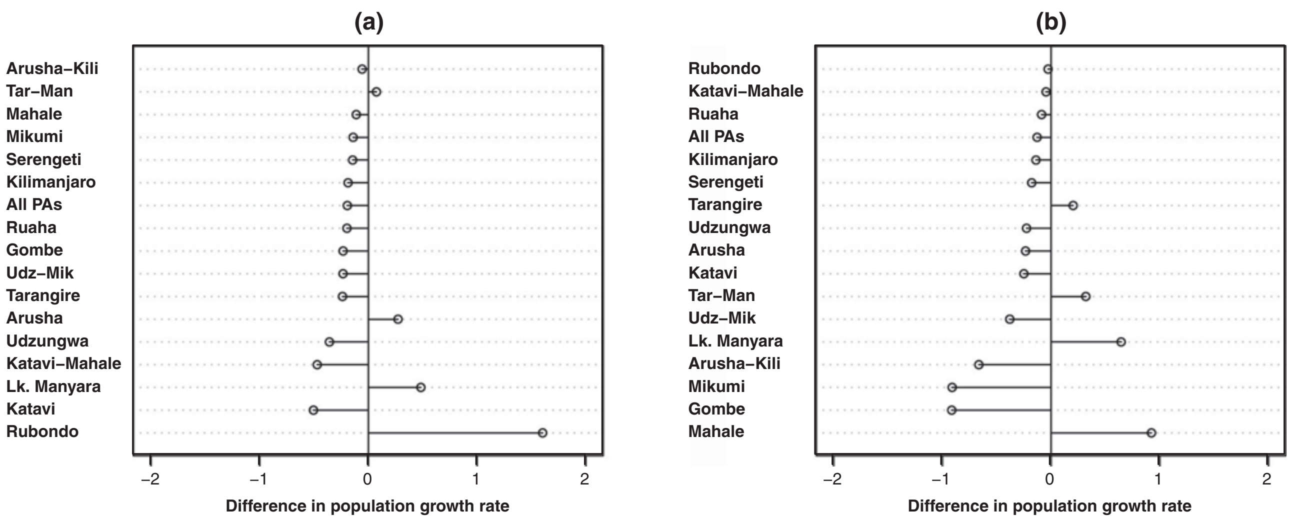

Figure 4. Differences in rural mean population growth rate in areas (a) 0–10 and 10–20 km from protected area borders and (b) 0–20 and 20–40 km from protected area borders (positive values, higher growth immediately adjacent to the protected area [i.e., potential for attraction]; negative values, lower growth immediately adjacent to the protected area). Comparisons are made for all protected areas together (all PAs), individual protected areas, and individual complexes where multiple protected areas existed within 80 km (Arusha-Kilimanjaro, Katavi-Mahale Mountains, Tarangire-Lake Manyara, and Udzungwa Mountains-Mikumi). Absolute values are from least to greatest difference, top to bottom.

when 0–20 km buffers were compared with 20–40 km buffers (Fig. 4b, all PAs). In terms of individual parks, 9 of 12 had lower mean growth in 0–10 km buffers than in 10–20 km buffers. When comparisons were made for individual parks with 20 km wide buffer zones, some parks showed different relationships with wider than with narrower zones (i.e., parks with lower growth rates in their 0–10 km than in 10–20 km buffers but higher growth rates in 0–20 km than in 20–40 km and visa versa). Despite these discrepancies, when comparing mean growth rate values across all PAs for both narrow and wider buffer zones the majority of individual parks had lower rates at their immediate boundaries.

Across wards, nonparametric tests did not support that growth rates are higher in wards within 10 km of PA borders than in nonadjacent wards ($W = 14{,}9342$, $p = 0.246$). When considering conservation outreach activities, growth rates were slightly higher in wards where projects were conducted than in all wards combined ($W = 90{,}370$, $p = 0.093$), but the relationship did not exist when comparing project wards with those wards also adjacent to PAs but without projects ($W = 5408$, $p = 0.155$).

Discussion

We found no convincing evidence of disproportionately high population growth rates due to in-migration to PAs. The multivariate models indicated that low population density and land productivity were the 2 factors associated with in-migration, but they failed to show a positive relationship between migration and PA adjacency. Fertility must be considered when making these claims. Fertility is generally higher in remote rural areas, among resident and in-migrant populations alike (Carr et al. 2006), and PAs tend to be located in similar isolated areas (Joppa & Pfaff 2009). Therefore, disproportionately high growth driven by fertility may confound conclusions about in-migration based only on growth rates. When fertility was included (despite considerable uncertainty about the size of its effect), we were able to discern an alternative explanation to PA-driven in-migration: rural people moved to PAs access available and productive land. In Tanzania, it has been documented that rural farmers and livestock keepers are primarily motivated by land resources when making migration decisions (e.g., Charnley 1997; Brockington 2001). More specifically, Estes et al. (2012) demonstrated that in-migration around Serengeti National Park was driven by access to available and productive farmland, which occurred as part of a larger migration process affected by resource constraints in origin areas as well.

The hierarchical structure of these models controlled for unobserved geographic effects across rural districts and showed there was variability in ward-level rates of in-migration and major factors influencing migration, despite populations generally moving to areas of fewer inhabitants and higher, less variable productivity. For example, differences in district-level varying effects indicated that for some rural areas growth rate and population density were positively associated (Fig. 3a), which was inconsistent with the overall trend but suggests that in a small subset of districts people moved to more densely populated rural areas. This is not surprising considering that factors other than available land can influence rural–rural migration decisions. Similar but less variable relationships existed across districts between productivity measures and rates of in-migration (Figs. 3b & 3c). This need to account for geographic differences in Tanzania supports the idea that migration is a complex process and that people may move from and to rural areas for diverse reasons (Barbieri et al. 2009; Zommers & MacDonald 2012). Therefore, there are potential dangers associated with drawing general conclusions or national policy recommendations from locally based results because interdistrict variability is evident, just as problems arise from applying local recommendations drawn solely from large-scale findings.

Results from the analysis of the spatial relationship between PAs and growth rates supported the multivariate model outcomes. The majority of PAs had lower growth rates immediately at their borders than in more distant buffer areas, yet this relationship was not universal. Not surprisingly, geographic variation in social and ecological context across Tanzania suggests that different mechanisms potentially drive growth rates in different areas. In other words, even if higher growth rates were observed at PA edges than in nearby surrounding areas, therefore indicating the potential for PA attraction, park-specific interpretations must be made carefully.

For example, relatively higher growth rates within the 10-km buffer directly adjacent to Arusha National Park (Fig. 4a) may have been driven by the concentration of safari operators and associated tourism economy. This was an indirect form of PA attraction that Hoffman (2011) noted in Costa Rica. However, the relationship was reversed in the 20-km buffers around the same park (Fig. 4b). This result may be related to diverse patterns of land use, including grazing, smallholder farming, and plantation agriculture, in different areas around the park at greater distances from its borders. Such discrepancies may be more likely where buffers of increasing distance include more heterogeneous landscapes, which was potentially the case in Rubondo Island National Park, where the PA boundary was the island itself and where the nearby fishing- and trade-driven lakeshore development differed from inland agricultural areas (Bootsma & Hecky 1993; Nunan 2010). In addition, consistent patterns across the increasing buffer distances may still fail to uncover multiple dynamics present around the same PA. Serengeti National Park appeared to experience lower growth rates in both its immediate 10- and 20-km buffer zones, yet closer analysis by Estes et al. (2012) show strong local variability in growth, reflecting different patterns of in-migration and land use conversion on the eastern and western borders. Lower rates may also be affected by PAs under different designation in the area, but we examined only populated rural wards subject to in-migration. Despite limitations, the buffer analysis corroborates results from the multivariate models that suggest no apparent PA-driven in-migration and demonstrate variation in the national parks network, which supports that multiple factors influence migration outcomes.

Results of our nonparametric tests supported the general finding of no in-migration to rural wards adjacent to PAs, but there are limitations to such tests applied to migration dynamics in general. For example, testing for a difference in growth rates based on a single classification (i.e., adjacency to PA) assumes the classification is unconfounded with all other factors determining growth rate, such as fertility, geographic, and edaphic features that might affect productivity. Further problems arise when simple tests are used in cross-national comparisons because census classifications (e.g., rural-urban, enumeration units) differ between countries (Bilsborrow 2002). Thus, although results of nonparametric tests agreed with those of our multivariate modeling and spatial analyses, we caution generalizing conclusions based simply on growth rates.

We found no convincing evidence of in-migration specifically to access conservation outreach resources provided by TANAPA (Fig. 2). Similarly, results of nonparametric tests did not suggest that wards with outreach projects had higher growth rates than other wards near national parks.

These conservation outreach projects were first implemented in 1988 in Serengeti National Park, and the program was formalized and expanded to all parks in 1994. The potential of such projects to attract in-migrants in Tanzania in general was previously noted (Barrett & Arcese 1995). TANAPA outreach supports specifically the same activities which have been used to explain a mechanism of PA-attraction (e.g., de Sherbinin & Freudenberger 1998; Oglethorpe et al. 2007; Wittemyer et al. 2008); communities themselves propose projects including most commonly the construction of schools and health centers, but also water and road infrastructure and financial support groups. Thus, it could be inferred such projects improve conditions thereby acting as potential pull factors (Scholte & de Groot 2010), though our conclusions do not support this mechanism of attraction in the context of national park outreach in Tanzania.

It can be argued, however, that benefits from outreach projects supporting broader community development may influence rural migration. For example, projects can provide jobs associated with the implementation of activities (Noss 1997). Yet in Tanzania, the national park-specific programs employ a nominal number of local staff (A. Mbugi, personal communication). More generally, although education, health care, and infrastructure can reduce the probability of out-migration (Barbieri et al. 2009; Massey et al. 2010), and lack of these services can contribute to out-migration from rural communities (Lopez-Carr 2012), there is as yet no clear evidence that people in-migrate to rural communities principally to access these facilities. The activities supported by TANAPA are substantial—in some parts of the country outreach funded the single primary school or dispensary in villages with no other services—but the outreach program as it is conducted does not provide sufficient benefits to drive in-migration. Similar shortfalls in provisioning benefits from conservation organizations to rural people are observed across southern Africa (Scholfield & Brockington 2009).

In considering the relationship of PAs and outreach together with migration, our results contribute to the debate on migration to PAs and the effect of PA outreach (Igoe et al. 2008; Wittemyer et al. 2008): rural people in Tanzania likely make their decisions based on geographic factors related to farming and herding livelihoods rather than proximity to PAs and associated conservation activities. However, these findings must be interpreted within the limitations of our analysis insofar as livelihood activities themselves (e.g., settlement, land clearing, and overgrazing) can result in cumulative effects on land productivity (though we see no ward-level trend in NDVI; Supporting Information) and potential suitability for subsequent migrants. Furthermore, although we found that PAs and outreach in Tanzania did not directly attract migrants, we cannot deduce from our findings the ultimate effects of PAs and conservation initiatives on local livelihoods. For example, it remains uncertain whether, on average, PAs impose heavy costs that associated benefits including outreach cannot offset or whether PAs and outreach together impact livelihoods positively but without attracting migrants. Only direct comparisons of migrants' circumstances before and after a migration event (Salerno, unpublished data) can address such questions. Our principal conclusion is that for migrants these conservation factors, whether positive or negative, are outweighed by the need for productive land to support rural livelihoods.

For example, in the Katavi-Rukwa ecosystem, an area with which we are familiar, in-migration is driven primarily by the search for land suitable for agriculture (Borgerhoff Mulder et al. 2007). Thus, observed population growth at PA borders is likely due to PAs being located in remote areas of available and productive land for livestock keeping and farming, regardless of park-based conservation outreach activities. Though human settlement near PAs may still result in land change and isolation regardless of the attraction mechanism (DeFries et al. 2005), a more advanced understanding of the diverse types of migrants, their decision processes, and their varying impacts on resources (Zommers & MacDonald 2012) is necessary for effective management. The capacity of conservation efforts to understand these systems and translate knowledge into informed project design increasingly determines social and ecological success (Brooks et al. 2012).

Significant to the study of migration and conservation science, our results show the limitations and benefits of investigating in-migration around PAs with existing methods. We argue that hierarchical multivariate models with fine-grained units of analysis and controls for fertility produce results best suited for making conclusions about the relationships among PAs, conservation outreach, and migration at larger scales. Future research should include investigation into the drivers of migration in origin areas, the relationships between types of conservation initiatives and in-migrants, and how strict, multiuse, and community-managed PAs differentially affect migration behaviors.

The implications of our work for conservation practice suggest that Tanzania's conservation outreach programs do not pose threats to protected biological diversity by attracting in-migrants or contribute to anthropogenic pressures through population increase. In addition, though people do not move preferentially to areas adjacent to PAs, if parks and reserves are located in areas of available and productive land, in-migration is more likely to result. Therefore, the management of PAs must be conducted within the wider landscape of human-occupied lands, based on appropriately scaled evidence.

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Supporting Information

Further description of the methods and interpretation regarding NDVI (Appendix S1) and multivariate model results (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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