



# HUMAN IMPACTS ON BIODIVERSITY CONSERVATION

MAY 2010

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Conservancy   
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# HUMAN IMPACTS ON BIODIVERSITY CONSERVATION

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# EXECUTIVE SUMMARY

The Nature Conservancy is one of the largest and most respected conservation non-profit groups in the world. Founded in 1951, the Conservancy works in 37 countries with a portfolio of over one thousand projects. Its conservation strategy evolved from a traditional focus on ecology and research to one that includes human and socioeconomic development initiatives in and around conservation areas. This shift was driven by the recognition that humans have a significant impact on the environment and a desire to achieve both biodiversity preservation and social responsibility goals.

The Conservancy consulted the Environmental Science and Policy program at Columbia to analyze relationships between humans and their environment and to gain a greater understanding of the dynamics of human populations around conservation sites. Changing human dynamics affect natural landscapes, and because of this, it is necessary to understand threats at the project level. This project explores the variables of population, poverty, consumption, and land use in order to gain insight into drivers of biodiversity threats; we seek to understand the global, regional and site specific dynamics of each of these variables. Pairing the Conservancy's ConPro database with geospatial mapping and statistical tools, we reveal trends that contribute to the threats faced by conservation sites. We then apply case studies and literature to highlight specific trends and comprehend these variables.

In our statistical analysis, we identified a pattern of increasing human population density with increasing distance from conservation sites. We used a comparative analysis of population growth rates to identify a number of sites that are at risk for future population pressure. Data analysis also supports the existing literature that correlates high population growth with higher levels of poverty, and suggests that, if poverty alleviation initiatives are incorporated into conservation plans, they may slow the rate of population growth. Analysis of land use at sites suggests that high population densities have a greater anthropogenic impact on their surroundings. Consumption data, case studies and literature also indicate that global consumption can have a large impact on land use and conservation.

Our study allows us to distill recommendations for conservation planning to the Conservancy. First, the Conservancy recognized the need for a better ability to compare approaches across case studies. The ConPro database can be a powerful organization-wide tool for conservation planning, since it allows site workers to access information on similar projects. Implementing this tool requires greater internal awareness of the database and a higher level of data completeness within the database itself.

Lastly, the Conservancy should continue to clarify the relationship between human populations and threats to biodiversity conservation, and strive to identify such relationships at the site level. Planners and site managers should be aware of projected human populations and incorporate such projections into conservation planning to ensure the viability of conservation efforts into the future.

We conclude that population data offers the greatest potential to provide the Conservancy with a dynamic perspective on human impact relative to its sites. There are several considerations behind this conclusion. First, the population data set is the most robust of all data sets examined both geospatially and temporally. Second, population can be considered as a partial proxy for the other data given its fundamental relationships. Population density and growth influence both human consumption and land-use and have been shown to correlate with poverty. Third, while population data can provide insight about human dynamics at the site-level, it can also serve a regional comparison or prioritization tool. In this vein, we have created a site-look-up model for Conservancy staff, both central and on the ground, to use and to follow human patterns.





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# INTRODUCTION

The popular slogan “Save the Planet,” represents the traditional concept of conservation, pitting the desire to protect ecosystems and the flora and fauna within them against the needs of communities that rely on natural resources. This ideological division fails to acknowledge the adaptive relationship possible between the ecosystems and the people who inhabit them. Recently, it has become more common to incorporate humans as an essential part of the conservation planning process, treating community members and surrounding populations as potential stakeholders, rather than as threats. The Conservancy asked us to examine human population characteristics at a global, regional and local level, in order to gain an understanding of the human patterns surrounding sites, to better understand how people contribute to threats and affect conservation targets, and to identify opportunities to engage locals in site management. By creating successful strategies, the Conservancy has the potential to preserve global habitats, assure resource availability and biodiversity within sites for future generations, and improve livelihoods of human populations that live in and around conservation projects.

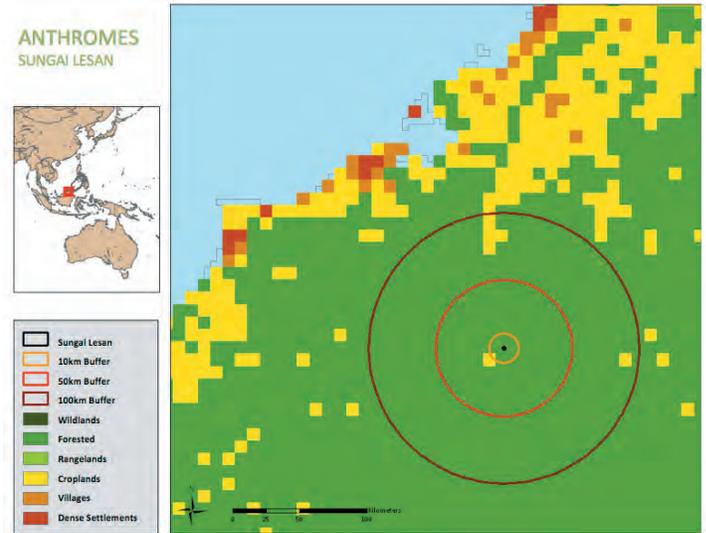
The Nature Conservancy focuses on preserving unique and often-threatened life within ecosystems as well as maintaining habitats that provide essential services to the surrounding and global community. The term “biodiversity” is generally understood to encompass the vast variety of existing flora and fauna—the totality of genes, species and ecosystems of any given region (Daily 1997). The interaction between these living organisms and their inanimate habitat are responsible for “ecosystem services” (IBC 2010). Through ecosystem services, biodiversity as a whole creates a number of key resources that allow human communities to thrive. These include provision of food and fuel, purification of air and water, stabilization and moderation of the Earth’s climate, generation and renewal of soil fertility by nutrient cycling, control of pests and diseases, maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines, and other products, as well as cultural and aesthetic benefits (CBD 2010). To date, scientists have identified a little more than a tenth of the estimated 13 million life forms on Earth, creating an urgency to conserve habitats in which the unidentified life forms may live so as not to lose the benefits we may be unable to appreciate today (Cracraft 2002).

Successful conservation requires we consider human factors beyond the borders of a protected area. The importance of a holistic approach can be best understood by examining a project that was limited in scope and thus fell short of conservation goals despite great effort (Meijaard and Hartman, 2010). The Conservancy website lists the Lesan River Protection Forest in Indonesia as a 12,000-hectare swath of the Lesan River and home to one of the richest remaining biodiversity areas, and rare species such as the iconic orangutan. Here, the Conservancy focused on protecting the area within the site, but did not sufficiently incorporate the rapidly changing social and economic factors surrounding the site into the site’s conservation plan, ultimately leading to the destruction of critical habitat.

The Conservancy’s ultimate goal at Lesan was to protect the ecosystem and the orangutans from the threat of encroaching farmlands. An essential part of its approach included outreach to the indigenous



tribes within the project site, as well as to the Indonesian government, the private sector and nearby NGO stakeholders. According to the website, the Conservancy was very successful at preserving the site itself, due in part to the indigenous tribes' increased understanding of the benefits from maintaining the forest and their support of the project. However, within seven years after the project's initiation, the area around the project site had experienced significant deforestation. Figure 1 shows significant croplands surrounding the Lesan conservation forests, and our statistical analysis revealed a 160% increase in the rate of deforestation in Indonesia from 1990 to 2005. The rapid land change around the site occurred as a result of surrounding tribes selling their lands to oil palm plantations in order to profit from a booming biodiesel industry (Brown and Jacobson 2005). The Conservancy may have been able to mitigate the rising socioeconomic pressures around the site, through better outreach. Though ultimately, land use changes outside the immediate conservation site compromised the condition of the site's habitat and viability of the orangutan and other species.



**Figure 1:** Depiction of land type in 2004 at the Lesan River Protection Forest and surrounding 10, 50 and 100 km buffers. Forested areas predominate inside the conservation and buffer zones, however croplands are visible along the coast and North of the buffers, some of which appears to enter the buffer zones.

Assessing trends of population, poverty, consumption, and land use for conservation both at site levels and beyond can inform future efforts to protect biodiversity. An understanding of many factors in and around the site--such as nearby communities, ecosystem structure and private industry--could have enabled the Conservancy to create a strategic plan that included further collaboration with the oil palm industry regarding placement of oil palm crops. This would have allowed the indigenous people to continue to earn some money from sale of land, and subsist off remaining protected forest. The site's web listing concluded if the Conservancy had more completely addressed human factors in the areas surrounding the site early in its project design, it may have discovered an alternative method to address the drivers of deforestation, or allowed economic drivers to work within the context of conservation.

Biodiversity loss is occurring one hundred times faster since humans appeared on the global scene (Chapin et al. 1998). Understanding the four primary anthropogenic factors that are believed to be responsible for this phenomenon--increasing human population, poverty, consumption and land use change--is essential to slowing and mitigating any resultant impacts. This project seeks to understand the global, regional and site-specific dynamics of each of these four variables. Geospatial maps and tools, in conjunction with statistical analysis, can reveal trends that threaten these sites and their associated biodiversity. Case studies highlight how the Conservancy approaches conservation threats at a sample of its sites, identifying both successes and areas in need of improvement. Literature review completes our analysis by complementing the global statistics and the case studies through provision of insight into trends in the variables and approaches to mitigating human impacts on biodiversity. We conclude by providing the Conservancy with policy recommendations on how to approach and mitigate human impacts.



# LITERATURE REVIEW

## PROJECTIONS AND TRENDS OF THE HUMAN VARIABLES

We searched the existing literature for information on how four variables: population, poverty, consumption, and land use, in order to better understand how humans impact biodiversity conservation sites. Below we describe some of the trends identified in the literature.

### POPULATION

Humans and their associated activities pose the largest threat to biodiversity within conservation sites. Changes in population contribute to poverty, consumption, and more intense land use on local, regional and global scales. Using population data we can extrapolate some trends related to impacts on biodiversity and ecosystem health. Global analysis shows that humans inhabit almost all regions of the world and that human population is predicted to grow from 6.1 billion in 2009 to 8.9 billion in 2050 and 9.22 billion in 2075 (World Bank 2004). Factors that affect population numbers include the relationship between life expectancy and birthrates, which vary widely from region to region. Human migration also affects local and regional population levels, but does not change the global figures. Understanding why population is increasing and where it is growing is essential for sustainable development. Scientific research can shed light on the maximum ecological carrying capacity, but mechanisms to manage population growth's potential effects on natural systems are less well developed.

High population growth rates often correspond to low national development levels, as well as areas of high endemic biological diversity (World Bank 2004; Cincotta et al. 2000). World Bank data shows that industrialized countries have stable or negative birth rates, while developing countries have high birth rates (World Bank 2004). According to a World Bank 2004 report, Africa has the highest 2000 total fertility rate, with an average five children per woman, and the continent is projected to maintain the globe's highest fertility rates until 2050 and beyond. Asia and Latin America have the second highest fertility rates at fewer than three children per woman during a lifetime (World Bank 2004).

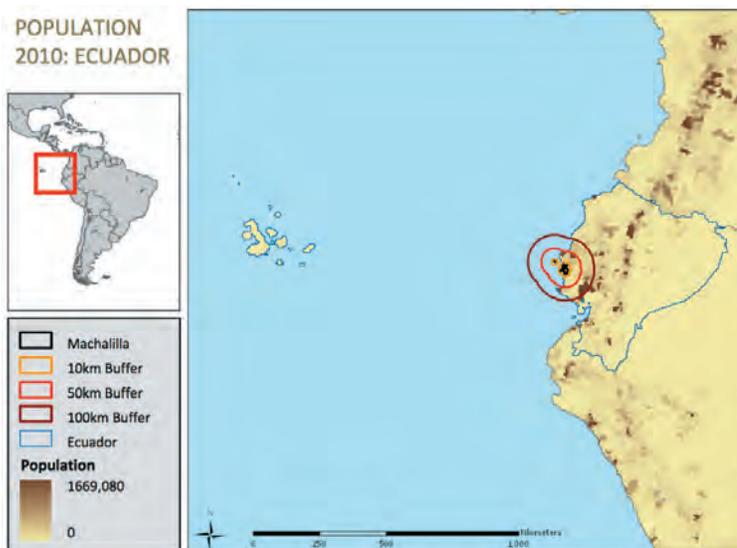


Figure 2: Map of human population of Ecuador and the Galapagos in 2010. Dense population appears to be clustered along the western coastline in an area of high biodiversity, as implied by Cincotta (2000). The Machalilla National Park is the conservation area depicted in this map.

Africa, Asia and Latin America also contain 25 biodiversity hotspots that are home to an estimated 35% of all vertebrate species and 44% vascular plant species in only 1.4% of Earth's land area (Cincotta et al. 2000; Myers et al. 2000). Cincotta et al. (2000) state there are three areas of high priority with high biodiversity and low human impact; but these sites are threatened by growing human population: Madagascar, Caribbean-Western-Ghats-Philippines and Tropical Andes-Choco-Darien-Western Ecuador corridor along coastal Ecuador and Columbia. Examination of our data for Ecuador and Machalilla National Park in Figure 2 shows high population growth along the western coast of Ecuador, an area Cincotta et al. (2000) cites as one of the threatened hotspots of biodiversity.

Increases in life expectancy play an important

role in linking higher fertility with higher population growth. During the past century, overall global health has improved resulting in higher lifespan (McMichael et al. 2004). Regions of higher life expectancy generally have a positive correlation to politically stable and wealthy countries, though wealth does not necessarily lead to elevated life expectancy (McMichael et al. 2004). Studies predict populations to stabilize by 2075 because of lowered fertility and increased life expectancies (McMichael et al. 2004; World Bank 2004).

Human migration is another factor that can contribute to population change at the regional and local levels. Migration has been facilitated by improvements in transportation, allowing people to reach their desired destination faster and expand their geographic options (Meyerson et al. 2008). Drivers for migration include economic, environmental and social factors. Climate change is expected to play a growing role as a driver of migration as effects begin to manifest (Meyerson et al. 2008). Migration can occur between countries, but the bulk of human migration is intra-national (Klugman 2009). An example of migration can be seen in the Galapagos, shown in Figure 3, where a 4.9% annual population increase from 1990-2010 can only be explained by migration. Biodiversity in the Galapagos is threatened, not only by increasing human populations but also by a rise in invasive species related to human traffic (Mauchamp 1997). In the Galapagos, an expanding tourism industry provided the necessary economic incentive to trigger human migration. Planning for tourism must be strategically done, as corresponding population growth and development can cause damage when infrastructure becomes overwhelmed, leading to such things as improper sewage disposal or excess human disturbance. These phenomena have been witnessed in some ecotourism ventures in Costa Rica (Weaver 1999).

Increasing the concentration of people in an area can deplete natural resources and affect the natural landscape. These effects may manifest as reduction of water tables due to an increase in population, and may even be seen in rural and suburban areas (Meyerson et al. 2008). Conversely, migration to urban areas can reduce stress on conservation zones; cities are known to efficiently provide opportunities for employment, childcare, medical care, mass transportation, food production, and energy consumption (Klugman 2009).

Though no clear metric exists to evaluate the threat population poses to biodiversity, it is logical that ever-increasing populations threaten to exceed the number of people that the landscape can sustainably support, leading to environmental degradation (McKee et al. 2003). Family planning policies are incredibly controversial, but can slow population growth or even induce negative population growth. Understanding cultural issues that drive birth-based population rates in each individual country may demand a great deal of time and resources, but taking this time to understand the cultural, social or economic causes of high birthrates will help identify the underlying drivers. In some continents such as Africa, children are a symbol of fertility and status, and a large family structure is deeply ingrained in culture (Makinwa-Adebusoye 2002). Other actions, such as distribution of condoms, can reduce unplanned pregnancies (Steen et al. 2007; Hendriksen et al. 2007).

Empowerment of people—especially women—through training and education may provide enhanced opportunities for employment, corresponding increases in income and access to a better life. Educated

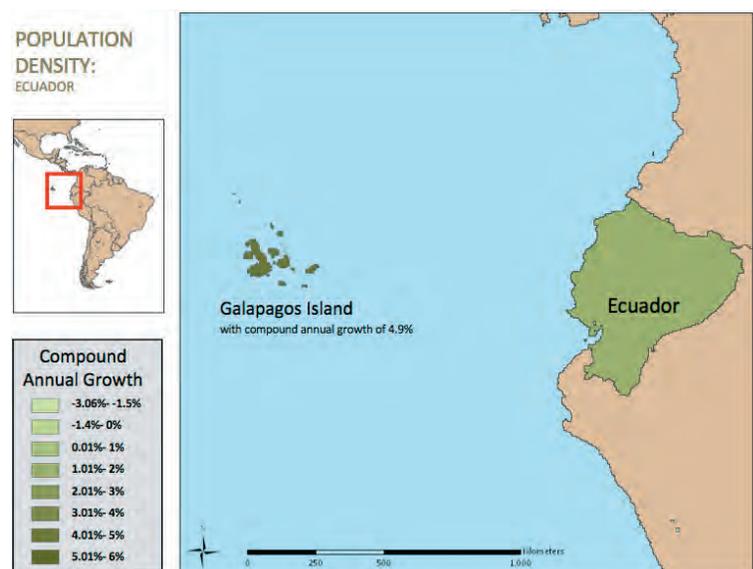


Figure 3: Compound annual growth in Ecuador and Galapagos for 1990-2000. Galapagos compounded annual growth of 4.9% exceeds the growth in Ecuador, which is higher than average growth of the world, but less than double this growth.





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individuals may also migrate away from conservation zones, where development and employment opportunities are limited. Education may also delay reproduction resulting in a possible reduction in fertility rates (Hendriksen et al. 2007). It is of note, however, that education's impact on fertility is hotly debated (Myrskylä et al. 2009).

## **POVERTY**

The Millennium Development Goal states that success in achieving environmental stability hinges upon the elimination of poverty (Ash and Jenkins 2007). Predicting global and regional poverty trends over time is extremely difficult. Assessments of poverty rates in the 1970's showed that almost all countries were developing economically. However, only 1% of 1.3 billion extremely poor people increased wealth in the 1990's, falling short of predictions (Ash and Jenkins 2007).

People of limited economic means are especially dependent on land and ecosystem integrity for resource provisions, since they are unable to buy or import substitute products (Ash and Jenkins 2007; Sachs 2005). Examining national development remains a useful means of prioritizing areas of concern. Developed and relatively well-off developing countries, including India, Brazil, and China, widen the economic disparities between the rich and poor (Vandemoortele 2002), and make less useful the distinction between developed and developing countries in assessing poverty. In this section we will examine how extremely poor nations affect biodiversity and conservation efforts, providing insight into the causes of these impacts and recommendations to mitigate drivers.

The poorest countries share several key characteristics, including lack of basic medical care, education, and employment opportunities, unreliable savings strategies, and heavy reliance on local natural products for food, shelter and income (Sachs 2005). These countries have high levels of endemic biodiversity and generally an abundance of mineral wealth (Wilkie et al. 2006). Despite their wealth in natural resources, many countries are unable to turn mineral wealth into development capital due to corrupt governments that siphon off money and power (Humphreys et al. 2007). Poverty creates the opportunity for exploitative natural resource extraction by corporations and is a major driver of biodiversity loss (Wilkie et al. 2006; Cincotta et al. 2000).

Foreign aid schemes designed to assist the poorest counties have been widely debated, as such schemes may also be subject to government corruption (Sachs 2005; Moyo, 2009). These schemes can be useful in biodiversity conservation by providing alternate means of food, medicine, and other products, thereby reducing the stress on local ecosystems. While driven by good intention, aid, whether in the form of money, food or medicine is only effective if it reaches intended recipients.

By examining a government's behavior and actions to address poverty or income fluctuations, such as savings structures in Kenya, we can better understand how to address threats to biodiversity (Fafchamps et al. 1998). Some rural Africans invest in livestock to stabilize their sporadic income. An increase in livestock leads to more grazing, and, in turn unsustainable management of grazing lands or conversion of natural landscape to pasture. Livestock are also susceptible to disease and adverse weather conditions. Global warming is predicted to exacerbate both the sensitivity to disease and the proclivity for drought, and may decimate livestock and savings (Fafchamps et al. 1998). Creation of alternative savings programs may be a policy tool that could help to curb the direct impacts of poverty on biodiversity.

It is essential to understand the drivers of local behavior, in order to identify issues of concern and to develop functional mitigation strategies (Baulch and Hoddinott 2000). Developing conservation programs like well-planned ecotourism programs may allow locals to escape the poverty trap and participate directly in conservation. The Conservancy has been successful at involving local stakeholders in its initiatives, often winning over indigenous populations with its conservation programs that provide alternative or increased income that does not impose on their traditional lifestyles (Hoekstra et al. 2010). The Conservancy's Condor Bioserve project in Ecuador is an excellent example of integrating indigenous groups with conservation efforts. In that project, the Conservancy partnered with existing organizations to encourage responsible use of natural resources for industry while preserving the mission of the bioserve and the people within it (The Nature Conservancy in Ecuador 2010).

Based on our literature review, most successful conservation programs incorporate government support and strong focus on local groups. These programs place a high value on local stakeholder input, and provide education and training, thereby advancing stakeholder power and cultivating permanent improvement tools (Moyo 2009). Alternative mechanisms promoted by critics of foreign aid are free trade, foreign direct investments, microfinance and education as alternatives to help alleviate poverty (Moyo 2009). These long-term investment schemes target local populations, and when successful, examine current local needs, develop trade markets and build skills for the future (Moyo 2009).

## **CONSUMPTION**

It is necessary to define types of consumption in order to determine drivers behind this complicated variable. We explore two levels of consumption: local and global. Local consumption is the use of primary products or other natural resources for basic human needs, while global consumption primarily includes commercial ventures that extract natural resources from one region and import those resources to another (Ezaza 1988). For our purposes we treat consumption as distinctly different from production of exportable goods. Generally speaking, populations in wealthy, industrialized countries have the highest rates of consumption, as high income allows for increased consumption of net primary productivity (NPP). NPP is used as a measurement of the conversion of natural resources, and in the case of our dataset the measurement of solar energy that is converted into organic matter (Imhoff et al. 2004).

International conservation groups are often critical of local resource extraction in impoverished countries (Wilkie et al. 2006). Expanding population and limited consumer power drives increased extraction of resources such as raw timber to create charcoal for cooking, or conversion of land to farms for food production (Wilkie et al. 2006). In the case of charcoal, innovation and access to technology, such as solar



ovens, can address unsustainable wood harvest. In impoverished regions, however, such innovation may be cost-prohibitive, absent microfinance loans (Wilson and Green 2000; Moyo 2009).

Overall global consumption has trended upward over time in countries with high levels of economic development (Omer 2007). In 2005, local trends in energy consumption showed that industrialized countries and rapidly developing countries have extremely high consumption rates compared to the poorest regions of the world. Energy consumption in the United States, for example, has increased five times faster than energy consumption in other countries (USEIA 2007). High-energy use in industrialized countries may be due to heavy reliance on high-energy consuming products and technologies (Parikh 2010).

Industry-driven consumption, such as mining or oil extraction can cause severe environmental degradation in impoverished regions (Omer 2007). For example, mountaintop removal coal mining techniques address energy needs and miner safety, but completely eliminate mountaintop habitats and can decimate downstream and adjacent habitats via pollution and sedimentation (Pangsapa and Smith 2008). Well-funded private industry poses a large threat to biodiversity through resource extraction. Thus, it is important that conservation organizations build long-term relationships with these companies and encourages sustainable development schemes as a conservation-planning tool (Pangsapa and Smith 2008). Industrial development may provide immediate economic benefit to local populations through increased employment opportunities and income from land sales. Unfortunately, such development and corresponding land use often have significant negative impacts on biodiversity and may thwart conservation efforts. Education and conservation-based, income-generating ventures (e.g. ecotourism) may provide sustainable, alternative sources of income (Hoekstra et al. 2010).

Environmental degradation often results from excessive consumption and ineffective waste disposal methods. A prime example of this is the infamous Great Pacific Garbage Patch - a gyre of marine litter characterized by exceptionally high concentrations of plastic, chemical sludge, and other debris. These pollutants are consumed by marine birds and mammals and have the potential to enter our bodies through our consumption of contaminated food or water (Moore 2003; Rahim 2010). Methods of addressing consumption and wasteful behavior include waste tracking, creating more effective disposal systems, enhancing corporate responsibility for waste products, government sanctions and ensuring that waste does not impact high priority conservation areas (Moore 2003; Rahim 2010).

Renewable sources of energy such as solar, wind, and biomass may help reduce pressure on finite resources without hindering industrial countries energy demands. Such technological advancements do not remedy the driver of broad scale consumption, which is human behavior (De Young 1996). Addressing consumption is difficult; it is useful, however, to examine how legislation and corporate policies have been successful in changing consumptive behavior. For example, the European Union and Wal-Mart were very successful in their respective efforts to ban or reduce the purchase of energy intensive incandescent bulbs (Edge and McKeen-Edwards 2008; Barbaro 2007).

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## LAND USE

Land use change has been linked to the other human variables explored here. It can be driven by population increases, poverty and consumption patterns (Brown et al. 2007). Anthropogenic influence has greatly altered most natural biomes, with few areas remaining on Earth that have little or no human presence (Ramankutty and Foley 1998). Wildlands, or areas with little human influence, have generally remained so due to natural barriers such as vast deserts or mountain ranges that restricts human access (Xu et al. 2007). Population, poverty and meteorological trends can help shed light on potential human settlement patterns. For example, agriculturalists may move due to degradation of viable farmlands or water depletion (Fearnside 1983). Providing education on sustainable land use and farming practices may therefore reduce pressures on the environment by reducing conversion of pristine land into cropland. In order to prevent the degradation of remaining pristine areas, it is essential to develop educational programs that maintain or enhance human-use land, for example, by improving soil nutrient retention (King 1987).

Understanding the impact of humans on biodiversity is difficult. The recovery of areas from which humans have been removed can provide insights into what a non-impacted site might be. The demilitarized zone in North Korean border with South Korea is an excellent example. Humans are prohibited from entering the area, reportedly allowing a number of endangered species, such as the leopard, lynx and Asiatic Black Bear, to live undisturbed (Dudley et al. 2002). Understanding the dynamics of the recovery of some of these species and habitats in the absence of humans may shed further light into how specifically humans affect ecosystems and may suggest new strategies for conservation.



# DATASETS AND LEVELS OF ANALYSIS

For a more complete examination of datasets and challenges faced please refer to Appendix B.

## POPULATION

We obtained population data from Columbia's Center for International Earth Science Information Network (CIESIN 2005) for the years 1990, 2005, 2010, and projected data for 2015.

## POVERTY

Two datasets represent poverty: infant mortality rate (IMR) and human development index (HDI).

- The IMR dataset, which we obtained from CIESIN (2010), represents the number of deaths per 1000 children under the age of 1 at a sub-regional level. IMR represents a composite of available sub-national and national IMR from 1990 to 2003 adjusted to 2000 levels.
- The Conservancy's "Direct Benefits to Poor People from Biodiversity Conservation" (2004) defines poverty in terms of three dimensions: opportunity, security, and empowerment. These metrics are represented in the HDI index, at years 1990, 1995, 2000, and 2005 (UNDP 2009).

## CONSUMPTION

Four separate datasets represent consumption:

- Human Appropriation of Net Primary Productivity data was originally published by Imhoff et al. (2004), and obtained from CIESIN-SEDAC. This dataset provided us with data on a national level in Microsoft Excel format and represents the energy used in the consumption of wood, fiber, paper, meat, vegetables, egg and milk (measured in gigatons of carbon).
- Deforestation data, obtained from the World Development Indicators 2006 (World Bank 2006). Data represents deforestation on the national and regional level in 1990 and 2005.
- Energy consumption data, obtained from the US Energy Information Administration Independent Statistics and Analysis Database for 1990 and 2005 (USEIA 2007). These data represent primary energy consumption from sources such as solar, wind, fossil and nuclear (measured in quadrillion BTUs).
- Gross Domestic Product (GDP) data, obtained from the International Monetary Fund World Economic Outlook Database October 2009 (IMF 2009) and the CIA World Fact Book (CIA 2009).

## LAND USE

We re-categorized the geospatial maps representing land use based on Anthromes. This dataset originally compiled by Ellis and Ramankutty (2008), was obtained from CIESIN. Anthromes represents a composite of the human ecological impact on land and the information presented was compiled from January 2003 to December 2005.

## CONPRO SHAPEFILES

We obtained a Microsoft Access file of 1008 global projects from the Conservancy's ConPro database. This file contained 597 project polygons; Jon Fisher provided an additional seven shapefiles not available on ConPro. ConPro represents the Conservancy's database, listing information on sites including project



managers and their contacts, threat rankings and conservation targets that we later used to flesh out our case studies.

## **LEVELS OF ANALYSIS**

We used three metrics to compare datasets:

- (1) Global
- (2) Regional, as defined by the Conservancy
- (3) Project Sites and Buffers

We conducted analysis at Conservancy project sites (B0 level analysis) and buffers at 10km (B10, B standing for buffer), 50km (B50), and 100km (B100) from the project site. We selected a 10km buffer because high population growth has been shown to occur around the edges of conservation areas (Wittenmeyer et al. 2008). A 100km buffer reflects the capacity of urban populations to alter ecosystems through resource extraction (Cincotta et al. 2000). The Conservancy expressed interest in examining human dynamics within 50 km.

## **TESTS**

We analyzed these data sets with ArcGIS's ArcMap software and Microsoft Access and Microsoft Excel software. For a full description of analytical methodologies see Appendix C for an introduction to technical methodologies, and the Technical Documents deliverable which accompanies this report.



# GLOBAL AND REGIONAL STATISTICAL RESULTS

The Conservancy’s ConPro database contains 1008 conservation sites. The Conservancy provided GIS shape files for 603 of those sites for geospatial data analysis. Of those, 588 were successfully integrated into our analysis; please see Appendix B for the issues we encountered. We examined the set of GIS available ConPro sites from a global perspective with regards to four variables; population, poverty, consumption, and anthromes, in order to determine characteristics of the Conservancy’s overall site portfolio. Data for each individual site are provided in two different forms for the Conservancy. We have supplemented the Conservancy’s Microsoft Access database with all of the data and results created in our analysis. In addition, because Access is an unfamiliar program to many people, we have created a user-friendly Microsoft Excel-based tool to easily retrieve a complete picture of data for any Conservancy site included in our analysis. Both the database and the Excel tool are further described in Appendix C and provided to the Conservancy under separate cover. To document the sources, assumptions, and descriptions of each piece of data, we created a data dictionary to accompany these tools. Although the results presented below are aggregated at the regional and global levels, complete site and country-specific data can be found in our database and Excel tool. Population figures for conservation sites and buffers correspond with the GIS shapefiles provided by the Conservancy, and may not represent the true populations living within and around conservation sites.

For the purposes of this study we use the word site to refer to a conservation project, as defined by the Conservancy in their ConPro database at <http://maps.tnc.org>. A conservation project is defined as “a set of strategies taken by a defined group of practitioners working to achieve specific conservation goals and objectives for a set of conservation targets. Historically these actions and actors have been defined as part of the Conservancy’s Conservation Action Planning work.

## LAND AREA

The results of the spatial analyses are predicated on the total land area of the conservation sites. To provide context for our analysis, we first begin with an overview of conservation sites by the Conservancy’s regions, as shown in Table 1, which shows land area data for 531 of the 588 conservation sites with GIS data. Sites excluded from this table are either marine or sites with boundaries too complex for GIS analytics (see the Technical Documents for a more thorough review of GIS analytics challenges). The area data include only the land area within a conservation site and excludes area covered by surface water (lakes, oceans, etc.) as defined by CIESIN’s Nations and Natural Boundaries shapefile. The area metric presented here is used for population density analysis.

Table 1: Conservation Site Land Area Characteristics by Conservancy Region.

	Global	North America	Latin America	Asia/Pacific	North Asia	Africa
<b>No. of sites</b>	531	427	78	15	9	2
<b>Total area (sq. km)</b>	5,048,825	2,548,167	689,252	86,361	91,357	1,633,689
<b>Average</b>	9,508	5,968	8,837	5,757	10,151	816,844
<b>Maximum value</b>	1,354,285	491,262	100,690	58,910	67,013	1,354,285
<b>Minimum value</b>	3	3	5	63	28	279,404
<b>Standard deviation</b>	64,406	26,065	14,152	14,097	21,458	760,056

The Conservancy sites vary dramatically in size, ranging from areas of just three km<sup>2</sup> to projects of more than one million km<sup>2</sup>. Further, the standard deviation of land area in each region exceeds the average land area size, which indicates a considerable presence of small sites along with a number of very large sites. There is a wide spatial distribution of sites as well. Africa, North Asia, and Asia/Pacific have fewer than 20 sites each, 78 sites are contained within Latin America, and North America has over 400 conservation sites.

## POPULATION

An aggregate of global site population data shows that, as of 2010, an estimated 126 million people live within the boundaries of the conservation sites included in our analysis. Areas within the immediate 10 km buffers of the sites provide a home to an additional 64 million people, about half the population of that living within the sites themselves. Approximately 207 million people reside between 10 km and 50 km from the sites, and there are 132 million people between 50km and 100 km from the sites.

By 2015 the population within the conservation sites is expected to grow by nearly 8 million people, 6.3% of the current 2010 population. This growth rate is slightly higher than the growth projections for the surrounding buffers, which are estimated to grow between 5.7 and 5.8%.

Our population analysis seeks to identify population density and growth trends at the regional level. First, we examined present day population densities to understand the existing relative concentration of people around conservation sites. Next, we analyzed twenty-year growth rates to provide insight on what areas are experiencing the greatest change in population levels. Third, we related historic growth with present day density to understand how these variables relate to each other today and to posit how they might impact future population density. Fourth, we incorporated geospatial analysis to assess how population density and growth rates are changing in the immediate (10 km) and more distant (50 km) surroundings of the Conservancy's conservation sites. Notably, many areas experiencing high human population growth also have high concentrations of biodiversity (Cincotta et al. 2000).

### Population Density Today

Global human population averages approximately 50 people per km<sup>2</sup>. To begin our analysis, we examined population density within sites and surrounding 10 km buffer areas and compared these statistics with the global average. Figure 4 illustrates the breakdown of current population density for the Conservancy sites, and reflects how the sites and 10 km buffer areas compare to the global average. Globally, nearly 80% of the Conservancy sites have population densities below the world average. The composition of sites in North America mirrors the global breakdown, largely due to the number of sites in North America. North America, with 474 sites, represents 80% of the sites included in the global analysis. Of the 84 sites included in the Latin America region, only 10% (approximately 8 sites) have population densities that exceed the global average. In general, the Latin American portfolio is skewed towards low

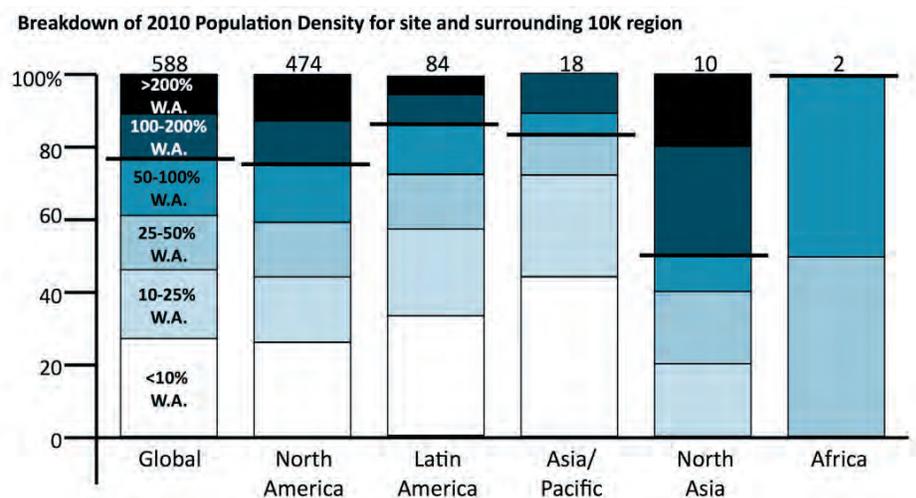


Figure 4: 2010 Population Density by the Conservancy's Regions  
W.A. = World Average, 50 people per square kilometer. Solid bars at regional level indicate the point where density crosses the world average. The number of sites in each region is listed above each bar.

population density relative to North America and the global portfolio. The Asia/Pacific region has a lower density profile relative to the ten sites in North Asia. Finally, with only two sites in the Africa region, it is difficult to derive trend data based on this type of analysis.

**Population Growth Rates: 1990-2010**

We further characterized each site and its buffer by classifying historic compound annual population growth rates in one of the following ways: greater than twice the world average, between 100% and 200% of the world average, between 50% and 100% of world average, less than 50% of the world average, and less than zero (declining populations). Figure 5 shows the distribution of sites between these five groups of population growth.

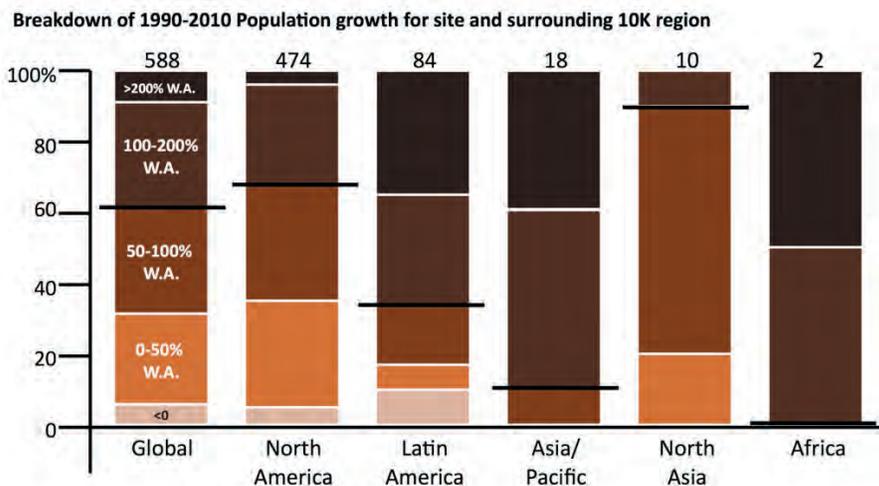


Figure 5: 1990-2010 Population Growth Rates by Regions as Defined by the Conservancy. W.A. = World Average, 1.3% per annum. Solid bars at regional level indicate the point where growth rate crosses the world average.

Consistent with the population density analysis, the North American region mirrors global population growth rates. Interestingly, North America seems to under-represent the highest growth rate category, indicating that non-North America make up the highest growth rate category in the global breakdown. We see this trend reflected in the other regions. For example, Latin America and Asia Pacific both contain 40% of the sites in the highest growth category

**Relationship Between Population Density and Growth**

Both Latin America and Asia/Pacific regions appear to be skewed towards low density, shown in Fig. 4 and towards high growth, shown in Fig. 5. In contrast, the North American data ranges are fairly consistent in both Figs. 4 and 5. To further understand this dynamic, we segmented all sites based on both current population density and historic growth.

Global breakdown of sites by population density and growth characteristic



Figure 6 shows that, 28% of the Conservancy sites that are currently high density are split evenly between high and low growth. The remaining 72% of the Conservancy sites that are low density today are relatively evenly split, 34% with low growth and 38% with high growth. Fig. 6 characterizes sites using a threshold value of 75% of world average for both density and growth dimensions.

This segmentation is an important lens for analysis because it illustrates both current population density and the potential for future population density. While only 28% of the sites are high-density today, the 38% of sites that are low-density but high-growth could shift these sites into the high-density classification if population growth rates are maintained. Should the calculated growth rates hold constant over the 2010-2020 time frame, the percentage of sites designated as high density will increase from 28% to

Figure 6: Relationship between population density and population growth for all sites. Low growth and density are both defined as less than 75% world average. The gray box represents those sites that have both high population density and high population growth.

34% over just 10 years. In absolute terms, this represents an addition of 32 sites into the high-density classification.

Similar figures for each of the Conservancy regions are included in Appendix A (Figures 7.1 – 7.5). Figure 7.2 illustrates the geographic distribution of sites across the categorization shown in Fig. 6 for the Latin America region.

### Geospatial Trends: Population Density and Growth Surrounding the Conservancy Sites

In addition to assessing population density and growth rates for the immediate surroundings of project sites, we also examined how the distribution of population surrounding the sites has changed over time. This analysis allows us to understand where population seems to be clustering near the Conservancy sites and where population seems to be growing most in site peripheries.

First, we looked at the static 2010 picture to examine the relationship between population density and proximity to the Conservancy sites. In doing so, we considered rings of area and population, as indicated in Figure 8. Results at the global and regional scales are represented in Fig. 8.

We noted that population density increases with distance from conservation sites. This trend is consistent in all the Conservancy regions with the exception of North Asia, where we noted fairly uniform population density at various distances from the site. This trend may be a result of the Conservancy’s history of working in areas with low human presence, and may be expected to change now that the organization is moving its focus to incorporating human populations as both collaborators and targets of conservation programs.

Next, we considered 1990-2010 compound annual population growth rates for the rings surrounding the Conservancy sites. This analysis allowed us to assess how intra-site population growth compares with growth rates for the surrounding areas. To evaluate growth patterns, we characterized the extent of growth imbalances between buffer regions. In doing so, we iden-

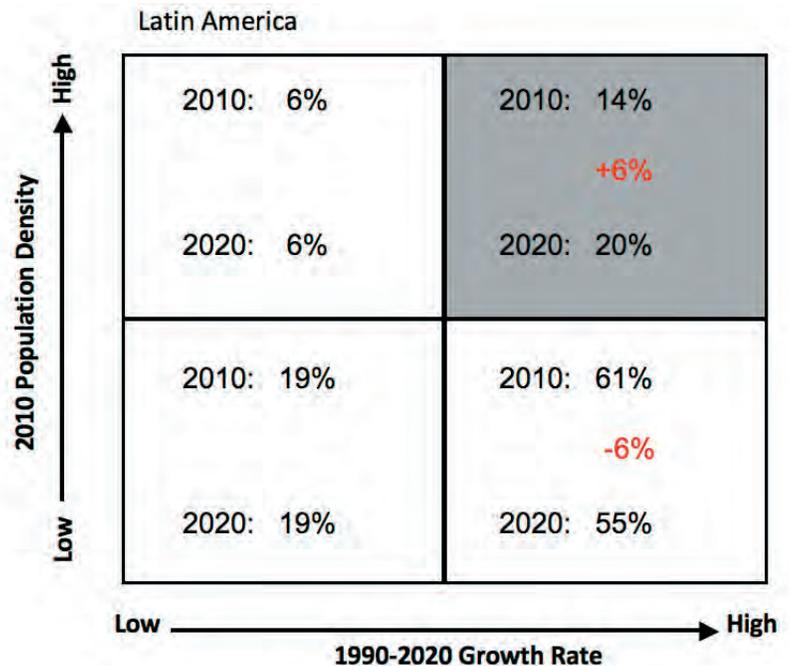


Figure 7.2: Latin America site distribution between population density and population growth over from 2010 to 2020.

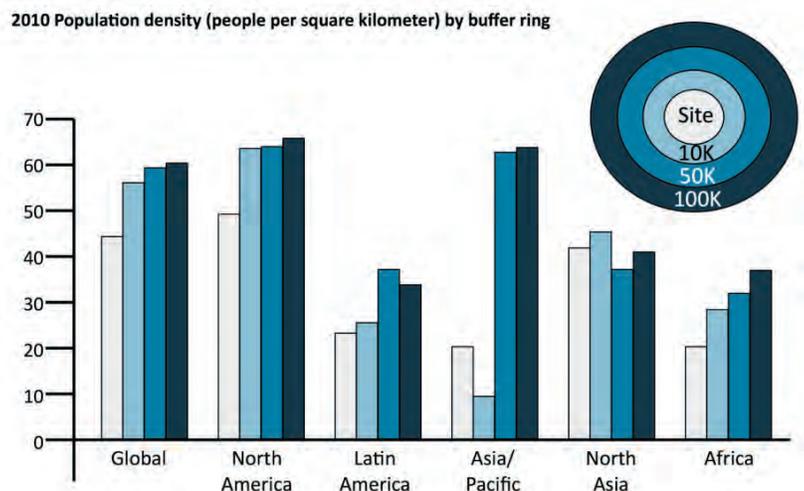


Figure 8: Relationship between population density and proximity to Conservancy’s sites. A trend of higher population density further from conservation sites predominates.

tified sites with neutral growth profiles--those in which intra-site growth and surrounding area growth rates differ by less than 0.1%--as well as sites with growth imbalances. Sites that have greater population growth in the peripheral area relative to within the site are considered to have “peripheral favor.” Conversely, sites with population growth greater within and immediately surrounding the site relative to the B50 buffer ring are considered to have “central favor.” Within each type of favor, we identified strong and weak segments based on the extent of the growth rate imbalance. Sites with compound annual growth rate differences between 0.1% and 0.75% are characterized as weak, while sites with differences greater than 0.75% are considered strong. Our findings, globally and by region, are shown in Figure 9.

Breakdown of sites by growth favor dynamics by region

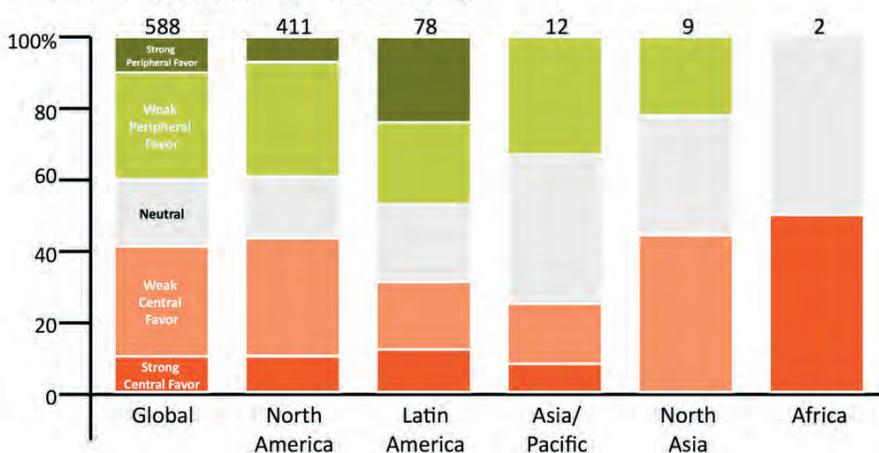


Figure 9: Relationship between population density and proximity to Conservancy site.

According to this analysis, approximately 20% of the sites are showing equivalent growth rates for the area encompassing the Conservancy sites and the B50 radial-area surrounding the site. The remaining 80% of the sites are evenly split between those that exhibit central favor and those that show peripheral favor. Regionally, in North America, Asia, Asia/Pacific, and Africa the majority of sites are either neutral or a “weak” category. In Latin America, sites exhibit the greatest variety, as demonstrated in Fig. 9.

In this region, 36% of sites are in the “strong” category; 24% show strong peripheral favor and 12% show strong central favor. A site showing central favor exhibits growth within the B50 buffer interval that is at least 0.75% higher than growth between the B100 and B50 buffers. Sites showing peripheral favor have higher growth between B100 and B50, and low growth from B50 inwards.

To provide perspective on the impact of differential compound annual population growth rates on the geospatial dynamics at a site, Table 2 illustrates the population density dynamics for a site with strong versus weak central favor. Over a 20-year period, a small difference in compound annual growth can make a considerable impact on the overall percent increase in density for a given area. Figure 10 illustrates the geographic distribution of sites across the categorization shown in Fig. 9 for Latin America.

Table 2: Illustration of impact of CAGR rates on overall density increase.

	1990	2010	(1990-2010) CAGR	Density % Increase
<b>Strong Central Favor: B0 to B50 CAGR Delta: 1.4%</b>				
B0	16	23	1.8%	43%
B10	152	193	1.2%	27%
B50	46	50	0.4%	8%
B100	583	611	0.2%	5%
<b>Weak Central Favor: B0 to B50 CAGR Delta: 0.4%</b>				
B0	6	9	2.3%	58%
B10	7	11	2.0%	49%
B50	15	21	1.9%	46%
B100	33	52	2.3%	56%

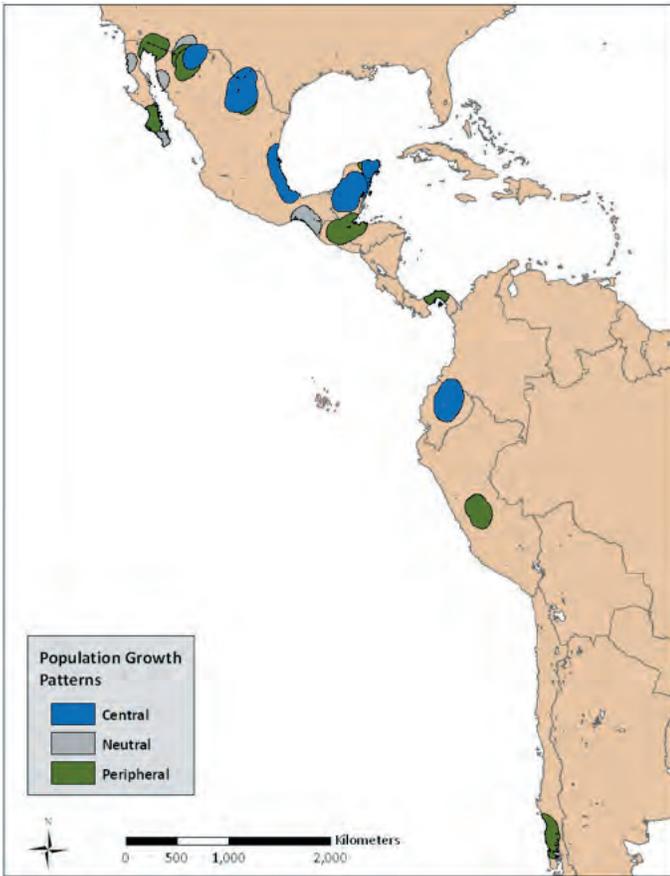


Figure 10: Depiction of sites in Latin America with central, neutral or peripheral population growth. Only publicly available sites are shown.

## POVERTY

We have classified the poverty level of the Conservancy sites using classifications developed for the Infant Mortality Rate (IMR) data set. The distribution of the Conservancy project sites with active GIS shapefiles with regard to national poverty and the Conservancy region is shown in Table 3.

Notably, only four project sites are classified as extremely poor or very poor. An additional 46 sites are classified as poor, while another 537 are classified as moderately poor or not poor. The distribution of sites relative to poverty is likely due to the fact that most sites are located in the United States, where the Conservancy initially focused its conservation efforts. These results are also a function of project growth and expansion that has been dictated by government grants, donor funding and a focus on iconic conservation sites. Poverty may become an increasing concern as the Conservancy continues to expand its initiatives in less developed regions.

We used HDI and IMR as poverty data sets to get a national level time series analysis. We conducted a correlation analysis of Human Development Index (HDI) to IMR to determine whether the data sets were substitutable. The scatterplot in Figure 11 shows the high degree of correlation between the two data sets. This correlation is unsurprising when we consider that infant mortality rate is one of the factors taken into account in the calculation of the HDI rankings. Because of the close correlation between

HDI and IMR we can be confident that, in using only one of the metrics to represent poverty, we will not misrepresent our findings on poverty.

We further compared HDI in countries where the Conservancy works with the rate of population change in those countries. This analysis is presented in Figure 12 where increasing population growth rates are generally associated with higher levels of poverty. The trend is especially evident in Latin America and is consistent with trends observed in supporting literature (World Bank, 2004). This suggests that, in locations where the Conservancy sites are facing the threat of increasing population, programs that alleviate poverty and improve quality of life may be successful at reducing population pressures.

We were unable to fully assess the direct impacts of poverty on conservation sites, given that currently available datasets are only pertinent to national or sub-national poverty analysis. Accordingly, we relied, to a certain degree, on literature and case studies to supplement this information and to identify economic drivers of population migration.

Table 3: The distribution of the Conservancy sites by region and poverty level (IMR classification).

Poverty Level	North America	Latin America	Asia/Pacific*	North Asia	Africa	Total
Extremely Poor					1	1
Very Poor			2		1	3
Poor	2	36	8			46
Moderately Poor		42	3	10		55
Not Poor	472	6	4			482
Total	474	84	18	10	2	587

\*One additional site was not classifiable because it was located in a country for which no IMR data was available.

## HDI vs. IMR

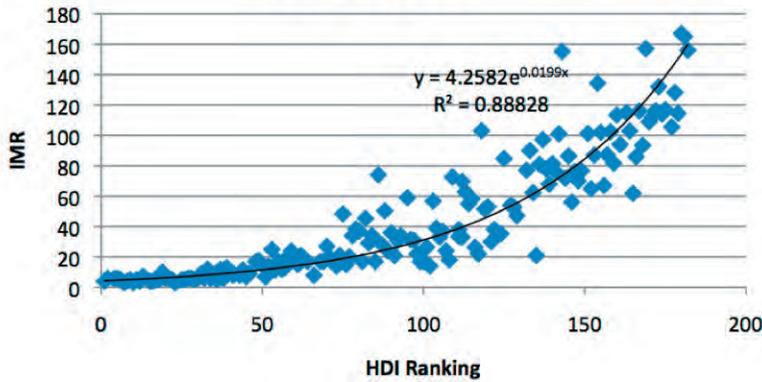


Figure 11: Correlation of HDI and IMR data for countries in which both datasets provided coverage. The two data sets are highly correlated ( $R^2 = 0.89$ ).

## HDI Rank vs. Population Growth Rate

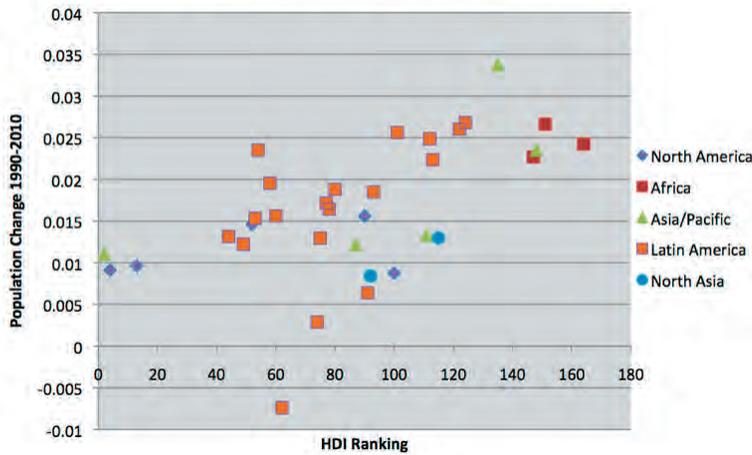


Figure 12: HDI ranking versus population change, colored by region. Population growth increases with increasing levels of poverty.

## Deforestation Rate vs. HANPP of Wood

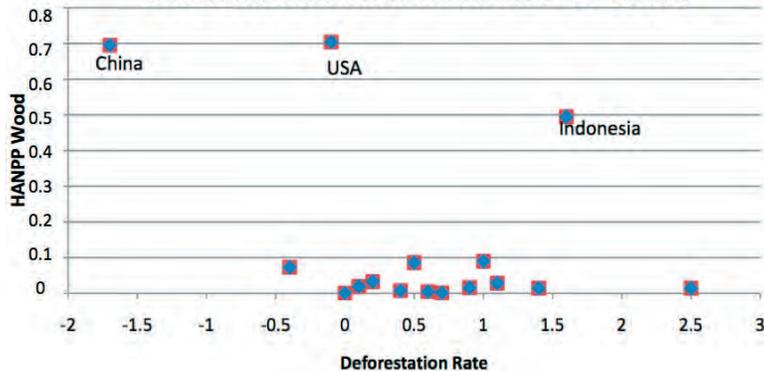


Figure 13: National deforestation rates compared with country level HANPP of wood for countries in which the Conservancy conducts conservation work.

## CONSUMPTION

Deforestation is a threat common to 527 Conservancy sites, according to the ConPro database. We therefore sought to identify trends in timber products consumption for each country in which sites threatened by deforestation were located. We sought to determine if timber products harvested from within these countries were used locally, implying that timber is harvested to meet local resource demand. A comparison of the HANPP of wood products with national deforestation rates is shown in Figure 13.

As illustrated in Fig. 13, China, the United States and Indonesia are outliers with particularly high timber HANPP consumption. Despite high HANPP, China and the US both show negative rates of deforestation, indicating forest increase despite high wood consumption. Such a trend implies that the US, China and other countries with negative deforestation rates may be importing timber products from countries with high deforestation rates but low HANPP, such as Honduras (Deforestation Rate = 2.5, HANPP Wood = .014). However, beyond these three outliers there does not seem to be a correlation between deforestation and wood consumption at the country level. We will examine similar consumption observations and address commodity imports in our case studies.

Agricultural development also leads to deforestation, through the clearing of land for crops. We therefore compared deforestation rates to the proportion of GDP derived from agriculture in those countries. The results are presented in Figure 14. Fig. 14 shows the distribution of deforestation rates as the agricultural-related GDP increases. The data suggest that, beyond a threshold of agriculture as 10% of GDP, there appears to be an increase in deforestation rate, but when agriculture comprises about 25% of GDP, deforestation rates decline. These results may be due to the fact that areas of high agricultural output have already been deforested for some time, making the rate of deforestation a moot point. However, given the scarcity of sampling points, we could not confirm this assumption. The lack of data also made it difficult for us to assess the threats posed by local land conversion for subsistence farming in and around conservation sites.

## LAND USE

Anthromes describe human-impacted land use. We have characterized land use in six different ways; three land use categories representing high human impact (cropland, dense settlements, and villages), and three representing low human impact (forests, wildlands and rangelands). Each Conservancy site has been assigned a primary anthrome, based on which of these land uses is dominant in the site and within 10 km of the site. Wildlands and forests are considered areas of the lowest impact. We added rangelands to this low impact list, recognizing that Africa contains vast areas of rangeland and few forests and wildlands, and because cropland is distin-

## Percent GDP as Agriculture vs. Deforestation Rate

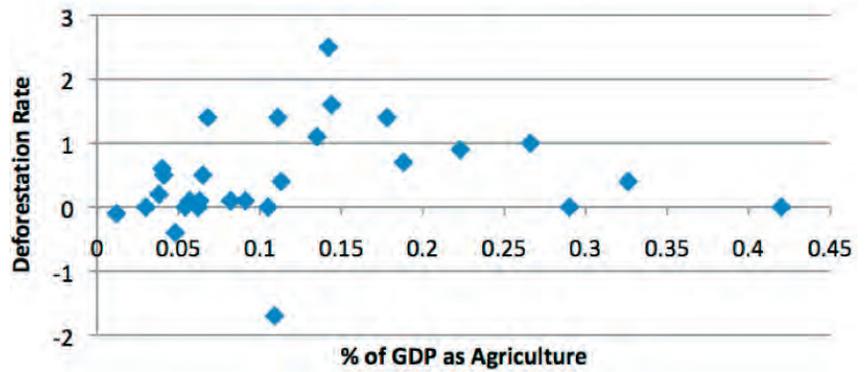


Figure 14: Percentage GDP as Agriculture compared with national deforestation rates where the Conservancy works.

Table 4: Number of sites exhibiting each of the primary anthromes, by region.

Level of Anthropogenic Impact	Primary Anthrome	Africa	Asia/South Pacific	Latin America	North America*	North Asia	Global
High	Cropland		3	6	19		28
	Dense Settlement			1	10		11
	Villages		8	44	107	4	163
Low	Wildlands				13		13
	Forests	1	5	16	233	6	261
	Rangelands	1	2	21	81		105
	<b>Total</b>	<b>2</b>	<b>18</b>	<b>88</b>	<b>473</b>	<b>10</b>	<b>581</b>

\*An additional 10 sites in North America had insufficient data to be classified.

guished from rangeland. Primary anthromes by region are shown in Table 4 below.

The classification in Table 4 gives a sense of the environments where the Conservancy works. Globally, the Conservancy works extensively in areas that are primarily forests (45% of sites), rangelands (18%), and villages (28%). The remaining sites are located in areas that are primarily cropland (5%), dense settlements (2%), and wildlands (2%). Talled another way, 65% of the Conservancy sites show low levels of anthropogenic impact in land type, while 35% are expected to show higher levels of human landscape modification.

## Population Density vs. % Low Anthropogenic Impact Anthromes

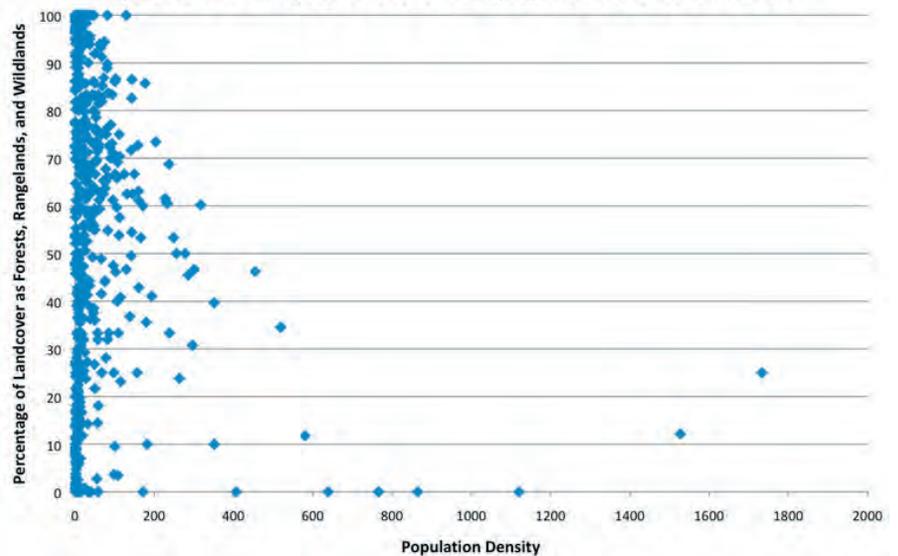


Figure 15: Scatterplot showing population density and population growth vs. the % land cover of Wildlands, Forests, and Rangelands.

We conducted a comparative analysis of anthromes to population density and population growth for 588 sites with operational GIS data. We performed scatterplots of population density and population growth vs. the sums of the percentage of land at each site taken up by wildland, forest, and rangeland anthromes. The results are shown in Figure 15.

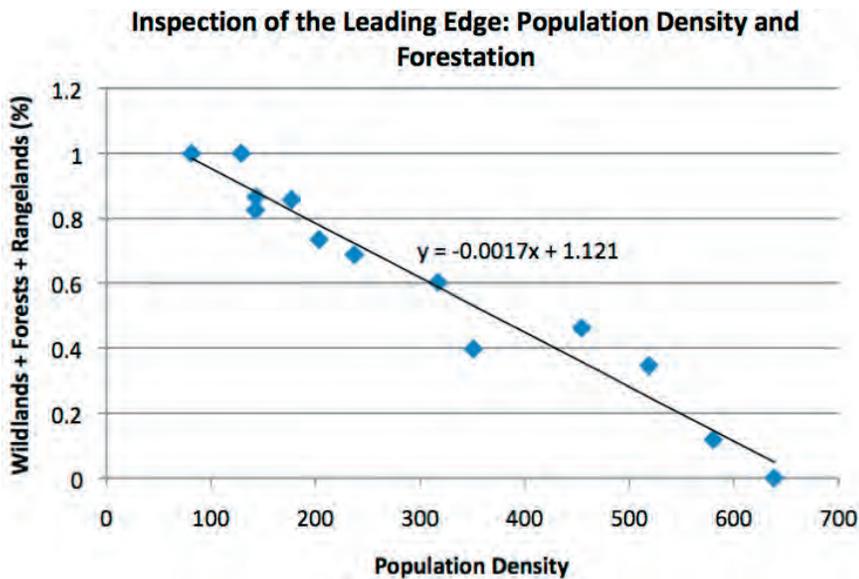


Figure 16: Leading edge of population density vs. summed wildlands, forests, and rangelands land cover plot. The trend line has a best fit equation of  $y = -0.0017(x) + 1.121$ , where  $y$  is the ration of wildlands + forests + rangelands to total land cover and  $x$  is the population density. The function is bound by an upper limit of 1 and a lower limit of 0.

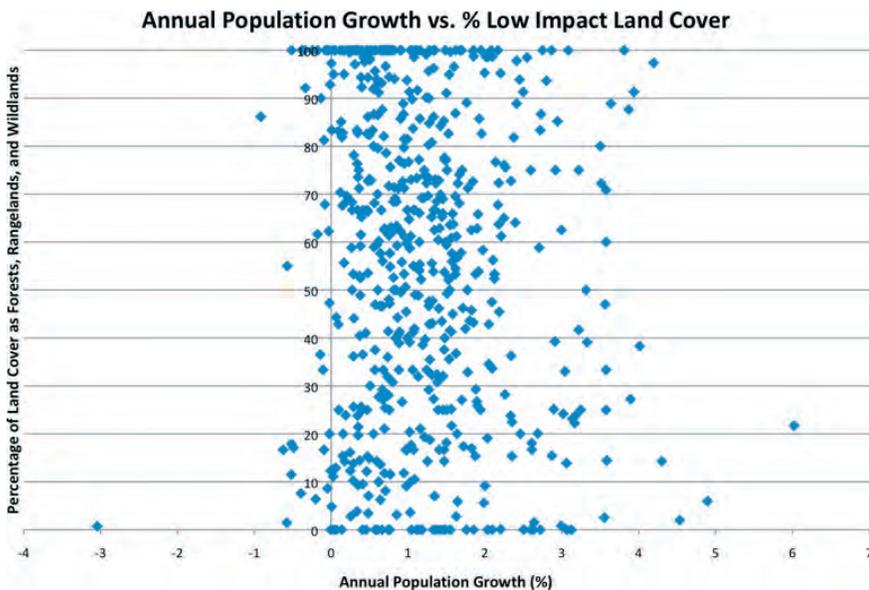


Figure 17: Annual population growth within conservation sites vs. percentage of land cover provided by wildlands, rangelands, and forest.

Fig. 15 shows that there is little predictable correlation between population density and the percentage of land cover with minimal anthropogenic impact, especially at low population density. There may be a limiting factor relationship at population densities greater than 80 persons per  $\text{km}^2$ , especially if we exclude outliers with population densities greater than 1500 persons per  $\text{km}^2$ . A curve fitted to those points on the right-most edge of the population density plot is shown in Figure 16. Fig. 16 suggests that, at high population densities (greater than 80 persons per  $\text{km}^2$ ), there may be a function that describes the upper limit of low-anthropogenic impact land that is can be maintained within conservation areas. It is important to distinguish that this function does not predict the amount of land that will have low anthropogenic impact, but merely postulates a maximum amount of land within each conservation site that could be relatively free from anthropogenic impact.

We plotted population growth against the percentage of land cover as wildlands, forests, and rangelands in Figure 17. Fig. 17 shows a wide distribution of points at all levels of population growth and suggests that there is no relationship between rates of population growth and the amount of land cover that shows a low level of anthropogenic land impact.



M. Godfrey, 2004

## CASE STUDIES

We present twelve case studies that reflect trends in our data, selected based on regional coverage. We also included sites that have received significant recent media attention, or because they were identified in our statistical analysis as having noteworthy human trends. We used these case studies to provide real world context to our narrative of human patterns that threaten biodiversity and which underlie some of the strategies already employed at the sites. Much of the research and information presented below comes from the TNC website and interviews with the site managers. Maps listed are in Appendix A.

Case studies reflect how human dynamics are impacting conservation projects, and can provide insight into how these impacts can be managed. In the words of Scott A. Morrison, Director of Science in the Conservancy's California Program:

In another corner of the world, I must surely have counterparts working to solve conservation problems that are more similar than not to the site I'm working on here in California. Across any biome, a multitude of conservation strategies are being designated and tested. Some will succeed; some will fail. Either way conservation colleagues from elsewhere would surely benefit from the lessons learned. Communication of successful innovation (and just important, the failures) could inform actions in places where systems and challenges are similar. Indeed if we were to plan and implement our individual conservation efforts as if they were treatments in a vast collaborative experiment in conservation practice, we might sooner elucidate ways of increasing the return on investment of ever-sufficient conservation resources. Each of our efforts could be informing another's. Each success could be positioned to advance the next (in Hoekstra et al. 2010).

### **Lesan River Protection Forest, Indonesia Case Study: Conservation Looking Forward**

In 1999, the Nature Conservancy learned that the Sungai Lesan site in Indonesia was threatened by agricultural development. In an attempt to protect the site, the Conservancy formed partnerships with four local villages located within the site, the local government, private sector, and NGO stakeholders (Meijaard and Hartman 2010). These partnerships stabilized conditions in the site itself, however, in 1996, the Conservancy discovered large-scale deforestation near the site that was attributable to palm oil plantation development. The Conservancy also uncovered plans for the completion of a palm oil refinery near the site, and for continued plantation expansion.

Palm oil is a leading agricultural commodity manufactured for use as cooking oil, as well as biodiesel (Brown and Jacobson 2005; Koh and Wilcove 2008). Increasing demand for greener energy sources, from soybean, sugar, corn and palm oil, puts direct pressure on undisturbed Indonesian and Malaysian tropical forests (Fargione et al. 2008). As it stands, 89 percent of palm oil is grown on newly cleared rainforest or peat swamps in Indonesia, and demand is expected to double by 2020, encompassing an area of over one million hectares (Fig. 1). To accommodate the rising demand for palm oil, 160 square miles of palms must be planted annually over a 20-year period (Brown and Jacobson 2005).



The Lesan River site is an example of a project where the Conservancy might consider more robust partnerships with private industry and indigenous tribes outside of the site boundaries in an attempt to protect pristine migration corridors while still accommodating global demands for palm oil. In addition, success stories from other sites that experienced similar threats could be used as a model for project managers at the Lesan River site in order to reassess their goals and incorporate ideas from the successful to better find and address gaps in their current projects.

### Valdivian Coast Reserve Case Study: Human Population Dynamics and Improved Livelihoods

As of 2010, 188,228 people live within the Valdivian Coast Reserve, Chile, shown in Figures 18 and 19. Our analysis showed increasing population growth rate with increasing distance from the site, ranging from 0.63% annual growth within the site and rates increasing to 0.74%, 0.8%, and 1.7% at 10km, 50, k and 100 km buffers respectively. This distribution of population growth reflects the remote location and relative isolation of the site. The Conservancy already employs a number of conservation initiatives targeted at the local population, such as integration of local communities into conservation efforts. The Conservancy can supplement these strategies based on anticipated population growth and land use (e.g. cattle farming, ranching, or plantation development) patterns associated with nearby villages.

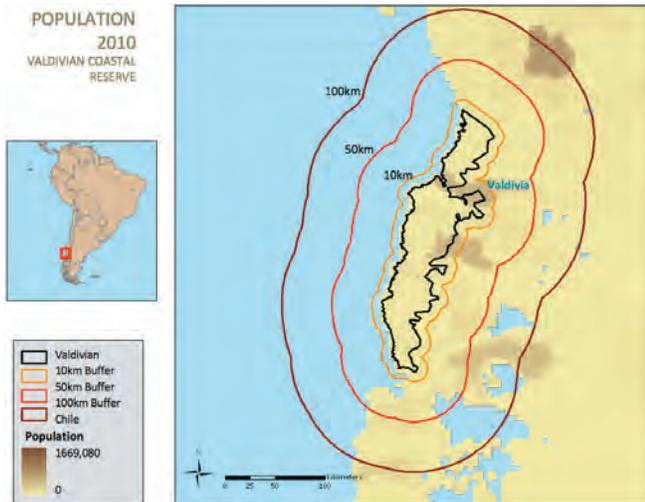


Figure 18: Human 2010 population distribution in and surrounding the Valdivian Coastal Reserve. High population density in the northern section of the conservation site is reflected by the city of Valdivia.

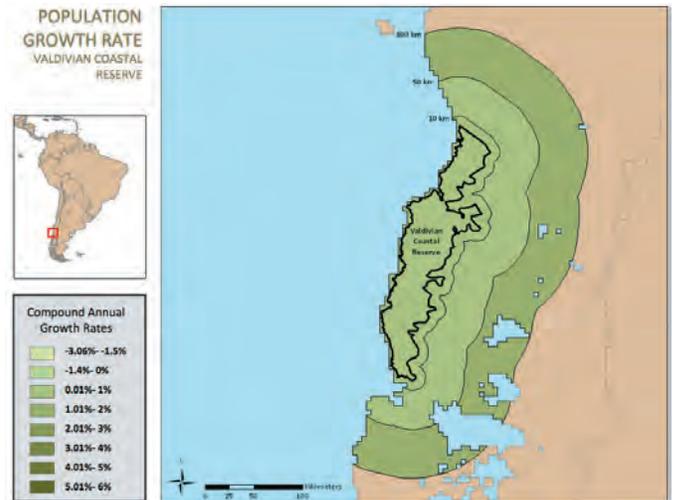


Figure 19: Population growth in and surrounding Valdivia conservation area. The area of highest growth as shown by the map is 100km of the buffer. The northern most human population as shown in Fig. 18 may give reason as to why growth remains high within the 100km buffer.

The Conservancy encourages public access to the reserve; trails, facilities, and signposts are regularly updated and maintained. Local people are employed as guides during the height of the tourist season to lead trips through the forest. Of concern is a proposed coastal road that would pass immediately next to the conservation site (Secaira 2010). We anticipate that this road has the potential to provide increased access into the remote interior of the Valdivian Coast Reserve. Increased visitation to the site and surrounding areas may result from this increased access. The Conservancy may prepare for this possible eventuality by monitoring the status of the proposed road as it moves through planning stages and, should the road be built, by assessing additional infrastructure, enforcement, and education needs to handle the increasing number of visitors.



**Motagua Valley, Guatemala Case Study:  
Population, Deforestation and REDD Schemes**

In the Motagua Valley, human migration away from the area has increased over time, Figure 20, exacerbated by the fact that many people move to the U.S. for financial opportunities (Sectarian 2010). Money earned abroad is often sent home where it is invested in melon cultivation. In the past, the agricultural sector was more diverse, but an increase in demand for agricultural land use has put a strain on biodiversity levels, especially as a common method of clearing forest is “slash-and-burn” technique.

Motagua faces high rates of deforestation, and the high population growth and low human development observed at Motagua may increase deforestation rates. Growth in human development can reduce deforestation despite high population growth if certain measures are taken, such as the provision of financial and intellectual resources (Jha 2006). Popular interest in sustainability in developed countries presents opportunities for the expansion of forest resources in regions with constraints on human development (Jha 2006). As it has done in other projects, such as the Noel Kempff Mercado Climate Action project, the Conservancy can tap into these opportunities through international investment schemes such as Reducing Emissions from Deforestation and Forest Degradation (REDD) and Afforestation/Reforestation (A/R).

Through REDD, developing nations can receive credits for lowering carbon emissions by reducing rates of deforestation and protecting greater areas of forested land. The money received should be applied toward financing local economies and diverting energy needs away from the biomass that is extracted from forests. The Conservancy views REDD as a system to generate financial incentives and carbon credit markets that will service the needs of developing nations and their people, conserve forests and protect biodiversity. The Conservancy has also developed a “global mechanism proposal”, with ambitious reduction goals for 2020. While the Conservancy has taken important steps toward mitigating threats to this site, it should consider developing a REDD project at the Motagua site in conjunction with a continuation of local partnership projects.

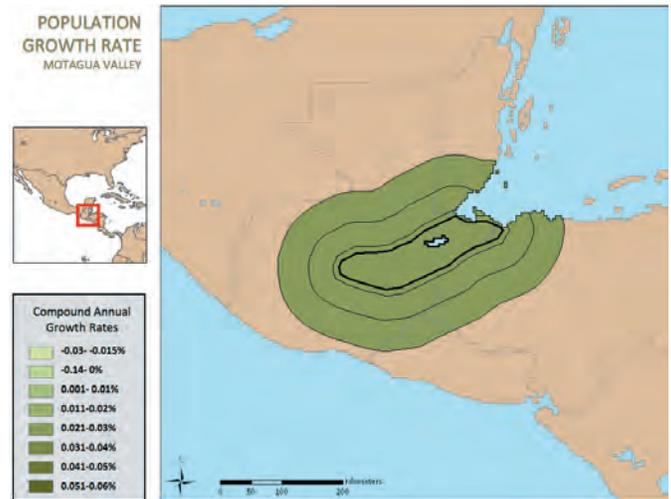


Figure 20: Growth within and surrounding Motagua Valley conservation site exceeds the world average. Within 100km of the site buffer, population growth increases from 2.04% within the site to 2.7%.

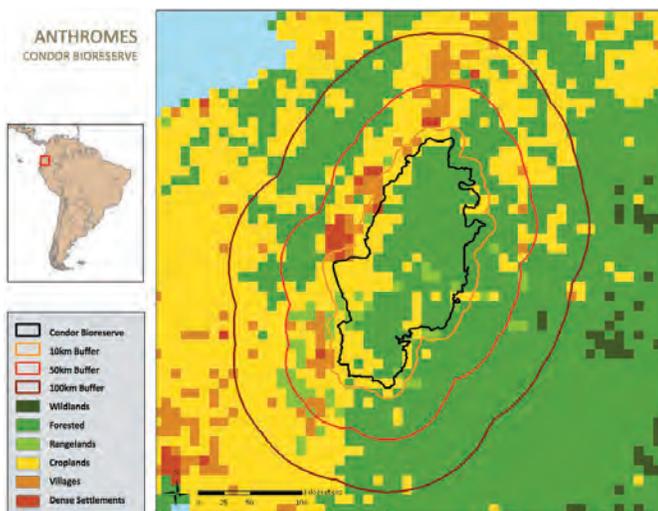


Figure 21: Depiction of the human land alteration surrounding the site as of 2004. While most of the site and areas to the southeast remain forested, areas of high impact (red) are shown within 50km of the site buffer.

**Condor Bioreserve, Ecuador Case Study:  
Success in Conservation Partnerships**

The Condor Bioreserve covers more than 21,000 square kilometers and provides freshwater to over 1.5 million people who live in and around the city of Quito, Ecuador. The city’s clean water supply is threatened by unsustainable agriculture and cattle ranching practices, infrastructure projects, illegal hunting and inappropriate logging exploitation (Figure 21).

The Conservancy has partnered with US Agency for International Development (USAID) in the Condor Bioreserve since 1997 and other stakeholders like La Fundacion Antisana, Fundacion Antisana, EcoCiencia, Fundacion Ecologica Rumicocha, among others with the goal to conserve water sources in Quito (Silvia 2003).



In the Condor Bioserve, as with other sites, the Conservancy partners with local communities to strengthen conservation efforts. For example, in the reserve, community members are employed as park guards. Furthermore, the Conservancy works with landowners to sustainably manage more than 2,000 acres in privately owned agricultural lands between the Antisana and Cayamba Coca reserves, to create a conservation corridor between the protected areas. The Conservancy also has a strong focus on supporting indigenous people in the bioserve. A local indigenous people, the Cofán, are working in the Andean foothills of the Condor Bioserve to implement the inaugural forest management plan to protect 37,000 acres of natural habitats.

### Rangelands of Northern Kenya Case Study: Livestock and Human Population Growth

The people of northern Kenya predominantly earn their livelihoods by raising livestock. Prior to the creation of the conservation site, a drought would typically result in a shortage of grass, leading to the slaughter of a large number of livestock. This slaughter, in turn, greatly depressed the prices that sellers could receive in the market for their meat. This effect made droughts incredibly destructive both economically and environmentally. Through the Northern Kenya Rangelands Trust (NRT), local communities manage grass banks to feed cattle and attend to region-wide livelihood needs, including water and pasture access and regional security.

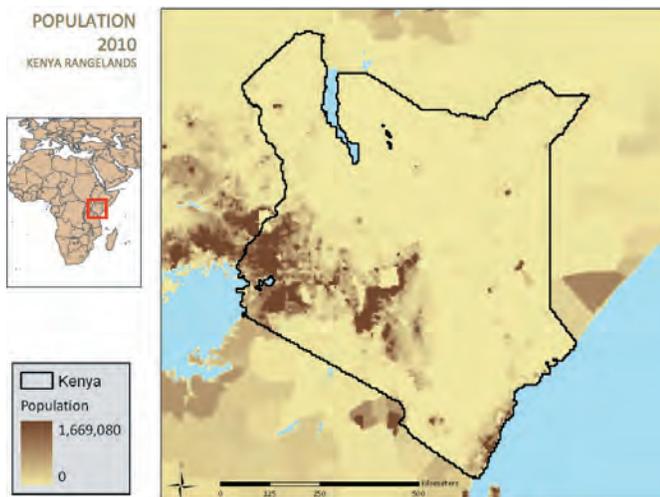


Figure 22: Kenya Rangelands conservation site reflects almost the entire nation. Average population density inside the site is 11.8 people per km<sup>2</sup> in 2010, and increases to 17.3 persons/ km<sup>2</sup> within 100km of the site.

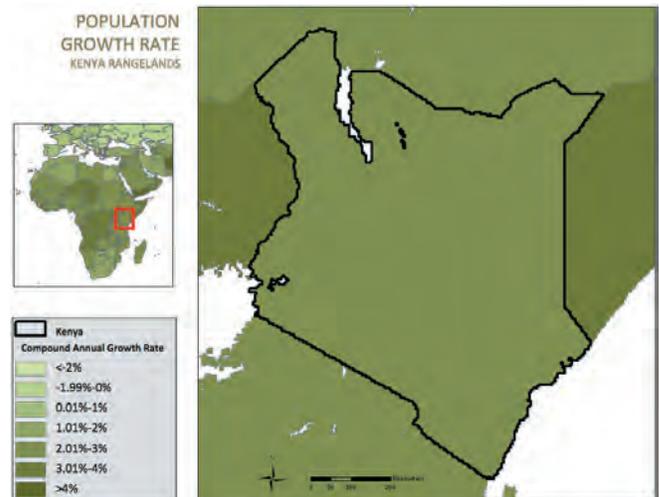


Figure 23: Growth within Kenya Rangelands site remains highest within the site itself (2.94%), and higher than the global human population growth average (1.3%) from 1990-2010.

Analysis of 2010 population figures for the NRT conservation area indicates a low population density within the conservation area of 11.8 persons per km<sup>2</sup>. Compared with the average population density for the area within 100 km of the conservation site, 26.4 persons per km<sup>2</sup>, or the population density for Kenya as a whole, 57.7 persons per km<sup>2</sup>, we see that current population pressure on the NRT communities is relatively low (Figure 22). The NRT may not always enjoy low population pressure given population growth between 1990 and 2010 reveals rapid growth at a rate of 2.87% per year (Figure 23). The impact of increased population pressures may be dramatic. The NRT's status as a group ranch limits the access of outside persons to grazing resources, but protects the local communities' access rights, thus protecting the interests of future generations.



The forecasted population growth will also likely increase the number of livestock grazed on NRT land, assuming a constant per-capita livestock number and, if sufficient livestock are introduced, may exhaust the grazing areas. Such an occurrence may put pressure on NRT management to open up additional land to grazing, thereby reducing the amount of land set aside for conservation. Therefore, rapid population growth poses a threat to the Conservancy's conservation efforts at this site.

### **Florida Keys, USA Case Study: Invasive Species, Development, and Potential Oil Spills**

According to the Conservancy Florida Keys website, several threats to the habitat and wildlife are listed, including tourism, boat docking, declining coastal water quality from wastewater and storm water flow from increased population, residential and commercial development, invasive plants, and climate change. The Conservancy has partnered with NOAA to conduct a reef restoration and resilience project. The Conservancy has also engaged in successful invasive species planning and prevention (Rice and Tu 2001).

According to its website, the Florida Keys Invasive Exotic Task Force has brought local environmentalists, municipalities, and county, state, federal and municipal stakeholders together to prevent and control invasive plant life (The Nature Conservancy in Florida 2010). This pilot project eliminated approximately 99% of the invasive species on the pilot site and established a "GreenSweep Initiative" to train and coordinate volunteers and residents to fight against invasive plant species. This project can be a model for other Conservancy projects, as we work to prevent the invasion and spread of both plant and animal non-native species in other Conservancy sites.

An emergent threat to the Florida Keys and other US coastal and marine sites is the natural gas and oil drilling recently promoted by President Obama, as well as the oil-rig explosion in the Gulf of Mexico (Broder 2010; Robertson and Lipton 2010). While the government does not allow drilling in environmentally sensitive areas such as Bristol Bay, Alaska, much of the southern Atlantic, Caribbean, and Arctic coasts and reef line is exposed to potential damage by exploration and exploitation. If oil and natural gas drilling is allowed, it is expected to potentially affect not only the Florida Keys reef system, but also many of the beaches and nearby communities.

### **Bay of Loreto National Park and San Pedro, Mexico: Development Threats and Demands**

Similar to the Florida Keys, the Bay of Loreto National Park in Mexico faces threats from development and population growth (Figure 24). Located near the southern tip of Mexico, the Baja Peninsula covers 2,065 square kilometers in the Sea of Cortez and includes five principal islands (Parks in Peril, Mexico 2010). The Bay of Loreto has been protected from commercial overfishing as a result of the Mexican Federal Attorney General's Office of Protection's strict enforcement of fishing regulations within the park. The sea is an integral part of the locals' lives, and today close to two-thirds of the total economic population works in the tourism sector due to fishing, kayaking, and scuba diving. Given that marine resources drive most of the local economy, minimizing any possible impacts to the quality and quantity of such natural capital is of great interest. Unfortunately, the coastline south of the town of Loreto is primed for major development to accommodate the expanding tourist trade. Development plans for the area could potentially increase the population by approximately a quarter million people. This large population growth will likely increase human intrusions into the park. The Conservancy should consider the projected population growth in its plans for minimizing threats to biodiversity.

Damages caused by increased population and development are exemplified in the groundwater depletion found in Arizona at the San Pedro sites was highlighted by a personal communication with San Pedro Sonora project staff. In drier wet seasons, the San Pedro River runs dry in some locations. Although the river



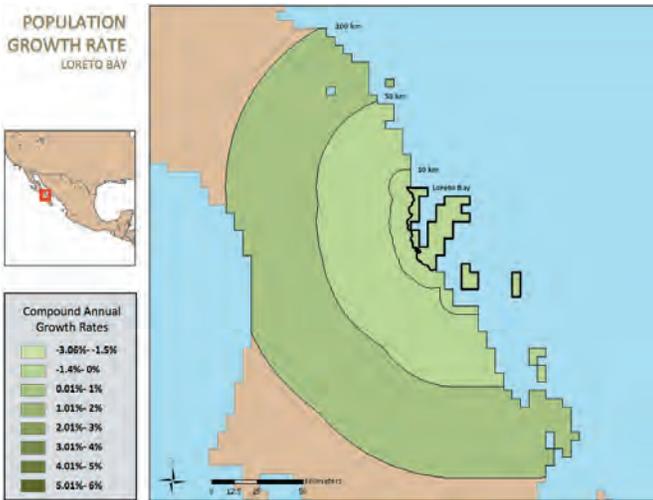


Figure 24: Loreto Bay has relatively mild growth within the site, however, elevated annual growth rates 50-100km of the site. This growth is thought to be as a result of development.

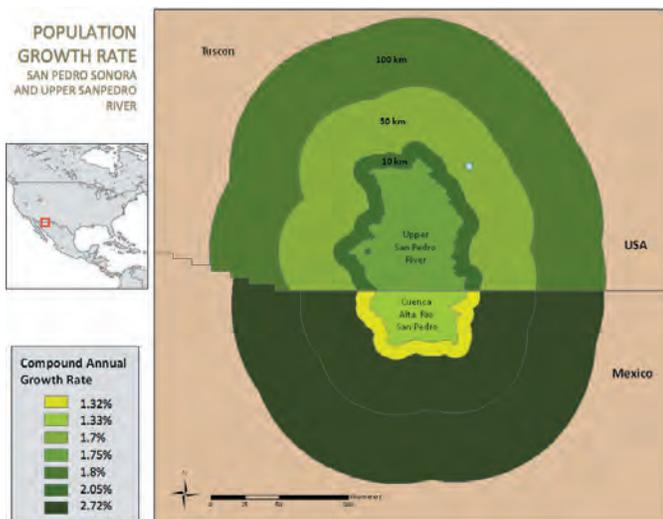


Figure 25: The two sites in the San Pedro are marked by difference in human population growth. While sites internal to the Mexican San Pedro (Sonora) sites have less compound growth, outside the 10km buffer, shows heavy population growth. Examining the US site shows moderate growth within the site, perhaps an implication of development

does not run dry in the 50-mile stretch that straddles the US-Mexico border, the population further north in Arizona relies upon the underground aquifer below the river. Accordingly, population growth in Arizona and unregulated pumping of groundwater depletes the groundwater resources (Christensen, 1999). Hydrologist Julie Stromberg, at the University of Arizona, has calculated that if the groundwater drops another three feet, which is likely, half of the remaining riparian forest, will die (Christensen 1999). An article by Stromberg in 2009, referred to similar levels of groundwater overdraft, although a review of these figures had not been done since 2002. In her report, she finds that groundwater pumping beyond the borders of the San Pedro Riparian National Conservation Area has affected the condition of plant growth in the riparian area (Stromberg 2009). Population growth surrounding the San Pedro site is seen in Figure 25.

In the early 1990s, the US government purchased land along the US stretch of the river to decrease irrigation. Issues remained, however, with overuse of the water supply. An international panel of experts agreed that better conservation on the Mexican side would help the water flow in the US, although it remained the United States' obligation to resolve the problem (Christensen 1999). This prompted the Conservancy to establish the site in Mexico.

### Zambezi River Basin, Africa and Yellowstone River, US: Effects of Hydroelectric Dams on Fish

Examination of the Florida Keys site raised a reoccurring issue of land use change driven by energy demands. Not surprisingly, one of the least developed regions of the world too has these same pressures (The Nature Conservancy in Africa 2010). Zambezi hydro dams address regional energy needs but have

severe ramifications on the seasonal river flows in Africa. Four hydro dams halted normal flow of the river, harming wild animals that were poorly adapted to the artificial lakes and resulting in the conversion of former floodplains into agricultural grazing grounds (The Nature Conservancy in Africa 2010). Fishing, the principle livelihood of several of local tribes, was also harmed.

The Conservancy has previously worked to improve fisheries around hydroelectric installations at the Yellowstone River project. Through an interview with Yellowstone River staff, are three general methods to allow fish passage around dams: a passage, or small aqueduct, can be created to allow fish to go around a dam, an elevated system of pools (a ladder) can be created to get fish over a dam, or a dam can be removed entirely. To the extent that it is not feasible to remove a dam, a fish ladder is often the most economically viable option. The design of fish ladders varies significantly but the most important design element is water flow control. High runoff during the wet seasons or isolated storm events can inundate fish ladders and render them impassable.

Yellowstone Fish ladder technology has evolved to optimize conditions for a specific species in order to minimize usage by undesired species (Kocovsky et al. 2009). Yellowstone River is one such success of allowing for fish movement. For example, farmers divert river flow via diversion structures, blocking all or part of the river channel, and, in turn, impede the distribution and movement of fish species. An existing Intake Diversion Dam and other unscreened diversions can entrain nearly half a million fish annually. The endangered pallid sturgeon is among the 34 species to be conserved. The Conservancy, in partnership with government agencies, works to design and install economically feasible fish passage structure that preserves the diversion of water for agriculture, and allow fish to freely navigate all reaches of the Yellowstone River.

### Meili Snow Mountain National Park, China Case Study: Local Transformations of Energy

While Meili Snow Mountain Range mountain range is important to biodiversity, it is critical to local residents' livelihood. The population in and around the site has remained close to 11,000 for the past 20 years, with only mild population growth as shown in Figure 26 and confirmed by the project manager (Wang 2010). This area is one of the poorest areas in China, despite the double digit GDP growth rate of the country. Meili lacks basic necessities like roads, clean water, and waste removal services. Locals rely on local wood collection for cooking, heating and construction.

In order to reduce dependence on wood collection, the Conservancy introduced "alternative energy" to 21 villages along the slopes of Meili and banks of the Mekong River (The Nature Conservancy in China 2010). Along with the local government agencies, the Conservancy installed household scale fuel-efficient stoves and furnaces using alternative energies such as solar, biogas, and micro-hydropower. To date, 2500 household alternative energy devices have been installed in Yunnan Province, 37% of them in Meili villages.

By introducing ecotourism to this area, both the local government and the Conservancy hope to create new jobs around carefully planned ecotourism and create other locally relevant sustainable livelihoods. However, ecotourism itself may bring some additional challenges or threats to the ecosystem such as higher consumption or inappropriate waste disposal and dumping. Additional methods of management include education and training programs of local people in resource protection and resource management, partnered with the Chengdu Research Institute of the Chinese Academy of Sciences on a study of the mountain pastoral ecosystem. The information will be used to help animal husbandry agencies improve the quality of the pastures to achieve optimum grazing while protecting ecosystem integrity. The Conservancy is also conducting wildlife surveys, develops ecological monitoring systems for the National Park program, and demonstrates green buildings with less wood consumption to local communities.

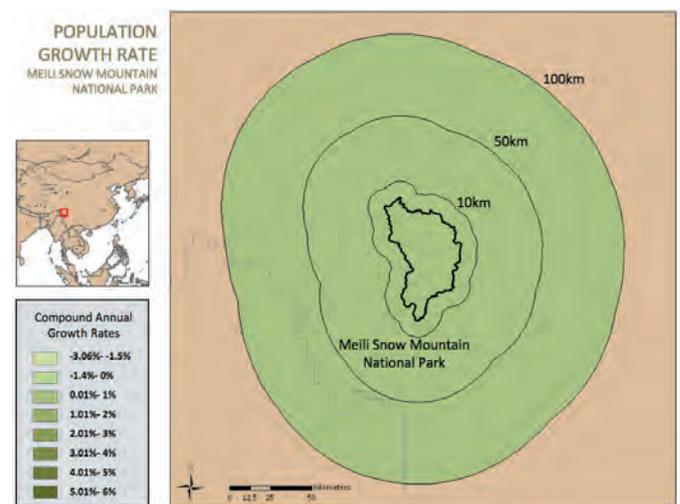


Figure 26: Compound population growth in Meili Snow Mountain National Park. Area shows mild growth 0.38% inside the site and 0.73% within 100km of the conservation site, and supports the on the ground observations from the project manager.



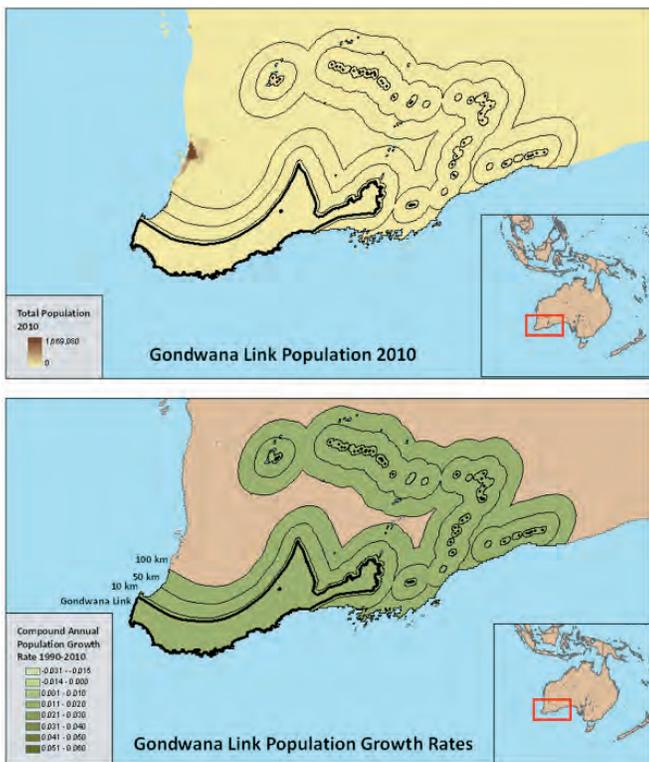


Figure 27: Visualization of the population growth and the growth rates surrounding the Fitz-Stirling site. The city of Perth represents the dense population north of the site and buffers. Overall growth in and surrounding the site is mild.

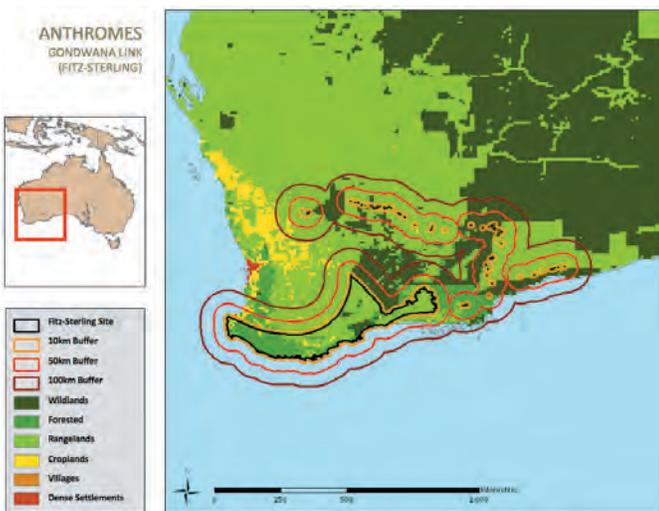


Figure 28: Anthropogenic impact in and surrounding the Fitz-Stirling case study is depicted. Many of the coal mines that exist in this area, run north of the site, along the western coast.

### Fitz-Stirling, Australia Case Study: Global Consumption Affects Local Site

Restoration of Fitz-Stirling site has largely been successful; the project is ranked as one of Australia’s top 25 ecological restoration projects by the Global Restoration Network (The Nature Conservancy in Australia 2010). Stakeholders for the restoration project include local indigenous groups from Albany and Jerramungup. Local farmers are also instrumental in advancing the goals of this project and are involved in restoration activities, like biodiversity planting. Private sector stakeholders include businesses from Western Australia, Shell Development Australia, Consolidated Minerals, and Mt. Barker Free Range Chicken. Mining companies have made donations to the restoration project, and other environmental programs provide funding for fire threat analysis.

Project success has been facilitated by an overall favorable attitude toward the environment among the regional populace and by the availability of funding for such restoration projects. Projected population growth in the area surrounding Fitz-Stirling is only 1.04%, which is less than the 1990-2010 growth rate of 1.48% (Figure 27). However, 50 km away from the site, the population growth rate has been projected to increase from 1.01% in 1990-2010 to 1.04% in 2010-2015. This growth rate is attributed to rising population levels near the coastal areas. Future planning in this region should incorporate the projected population growth, consumption trends, such as commodity trading in coal, and associated land use changes.

An additional threat includes increased coal exports due to booming foreign economies and was revealed to us during our interactions with Conservancy staff. According to the US Energy Information Administration, Australia is the world’s largest exporter of coal, mainly supplying markets in Asia. A country-by-country breakdown shows that 40% of Australia coal exports go to Japan, 16% to Korea, while 9% go to Taiwan, China and India respectively. With increasing GDP in these nations, Australia will likely face increased coal demands. For example, China’s GDP growth rate of 8.59% for 1990-2010, coupled with the International Monetary Fund’s projection that the growth rate will continue to increase, indicate that reliance on coal will increase with population and GDP growth. This means that Aus-

tralia will likely experience the effects attributed to the economic growth of its trading partners. The definite effect of economic growth and increased demand on the coal rich regions of Southern Australia is uncertain but will need to be considered for strategic planning and analysis.





C. Peace, 2001

## ANALYSIS

### HUMAN PATTERNS FROM LITERATURE REVIEW, STATISTICS AND CASE STUDIES

Approximately 80% of the 588 Conservancy shape files analyzed are located in areas with less than average world population density; 60% of these low density sites have slower than average growth rates. We also found a general trend in almost all regions: as distance increased from the site, the population density grew as well.

A number of studies have shown that high population growth is more prevalent in poorer regions of the world. Our analysis of population growth and poverty datasets corresponds with these findings. According to written reports, impoverished human populations with high population growth can degrade habitats because they are more reliant on local natural resources, and many of these increasing populations are situated in areas with high concentrations of biodiversity. Increased population can lead to unsustainable consumption or harvest. Higher population growth rates were found in almost 40% of sites with lowest population density, indicating that the Conservancy may see an increase in human population density at these sites in the coming years, depending on life expectancy. By working to alleviate poverty in and around conservation areas through education and alternative livelihoods, as suggested by the Motagua Valley case study (pg. 22) the Conservancy can lessen biodiversity threats from human settlement and population growth patterns.

Comparing high population density with the presence of land showing low anthropogenic impact implies a limiting relationship between these variables at relatively high population densities (density greater than 80 persons per km<sup>2</sup>). However, even some low population density sites showed high levels of anthropogenic impact.

We determined that deforestation is a threat common to just over half of all Conservancy sites listed in the ConPro database. A comparison of national deforestation rates with national wood consumption indicated that both China and the United States have the highest wood consumption rates but negative deforestation rates (indicating an increase in forest cover). This trend may be linked to exported global consumption patterns outsourced abroad as discussed above.

Human migration can be caused by a number of factors including civil conflict, resource availability, and opportunity, among others. Many migrations are intra-country as people seek economic improvements in their own livelihoods. For example the Galapagos sees an annual population increase of nearly 5% due to booming tourism and fishing industries. In contrast, case studies such as Valdivia and Lesan River



show higher population growth rates 100 km away from the conservation site, due in part to migration to nearby cities. Literature suggests migration away from conservation sites can alleviate pressures on conservation sites as fewer people rely on local products for survival. However, urban sprawl and increased consumption of necessities such as water rise during population expansion, may negatively impact conservation sites. This pattern has been observed at the San Pedro case study, where increased population kick-started Conservancy efforts to protect upstream water resources. Rising migration rates also increase the incidence of non-native species invasion.

While we were unable to fully evaluate implications of global consumption on biodiversity with our data sets, we were able to assess the impacts through literature and case studies. For example, rising energy needs in China increases mining activity in the Fitz-Stirling case study region. Similar threats to conservation from consumption-driven industry are seen also in Lesan River, Florida Keys and Zambezi River Basin cases. Industrial practices such as mountain top removal can be extremely damaging to local habitats. Ecotourism offers an alternative to industrial development as a means of earning a livelihood, but presents its own challenges.

The demand to see well-preserved conservation sites can itself be a threat. Real estate development to serve eco-tourists can be very damaging if not properly managed, and was observed in the case studies in countries with a significant tourism industry. The Conservancy may be able to partner with developers to minimize impacts to habitat and biodiversity.

We rank the human threats we have observed and studied as follows based solely on statistical results:

- (1) Population
- (2) Land use
- (3) Consumption
- (4) Poverty

Including a synthesis of literature and case study review we rank the threats as follows:

- (1) Population
- (2) Consumption
- (3) Land use
- (4) Poverty



# RECOMMENDATIONS

Based on the results of our literature review, statistical analysis, and case studies we provide the Conservancy with the following recommendations to help it improve its approach to and monitoring of human variables we explored in this study.

## **Address Quality and Completeness of Datasets and ConPro Database**

This report is based on the most accurate and complete data available, including materials provided by the Conservancy, cited geospatial data sources and a comprehensive review of literature. In conducting our analysis, we identified several significant gaps in data that, if filled, could assist the Conservancy in its endeavor to preserve land and biodiversity in and around its global conservation sites.

In conducting geospatial analysis, we faced challenges with respect to temporal scale and spatial resolution of data. Finding complete data sets that cover local, regional and global scales over time proved to be very difficult. Some of these deficits in data could, however, be resolved by the Conservancy through its work with local communities and groups living in close proximity to conservation sites. In particular, we cite issues with poverty and consumption, as data sets that lacked local scale resolution (Appendix B). The national and sub-national levels of these data could not be used to extrapolate down to site-specific poverty and consumption trends. While we tried to resolve this issue by using various datasets for poverty and consumption, local resolution would deepen our understanding of human-related biodiversity threats. Temporal trends could not be determined from the anthromes and IMR data available. While a simple snapshot in time of anthromes is useful to determine current human-driven conversions of land, it does not provide a temporal reference to understand how land use has changed over time.

- Recommended action: In conjunction with its ongoing outreach efforts, the Conservancy should incorporate a system of monitoring and qualitatively or quantitatively analyzing local poverty and consumption levels. The Conservancy might consider gathering local level poverty and consumption data to determine how these human dynamics directly threaten local biodiversity and conservation targets through census, survey or interview. Additionally, it would be useful to incorporate satellite imagery with existing anthrome spatial files, in order to overcome the data deficits for land use change.

We identified a total of 1008 projects from the ConPro database and received a total of 603 shape files from the Conservancy. Of the 603 sites with available shapefiles, 474 are based in North America. A lack of data regarding international sites made it difficult to extrapolate international trends or trends relevant to Conservancy sites within Africa, North Asia, and South Asia. In addition, Conservancy data for some of the sites, such as the Kenya Rangelands and the Zambezi River Basin, represent huge tracts of land, encompassing entire countries or more, making it impossible to assess human activity trends on a local level.

- Recommended action: The Conservancy should compile shape files for all project sites, which accurately represent project area in a central resource like the ConPro database.

C. Phillips





### **Use and Enhance the ConPro Database as a Key Conservation Tool**

The ConPro database has the potential to be a useful conservation planning tool as well a comprehensive database. The Conservancy recognizes the need for a means of identifying projects, which share similar characteristics, threats, and strategies. In the Conservancy's recently published Atlas of Global Conservation, Mr. Morrison, California Program, acknowledges that the potential value of sharing successes and challenges across sites, and collaboration on how to overcome gaps in local conservation capacities, could potentially increase the effectiveness and efficiency of the Conservancy's conservation work.

The Conservancy could readily utilize the existing ConPro database as a conservation planning, cross-reference tool. Specifically, Conservancy project personnel could use ConPro to review challenges, threats and/or targets encountered at similar sites and adopt successful techniques or avoid unsuccessful techniques for use at their own project sites. Currently, however, many Conservancy personnel are not aware of the ConPro database or its applicability as a sound planning and collaborative tool.

In conducting an informal web survey of Conservancy site managers, we asked for general information, such as how local population data is incorporated into the conservation planning process. In this survey we also asked managers to identify their respective project sites by ConPro project identification number. Of the 110 distinct responses we received (as of April 12, 2010), only 24 respondents (22%) correctly identified their site's ConPro Project identification number. Notably, a number of respondents placed only question marks in the answer field, suggesting that they did not know that their project had been assigned an identification number with the Conservancy. Absent wide dissemination of ConPro data, site personnel cannot access potentially informative data on other projects. This is of special concern in remote field offices, where personnel may not be regularly updated about relevant developments at the Conservancy's other project sites.

- Recommended action: As a critical step in conservation planning, we recommend that the Conservancy disseminate ConPro database information to all site personnel, detailing how ConPro can be used to identify successful actions that may be duplicated at other sites.

We ascertained that the ConPro database, which provides a wealth of information about project sites, does not contain complete sets of data for all Conservancy projects. For example, some information was missing for the Conservancy's Chiapas site in southern Mexico, and no information has yet been entered into ConPro for the Conservancy's Montana Legacy Project, despite the fact that comprehensive data has been compiled for the site (e.g. Conservation Action Plans and GIS shape files). Moreover, GIS data was only available for 603 of the 1008 sites in the ConPro database. These deficits in data limit the Conservancy's ability to conduct accurate and detailed geospatial analyses of its sites, may obfuscate some trends that might otherwise lead to implemental actions, and may suggest potentially misleading trends that are artifacts of incomplete data.

- Recommended action: Accordingly, we also recommend that, to the extent possible, the Conservancy include complete data in ConPro for all of its sites.



### **Incorporate Framework for Assessment of Human Factors at the Site Level**

The Conservancy has many tools such as the “Five-S” Framework for Site Conservation Planning already in use to help site managers determine conservation targets, identify and monitor stresses and sources of stress to the targets, as well as recommend strategies to mitigate these threats (The Nature Conservancy 2003). Many of the Conservancy’s existing threat classifications are human-related such as road or dam construction and primary housing development; however, stress identification is based on a narrow direct interaction between the stress and the conservation target.

- Recommended action: To better determine the severity, longevity, and identification of indirect drivers of threats, the Conservancy’s existing threat designations should be bridged with the broader trends in the human variables including population growth and density, consumption and land use patterns, and poverty indicators.

Site level assessment of the human population dynamics and activity may lead to a better understanding and ability to predict the potential intensity of stresses and sources of stress on site biodiversity and conservation targets.

- Recommended actions: The Conservancy should employ a number of tools such as field observations, interviews, surveys, government statistics and reports, and geospatial analysis in order to accurately assess the human population and human activity occurring locally and regionally around conservation sites. Mapping the trends of human dynamics and other threats in relation to the conservation target distribution at sites would help identify specific areas in need of immediate attention.
- Regarding population, the Conservancy should assess how the human population is changing over time (Liu et al. 1999). As applicable, for each project, site managers should evaluate whether local human population growth or change is driven by migration, birth and death rates, or is connected to other variables, such as poverty. Experimenting with poverty alleviation programs including initiatives such as education can increase access to economic opportunity. One project manager cited these methods as a means of reducing the rate of population growth at the Northern Rangelands of Kenya site (Brown 2010).
- Regarding land use, the Conservancy should define land use patterns by monitoring land type, rates of land conversion, and land use patterns over time. These trends may help determine or predict future habitat quality and overall biodiversity health at a site. Identifying slated local development and infrastructure projects is also important in order to prepare for and proactively address potential negative impacts on biodiversity at sites.
- Regarding poverty, which is related to land use and consumption patterns, the Conservancy should assess local levels of income in comparison to countrywide economic indicators. Infant mortality rate and other indicators can be used to assess the poverty levels at sites over time, as demonstrated in our statistical analysis.
- Regarding consumption patterns, the Conservancy should monitor natural resource use for both local and industrial purposes. Surveys of national and/or local government resource management staff should be conducted to ascertain common conservation policy goals and challenges to achieving such goals in and around Conservancy project sites. The Conservancy should also continue to engage stakeholders and local communities in and around Conservancy project sites by, one, surveying and assessing their respective needs and concerns; and, two, allowing for their active involvement in site conservation management. Based on the outcome of research on stakeholder and community concerns and perceptions of conservation work, the Conservancy can establish “buffer zones” around the perimeters of its project sites where sustainable use of natural resources may be allowed and monitored.



### Other Recommended Strategic Initiatives

In addition to pursuing the foregoing recommendations and the numerous conservation tools it already utilizes, the Conservancy should consider employing the following strategies:

- Encourage the government of countries in which Conservancy project sites are located to participate in international environmental treaties that may support the Conservancy's conservation efforts.
- Ascertain if any critical habitat corridors exist between Conservancy project sites and outside habitats. If such corridors are present, to the extent feasible research stakeholder and community concerns pertinent to each corridor area; develop threat and target assessments for each corridor; expand project sites to encompass corridors; and/or, establish "safety zones" in each corridor, by working with local agencies in placing restrictions on development, hunting, and other extractive uses within the corridor area. Engaging with private industry can help ensure industrial development takes into account conservation planning.
- Increase partnerships with medical and education related non-profits, in order improve livelihoods, health and employment opportunities. Education has the opportunity to delay reproduction and thus potentially decrease population, especially when focused on women.
- Continue to pursue the development of voluntary market conservation incentives to facilitate investment in the preservation of some or all Conservancy project sites. Current relevant investment schemes include Reducing Emissions from Deforestation and Forest Degradation (REDD) and Afforestation/Reforestation (A/R). Activities such as the Conservancy's Noel Kempff Mercado Climate Action Project serve to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. In preparing to pursue further projects, the Conservancy should conduct a comprehensive assessment of companies that may be interested in partnering with the Conservancy to invest in the voluntary carbon market.
- Based on surveys of stakeholders and local communities in and around its project sites, ascertain and fill in deficits in conservation education including disseminating materials regarding threats, targets and human impact data, and distributing information on methods to mitigate human impacts.



# CONCLUSION

The Nature Conservancy boasts a long tradition of protecting natural landscapes through a science-based approach – preserving nature for nature’s sake. The Conservancy has now broadened its conservation approach to include human and socioeconomic considerations, recognizing that humans are inextricably linked to the environment and have a significant impact on biodiversity. Through this more holistic approach to conservation, the Conservancy aims to turn human threats into assets for its projects, mitigate human impacts on biodiversity, and improve the quality of human life.

In support of the Conservancy’s conservation initiatives, we seek to further examine the relationship between human dynamics and conservation, through the analysis of four variables: population, poverty, consumption and land use. Our research found common themes throughout all regions. For example, population density increases with distance from conservation sites, indicating that it is imperative that the Conservancy looks beyond the site level when planning conservation efforts. Additionally, areas of high population growth appear to coincide with areas that suffer from high levels of poverty. Our review of literature revealed that impoverished areas may coincide with areas that are the richest in biodiversity. The poverty present in this area contributes to an increased probability of habitat degradation due to heavy reliance on natural products. Our review of statistics, case studies and literature also revealed increasing trends in global consumption, especially in the United States and China. High consumption rates in these developed countries impact environments in lesser-developed countries, as such consumption is primarily satisfied through resource extraction abroad. Thus, while high rates of population, poverty and consumption at the local level pose significant threats to the environment, so too do global trends in consumption.

We provide recommendations based on both the trends we observed and the challenges we faced. By using ConPro as an agency-wide tool the Conservancy can better monitor human trends in and around project sites and share conservation methods between projects with similar threats or human trends. The Conservancy can also utilize our case studies and statistical analyses as a framework for conservation planning in and around all of its sites, referencing trends and predictions in population, poverty consumption and land use. We also propose increasing strategic partnerships with private industries, as well as educational and medical non-profits, in order to improve conservation planning and educate and empower local populations.

Looking forward from the slogan “Save the Planet,” we hope that our research and recommendations shed light on potential human impacts on biodiversity, in a way that will give rise to policies that the Nature Conservancy can incorporate, not only to safeguard nature as it has always done, but to protect all of mankind.



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# APPENDIX A FIGURES AND TABLES

## Anthromes Case Study: Sungai Lesan, Indonesia

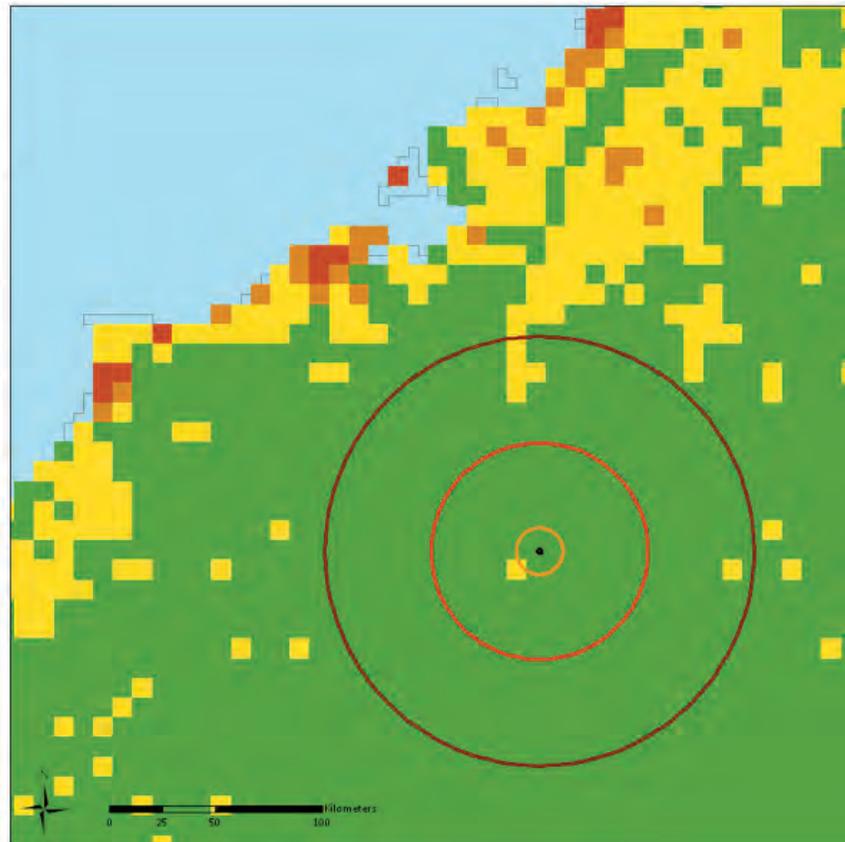
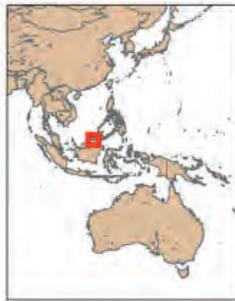


Figure 1: Depiction of land type in 2004 at the Lesan River Protection Forest and surrounding 10, 50 and 100 km buffers. Forested areas predominate inside the conservation and buffer zones, however croplands are visible along the coast and North of the buffers, some of which appears to enter the buffer zones.

## Population 2010 Case Study: Ecuador

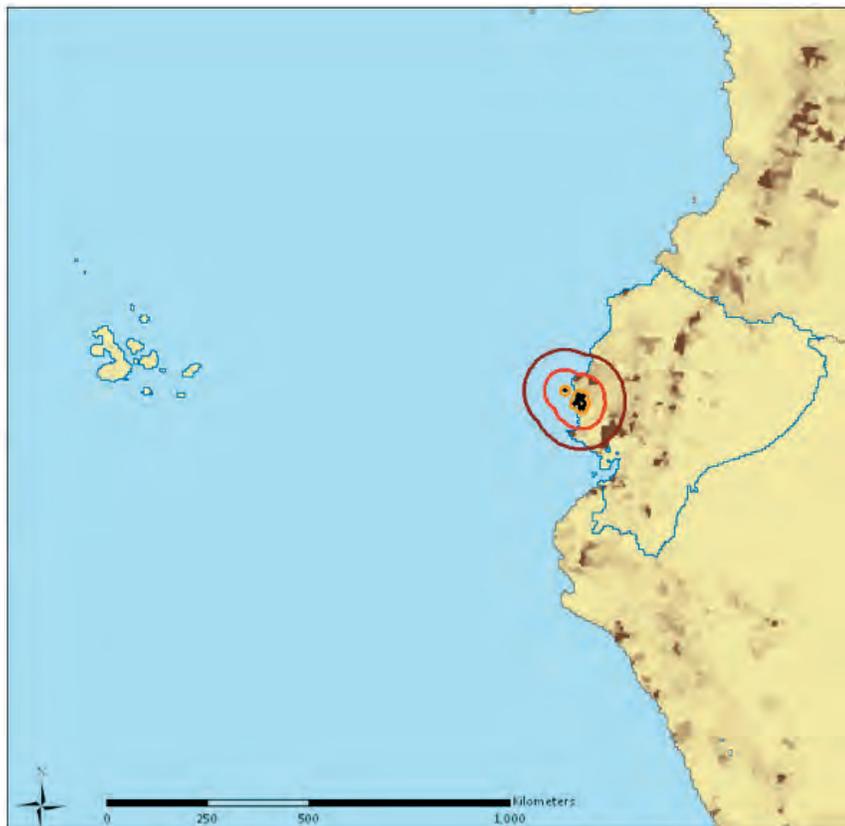
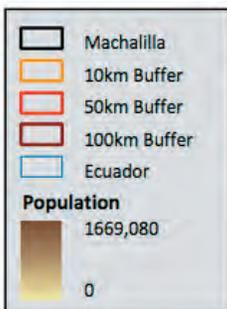


Figure 2: Map of human population of Ecuador and the Galapagos in 2010. Dense population appears to be clustered along the western coastline in an area of high biodiversity, as implied by Cincotta (2000). The Machalilla National Park is the conservation area depicted in this map.

**Population Growth  
Case Study:  
Ecuador**

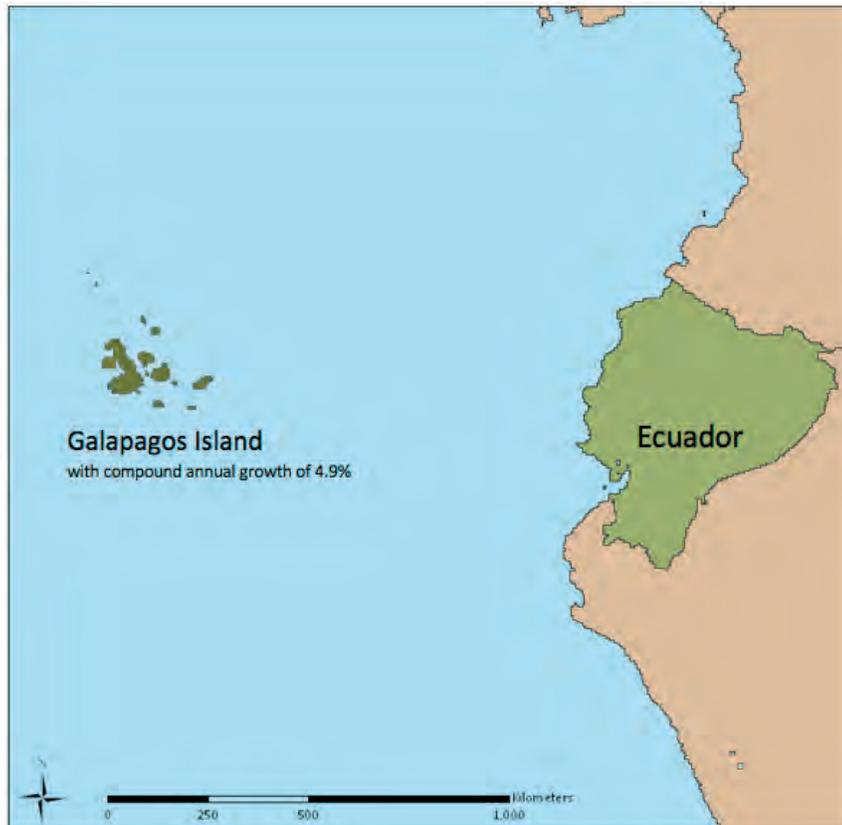
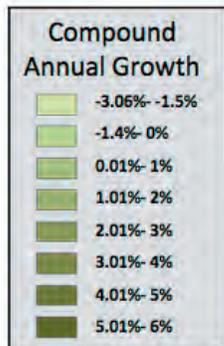


Figure 3: Compound annual growth in Ecuador and Galapagos for 1990-2000. Galapagos compounded annual growth of 4.9% exceeds the growth in Ecuador, which is higher than average growth of the world, but less than double this growth.

**Table 1: Conservation site land area characteristics by TNC region**

	Global	North America	Latin America	Asia/Pacific	North Asia	Africa
No. of sites	531	427	78	15	9	2
Total area (sq. km)	5,048,825	2,548,167	689,252	86,361	91,357	1,633,689
Average	9,508	5,968	8,837	5,757	10,151	816,844
Maximum value	1,354,285	491,262	100,690	58,910	67,013	1,354,285
Minimum value	3	3	5	63	28	279,404
Standard deviation	64,406	26,065	14,152	14,097	21,458	760,056

**Table 2: Illustration of impact of CAGR rates on overall density increase**

	1990 Population	2010 Population	(1990-2010) CAGR	Density % Increase
<b>Strong Central Favor: B0 to B50 CAGR Delta: 1.4%</b>				
B0	16	23	1.8%	43%
B10	152	193	1.2%	27%
B50	46	50	0.4%	8%
B100	583	611	0.2%	5%
<b>Weak Central Favor: B0 to B50 CAGR Delta: 0.4%</b>				
B0	6	9	2.3%	58%
B10	7	11	2.0%	49%
B50	15	21	1.9%	46%
B100	33	52	2.3%	56%

**Breakdown of 2010 Population Density for site and surrounding 10K region**

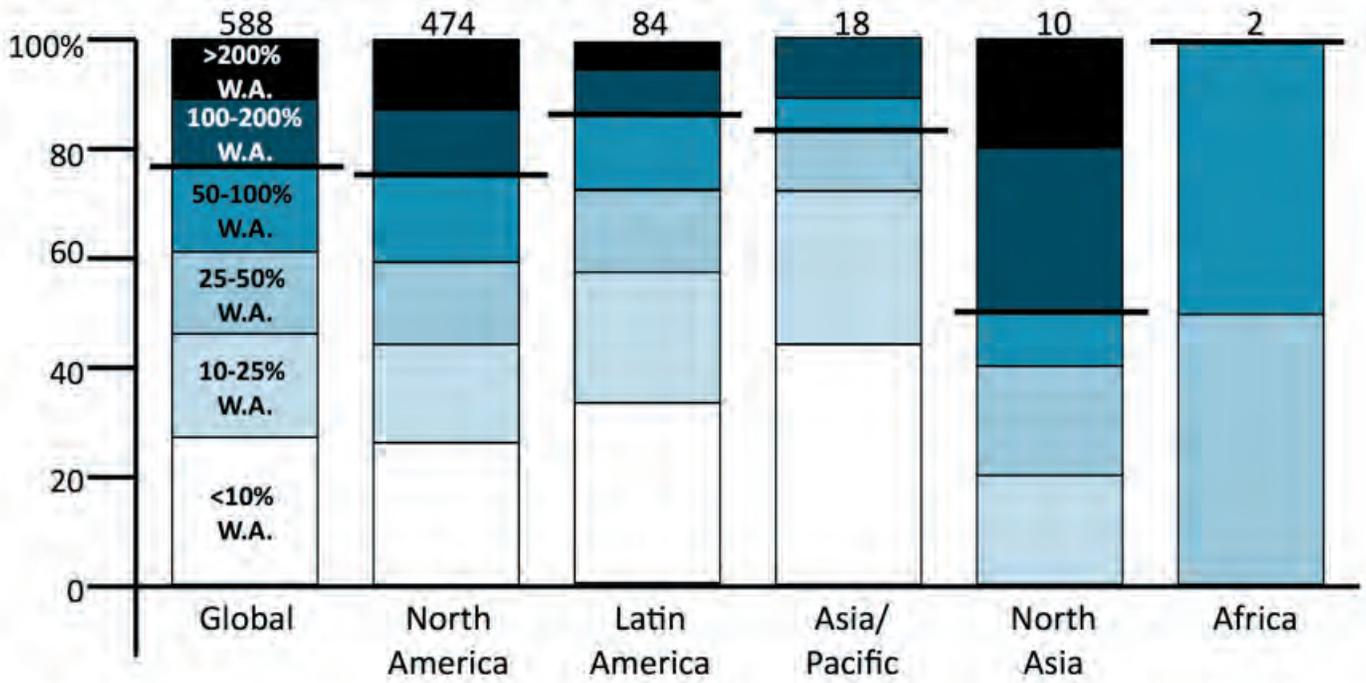


Figure 4: 2010 Population Density by the Conservancy's Regions. W.A. = World Average, 50 people per square kilometer. Solid bars at regional level indicate the point where density crosses the world average. The number of sites in each region is listed above each bar.

**Breakdown of 1990-2010 Population Growth for site and surrounding 10K region**

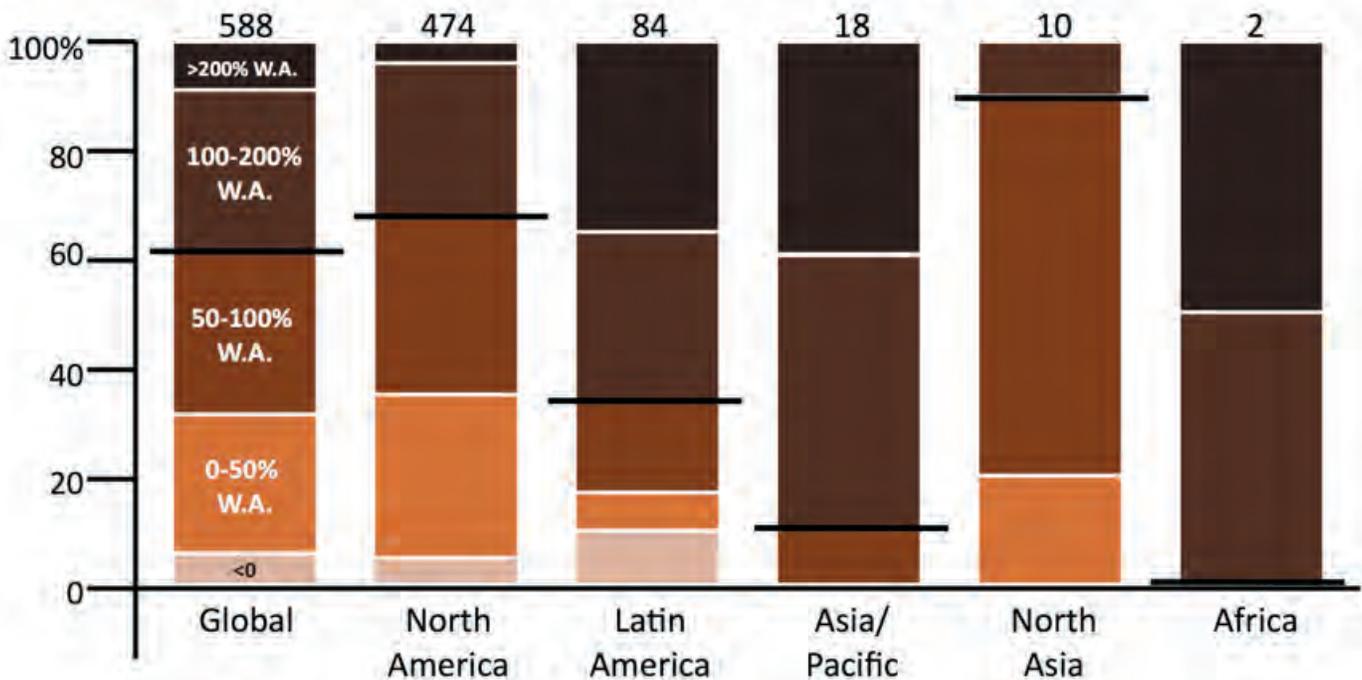


Figure 5: 1990-2010 Population Growth Rates by Regions as Defined by the Conservancy. W.A. = World Average, 1.3% per annum. Solid bars at regional level indicate the point where growth rate crosses the world average.

## Global breakdown of sites by population density and growth characteristic

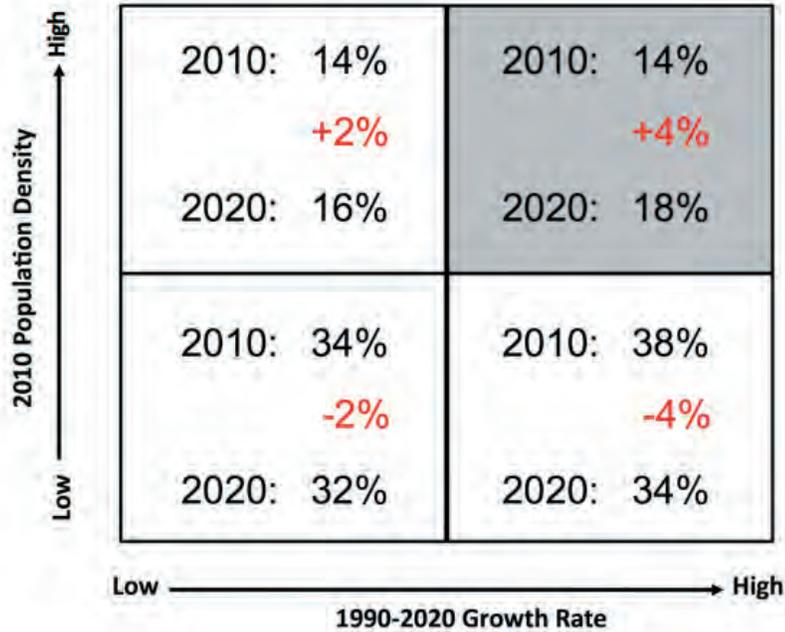


Figure 6: Relationship between population density and population growth for all sites. Low growth and density are both defined as less than 75% world average. The gray box represents those sites that have both high population density and high population growth.

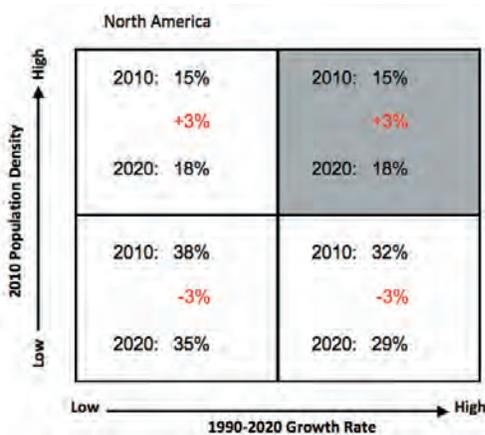


Figure 7.1: North America site distribution between population density and population growth over from 2010 to 2020. The gray box represents those sites that have both high density and high growth.

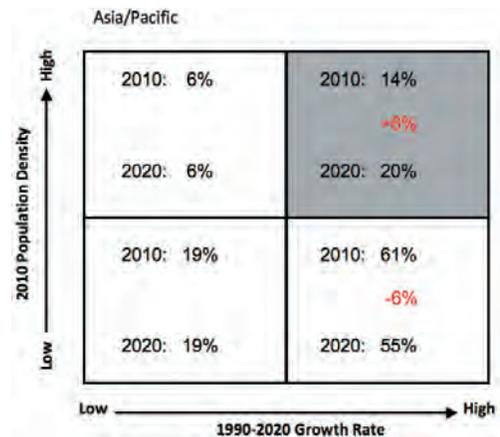


Figure 7.3: Asia/Pacific site distribution between population density and population growth over from 2010 to 2020. The gray box represents those sites that have both high density and high growth

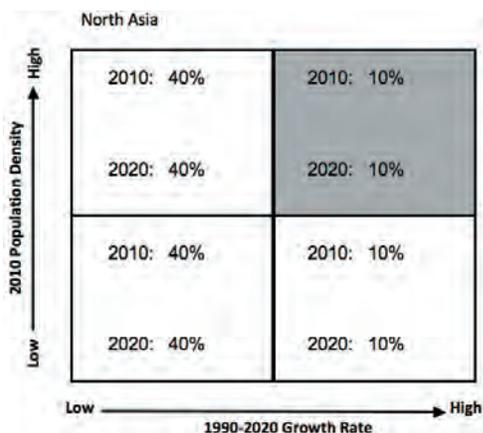


Figure 7.4: North Asia site distribution between population density and population growth over from 2010 to 2020. The gray box represents those sites that have both high density and high growth

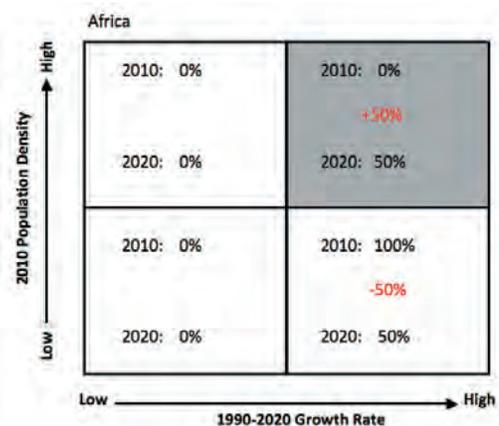


Figure 7.5: Africa site distribution between population density and population growth over from 2010 to 2020. The gray box represents those sites that have both high density and high growth

2010 Population density (people per square kilometer) by buffer ring

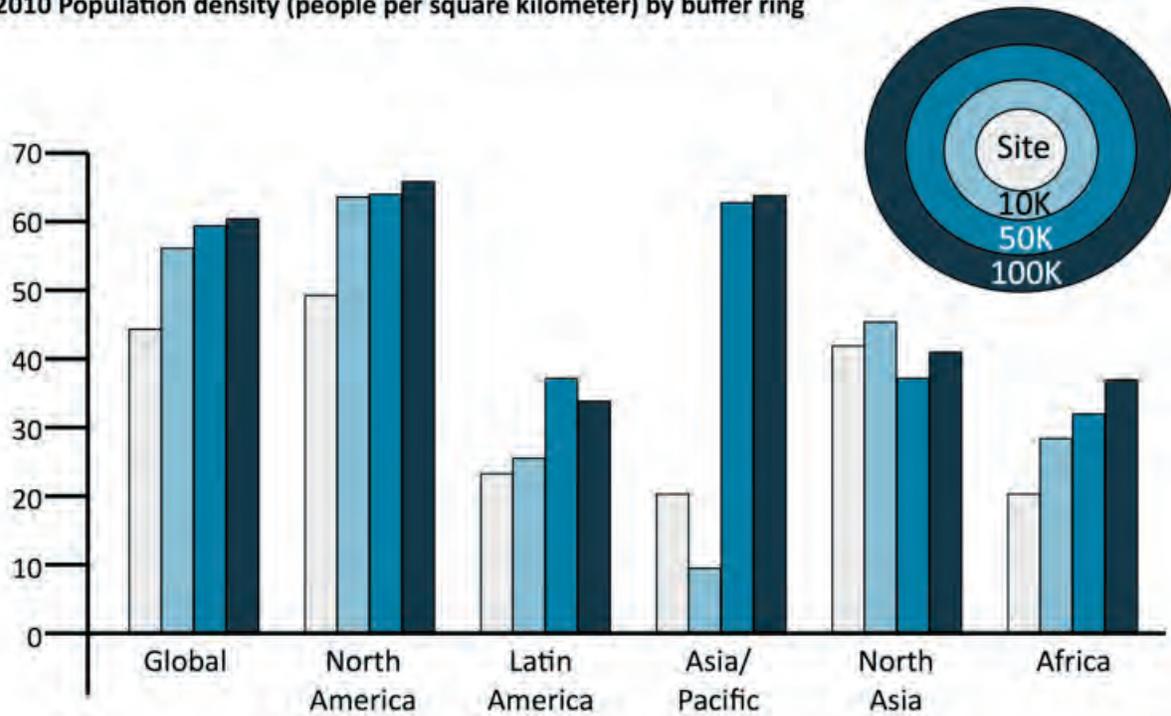


Figure 8: Relationship between population density and proximity to Conservancy’s sites. A trend of higher population density further from conservation sites predominates.

Breakdown of sites by growth favor dynamics by region

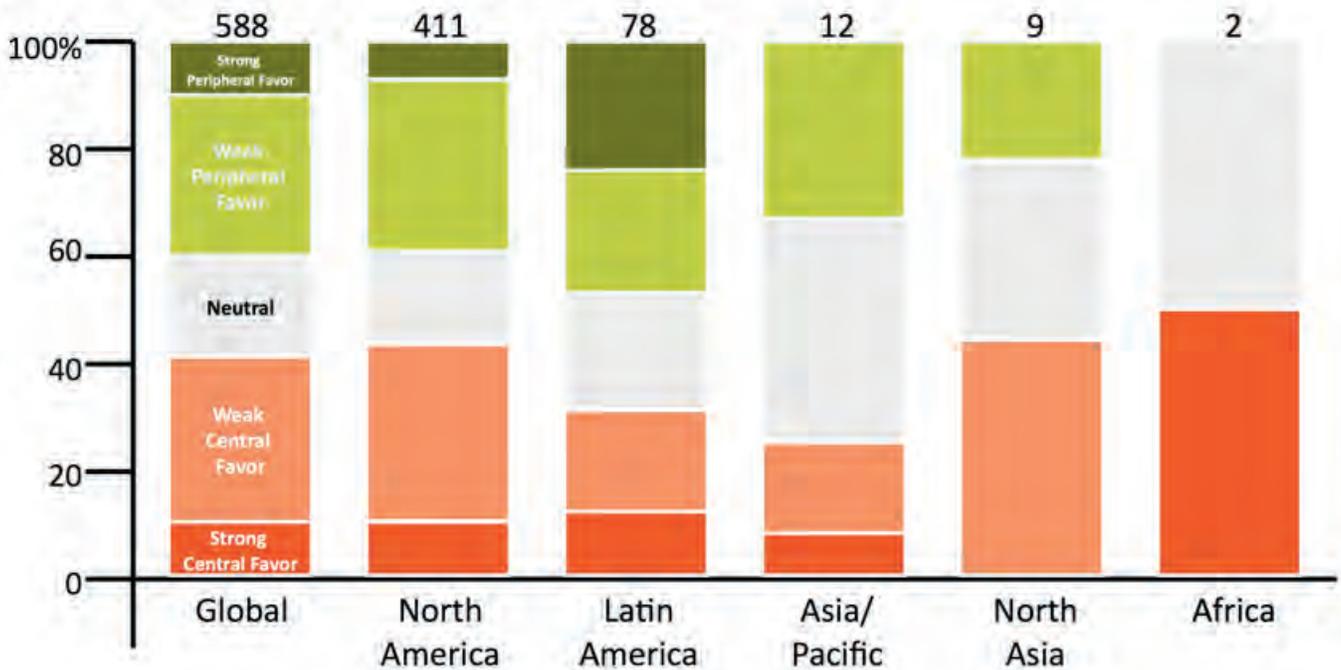


Figure 9: Relationship between population density and proximity to Conservancy site.

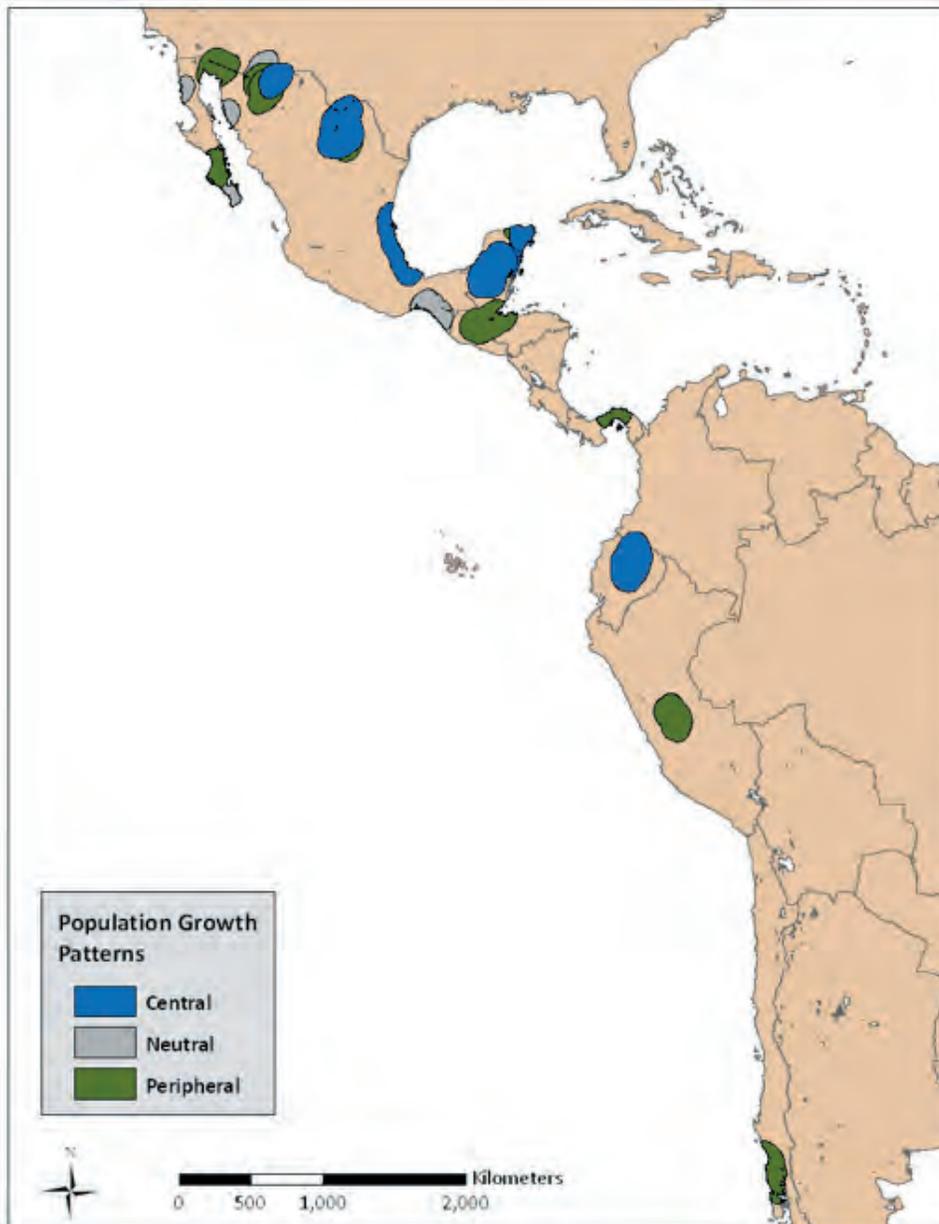


Figure 10: Depiction of sites in Latin America with central, neutral or peripheral population growth. Only publicly available sites are shown

Table 3: The distribution of the Conservancy sites by region and poverty level (IMR classification)

Poverty Level	North America	Latin America	Asia/Pacific*	North Asia	Africa	Total
Extremely Poor					1	1
Very Poor			2		1	3
Poor	2	36	8			46
Moderately Poor		42	3	10		55
Not Poor	472	6	4			482
Total	474	84	18	10	2	587

\*One additional site was not classifiable because it was located in a country for which no IMR data was available.

## HDI vs. IMR

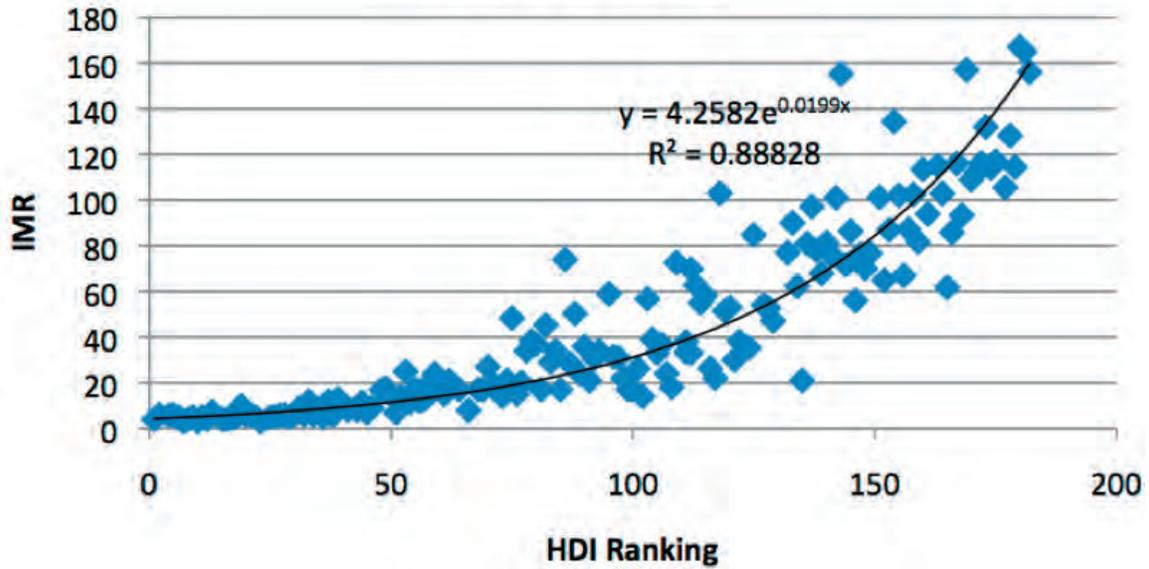


Figure 11: Correlation of HDI and IMR data for countries in which both data sets provided coverage. The two data sets are highly correlated ( $R^2 = 0.89$ ).

## HDI Rank vs. Population Growth Rate

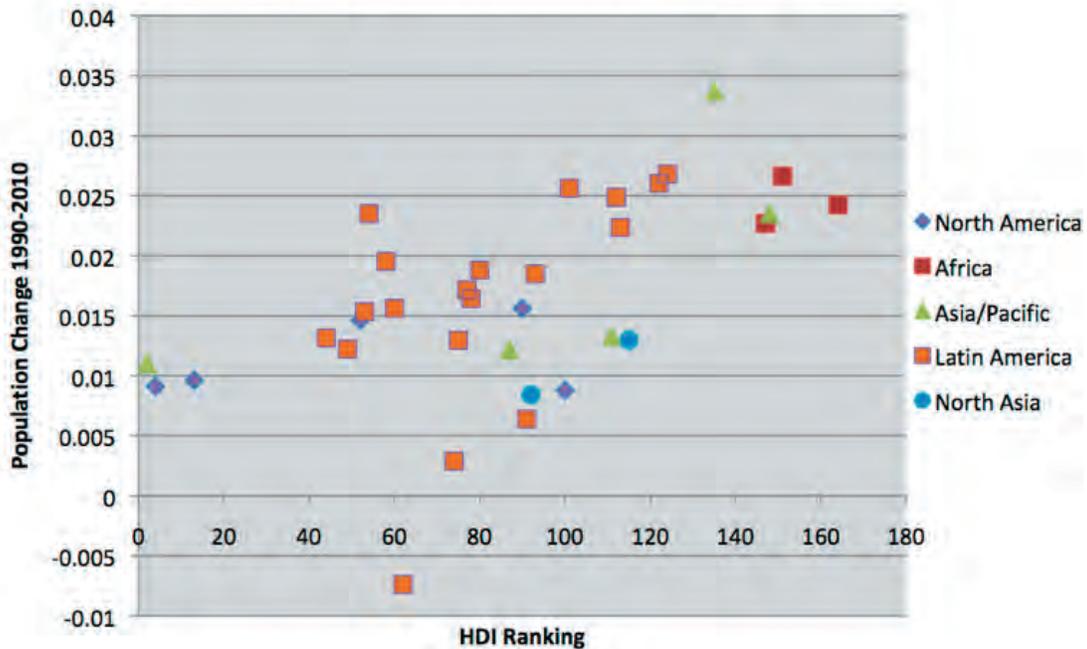


Figure 12: HDI ranking versus population change, colored by region. Population growth increases with increasing levels of poverty.

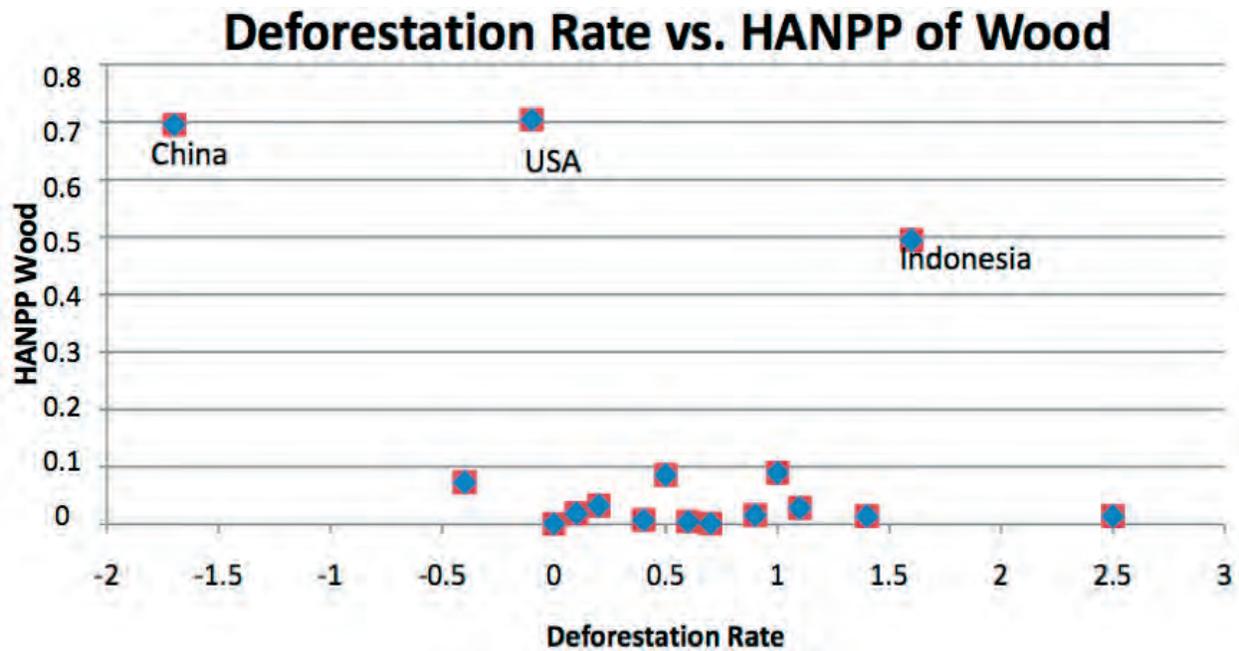


Figure 13: National deforestation rates compared with country level HANPP of wood for countries in which the Conservancy conducts conservation work.

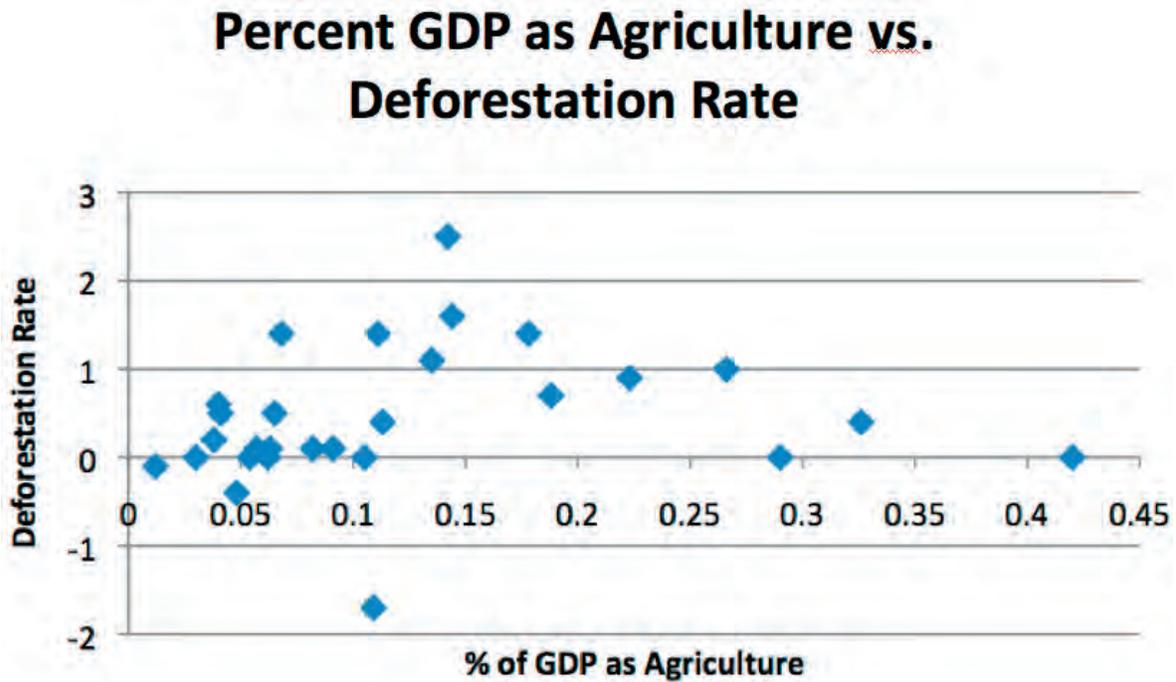


Figure 14: Percentage GDP as Agriculture compared with national deforestation rates where the Conservancy works.

**Table 4: Number of sites exhibiting each of the primary anthromes by region**

Level of Anthropogenic Impact	Primary Anthrome	Africa	Asia/South Pacific	Latin America	North America*	North Asia	Global
High	Cropland		3	6	19		28
	Dense Settlement			1	10		11
	Villages		8	44	107	4	163
Low	Wildlands				13		13
	Forests	1	5	16	233	6	261
	Rangelands	1	2	21	81		105
	<b>Total</b>	2	18	88	473	10	581

\*An additional 10 sites in North America had insufficient data to be classified.

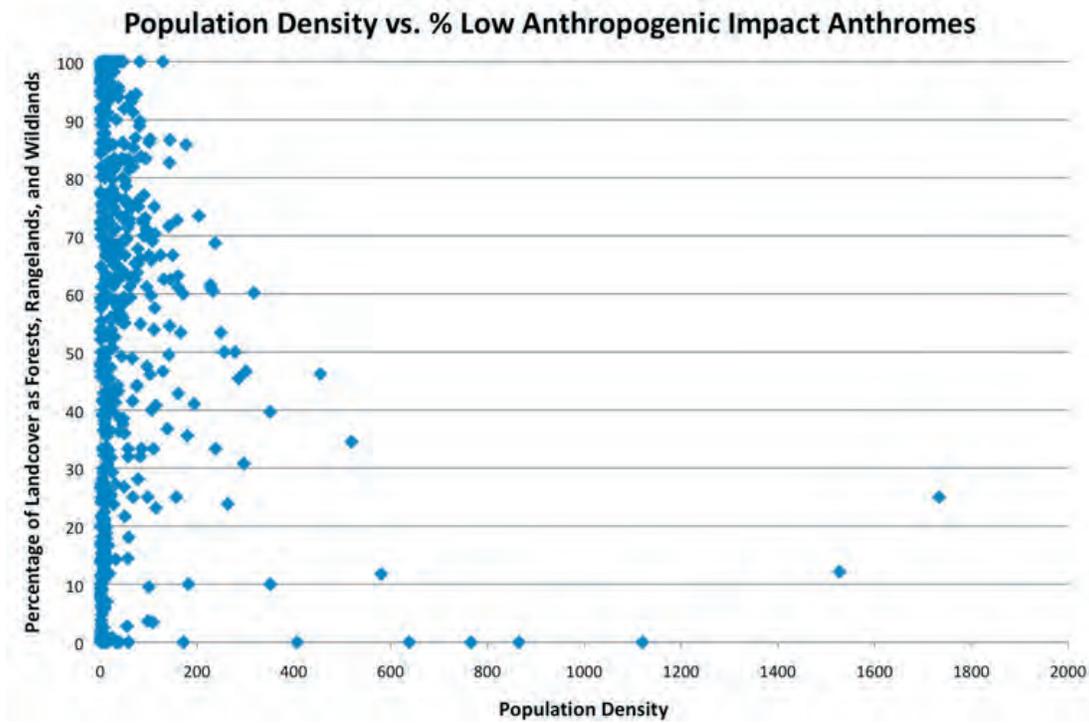


Figure 15: Scatter plots showing population density (left) and population growth (right) vs. the % land cover of Wildlands, Forests, and Rangelands.

### Inspection of the Leading Edge: Population Density and Forestation

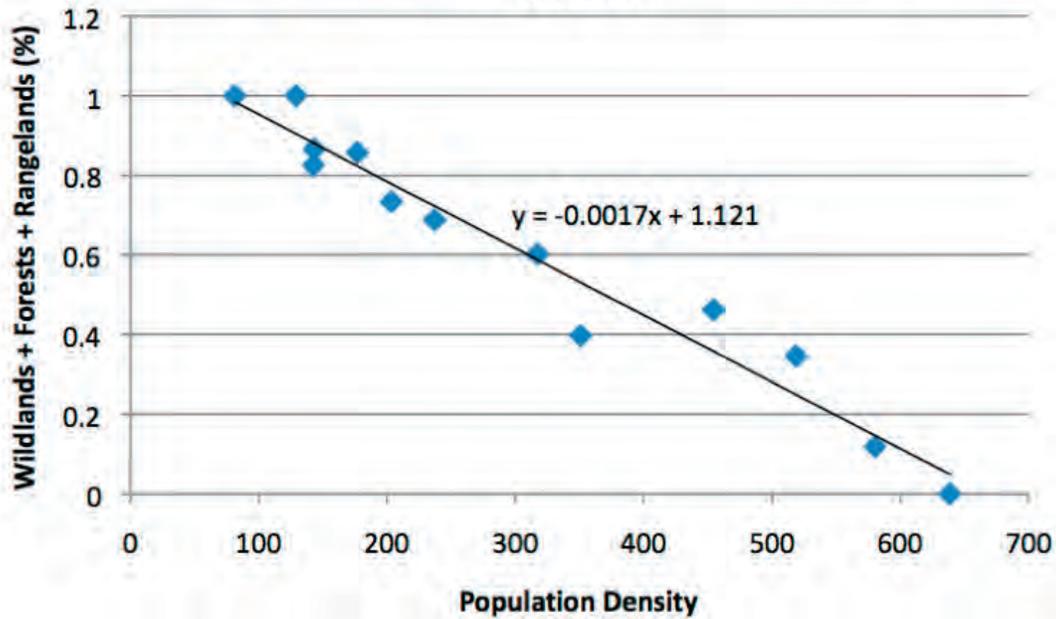


Figure 16: Leading edge of population density vs. summed wildlands, forests, and rangelands land cover plot. The trend line has a best fit equation of  $y = -0.0017(x) + 1.121$ , where  $y$  is the ration of wildlands + forests + rangelands to total land cover and  $x$  is the population density. The function is bound by an upper limit of 1 and a lower limit of 0.

### Annual Population Growth vs. % Low Impact Land Cover

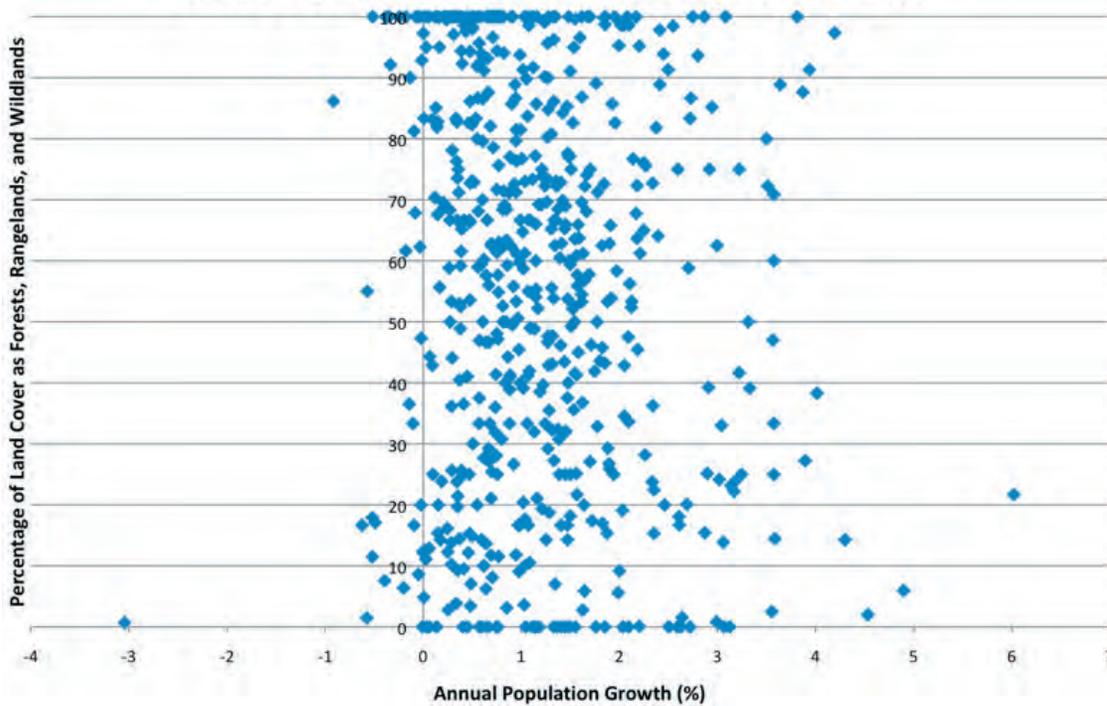


Figure 17: Annual population growth within conservation sites vs. percentage of land cover provided by wildlands, rangelands, and forest.

**Population 2010  
Case Study:  
Valdivian Coastal  
Reserve, Chile**

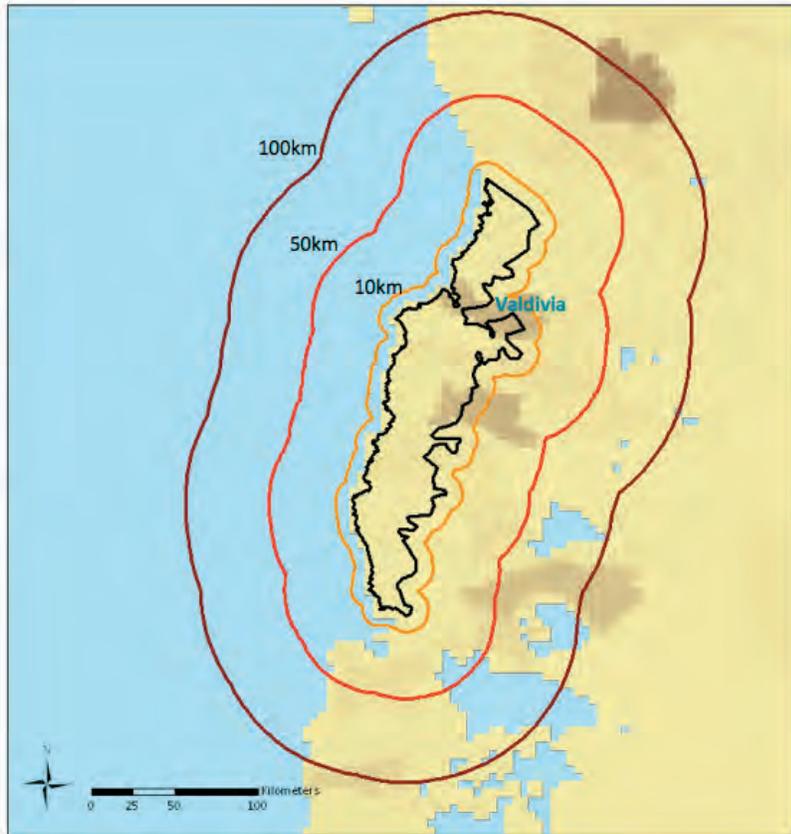


Figure 18: Human 2010 population distribution in and surrounding the Valdivian Coastal Reserve. High population density in the northern section of the conservation site is reflected by the city of Valdivia.

**Population Growth  
1990-2010  
Case Study:  
Valdivian Coastal  
Reserve, Chile**

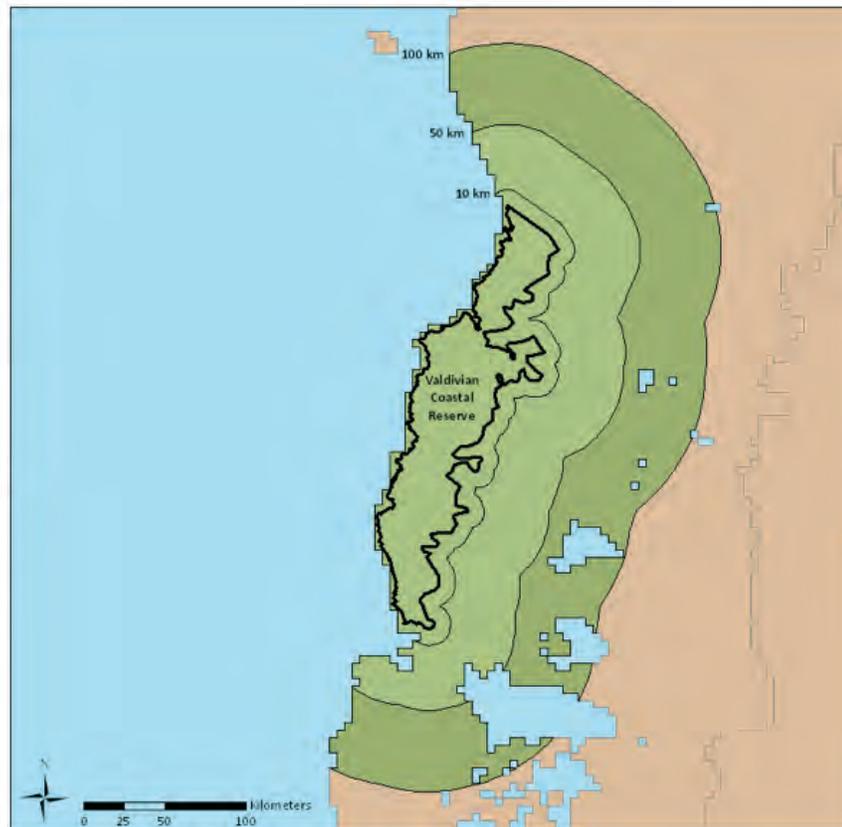
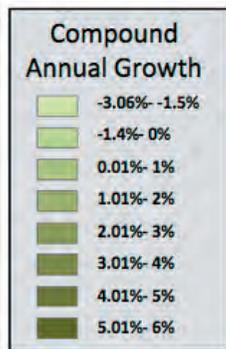


Figure 19: Population growth in and surrounding Valdivia conservation area. The area of highest growth as shown by the map is 100km of the buffer. The northern most human population as shown in Fig. 18 may give reason as to why growth remains high within the 100km buffer.

**Population Growth  
1990-2010  
Case Study:  
Motagua Valley,  
Guatemala**

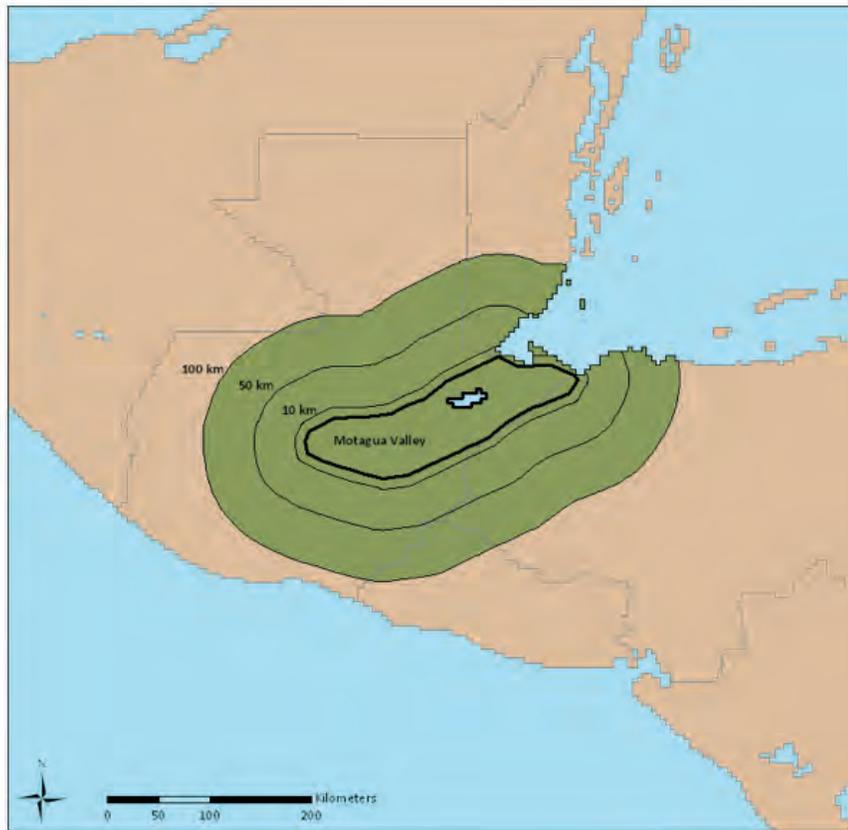
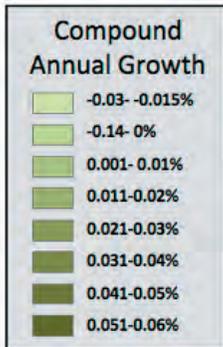


Figure 20: Growth within and surrounding Motagua Valley conservation site exceeds the world average. Within 100km of the site buffer, population growth increases from 2.04% within the site to 2.7%.

**Anthromes  
Case Study:  
Condor Bioreserve,  
Ecuador**

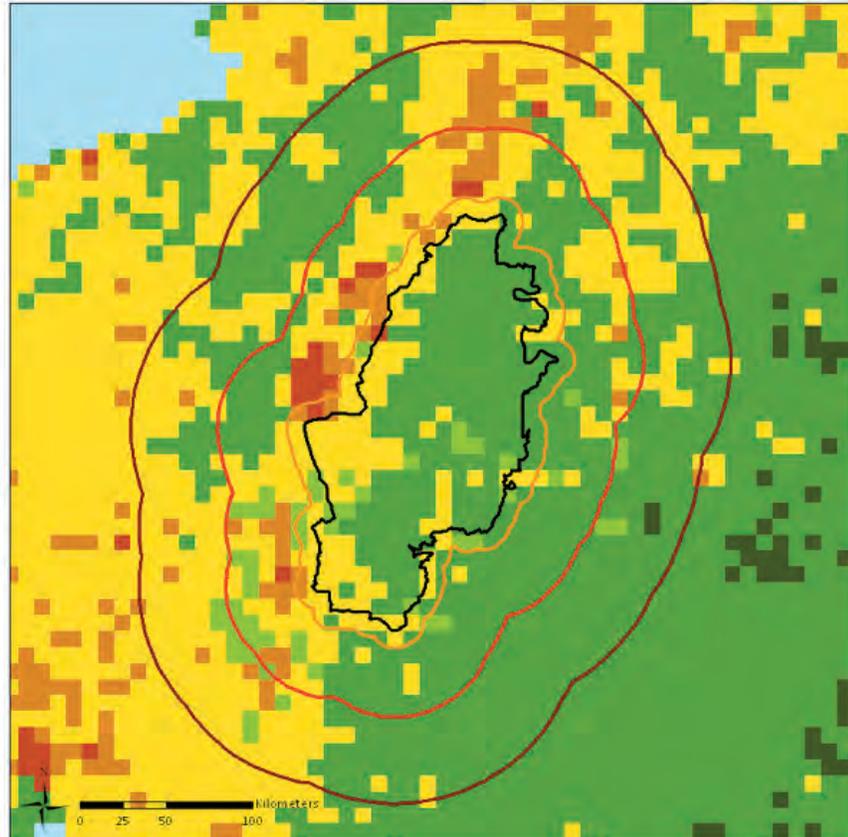


Figure 21: Depiction of the human land alteration surrounding the site as of 2004. While most of the site and areas to the southeast remain forested, areas of high impact (red) are shown within 50km of the site buffer.

**Population 2010**  
**Case Study:**  
**Kenya Rangelands**

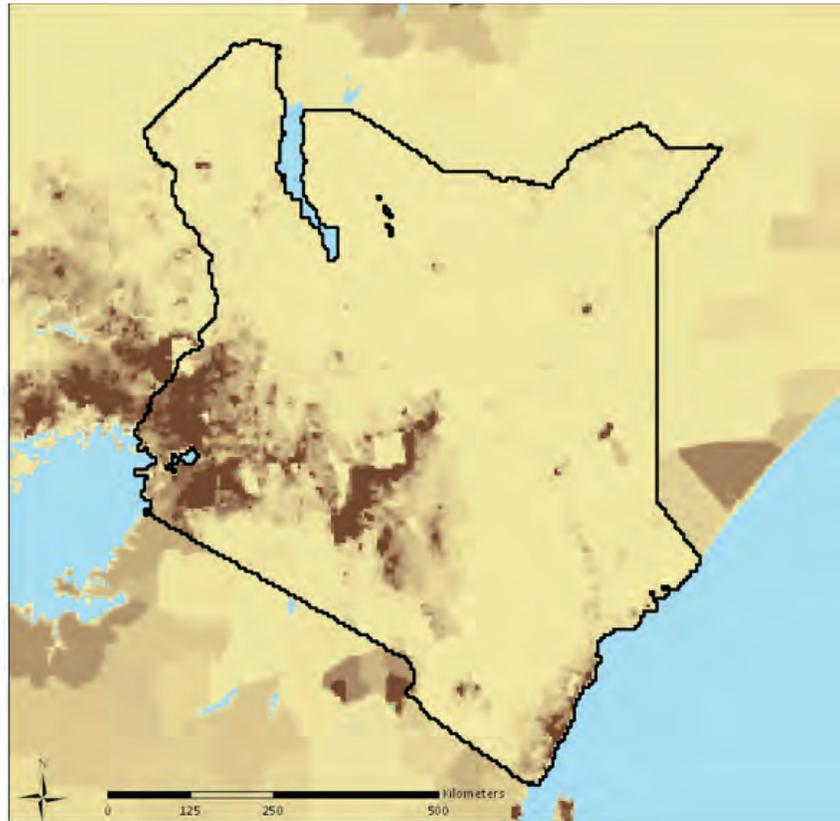


Figure 22: Kenya Rangelands conservation site reflects almost the entire nation. Average population density inside the site is 11.8 people per km<sup>2</sup> in 2010, and increases to 17.3 persons/ km<sup>2</sup> within 100km of the site.

**Population Growth Rate**  
**1990 - 2010**  
**Case Study:**  
**Kenya Rangelands,**  
**Kenya**

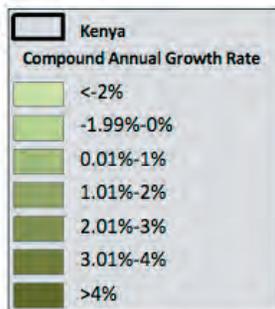
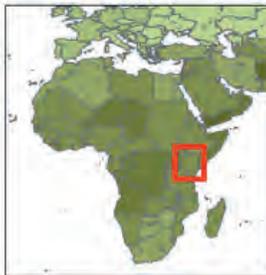


Figure 23: Growth within Kenya Rangelands site remains highest within the site itself (2.94%), and higher than the global human population growth average (1.3%) from 1990-2010.

**Population Growth  
1990-2010  
Case Study:  
Loreto Bay,  
Mexico**

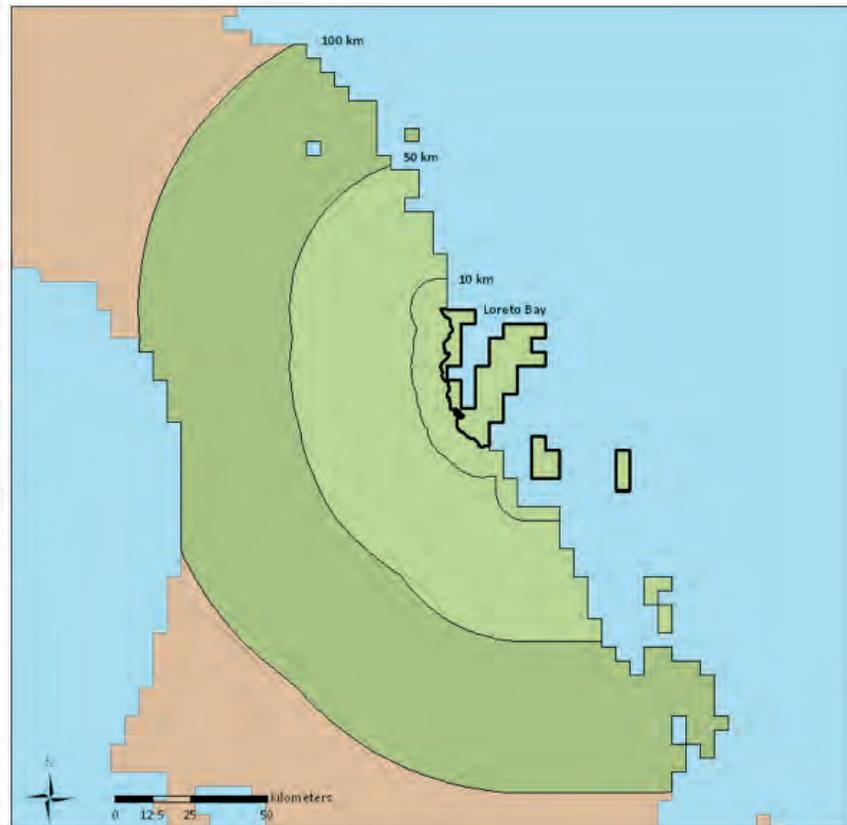
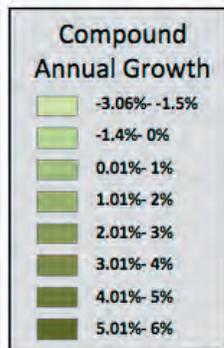


Figure 24: Loreto Bay has relatively mild growth within the site, however, elevated annual growth rates 50-100km of the site. This growth is thought to be as a result of development.

**Population Growth  
Case Study:  
San Pedro River,  
Mexico and USA**

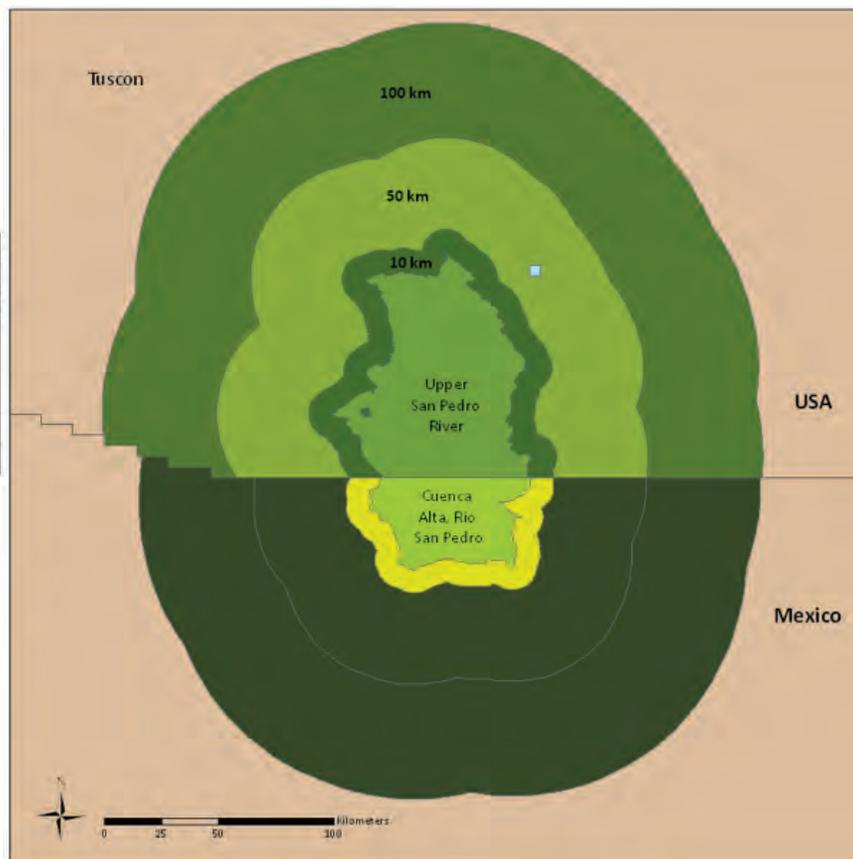
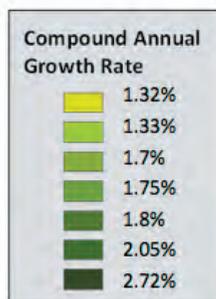


Figure 25: The two sites in the San Pedro are marked by difference in human population growth. While sites internal to the Mexican San Pedro (Sonora) sites have less compound growth, outside the 10km buffer, shows heavy population growth. Examining the US site shows moderate growth within the site, perhaps an implication of development

**Population Growth  
1990-2010  
Case Study:  
Meili Snow Mountain  
National Park,  
China**

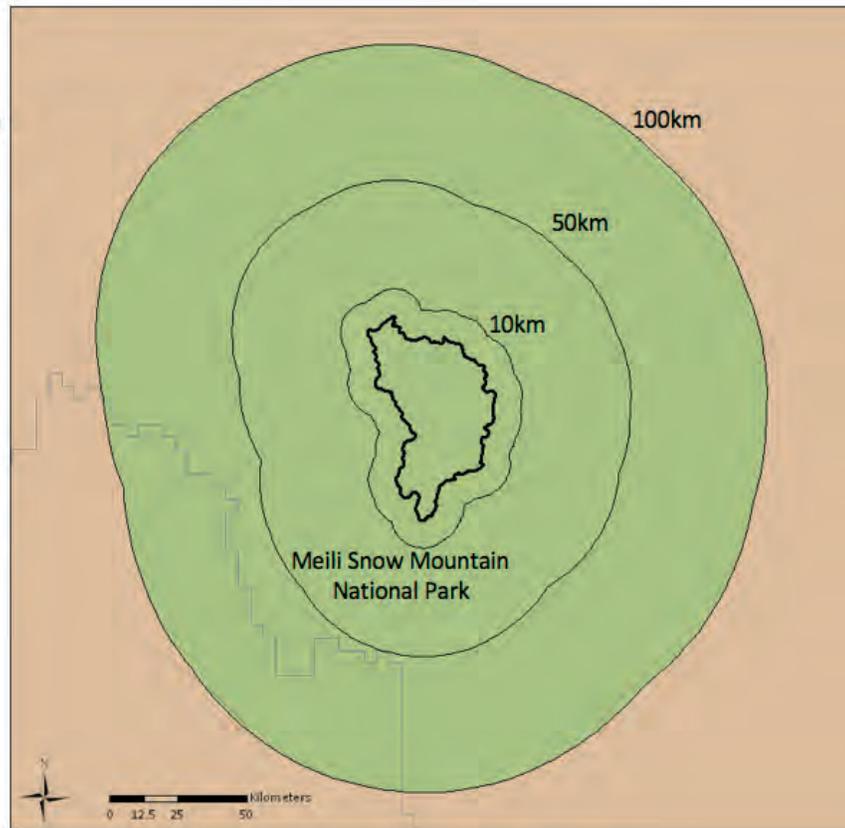
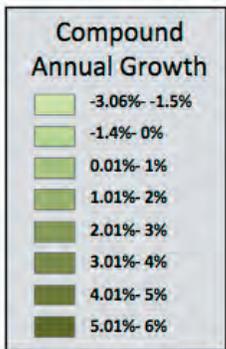


Figure 26: Compound population growth in Meili Snow Mountain National Park. Area shows mild growth 0.38% inside the site and 0.73% within 100km of the conservation site, and supports the on the ground observations from the project manager.

**Anthromes  
Case Study:  
Fitz-Stirling,  
Australia**

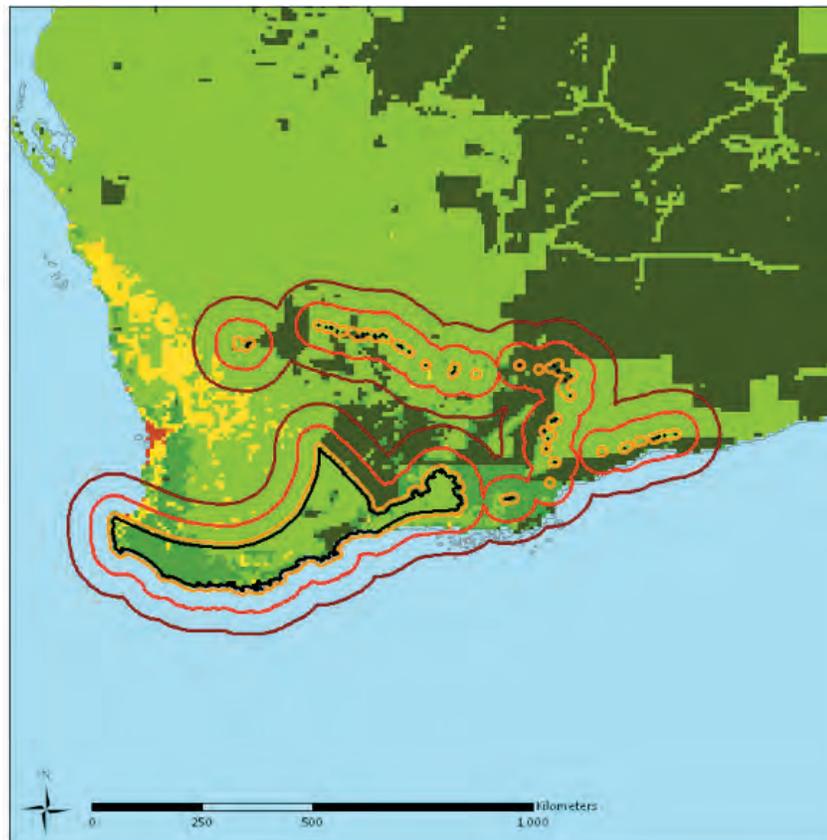
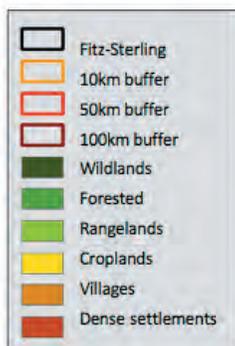


Figure 28: Anthropogenic impact in and surrounding the Fitz-Stirling case study is depicted. Many of the coal mines that exist in this area, run north of the site, along the western coast.

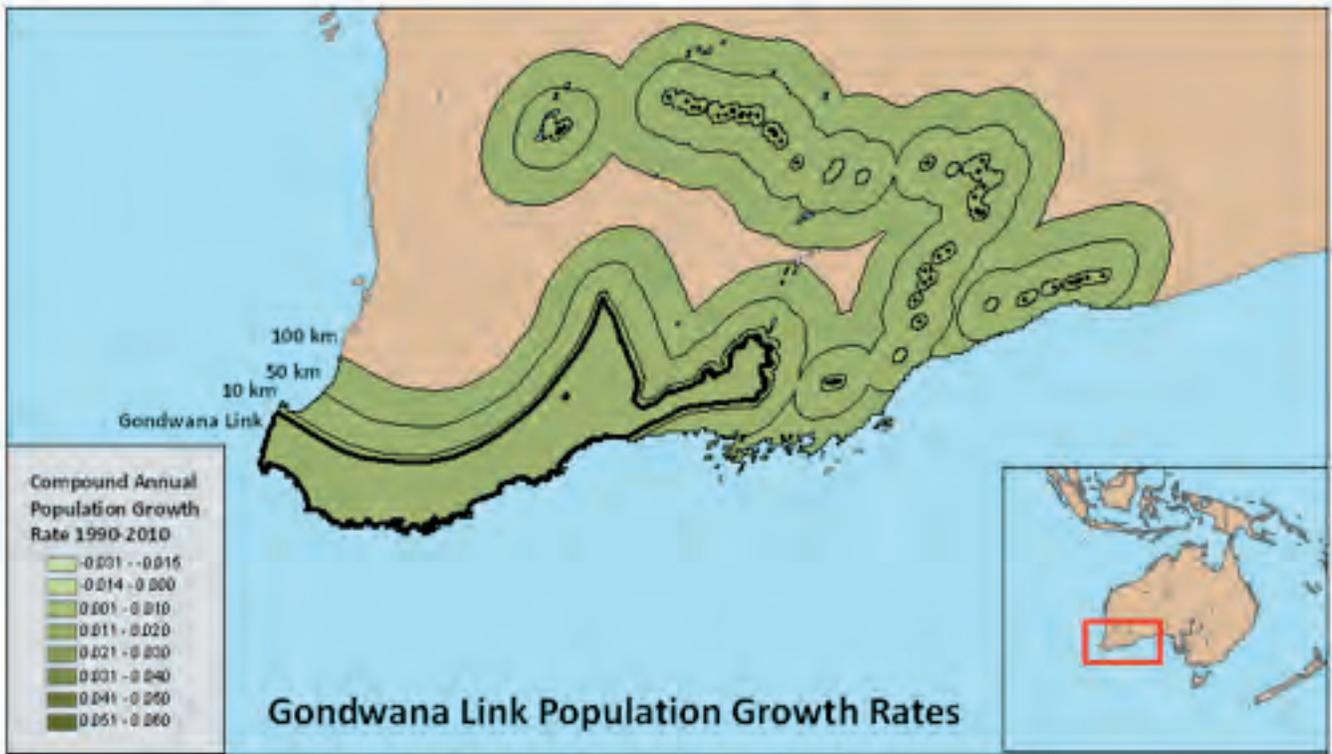
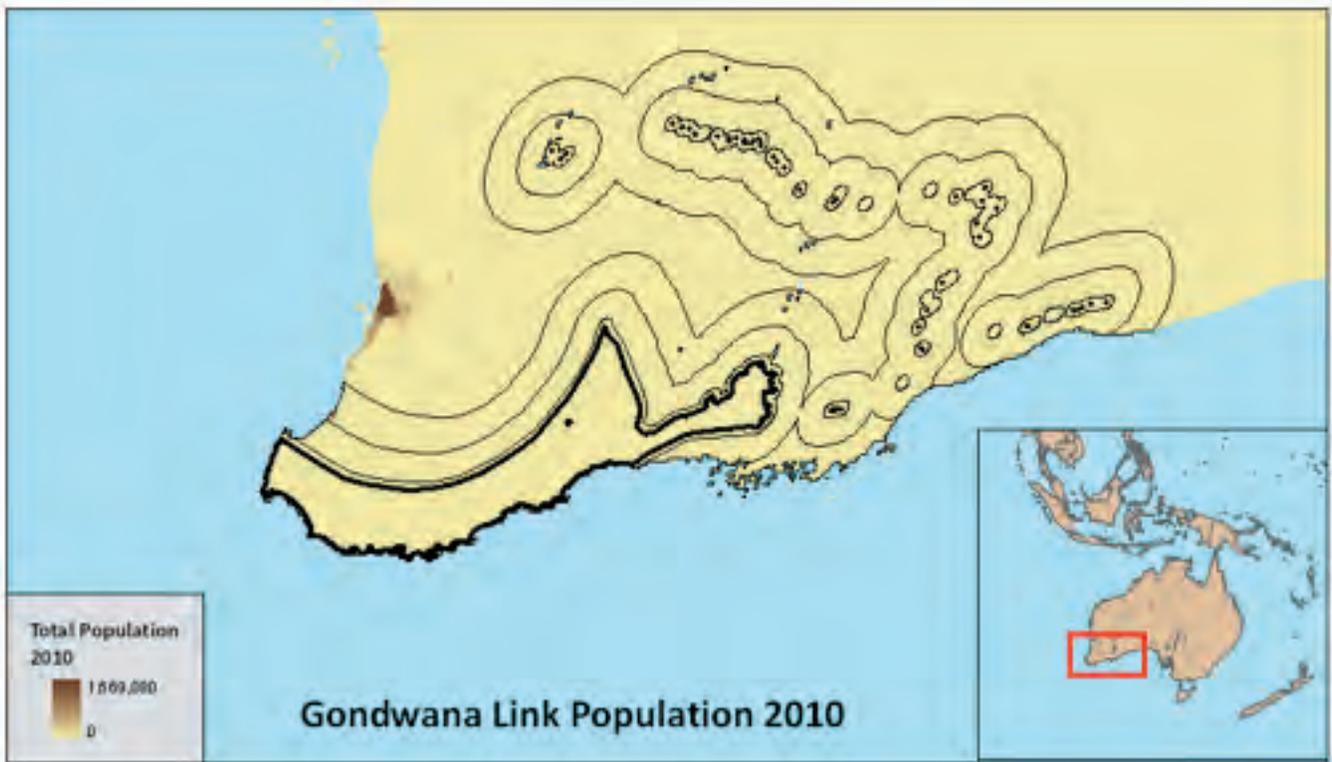


Figure 27: Visualization of the population growth and the growth rates surrounding the Fitz-Sterling site. The city of Perth represents the dense population north of the site and buffers. Overall growth in and surrounding the site is mild.

# APPENDIX B

## DATABASE DETAIL AND CHALLENGES

### Input Datasets

We examined four datasets to ascertain their impact on the Conservancy's conservation sites: Population, poverty, consumption and land use.

POPULATION data was obtained from Columbia's Center for International Earth Science Information Network (CIESIN) for the years 1990, 2005, 2010, and projected population in 2015 at a resolution of 2.5 Arc-Minutes (16 sq. km at the equator). The Gridded Population of the World Version 3 (GPWv3) dataset is a globally consistent and was developed between 2003 and 2005 for use in research and policy making. This data was used to create population statistics for several different geographic areas, including the conservation sites, surrounding buffer areas, countries, and TNC regions.

POVERTY is represented by two separate datasets, infant mortality rates (IMR) and human development index (HDI). TNC defines poverty in three dimensions: opportunity, security, and empowerment (TNC, Direct Benefits to Poor People from biodiversity conservation, 2004), which is represented by the HDI index. The datasets selected for poverty were chosen because of their global coverage and partial consistency with TNC's framework for assessing poverty.

- IMR dataset was obtained from CIESIN and represents number of deaths per 1000 children under the age of 1 at a sub-regional level. Infant mortality rate was obtained from the UN and this data set has been cited as a relevant poverty indicator in previous studies; IMR represents a composite of available sub-national and national IMR from 1990 to 2003 adjusted to 2000 levels. High rates of IMR correlate to levels of extreme poverty and low rates of IMR represent no poverty. An advantage of using IMR data as a proxy for poverty levels is that it is not influenced by skewed wealth distribution where a few very wealthy people can make regions appear less poor than they truly are (De Sherebinin, 2008). The IMR dataset inherently incorporates many aspects of poverty such as education levels, clean water availability, and child malnutrition. However, the dataset does have limitations that including that it cannot be analyzed over time and lacks spatial resolution to the scale of the population dataset grid eliminating the possibility of conducting a conservation site specific analysis of IMR rates to assess poverty levels surrounding sites. To broaden the scope and include other components of poverty in the analysis, the Human Development Index (HDI) was utilized.
- HDI provides both temporal data and additional poverty indicators to supplement IMR data. It shows countrywide rankings of nations designated as low human development to high human development at years 1990, 1995, 2000, and 2005. The Index takes into account a number of dimensions such as a long and healthy life (Life Expectancy at Birth), the adult literacy rates and gross enrollment ratio (Education Index) and a dimension of a country's standard of living (Human Development Report, 2009).

CONSUMPTION is represented by four separate datasets: Human Appropriations of Net Primary Productivity (HANPP), deforestation, energy consumption and Gross Domestic Product (GDP).

- Human Appropriation of Net Primary Productivity dataset is from CIESIN-SEDAC. The dataset provided us data in excel form on a national level and represents the energy used in the consumption of wood, fiber, paper, meat, vegetable, egg and milk (measured in gigatons of carbon). We imported the excel data into a world map with country boundaries to make our own layer of

HANPP, on national level. Then we re-classified the data in Excel and imported it into the region layer created by population team to get the HANPP layer on regional level. Purpose: The purpose of these data is to determine the intensity of human consumption of the net primary production of the land.

- Deforestation data was obtained from Lexis/Nexis Statistical Database “World Development Indicators 2006.” Data represents deforestation on national and regional level in 1990 and 2005. Data is in absolute number (total area forest loss) and percentage. Deforestation is directly linked as a significant impact on biodiversity loss.
- Energy consumption data was obtained from the US Energy Information Administration Independent Statistics and Analysis Database “World Total Primary Energy Consumption 1980-2006.” The years we examined were 1990 and 2005. These data represent the primary energy consumption from sources such as solar, wind, fossil and nuclear (measured in quadrillion BTUs). The purpose of these data is as an important component of consumption. Our belief, to be researched further is that there is a correlation between energy consumption and biodiversity loss.
- Gross Domestic Product (GDP) is contained within two datasets, the first was obtained from International Monetary Fund “World Economic Outlook Database October 2009.” Data is country level GDP based on purchasing power parity from 1990 to 2010. GDP growth rate was calculated from 1990-2010 (last 20 years) and 2005-2010 (last 5 years). GDP by Industry data was obtained from the CIA World Factbook “Latest Possible Data.” Data is broken down into industry, agriculture and services. There are two purposes for using a country’s GDP, one, to link economic level with biodiversity loss. The second data set is used to link reliance of industry or agriculture on biodiversity with the believe rates of biodiversity loss is industry specific.

LAND USE, or Anthromes, geospatial map was created through a collaboration between CIESIN and TNC. Anthromes represents a composite of the human ecological impact snapshots from January 2003 to December 2005. The classifications were manipulated from 21 categories of anthropogenic land use change into six broad listings using Excel and GIS applications. These six classifications are Villages, Wildlands, Rangelands, Densely Populated Settlements, Croplands, and Forested. This data manipulation was necessary to derive meaningful global level analysis. Individual case studies will revert back to the original Anthromes classifications in order to glean a better picture of how land use change affects the project sites. The similarities between biomes and Anthromes data are included because of the wide reaching effects of humans and represents how the natural ecology stated in biomes has changed.

## Levels of Analysis

Analysis was performed at three general geographic levels:

- TNC Regions The Regions layer is organized to reflect the Conservancy’s regions and derived from the CIESIN National Boundaries shapefile. Should TNC decide to include additional countries into their regions, country specific data is available for them to modify their region map by adding and subtracting countries.
- Country and national boundaries were obtained from CIESIN. We manipulated the original data to include an insert for Greenland, as it was not present in the original map. All human impacts were analyzed to this level.
- Project Sites and Buffers represents the TNC project sites and buffers surrounding them. Only the Population and Anthromes datasets were analyzed to this level. In addition to evaluating data at the site level (termed “B0” in our data), we also looked at three buffers of varying distance. B10 includes a 10 km buffer of the project site. Our team chose to add examine this buffer level to de-

termine if population dynamics vary between the area within the site and its immediate surroundings. Our interest in this level was spurred by an article published in Science, which showed that population growth within 10km of protected areas is relatively high (Wittemyer 2008). B50 was originally requested by TNC, and shows a buffer of 50 km surrounding the sites. B100 captures the 100 kilometer radial area surrounding each site. This buffer choice was inspired by a Nature paper that showed that urban populations up to 100 kilometers from an ecosystem can have an impact on the site (Cincotta et al. 2000).

## **Challenges with Datasets and Layers**

### *Overlapping Project Sites and Buffers*

In some cases, buffer areas for different conservation sites can overlap with each other. In addition, our team encountered conservation projects that had overlapping site boundaries. When appropriate, our team used dissolved GIS layers to eliminate overlaps and clarify analysis.

### *Temporal Scale of Data*

Most human impacts we examine include some type of temporal data to supplement and deepen our analyses. However, it is of note that portions of our impact datasets, such as IMR and Anthromes Land Use, only show one year with no means to compare over time. Additionally, these snapshots do not represent a single point in time or a single year, but are a data composite that spans a few years.

### *Spatial Resolution of Data*

There is a varying degree of resolution from dataset to dataset; some data is available on the scale of kilometers while other data is only available at the country level. The population and Anthromes data sets were the only sets with data that could be analyzed at the site or buffer level. Other datasets are analyzed to a sub-national or countrywide analysis. Because of the implications of extrapolating data from a country and applying it to a small percentage of land, we were hesitant to continue analysis on buffer layers at that level. There is no way to fully compensate for these discrepancies, however, we can determine per capital levels of consumption and poverty based on the local populations and the countrywide breakdowns.

### *Challenges with ArcGIS*

We had difficulties loading complete levels of analysis from ConPro project sites and buffers. In some situations, we could not use the total sites provided as computers would frequently freeze or crash. We consulted local experts at Electronic Digital Services (EDS) in Lehman Library, Columbia University. While they were able to assist in many troubleshooting issues, some of our challenges with the Hawthstool options could not be addressed by them. In such situations we documented any problems we encountered.

### *Challenges with Consumption Data*

Our team encountered several challenges with global consumption data sets. For example, the HANPP data files from CIESIN-SEDAC did not contain an attribute table. This necessitated that a new map layer be made from the data available. This data was available only at a country level for the year 1995. Further challenges arise from the shifting geopolitical nature of the world map from the year 1990 to present day. We have observed specifically that with the fall of the Soviet Union and the nationalist realignment of Eastern Europe, there are a multitude of discrepancies with the temporal geopolitical map.

### *Challenges with Anthromes Data*

The reclassified anthrome categories may oversimplify the nature of the surrounding land use -- thus inhib-

iting a meaningful statistical analysis. For example, the “Forested” anthrome includes a “Remote Forest” category, which is more like a “Wildland” (e.g. 0 human population), but also “Populated Forests”, which are very different. The “Rangelands” category has a similar issue. Although one solution may be to use the expanded anthrome classification scheme, the resulting complex patchwork around each site makes it difficult to draw any conclusions or note any specific local or regional patterns. Additionally, anthromes are derived from a number of variables, including population density. Thus, it would be redundant to say that X anthrome is associated with Y population density or vice versa.

#### *Water Presence in Sites and Buffers*

While examining the TNC shapefile, it became clear that a few project sites are primarily marine-based preservation efforts (Being Straight and Coral Triangle), and other sites contain large-landlocked waterbodies or coastlines. We determined the latter sites would still be useful to our analysis as they may represent habitats such as mangroves or salt marshes, even though they would skew data. In order to compensate these discrepancies, we individually examined sites at the B100 level and isolated those sites completely contained within the created countries layer. Sites that contained water at B100 were listed as a presence and estimated percentage of water contained in each buffer layer, or project. During our analysis of these sites, we flagged each project with water presence, which was also taken into account during our case study analysis. The Access Database contains a table listing the water classifications for each site.

# APPENDIX C

## DESCRIPTION OF SUPPLEMENTARY MATERIALS

In addition to this report, our team has created several supplementary materials for The Nature Conservancy. This appendix describes these materials, which have been provided electronically to The Conservancy.

### ACCESS DATABASE

At the start of our project, we received an Access Database from TNC including several types of data. In addition to having a complete listing of all TNC sites, the database included shapefile data for 597 sites. Our team has supplemented this database with both the data used in our analysis and with our results. Each table added to the database begins with the prefix “CU” so it is easy for TNC to see what Columbia has contributed to the database. The database is organized around the following categories:

- Anthromes
- Consumption
- Population
- Poverty
- General Data

As an example of the data included, for population we show both the actual population values derived from GIS zonal statistics as well as the population-related calculations that we performed (e. g. density values and growth rates). Further, this data includes segmentation information that we created in our analysis, such as what density bucket each site falls into relative to world average density.

Our goal in compiling this database is to build on TNC’s existing data in a clear, connected way. Should TNC choose to incorporate any of our research data into existing systems, we hope that the organization of this database can help facilitate that process.

### DATA DICTIONARY

All data sources and assumptions for each column in each data table have been documented in a data dictionary file. This file will allow TNC to understand the meaning and key assumptions behind each piece of data provided.

### SITE LOOK-UP TOOL

Since Microsoft Access is not a universally used program, we have created an excel-based site lookup tool based on the Access database data to allow TNC a user-friendly option for examining our complete data set for a particular site. The site look-up tool combines relevant results of our analysis with data provided by TNC pertaining to site threats and conservation strategies. Our objective in creating this look-up tool is to demonstrate one way that human impacts data can be considered alongside TNC data to support the conservation planning process.

### GIS LAYER FILES

To facilitate further analysis of human pressures on TNC sites, we are providing the shapefiles we created over the course of this project. Many of the shapefiles we collected contained either incomplete or extraneous information and required some manipulation before we could conduct our analyses. Examples include the Gridded Population of the World rasters, which displayed population values in the oceans as well as on land, and the National Boundaries layer, which omitted much of Greenland. Other shapefiles

had to be created specifically for the purposes of this project, such as the 10 km, 50 km, and 100 km site buffers.

In addition to providing the layer files, we are including an overview document (GIS data dictionary) that describes each file in more detail.

#### ELECTRONIC MAP COLLECTION

We designed several maps over the course of the project that we were not able to include in the paper, flash video, or presentation. We are including these in case they can be of value to TNC.