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# Factors Influencing Conservation Success or Failure in Tiger Range States

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## ABSTRACT

Tigers are currently found in 13 countries. Three of eight recognized subspecies are extinct and the other subspecies are considered endangered throughout their range. Major threats to tigers include habitat and prey loss and poaching. Most studies of tiger decline, to date, have explored direct threats. This study uses a range-wide approach to explore possible underlying drivers of tiger decline. I used recent tiger population estimates and identified 6 biological measures and 27 socioeconomic measures to ask why some countries are more successful in conserving tigers than others. Data were analyzed using correlation and regression analyses in SPSS. Higher rates of education, greater democracy, and lower levels of poverty were significantly associated with successful tiger conservation. These factors likely promote more successful conservation due to increased levels of citizen support, greater local participation, increased scientific and implementation capacity, and increased funding for conservation. Furthermore, countries with an internal commitment and external non-governmental involvement, such as Nepal, can succeed at tiger conservation even without good measures of the identified factors. The factors found to significantly contribute to successful tiger conservation are also likely to impact conservation of other species throughout the world.

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# INTRODUCTION

Biodiversity is threatened globally due to both natural and anthropogenic causes (Cardillo et al. 2004, Araujo and Rahbek 2007, Wilson et al. 2007). The World Conservation Union (IUCN) estimates that over 12,000 species are threatened with extinction (Graham 2003, IUCN 2008). As human populations have increased, especially in the past century, anthropogenic impacts on species have spread to almost every area of the world (Cohen 1995).

Habitat destruction, hunting, and other human impacts are the main threats to species survival (Wilson 1991). The proximate causes of wildlife population declines are often species specific. The underlying cause, however, is human impact resulting from high human population size and density, and extensive resource use resulting in habitat fragmentation and degradation, loss of food resources, increased number of invasive species, and human hunting (Cardillo et al. 2004, Gaston 2005, Kauppi et al. 2006, Naidoo and Ricketts 2006). For already threatened species, wildlife populations are at risk for inbreeding depression and disease due to small numbers (Brook et al. 2002).

Worldwide, these natural and anthropogenic threats to species populations result in a need for conservation efforts to protect vulnerable species. However, funding and resources for conservation is limited (Wilson et al. 2007, Carwardine et al. 2008). Strategies are needed to prioritize conservation funding and effort to the most cost-effective projects (Lindsey et al. 2005, Naidoo et al. 2006, Wilson et al. 2007, Carwardine et al. 2008, Joseph et al. 2008).

Historically, conservation organizations place a priority on protected areas and undeveloped spaces because they are important sanctuaries for wildlife from human influence. Species populations tend to be higher and healthier within protected areas than in surrounding regions (Naidoo and Ricketts 2006). Considerable effort has been made to prioritize the acquisition of protected areas to preserve the greatest amount of overall biodiversity (Naidoo et al. 2006). However, comparatively little research or conservation has been directed towards reducing the underlying causes of threats to biodiversity.

Wide-ranging species are particularly vulnerable to human-related and natural threats (Cardillo et al. 2004). Large carnivores intrinsically require more habitat than most species because higher order predators need abundant prey for maintenance and reproduction. Areas with abundant prey are decreasing due to expanding human populations and increasing development (Weber and Rabinowitz 1996, Sunquist et al. 1999).

In Asia, habitat and prey are decreasing due to high population growth rates and increasing economic development (Marcoux 2000, FAO 2003, Kauppi et al. 2006, Mazard 2007). While some countries, such as China, have initiated reforestation programs in the past few decades, the majority of tiger range countries are losing forest cover annually, some more rapidly than others (Kauppi et al. 2006).

**This Study**

This thesis explores the various proximate and ultimate factors affecting tiger population declines and conservation efforts. The question I ask is why are tiger populations stable or increasing in some countries and not in others? I hypothesize that government spending on conservation, local support for conservation, and low levels of government corruption are associated with successful tiger conservation. Previous studies have suggested that land-use patterns, wealth, energy consumption patterns, and human density may have important impacts on tiger conservation efforts (Forester and Machlis 1996, Harcourt et al. 2001).

I used tiger number, tiger population trend, and land area within Tiger Conservation Landscapes (TCLs) as dependent variables. On a country by country basis, I explored six factors that may impact tiger numbers directly. I also evaluated actions undertaken by the international community, nations, agencies, organizations, and individuals, in the form of 27 socioeconomic variables.

Understanding why tiger conservation is succeeding or failing could inform donors and governments about what factors and policies contribute to effective tiger conservation. Tiger conservation efforts might be improved, both with regards to more successfully conserving tigers and by improving the cost-effectiveness of conservation projects. Funding and human resources could then be redirected towards these factors. Furthermore, global conservation efforts have little understanding of the drivers behind biodiversity loss. This study begins to fill in that information gap.

## BACKGROUND

### Large Carnivore Conservation

Human impacts are especially important for large carnivores because these species often require large tracts of land (Berger 2006). Additionally, large carnivores tend to prey on large animals used by humans (Sunquist et al. 1999, Berger 2006). Large carnivores are also biologically more at risk of extinction as they tend to have long gestation periods and live at low population densities (Cardillo et al. 2004). In addition, species feeding at higher trophic levels, including large carnivores, are intrinsically more at risk for extinction (Cardillo et al. 2004).

The causes of population decline among carnivores are similar to other species, including habitat loss, human conflict, poaching, and exotics trade impacts (Cardillo et al. 2004). Human-carnivore conflict is often caused by carnivore related deaths of both humans and livestock (Helalsiddiqui 1998, Berger 2006). The worldwide exotics trade consists of the trade of animal parts and exotic pets. Common parts are hides, teeth, and bones. These tend to be used for decoration or local medicines (Mulliken and Haywood 1994, Zoological Society of London 2008). Poaching can be a result of human-carnivore conflict, the exotics trade, or various other factors.

Population declines in large carnivores are also due to state run or state supported eradication efforts in many areas. Large carnivores often have a negative public image due to government campaigns for eradication (Woodroffe 2000, Berger 2006). The public image of carnivores can determine the success of conservation and reintroduction efforts (Berger 2006).

Some conservation efforts have been successful, such as wolf (*Canis lupus*) restoration efforts in the United States (Berger 2006). Wolf populations were drastically reduced because of government extermination efforts. Since the listing of wolves under the Endangered Species Act of 1973 and the end of eradication programs, natural recovery and reintroduction efforts have combined to increase wolf populations significantly (Treves and Karanth 2003). In addition, brown bear (*Ursus arctos*) conservation in Scandinavia has been successful due to the end of very effective government run eradication programs. The bear population has since naturally rebounded to more sustainable levels (Swenson et al. 2001).

Other conservation efforts have been less successful. Local extinctions have occurred in many carnivore species, such as the African wild dog, cheetah, lion, mountain lion, jaguar, leopard, grizzly bear, and tiger (Seidensticker et al. 1999, Woodroffe 2000). These population declines are, in part, a result of habitat and prey loss and human hunting. Additionally, local extinctions occurred because of an insufficient number or an inadequate size of protected areas (Woodroffe 2000).

**History of Tigers**

Tigers once roamed through much of Asia, as far north as Russia and Kazakhstan and as far west as Turkey. Historically, tigers inhabited the lands of at least 23 current countries and were thought to number over 100,000 individuals (Seidensticker et al. 1999, Seidensticker et al. in press). This range has since declined to 13 countries (Figure 1). Additionally, three of the nine recognized subspecies have gone extinct in the past century (Seidensticker et al. in press).

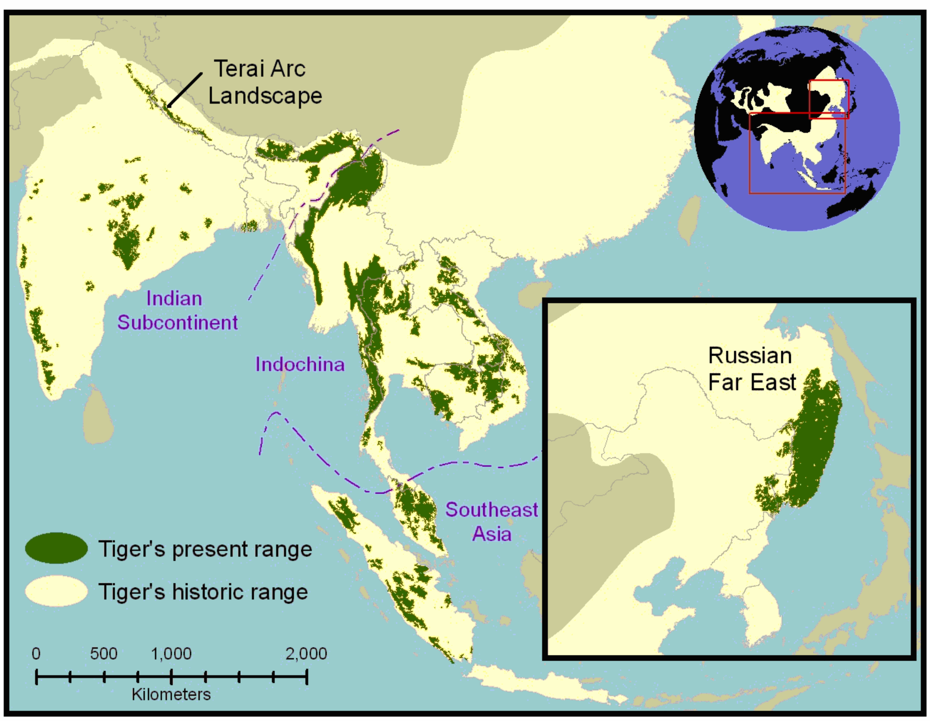


Figure 1. Map of the historic and current range of tigers (Save the Tiger Fund 2006).

The tiger is subdivided into eight subspecies. The subspecies alive today are: the Indian or Bengal tiger (*Panthera tigris tigris*), currently found in Bangladesh, Bhutan, China, India, western Myanmar, and Nepal; the Amur tiger (*Panthera tigris altaic*), found in northern China, North Korea, and southeastern Russia; the South China tiger (*Panthera tigris amoyensis*), formally found in southern China; the Sumatran tiger (*Panthera tigris sumatrae*), found on Sumatra, the largest island in Indonesia; and the Indochinese tiger (*Panthera tigris corbetti*), found in Cambodia, China, Laos, Malaysia, eastern Myanmar, Thailand, and Vietnam (Seidensticker et al. 1999). The Bengal tiger is the most abundant species representing about half of all wild tigers. The three extinct subspecies are the Caspian tiger (*Panthera tigris virgata*), the Javan tiger (*Panthera tigris sondaica*), and the Bali tiger (*Panthera tigris balica*). These subspecies were found in Afghanistan, Iran, Turkey, and on the Indonesian islands of Java and Bali (Seidensticker et al. 2008). There is current debate over the distinctiveness of tiger subspecies, especially the Malayan subspecies (*Panthera tigris jacksoni*), found in Malaysia (Wentzel et al. 1999, Luo et al. 2004, Seidensticker et al. in press), which some scientists have proposed as a new subspecies (Cracraft et al. 1998, Kitchener 1999, Kitchener and Dugmore 2000, O'Brien et al. 2005). The ranges of these subspecies use to blend together, but are not separated into independent populations (Figure 2).

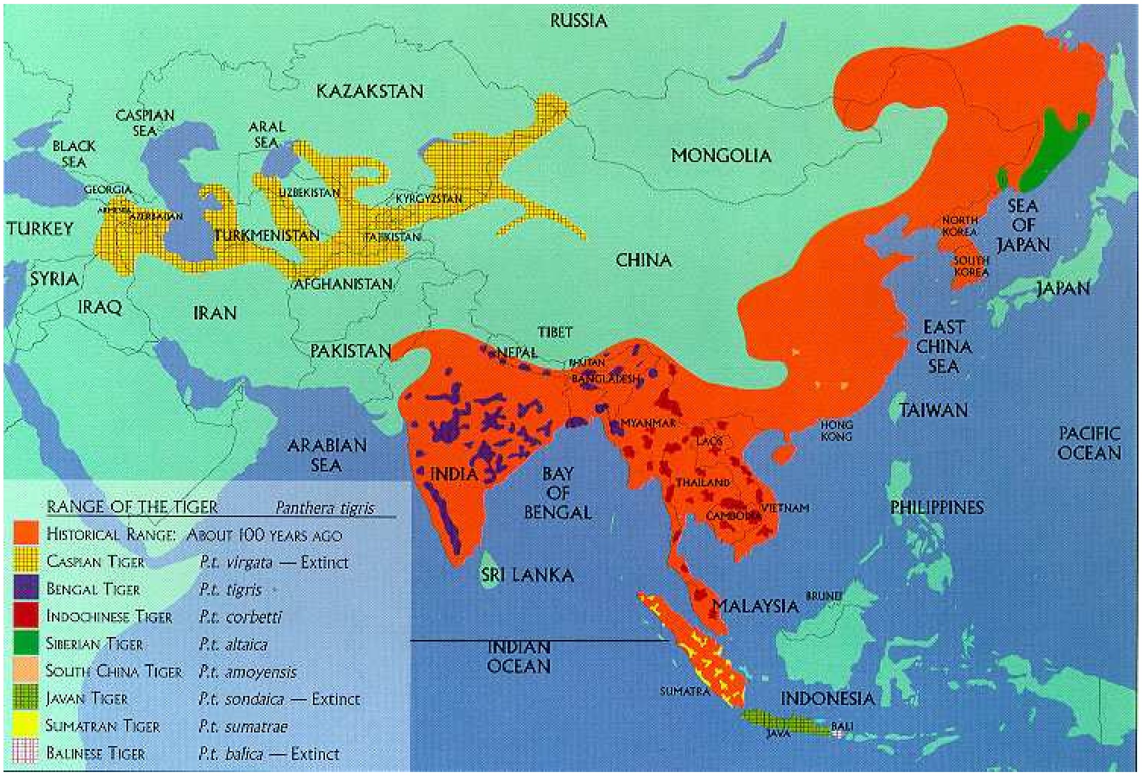


Figure 2. The historic tiger range overlain with the current range of existing subspecies or the former range of extinct subspecies (Environmental Investigation Agency 2009).

*Tiger Biology and Ecology*

Tigers are the largest carnivores in Asia and have some of the greatest habitat and prey requirements within the region (Sunquist et al. 1999). Tiger densities can be as low as 0.6 tigers per 100 km$^2$ or as high as 16 tigers per 100 km$^2$ (Karanth and Nichols 1998, Karanth et al. 2004). Tiger home ranges can be between ten square kilometers and hundreds of square kilometers (Long 2001). Along with this, tigers are found in a wide range of habitats including northern temperate forests, tropical rainforests, mangrove forests, swamps, and tall grass habitats. Tigers can be found in places with a wide range of altitudes, temperatures, and rainfall patterns (Sunquist et al. 1999).

Compared to many large carnivores, tiger populations can increase relatively quickly given favorable conditions. Tigers have a comparatively short gestation period of 103 days and first reproduce at a young age (Sunquist et al. 1999). For instance, the Amur tiger, in the Russian Far East, was able to recover from a small population of about 50 individuals in the 1930s to over 400 individuals in the 1990s (Wentzel et al. 1999).

Availability of prey is a good determinate of the viability of tiger populations (Biswas and Sankar 2002, Bagchi et al. 2003). Tigers require abundant of prey to survive and breed successfully (Sunquist et al. 1999). With reduced prey supply, tigers live at lower densities and more land is required to conserve a viable population. In addition, this increases the opportunity for human-tiger conflict. Additionally, lower prey numbers threaten tigers through lower individual survival, lower reproduction rates, and small populations (Karanth and Stith 1999). Tigers prey mainly on large ungulates. Throughout the tiger's range, diet is made up of muntjac, sambar, gaur, chital, serow, wild pig, langur, wild buffalo, barasingha, and hog deer to varying amounts, depending on prey availability (Karanth and Sunquist 1995, Karanth and Nichols 1998, Biswas and Sankar 2002, Bagchi et al. 2003, Johnson et al. 2006).

Tigers are often most abundant in areas of intermixing forest and grassland as these areas have the highest abundance of ungulate prey. In general, tiger populations increase with increasing prey biomass density (Sunquist et al. 1999). Forest area is necessary for tiger survival, both as a habitat for tigers themselves and as habitat for tiger prey.

*Human Impacts on Tigers*

Tigers are among the most threatened species within Asia (Seidensticker et al. 1999, Linkie et al. 2003, Barlow et al. 2008, IUCN 2008). Deforestation has occurred throughout Asia in the past few centuries, especially since colonization. Habitat is being lost, often due to land conversion to agriculture (Kinnaird et al. 2003). Economic expansion and human encroachment are also leading to habitat fragmentation (Marcoux 2000, Mazard 2007). Factors that are thought to drive deforestation include: expanded farming, high population densities, importation of timber, urban migration, economic development, and high poverty (Marcoux 2000, Kinnaird et al. 2003, Kauppi et al. 2006, Andam et al. 2008). Prey populations are threatened by the same deforestation trends. In addition, prey are poached for meat or trade (Karanth and Stith 1999, Ramakrishnan et al. 1999, Myanmar Forest Department and Wildlife Conservation Society 2003).

Tigers were and continue to be hunted for their fur and for use in local medicine (Kitchener 1999). Tiger pelts are used as decoration and clothing. Tiger teeth, claws, and bone are used in amulets and pendants. Additionally, tiger teeth and bone are used by the Chinese and other cultures for medicinal purposes (Jackson 1999). The exotics trade has occurred for centuries and continues through the present.

Human-tiger conflict has existed since the two species first came in contact. This conflict consists of loss of livestock or other economic goods to tigers. Additionally, human-tiger conflict exists over human injury and deaths caused by tigers (Treves and Karanth 2003). Livestock death is more common than human death. However, human death is quite common with 20-30 humans killed annually by tigers in Bangladesh alone (Lawson 2002, Nyhus and Tilson 2004b). Village poisonings of tigers are an import cause of continued tiger vulnerability (Ahearn et al. 2001).

*Subspecies Extinctions*

In the past century three tiger subspecies have gone extinct. The Bali tiger went extinct in the 1940s (Seidensticker 1987b). The Bali tiger population was likely never more than about 125 individuals when all habitats on the island were available. This island subspecies was pre-disposed to extinction. With Dutch colonization and intense land conversion to plantations, tiger habitat declined markedly and a viable population could not survive (Seidensticker 1987b).

The Caspian tiger is believed to have gone extinct in the 1970s (Sunquist et al. 1999). The two main causes of this extinction were the loss of tiger habitat and the loss of wild boar and deer as tiger prey. The loss of habitat and prey are due to the conversion of natural reed-beds along rivers to agriculture. Additionally, extremely large and deadly hunts for sport were conducted by military leaders against both tigers and prey (Sunquist et al. 1999).

Most recently, the Javan tiger went extinct in the 1980s. A loss of habitat and prey also lead to the extinction of this subspecies (Seidensticker 1987a). Throughout the 1900s, Java's forest was converted to teak plantations. Suitable tiger habitat, and therefore the only surviving tiger population, was only available in one reserve by the 1970s. Along with this drastic decline in habitat, there was a drastic decline in deer and wild boar populations through hunting, loss of habitat, and government eradication efforts (Seidensticker 1987a, Sunquist et al. 1999).

Currently, many tigers live in small, isolated populations (Dinerstein et al. 2006). These small populations are critically endangered due to human threats. Additionally, they are biologically at risk to inbreeding depression and may be less able to adapt to changing conditions, such as climate change, due to a lack of genetic variability (Wentzel et al. 1999). Furthermore, the South China tiger is considered likely extinct in the wild (Tilson et al. 2004). Meanwhile, there are still insufficient or unreliable estimates of tiger population numbers in many countries. The cost in money, time, and people is substantial for monitoring of tigers, especially at low numbers and densities. The current wild tiger population estimate is between 3,600 to 4,600 individuals (Seidensticker et al. in press).

**Tiger Conservation**

Tiger conservation efforts are underway in the 13 countries that tigers still inhabit. India began conservation efforts in the 1970s and many countries have since followed (Jackson 1999). Myanmar, Bhutan, Malaysia, Bangladesh, India, Indonesia, Russia, Thailand, and Nepal have all developed tiger action plans outlining their conservation objectives and programs (Seidensticker et al. in press). Conservation organizations and international agreements are also involved in tiger conservation throughout the tiger's range. Organizations with significant involvement include: the Save the Tiger Fund, World Wildlife Fund, the Global Tiger Forum, the Wildlife Conservation Society, the Zoological Society of London, and various national departments for the environment.

The decline of tiger populations has been studied for decades (Schaller 1967, Tamang 1982, Dinerstein et al. 2006). Many of these studies focus on single causes for declining tiger populations or focus on the biology of the tiger (Ramakrishnan et al. 1999, Ahearn et al. 2001, Bagchi et al. 2003, O'Brien et al. 2003, Karanth et al. 2004, Russello et al. 2004, Tilson et al. 2004, Johnson et al. 2006, Linkie et al. 2006, Sangay and Vernes 2008). Scientists have explored ways to monitor and more accurately estimate tiger population numbers through camera traps (Karanth et al. 1999, Azlan and Sharma 2006, Check 2006). In addition, conservationists have been exploring non-lethal methods to control tigers. This includes re-locating problem tigers to less populated areas and methods to deter tigers from human habitations (Goodrich and Miquelle 2005).

Various proximate causes for tiger deaths have been explored. The loss of habitat has been found to be the largest threat to tiger populations (Dinerstein et al. 2007). Most tiger populations are small and isolated due to habitat loss, habitat degradation, and a lack of corridors between populations (Wentzel et al. 1999). Areas with low human impact, especially legally protected areas, are important to tiger population survival (Carroll and Miquelle 2006).

While biological information is necessary to improve conservation and reintroduction efforts, political and social causes for the tigers decline are just as or more important for improved conservation efforts, but are much less understood. Past studies have tended to be small-scale, studying specific reserves, separate populations, or individual countries. There have only been a limited number of range-wide (the entire area in which tiger populations exist) studies (Mills and Jackson 1994, Dinerstein et al. 1997, Nowell 2000, Dinerstein et al. 2006). Tiger Conservation Units (TCUs) and Tiger Conservation Landscapes (TCLs) are the only range-wide attempt to define and label tiger habitat (Dinerstein et al. 1997, Dinerstein et al. 2006). Additionally, global studies on illegal trade have been conducted (Mills and Jackson 1994, Mulliken and Haywood 1994, Nowell 2000). These large-scale studies on tiger habitat and trade have either described current tiger occurrence or only explored direct threats to tigers. Most small-scale studies also only investigate direct threats to tigers. A better understanding of the ultimate factors behind the direct threats is needed to improve conservation efforts. To my knowledge, no study has yet explored country-level factors, such as a country's wealth, corruption levels, scientific knowledge, and spending for conservation, to explain why some countries are having more success with tiger conservation efforts.

## METHODS

I defined proximate variables as biological factors that directly impact tiger numbers. I defined ultimate variables as factors that impact the direct variables, such as economic incentives behind deforestation. I carried out a literature review of variables hypothesized to impact the ability of the country to successfully implement conservation efforts. In the final analysis, I used six biological variables (Table 1). I used 27 socioeconomic variables in the final analysis (Table 2).

Table 1. The six biological variables used in this analysis related to the various proximate variables identified as having a possible impact on conservation based on literature review.

| **Proximate Factors Identified** | **Variables Used** |
|---|---|
| Deforestation and habitat loss[1] | Forest area |
| Human-carnivore conflict[2] | Protected land area |
| Loss of prey species[3] | Protected land area |
| Low population numbers[4] | TCL land area |
| Natural catastrophes[5] | Human population affected by natural disasters |
| Disease and invasive species[6] | Number of red listed species |
| Poaching[7] | None |
| Other | Land area |

[1] (Forester and Machlis 1996, O'Brien and Kinnaird 2003, Cardillo et al. 2004, Dinerstein et al. 2006, Kauppi et al. 2006, Wilson et al. 2007)
[2] (Nyhus and Tilson 2004a, Dinerstein et al. 2006, Araujo and Rahbek 2007)
[3] (Dinerstein et al. 2006)
[4] (Seidensticker et al. 1999, Harcourt et al. 2001)
[5] (Kinnaird et al. 2003)
[6] (Forester and Machlis 1996, Cardillo et al. 2004, Wilson et al. 2007)
[7] (Dinerstein et al. 2006, Naidoo and Ricketts 2006)

Table 2. The 27 socioeconomic variables used in this analysis related to the various ultimate factors identified, through a literature review, as having a possible impact on conservation.

| **Ultimate Factors Identified** | **Variables Used** |
|---|---|
| Wealth[1] | Gross domestic product (GDP), GDP per capita, GDP index |
| Human population[2] | Population, population density |
| Corruption[3] | Corruption perception |
| Development[4] | Population growth rate, human development index rank, life expectancy |
| Poverty[5] | Unemployment rate, population below poverty level, human poverty index |
| Education[6] | Literacy rate, education expenditures, school life expectancy, education index |
| Fund apportionment[7] | Education expenditures, military spending |
| Agriculture and timber industry actions[8] | Labor force make-up by sector |
| Urban migration[9] | Urbanization, urban population growth rate |
| Energy policy[10] | Energy consumption per capita |
| Economic system[10] | External debt |
| Government type[3] | Political rights, civil liberties, democracy index, press freedom |
| Public perception of species and support for conservation[11] | None |
| Historical human impact[7] | None |
| Cultural history[7] | None |
| Agency training and action[12] | None |
| Inter-program cooperation[13] | None |
| National legislation[14] | None |
| Enforcement efforts[1] | None |
| NGO actions[15] | None |
| Exotics trade[16] | None |

[1] (Kauppi et al. 2006)
[2] (Cardillo et al. 2004, Gaston 2005, Araujo and Rahbek 2007, Andam et al. 2008)
[3] (Kinnaird et al. 2003)
[4] (Araujo and Rahbek 2007, Pejchar et al. 2007)
[5] (Araujo and Rahbek 2007, Andam et al. 2008)
[6] (Kinnaird et al. 2003, Kauppi et al. 2006, Andam et al. 2008)
[7] (Forester and Machlis 1996)
[8] (Kinnaird et al. 2003, O'Brien and Kinnaird 2003, Gaston 2005, Kauppi et al. 2006, Carwardine et al. 2008)
[9] (Kauppi et al. 2006, Andam et al. 2008)
[10] (Forester and Machlis 1996, Kauppi et al. 2006)
[11] (Weber and Rabinowitz 1996, Berger 2006, Naidoo et al. 2006)
[12] (Karanth and Nichols 1998)
[13] (Dinerstein et al. 2006)
[14] (Forester and Machlis 1996, Dinerstein et al. 2006, Kauppi et al. 2006)
[15] (Kinnaird et al. 2003, Dinerstein et al. 2006)
[16] (Weber and Rabinowitz 1996, Dinerstein et al. 2006)

There are no consistent estimates of tiger numbers available for all tiger range states. The dependent variable was therefore difficult to determine. I developed measures of tiger abundance for these analyses. I used the mean of the high and low estimates, based on a literature review, for each country to indicate raw tiger number (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Global Tiger Forum 2008, Seidensticker et al. in press). If recent estimates (from 2008) were available, they were used in this analysis. However, recent estimates were not available for Myanmar, Laos, Thailand, Cambodia, and Vietnam. For these countries, a Geographic Information System (GIS) data layer of Tiger Conservation Landscapes (TCLs) was used to determine the amount of land area in TCLs within each country. Reported tiger density for the Indochinese tiger (4.5 Indochinese tigers per 100 $km^2$) was then used to determine high and low tiger estimates based on the method used by previous estimates (Seidensticker et al. in press). In addition, there were no estimates available for North Korea. Tigers are believed to be present, but at very low numbers, between zero and nine tigers (Seidensticker et al. in press). Consequently, North Korea was excluded from the analysis. Tiger population estimates alone are not good indicators of tiger range state success in conserving tigers because the use of raw tiger numbers is skewed toward larger countries and countries with a larger amount of tiger range.

I normalized the estimates of tiger population size by calculating the number of tigers per 100 $km^2$ of TCL land area and number of tigers per 10,000 humans. TCLs are habitat areas of global importance for tiger conservation and are the landscapes believed to be the best chance of preserving viable tiger populations (Dinerstein et al. 2006). The number of tigers per 100 $km^2$ of TCL area provides an estimate of tiger density within available tiger habitat. Countries with larger land areas become less skewed towards success as occurred with raw tiger numbers. This proxy, however, penalizes states with colder climates and lower natural prey densities, such as Russia. The number of tigers per 10,000 people also reduces the large-state bias found with raw tiger numbers. However, this proxy penalizes states that do not have tiger habitat across their entire land area, but have human populations dispersed throughout the country. This is especially true for countries like Russia and China, which have large population centers located outside of tiger habitat.

I also calculated the change in tiger population size over time, estimated as either decreasing, stable, or increasing. The time period used was early 1990s to 2008. Estimates of tiger population from the early 1990s were identified through a literature review (Seidensticker et al. 1999, Nowell 2000, Long 2001, Global Tiger Forum 2008). Tiger estimates for 2008 were those used in the raw tiger number analysis. Data on tiger populations in the early 1990s were not available for Laos, Myanmar, and China. Through a literature review, I determined that these populations likely had decreasing trends (Mills and Jackson 1994, State Forestry Administration 1998, Nowell 2000, Myanmar Forest Department and Wildlife Conservation Society 2003). This measure is more likely to reveal the relative success or failure of countries to conserve tigers, but is difficult to determine correctly given the historical and current issues with determining accurate estimates of tiger population numbers.

A proxy for tiger populations was also used in my analyses. The proxy variable was the land area within TCLs. This proxy accounts only for area that tigers do or could inhabit. The quantification of land area in TCLs was conducted through GIS analysis. The TCL data layer was projected with an Asia South Albers Equal Area Conic for those countries below 12° N (Malaysia and Indonesia) (Wildlife Conservation Society et al. 2006). For all other countries, an Asia North Albers Equal Area Conic projection was used, which had a range between 15°-62° N.

For all variables, country level data were the unit of analysis. While this may skew the results for countries that do not have tigers or tiger range throughout their entire area, especially Russia, China, and Indonesia, the data are consistent throughout the data set. In addition, many of the independent variables, including GDP, democracy measures, and government spending, are not readily available at province levels or lower.

All statistical analyses were carried out using SPSS 16.0. Correlation analysis was conducted between the dependent and independent variables. Variables were first tested for normality through the skewness-kurtosis test. If variables were normally distributed, Pearson’s bivariate correlation test was used. If variables were non-parametric, Spearman’s bivariate correlation test was used or they were log transformed.

Transformed variables that became normally distributed were also tested using Pearson's bivariate correlation test.

Variables that were significantly correlated were then explored further through regression analysis. The linear regression analysis assumes normality of the data, so all non-parametric data were transformed by log base ten to achieve normality. Simple linear regression analysis was conducted on all normalized and significantly correlated variables. Multiple regression analyses were conducted to determine possible relationships between several independent variables and the dependent variable. Models were identified through a backwards regression model as well as through rearrangement of significant variables. For binomial data, such as stable or decreasing tiger populations, logistic regression analyses were conducted.

Correlation and simple regression analyses were also conducted between the various independent variables. If variables were highly auto-correlated ($r>0.9$), one variable was removed from the multiple regression analysis in which both occurred. Independent variable correlation allowed for one variable to be discussed as a proxy for the many variables related to it.

Given the difficulties in determining accurate tiger numbers or trends, successful tiger conservation was problematic to define. Consequently, three different definitions of success were used in my analyses. The first approach defines successful tiger conservation as a large number of tigers. A large number of tigers was defined as greater than 250 tigers within a country because a viable independent population requires at least 100 tigers (Dinerstein et al. 2006). Most nations contain more than one separate tiger population, so more than 100 would be required for viable tiger populations throughout the country (Dinerstein et al. 2006). Therefore, 250 is a reasonable indication of a high number of tigers and a high likelihood that at least one independent population is large enough to be viable. This threshold also defined the top 25% countries as successful. This immediately favors countries that contain larger tracts of tiger habitat and a large number of tigers, such as India. However, the number of tigers as a measure of success does recognize the biological importance of larger population sizes for genetic diversity and population stability.

Success in the second approach was defined as the overall trend in tiger populations. Populations were defined as either decreasing, stable, or increasing over time. The time period used was from the early 1990s to 2008. Estimation methods between the two time periods may have changed, such as in India (Seidensticker et al. 1999, Nowell 2000, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Check 2006, Wildlife Conservation Society et al. 2006, Global Tiger Forum 2008, Seidensticker et al. in press).

Success in the third approach was defined as a large amount of land area within TCLs. I defined a large amount of land area as greater than 100,000 $km^2$ within TCLs. A viable population of tigers requires at least 100 individuals (Dinerstein et al. 2006). At the tiger's lowest population density, less than one tiger is found per 100 $km^2$. A long-term tiger population could therefore be supported within 100,000 $km^2$. However, at higher tiger densities (>1 tiger per 100 $km^2$) a viable population would be possible.

Variables were then explored through the three different definitions of success to determine which factors were associated with conservation. Significant factors were studied further. They were also studied with regards to the countries identified as successful.

## RESULTS

I found that seven countries were considered successful under at least one definition of success. In addition, I found that 2 biological and 12 socioeconomic factors were significantly associated with successful tiger conservation. I first discuss the correlations among the various biological and socioeconomic variables. I then discuss the variables associated with each definition of success, first tiger abundance, then tiger population trend, and, lastly, land area within TCLs.

### Correlation among Independent Variables

I used simple linear regressions to analyze the relationship between the 6 biological and 27 socioeconomic factors used in this study. Various measures of government type and democracy (press freedom rank, civil liberties score, political rights score, and democracy index) were all significantly associated with each other. The education measures of school life expectancy, literacy rate, and education index were all correlated. In addition, high education levels were associated with higher per capita GDP, greater military spending, lower population growth rate and a lower measure of human poverty. Higher GDP per capita was also associated with lower measures of education (Table 3). Education measures and various measures of poverty were significantly associated overall.

Table 3. Significant results of simple linear regression models testing the relationship among 13 socioeconomic variables with each other (Baillie et al. 2005, UNDP 2007, Freedom House 2008, UNESCAP 2008, World Audit 2008, CIA 2009).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| Experimental Variable | | | | | |
| Democracy Index | | | | | |
| Other Variables | | | | | |
| Press Freedom Rank | 0.504 | 13.214 | -0.047 | -0.739 | 0.004** |
| Civil Liberties Score | 0.710 | 30.363 | -1.379 | -0.857 | 0.000** |
| Political Rights Score | 0.647 | 23.012 | -0.890 | -0.823 | 0.001** |
| | | | | | |
| Experimental Variable | | | | | |
| Military Spending | | | | | |
| Other Variables | | | | | |
| Population Growth Rate | 0.453 | 10.924 | -0.992 | -0.706 | 0.007** |
| External Debt | 0.632 | 21.638 | 0.007 | 0.814 | 0.001** |
| Literacy | 0.395 | 8.836 | 0.036 | 0.667 | 0.013* |
| Education Index | 0.362 | 7.809 | 4.546 | 0.664 | 0.017* |
| | | | | | |
| Experimental Variable | | | | | |
| School Life Expectancy | | | | | |
| Other Variables | | | | | |
| Literacy Rate | 0.333 | 6.998 | 0.063 | 0.624 | 0.023* |
| Education Index | 0.437 | 10.320 | 9.192 | 0.696 | 0.008** |
| GDP Per Capita | 0.789 | 45.881 | 4.899 | 0.898 | 0.000** |
| Human Poverty Index | 0.316 | 5.622 | -0.044 | -0.620 | 0.042* |
| | | | | | |
| Experimental Variable | | | | | |
| Literacy Rate | | | | | |
| Other Variables | | | | | |
| Education Index | 0.826 | 57.946 | 119.278 | 0.917 | 0.000** |
| GDP Per Capita | 0.302 | 6.183 | 32.219 | 0.600 | 0.030* |
| Human Poverty Index | 0.348 | 6.334 | -0.473 | -0.643 | 0.033* |
| | | | | | |
| Experimental Variable | | | | | |
| Population Growth Rate | | | | | |
| Other Variables | | | | | |
| Literacy | 0.441 | 10.474 | -0.027 | -0.698 | 0.008** |
| School Life Expectancy | 0.309 | 6.363 | -0.230 | -0.605 | 0.028* |
| Education Index | 0.371 | 8.090 | -3.268 | -0.651 | 0.016* |
| GDP Per Capita | 0.342 | 7.226 | -1.305 | -0.630 | 0.021* |

*p<0.05, **p<0.01

### Tiger Abundance

Successful tiger conservation was defined as a high total number of tigers in this approach. The top 25% of countries or, if a clear threshold was present, those countries above the threshold were defined as successful. Four countries (India, Malaysia, Thailand, and Russia) had more than 250 tigers (Figure 3). Countries with the highest tiger density (>0.5 tigers/100 km$^2$) were Bangladesh, Nepal, Malaysia, and India (Figure 4). Countries with the greatest number of tigers per person were Bhutan and Laos, with all other countries having tiger densities at least an order of magnitude lower (Figure 5).

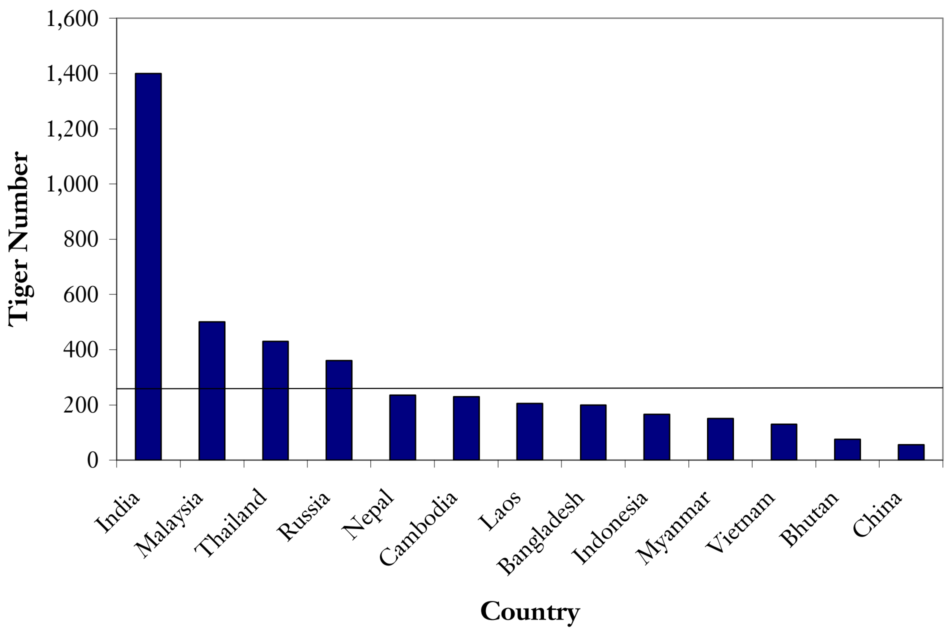


Figure 3. Estimated number of tigers within each tiger range state. Line shows 250 cut-off for defining success (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Global Tiger Forum 2008, Seidensticker et al. in press).

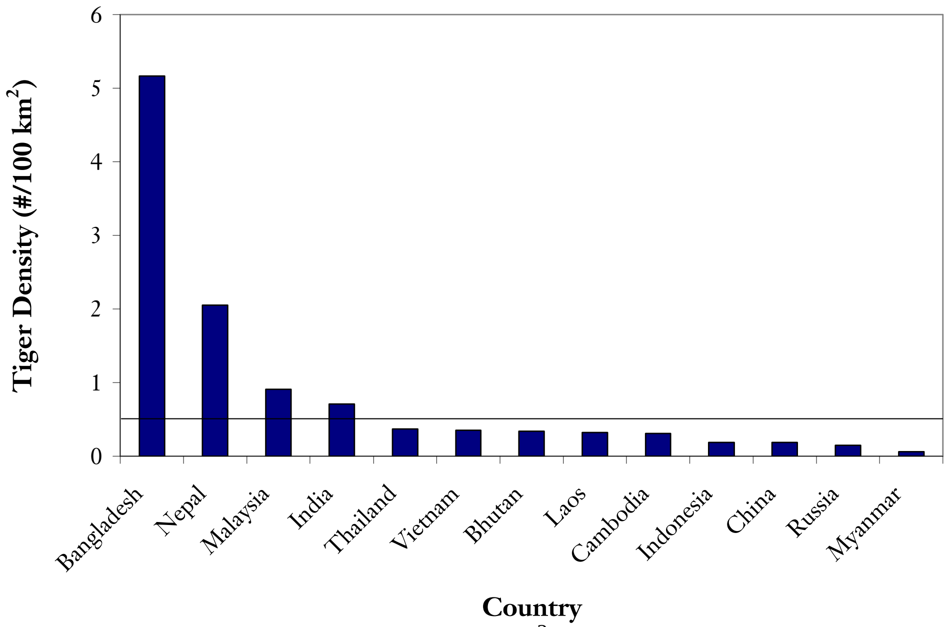


Figure 4. Tiger density (tigers per 100 km$^2$) for each tiger range state. Line represents 0.5 tigers/100 km$^2$ cut-off for success definition (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Global Tiger Forum 2008, CIA 2009, Seidensticker et al. in press).

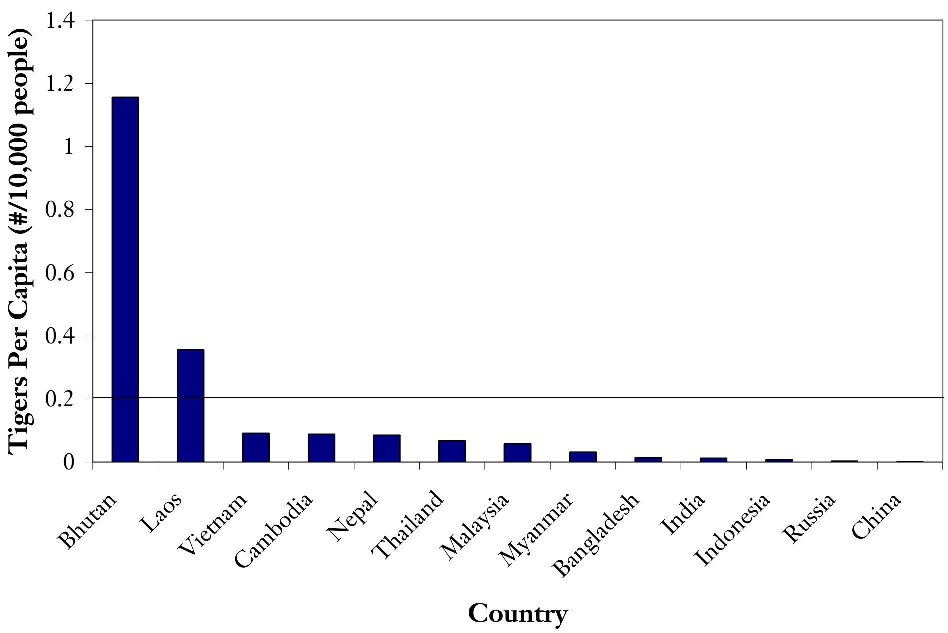


Figure 5. Number of tigers per 10,000 people for each tiger range state. Line represents threshold for defining success (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Global Tiger Forum 2008, UNESCAP 2008, Seidensticker et al. in press).

Four variables were significantly related to tiger abundance. Tiger populations were significantly larger in countries that were more democratic, had freer political rights, had freer civil liberties, and had greater press freedom (Figure 6). Of these, the level of democracy of a country had the greatest relationship to tiger numbers, accounting for 46.8% of the variance in tiger abundance (Table 4). However, all four variables were significantly correlated with each other (Table 3).

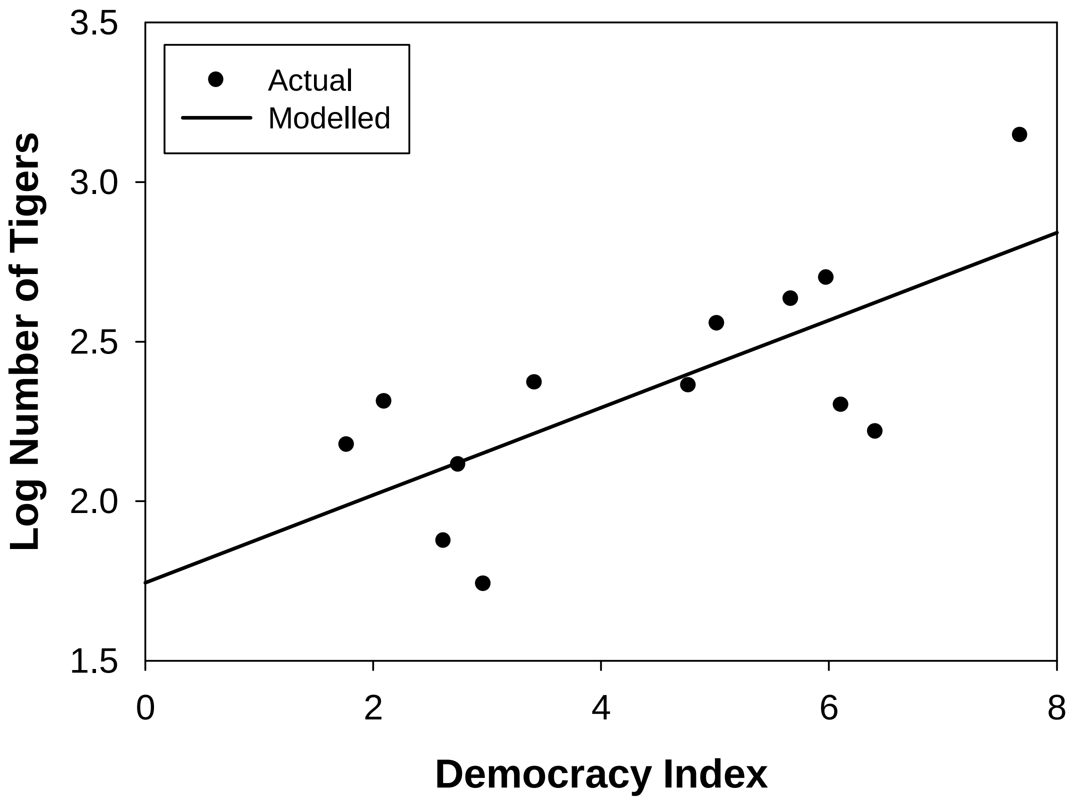


Figure 6. Scatter plot and linear regression model of the association between democracy index and log number of tigers. Equation: y=1.745+0.13x. Adjusted $R^2$=0.468.

Table 4. Statistically significant results of a simple linear regression for the log number of tigers and the biological and socioeconomic variables explored (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Freedom House 2008, Global Tiger Forum 2008, World Audit 2008, Seidensticker et al. in press).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| Democracy Index | 0.468 | 11.547 | 0.137 | 0.716 | 0.006** |
| Political Rights Score | 0.271 | 5.452 | -0.119 | -0.576 | 0.040* |
| Civil Liberties Score | 0.265 | 5.318 | -0.175 | -0.571 | 0.042* |
| Press Freedom Rank | 0.301 | 6.175 | -0.007 | -0.600 | 0.030* |

*p<0.05, **p<0.01

Four multiple regression models were found to have significant (p<0.05) or near significant (p<0.1) impacts on the number of tigers. Within the two significant models, no variable had a significant impact on the model, although democracy index had a near significant impact (Table 5).

Table 5. Results of multiple regression models for the log number of tigers (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Freedom House 2008, Global Tiger Forum 2008, World Audit 2008, Seidensticker et al. in press). Note: The dependent variable is the estimate number of tigers. N=13.

| **Variable** | **Standardized Coefficient** | **T-Value** | **Probability** |
|---|---|---|---|
| Independent Variables | | | |
| Civil Liberties Score | 0.493 | 0.882 | 0.401 |
| Press Freedom Rank | -0.398 | -0.932 | 0.376 |
| Democracy Index | 0.844 | 1.970 | 0.080 |
| Adjusted $R^2$ = 0.415 | | | |
| Model Significance = 0.051 | | | |
| | | | |
| Independent Variables | | | |
| Press Freedom Rank | -0.156 | -0.482 | 0.640 |
| Democracy Index | 0.600 | 1.853 | 0.094 |
| Adjusted $R^2$ = 0.428 | | | |
| Model Significance = 0.025* | | | |
| | | | |
| Independent Variables | | | |
| Civil Liberties Score | 0.852 | 0.374 | 0.717 |
| Democracy Index | 0.159 | 2.002 | 0.073 |
| Adjusted $R^2$ = 0.423 | | | |
| Model Significance = 0.026* | | | |
| | | | |
| Independent Variables | | | |
| Political Rights Score | -0.262 | -0.648 | 0.531 |
| Press Freedom Rank | -0.386 | -0.937 | 0.371 |
| Adjusted $R^2$ = 0.262 | | | |
| Model Significance = 0.088 | | | |

*p<0.05, **p<0.01

Tiger density based on tiger habitat area was significantly associated with six independent variables. Tiger density increased in countries with more civil liberties, a higher population growth rate, and a greater population density. In countries with more forest area, high literacy rates, and more education tiger density tended to be lower (Table 6).

Table 6. Statistically significant results of a simple regression for the log number of tigers per 100 $km^2$ Tiger Conservation Landscape area (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, UNDP 2007, Freedom House 2008, Global Tiger Forum 2008, UNESCAP 2008, CIA 2009, Seidensticker et al. in press).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| Forest Area | 0.247 | 4.942 | -0.014 | -0.557 | 0.048* |
| Human Population Growth Rate | 0.342 | 7.247 | 0.412 | 0.630 | 0.021* |
| Literacy Rate | 0.450 | 10.811 | -0.018 | 0.704 | 0.007** |
| Education Index | 0.342 | 7.249 | -2.067 | 0.630 | 0.021* |
| Civil Liberties Score | 0.253 | 5.068 | -0.239 | 0.562 | 0.046* |
| Log Population Density | 0.343 | 7.279 | 0.648 | 0.631 | 0.021* |

*p<0.05, **p<0.01

Four multiple regression models significantly impacted tiger density. Literacy rate made a statistically significant contribution to three of the four models and an almost significant contribution in the fourth. Human population density made a significant contribution to all four models (Table 7). The model containing only literacy rate and human population density as independent variables was significant (y = -0.340 + 0.558 (pop den) - 0.016 (literacy)) and accounted for 74.3% of the variation in the number of tigers per 100 $km^2$.

Table 7. Results of multiple regression models for the log number of tigers per 100 km$^2$ Tiger Conservation Landscape area (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, UNDP 2007, Freedom House 2008, Global Tiger Forum 2008, UNESCAP 2008, CIA 2009, Seidensticker et al. in press). Note: The dependent variable is the number of tigers per 100 km$^2$ of TCL area. N=13.

| **Variable** | **Standardized Coefficient** | **T-Value** | **Probability** |
|---|---|---|---|
| Independent Variables | | | |
| Human Population Growth Rate | 0.195 | 0.948 | 0.371 |
| Literacy Rate | -0.465 | 2.530 | 0.055 |
| Civil Liberties Score | -0.176 | -0.994 | 0.344 |
| Log Population Density | 0.440 | 2.530 | 0.035* |
| Adjusted $R^2$ = 0.741 | | | |
| Model Significance = 0.004** | | | |
| | | | |
| Independent Variables | | | |
| Log Human Population Density | 0.452 | 2.616 | 0.028* |
| Literacy Rate | -0.599 | -3.984 | 0.003** |
| Civil Liberties Score | -0.180 | -1.024 | 0.333 |
| Adjusted $R^2$ = 0.744 | | | |
| Model Significance = 0.001** | | | |
| | | | |
| Independent Variables | | | |
| Literacy Rate | -0.628 | -4.249 | 0.002** |
| Log Human Population Density | 0.544 | 1.024 | 0.004** |
| Adjusted $R^2$ = 0.743 | | | |
| Model Significance = 0.004** | | | |
| | | | |
| Independent Variables | | | |
| Population Growth Rate | 0.200 | 0.973 | 0.356 |
| Literacy Rate | -0.490 | -2.388 | 0.041* |
| Log Human Population Density | 0.530 | 3.557 | 0.006** |
| Adjusted $R^2$ = 0.741 | | | |
| Model Significance = 0.001** | | | |

*p<0.05, **p<0.01

Bangladesh and Nepal were removed from the analysis of the number of tigers per 100 km$^2$ because they were probable outliers. They had considerably high tiger densities than all other countries. Furthermore, they had some of the lowest indicators for literacy, education, and forest area. In addition, they had exceptionally high indicators for population density and population growth rate. With these two countries removed, only civil liberties was still significantly associated with tiger density (Simple

Regression, adjusted $R^2$=0.326, F-ratio=5.838, B=-0.162, standardized coefficient=-0.627, p=0.039). The equation for this relationship was: y = 0.232 – 0.162 (civil lib).

The per capita number of tigers was significantly impacted by five independent variables. In general, tiger number increased as forest area increased, urbanization decreased, military spending decreased, external debt decreased, and the number of threatened species in a country decreased. Military spending and external debt had the largest impact on per capita tiger numbers (Table 8).

Table 8. Statistically significant results of a simple regression for the log number of tigers per 10,000 people (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Baillie et al. 2005, Dinerstein et al. 2006, UNDP 2007, Global Tiger Forum 2008, UNESCAP 2008, CIA 2009, Seidensticker et al. in press).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| Forest Area | 0.268 | 5.401 | 0.026 | 0.574 | 0.040* |
| Urbanization | 0.270 | 5.442 | -0.027 | -0.575 | 0.040* |
| Military Spending | 0.681 | 26.632 | -0.703 | -0.841 | 0.000** |
| External Debt | 0.672 | 25.579 | -0.006 | -0.836 | 0.000** |
| Number of IUCN Listed Species | 0.394 | 8.789 | -0.007 | -0.666 | 0.013* |

*p<0.05, **p<0.01

Per capita tiger number was significantly modeled in five ways. Forest area, military spending, and external debt are the only variables that made significant or near significant contributions to the models (Table 9). The equation for a model containing only these three variables was: y = -1.126 + 0.017 (forest) – 0.358 (mil spend) – 0.003 (ext debt).

Table 9. Results of multiple regression models for the log number of tigers per 10,000 people (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Baillie et al. 2005, Dinerstein et al. 2006, Global Tiger Forum 2008, UNESCAP 2008, CIA 2009, Seidensticker et al. in press). Note: The dependent variable is the number of tigers per 10,000 people. N=13.

| **Variable** | **Standardized Coefficient** | **T-Value** | **Probability** |
|---|---|---|---|
| Independent Variables | | | |
| Forest Area | 0.346 | 3.135 | 0.014* |
| Military Spending | -0.346 | -1.738 | 0.120 |
| External Debt | -0.400 | -2.225 | 0.057 |
| Number of IUCN Listed Species | -0.133 | -0.968 | 0.361 |
| Adjusted $R^2$ = 0.870 | | | |
| Model Significance = 0.000** | | | |
| | | | |
| Independent Variables | | | |
| Forest Area | 0.370 | 3.446 | 0.007** |
| Military Spending | -0.429 | -2.394 | 0.040* |
| External Debt | -0.395 | -2.202 | 0.055 |
| Adjusted $R^2$ = 0.871 | | | |
| Model Significance = 0.000** | | | |
| | | | |
| Independent Variables | | | |
| Forest Area | 0.347 | 2.936 | 0.022* |
| Urbanization | -0.016 | -0.105 | 0.919 |
| Military Spending | -0.337 | -1.462 | 0.187 |
| External Debt | -0.398 | -2.059 | 0.079 |
| Number of IUCN Listed Species | -0.134 | -0.908 | 0.394 |
| Adjusted $R^2$ = 0.852 | | | |
| Model Significance = 0.001** | | | |
| | | | |
| Independent Variables | | | |
| Forest Area | 0.391 | 3.104 | 0.011* |
| Military Spending | -0.745 | -5.920 | 0.000** |
| Adjusted $R^2$ = 0.821 | | | |
| Model Significance = 0.000** | | | |
| | | | |
| Independent Variables | | | |
| External Debt | -0.449 | -1.739 | 0.113 |
| Military Spending | -0.476 | -1.844 | 0.095 |
| Adjusted $R^2$ = 0.731 | | | |
| Model Significance = 0.001** | | | |

*p<0.05, **p<0.01

### Tiger Population Trend

In this approach, success was defined as having a stable or increasing tiger population. Countries with stable or increasing tiger populations were Russia, Nepal, Thailand, and Cambodia (Figure 7).

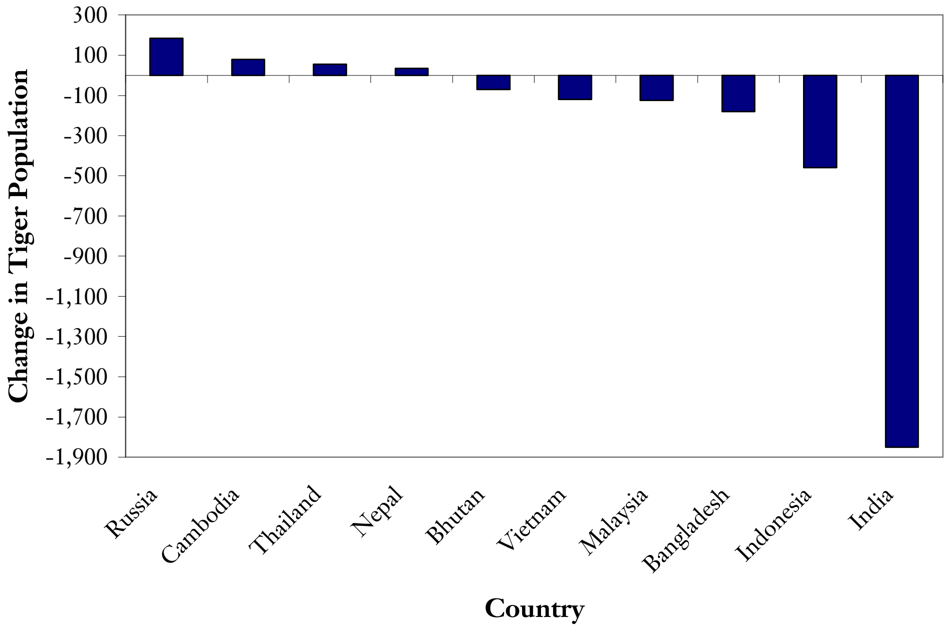


Figure 7. Change in tiger population between the early 1990s and 2008 for tiger range states, excluding China, Laos, and Myanmar (Seidensticker et al. 1999, Long 2001, Myanmar Forest Department and Wildlife Conservation Society 2003, Dinerstein et al. 2006, Global Tiger Forum 2008, Seidensticker et al. in press).

I used a logistic regression to test the binary variables “stable” (1) and “decreasing” (0) with the biological and socioeconomic factors. Countries were more likely to have stable tiger populations when school life expectancy was higher. School life expectancy had a significant impact on the tiger population trend and could account for 40.3% of the variance in tiger population trends (Table 10).

Table 10. Results of logistic regressions for a stable (1) or decreasing (0) tiger trend associated with the biological and socioeconomic variables. The Walds $X^2$ statistic assesses if the B coefficient is significantly different from zero (Wildlife Conservation Society et al. 2006, UNESCAP 2008, CIA 2009, Seidensticker et al. in press). Note: The dependent variable is the trend in tiger populations from the early 1990s to 2008. N=13.

| **Predictor** | **B** | **SE(B)** | **Walds $X^2$** | **df** | **Exp(B)** | **p** |
|---|---|---|---|---|---|---|
| Constant | -11.704 | 5.834 | 4.025 | 1 | 0.000 | 0.045* |
| School Life Expectancy | 0.997 | 0.525 | 3.600 | 1 | 2.709 | 0.058 |
| **Goodness-of-fit-test** | | | **$X^2$** | **df** | | **p** |
| Hosmer and Lemeshow | | | 8.932 | 4 | | 0.063 |
| $R^2$ = 0.403 | | | | | | |
| | | | | | | |
| Constant | -2.468 | 1.233 | 4.008 | 1 | 0.085 | 0.450 |
| Per Capita Energy Consumption | 0.002 | 0.001 | 2.599 | 1 | 1.002 | 0.107 |
| **Goodness-of-fit-test** | | | **$X^2$** | **df** | | **p** |
| Hosmer and Lemeshow | | | 6.378 | 8 | | 0.605 |
| $R^2$ = 0.2714 | | | | | | |

*p<0.05, **p<0.01

I further categorized tiger population trend as increasing, stable, or decreasing. Of the four countries previously defined as having stable tiger populations, Russia and Nepal were redefined as having increasing tiger populations (Wildlife Conservation Society et al. 2006, Seidensticker et al. in press). Independently, three variables had significant impacts on tiger population stability. Countries were more likely to have stable or increasing tiger populations if children had a longer school life expectancy and if there were fewer endemic and endangered species within the country (Table 11).

Table 11. Statistically significant results of a simple regression for the increasing, stable, or decreasing trend in tiger populations (Baillie et al. 2005, Wildlife Conservation Society et al. 2006, UNESCAP 2008, CIA 2009, Seidensticker et al. in press).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| School Life Expectancy | 0.340 | 7.176 | 0.677 | 0.628 | 0.021* |
| Per Capita Energy Consumption | 0.283 | 5.727 | 0.002 | 0.585 | 0.036* |
| Log Number of IUCN Listed Endemic Species | 0.372 | 5.730 | -2.203 | -0.671 | 0.048* |

*p<0.05, **p<0.01

There were two significant models of tiger population trends. The number of endemic threatened species had a significant impact in both. In one of the models, both the number of endemic threatened species and school life expectancy significantly contributed to a stable or increasing tiger trend (Table 12). The equation for this model was: y = -0.856 + 0.605 (school life) – 2.158 (IUCN).

Table 12. Results of multiple regression models for the increasing, stable, or decreasing trend in tiger numbers (Baillie et al. 2005, Wildlife Conservation Society et al. 2006, UNESCAP 2008, CIA 2009, Seidensticker et al. in press). Note: The dependent variable is trend in tiger populations. N=13.

| **Variable** | **Standardized Coefficient** | **T-Value** | **Probability** |
|---|---|---|---|
| Independent Variables | | | |
| School Life Expectancy | 0.507 | 1.371 | 0.229 |
| Per Capita Energy Consumption | 0.046 | 0.118 | 0.911 |
| Log Number of IUCN Listed Endemic Species | -0.658 | -2.471 | 0.056 |
| Adjusted $R^2$ = 0.590 | | | |
| Model Significance = 0.061 | | | |
| Independent Variables | | | |
| School Life Expectancy | 0.542 | 2.618 | 0.040* |
| Log Number of IUCN Listed Endemic Species | -0.657 | -3.176 | 0.019* |
| Adjusted $R^2$ = 0.658 | | | |
| Model Significance = 0.017* | | | |
| Independent Variables | | | |
| School Life Expectancy | 0.429 | 1.283 | 0.229 |
| Per Capita Energy Consumption | 0.283 | 0.840 | 0.417 |
| Adjusted $R^2$ = 0.322 | | | |
| Model Significance = 0.057 | | | |
| Independent Variables | | | |
| Per Capita Energy Consumption | 0.473 | 1.835 | 0.116 |
| Log Number of IUCN Listed Endemic Species | -0.509 | -1.972 | 0.096 |
| Adjusted $R^2$ = 0.530 | | | |
| Model Significance = 0.044* | | | |

*p<0.05, **p<0.01

### Land Area within Tiger Conservation Landscapes

Success was defined as having a large amount of land area in TCLs. Countries with TCL area greater than 100,000 km$^2$ were Myanmar, Russia, India, and Thailand (Figure 8). The number of tigers was not significantly correlated with the total land area of TCLs (Pearson's r=0.190, p=0.535, n=13).

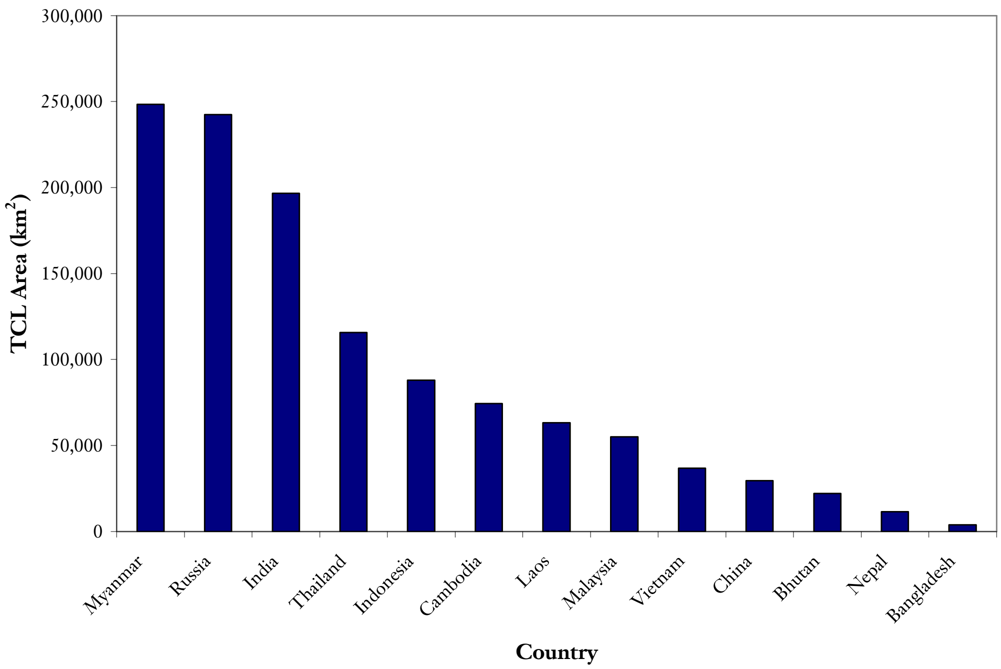


Figure 8. Land Area within Tiger Conservation Landscapes for each tiger range state (Dinerstein et al. 2006, Wildlife Conservation Society et al. 2006).

Three independent variables had a significant impact on the amount of TCL land area within each country. TCL area is greater in countries with more education, higher literacy, and a lower population growth rate (Figure 9). In addition, three variables had almost significant impacts on the area within TCLs. TCL area tended to be higher in countries with lower populations below poverty and lower urban population growth rates. Countries with more TCLs were also more likely to have slightly more threatened species (Table 13).

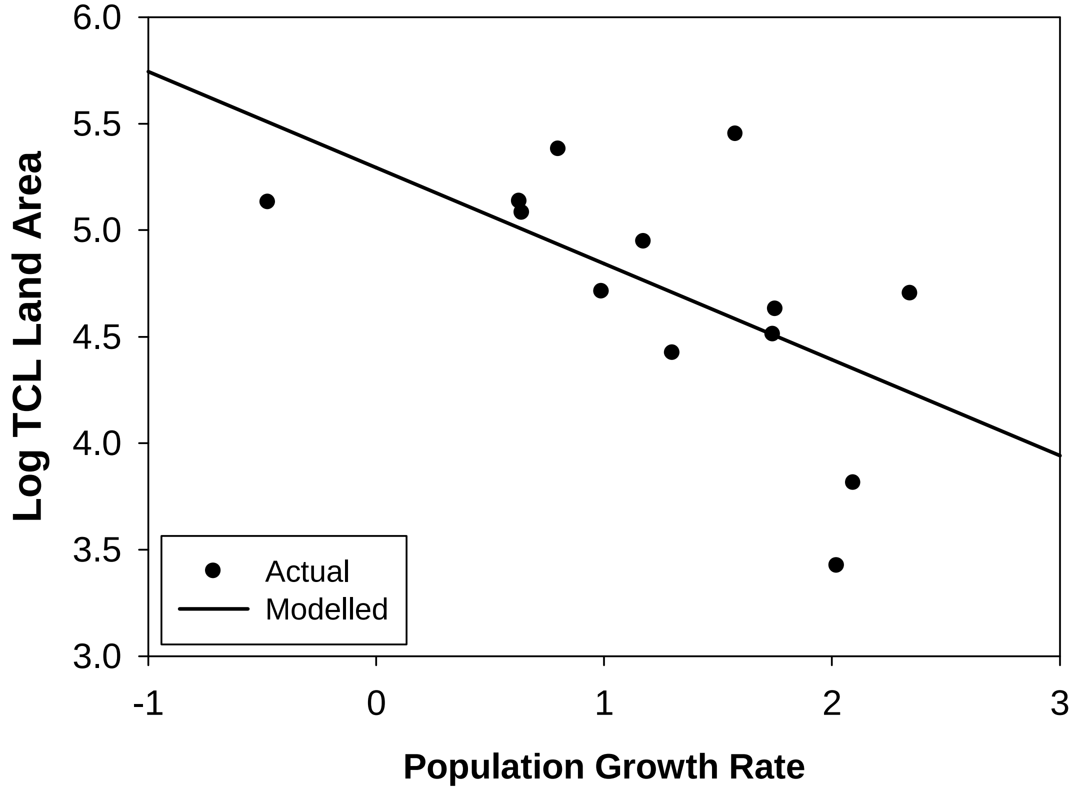


Figure 9. Scatter plot and linear regression model of the association between human population growth rate and log Tiger Conservation Landscape land area. Equation: $y = 5.294-0.45x$. Adjusted $R^2=0.291$.

Table 13. Statistically significant results of a simple regression for the area within Tiger Conservation Landscapes (Baillie et al. 2005, Dinerstein et al. 2006, Wildlife Conservation Society et al. 2006, UNDP 2007, UNESCAP 2008, CIA 2009).

| **Variable** | **Adjusted $R^2$** | **F-ratio** | **B** | **Standardized Coefficient** | **Probability** |
|---|---|---|---|---|---|
| Population Growth Rate | 0.291 | 5.922 | -0.451 | -0.592 | 0.033* |
| Literacy Rate | 0.429 | 10.022 | 0.020 | 0.690 | 0.009** |
| Education Index | 0.341 | 7.222 | 2.412 | 0.630 | 0.021* |
| Population Below Poverty | 0.174 | 3.530 | -0.024 | -0.493 | 0.087 |
| Urban Population Growth Rate | 0.222 | 4.422 | -0.207 | -0.535 | 0.059 |
| Number of IUCN Listed Species | 0.160 | 3.289 | 0.003 | 0.480 | 0.097 |

*p<0.05, **p<0.01

There were two significant models of TCL area. Only literacy rate significantly impacted the model (Table 14). The relationship between literacy rate and TCL land area was positive (Figure 10).

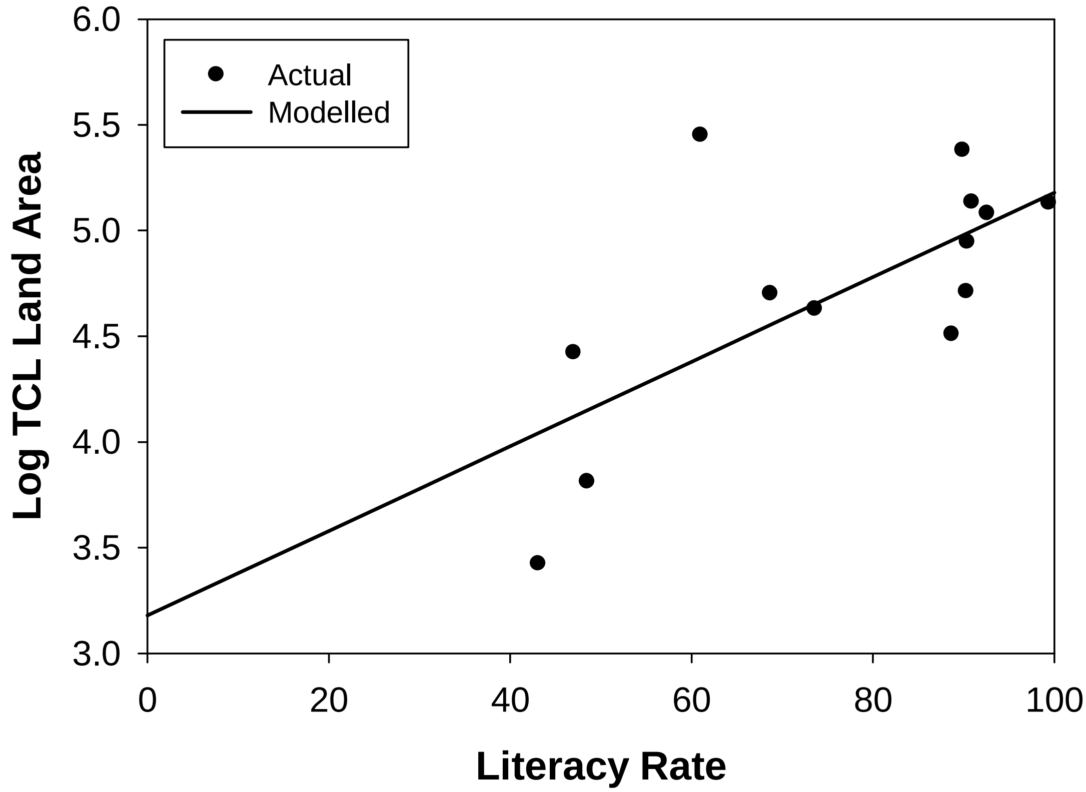


Figure 10. Scatter plot and linear regression model of the association between literacy rate and log Tiger Conservation Landscape land area. Equation: $y = 3.179 + 0.020x$. Adjusted $R^2$=0.429.

Table 14. Results of multiple regression models for the area within Tiger Conservation Landscapes (Baillie et al. 2005, Dinerstein et al. 2006, Wildlife Conservation Society et al. 2006, UNESCAP 2008, CIA 2009). Note: The dependent variable is the land area in Tiger Conservation Landscapes. N=13.

| Variable | Standardized Coefficient | T-Value | Probability |
|---|---|---|---|
| Independent Variables | | | |
| Population Growth Rate | -0.255 | -0.822 | 0.432 |
| Literacy Rate | 0.407 | 1.234 | 0.249 |
| Number of IUCN Listed Species | 0.274 | 1.139 | 0.284 |
| Adjusted $R^2$ = 0.417 | | | |
| Model Significance = 0.050 | | | |
| | | | |
| Independent Variables | | | |
| Population Growth Rate | -0.213 | -0.683 | 0.510 |
| Literacy Rate | 0.541 | 1.733 | 0.114 |
| Adjusted $R^2$ = 0.400 | | | |
| Model Significance = 0.031* | | | |
| | | | |
| Independent Variables | | | |
| Literacy Rate | 0.594 | 2.527 | 0.030* |
| Number of IUCN Listed Species | 0.251 | 1.067 | 0.311 |
| Adjusted $R^2$ = 0.436 | | | |
| Model Significance = 0.023* | | | |

*p<0.05, **p<0.01

As Class I TCLs are the best tiger habitat, the amount of area within just Class I TCLs was also used as a measure of success. Class I TCLs are habitat area that could support 100 or more tigers, contain evidence of breeding tiger populations, have lower levels of threats to tigers, and have some conservation efforts in place (Dinerstein et al. 2006). The four countries with the most Class I TCL area included three of the four countries with the most total TCL area (Russia, India, and Thailand) and also included Myanmar. Class I TCL area was not normally distributed, so a non-parametric correlation analysis was conducted. Amount of Class I TCLs in each country was significantly correlated with country land area (Spearman's r=0.736, p=0.004, n=13), urbanization (Spearman's r=0.615, p=0.025, n=13), urban population growth rate (Spearman's r=-0.651, p=0.016, n=13), education index (Spearman's r=0.577, p=0.039, n=13), and human poverty index rank (Spearman's r=-0.691, p=0.019, n=11).

### All Definitions of Success

There were 14 variables that were significantly associated with one or more definition of success (Table 15). Only two of these variables, forest area and number of red listed species, were biological factors. Most of the socioeconomic variables were measures of education, democracy, or human development.

Table 15. Statistically significant variables associated with the three definitions of success. The relationship was either positive (+), negative (-), or there was no relationship (N.R.).

| | Definitions of Success | | |
|---|---|---|---|
| **Variable** | **Tiger Abundance** | **Population Trend** | **TCL Land Area** |
| Biological factors | | | |
| Forest area | + | N.R. | N.R. |
| Number of red listed species | – | – | N.R. |
| Socioeconomic factors | | | |
| Civil liberties score | + | N.R. | N.R. |
| Democracy index | + | N.R. | N.R. |
| Education index | N.R. | N.R. | + |
| External debt | – | N.R. | N.R. |
| Literacy rate | N.R. | N.R. | + |
| Military spending | – | N.R. | N.R. |
| Per capita energy consumption | N.R. | + | N.R. |
| Political rights score | + | N.R. | N.R. |
| Population growth rate | N.R. | N.R. | – |
| Press freedom rank | + | N.R. | N.R. |
| School life expectancy | N.R. | + | N.R. |
| Urbanization | – | N.R. | N.R. |

## DISCUSSION

I am now going to explore the implications of these results. First, I look at the associations between tiger success and the various biological and socioeconomic factors identified as significant through the three definitions of success, tiger abundance, tiger population trend, and TCL land area. The most noteworthy findings of this study are the association between tiger conservation and measures of education, democracy, and poverty. I then explore the countries considered successful in greater detail.

### Tiger Abundance

When tiger abundance was used as a measure of successful tiger conservation, India, Malaysia, Thailand, and Russia ranked as the four most successful countries. The factor that had the greatest impact on tiger abundance was the level of democracy in a country (Table 4). Tiger conservation may be more successful in more democratic nations because of the increased involvement of NGOs and local peoples in conservation efforts (Mathews 1996). Conservation tends to be more successful when local people are involved in implementation efforts (Rippe and Schaber 1999). Additionally, more democratic countries tend to be better at negotiating and implementing international environmental agreements (Neumayer 2002). Democracy, press freedom, civil liberties, and political rights all were significantly associated with tiger abundance and, indeed, I found that these four variables were all significantly correlated with each other (Table 5).

Tiger density was higher in countries with higher human population growth rates, higher human population density, less forest area, low literacy rates, and less education (Table 7). This may be a factor of geography and climate. Tiger density is higher in areas with higher prey density, and prey density tends to be higher in warmer climates (Biswas and Sankar 2002, Bagchi et al. 2003, Karanth et al. 2004). The tiger range states with the highest tiger densities are Bangladesh, Nepal, Malaysia, and India. Bangladesh and Nepal ranked as two of the four least favorable countries with regards to high population density, high human population growth, low literacy, low education, and low forest area. These two countries may be skewing the regression analysis based on their considerably higher tiger densities and considerably lower measures of poverty, education, and forest area. Therefore, this relationship may only be predictive of location, not successful tiger conservation. If Bangladesh and Nepal were removed, the only variable that still significantly impacted tiger density is civil liberties score. As discussed earlier, higher civil liberties are associated with countries with a higher number of tigers. Tiger density would be expected to increase.

Military spending and external debt had the greatest impact on the number of tigers per 10,000 people (Table 9). However, in a model containing both variables, only military spending significantly contributed to the model (Table 9). The per capita number of tigers decreased as military spending as a percentage of GDP increased. Increased military spending may show that security concerns are more pressing than environmental problems, such as conservation (Price 2003). States may struggle from internal unrest or may view military superiority as important for international relations (Waltz 2000). Furthermore, states that are more secure, and may spend less on their military, would have more money and effort available to invest in conservation efforts. In addition, a model of forest area and military spending significantly explained per capita tiger number with both variables contributing significantly.

**Tiger Population Trend**

Using tiger population trend as an indicator of effective tiger conservation, Nepal, Cambodia, Thailand, and Russia were considered successful (Figure 3). School life expectancy (the number of years students spend in school, on average) and per capita energy consumption were both associated with stable or increasing tiger populations. Tiger populations over time varied little with per capita energy consumption and accounted for is only 27.1% of the variance in trend. However, tiger populations tended to be stable or increasing when per capita energy consumption is greater (Table 11). Greater per capita energy consumption was significantly and positively correlated with GDP per capita (Table 3). Therefore the relationship between greater per capita energy consumption and more successful tiger trends may be based on lower poverty levels in those countries. With lower poverty, more time and money can be spent on non-development issues, such as conservation (Adams et al. 2004, Agrawal and Redford 2006).

Countries with higher school life expectancy also tended to have stable or increasing tiger populations. This factor had a greater impact on tiger trends (Table 11). Greater school life expectancy is a measure of increased education within a country. Conservation efforts tend to be greater in countries with more highly educated populations (Brewer et al. 1992, Berkowitz et al. 1997). These efforts also tend to be more successful because of increased capacity to address problems (McDuff 2001, Saravia and Miranda 2004). Additionally, school life expectancy and other measures of education were significantly correlated with GDP per capita (Table 3). Therefore, countries with higher education levels tend to be wealthier. There would be more funding available for conservation and other environmental protection efforts. Considerable funding is required for conservation efforts, including scientific study, habitat protection, local capacity building, and law enforcement (Nowell 2000, Lynam et al. 2006, Barlow et al. 2008). Increased education levels promote more successful tiger conservation through greater societal concern for the tigers and their habitat, higher capacity, and, ultimately, greater funding for tiger protection efforts.

Tiger populations tended to be decreasing in countries with more endemic species that are listed as endangered by the IUCN Red List (Table 12). Tiger conservation success seems to be a good indicator of the successful conservation of other species. The number of listed species is a measure of both a country's conservation ability and factors that threaten species in the first place. Many of the factors threatening these species are likely the same as factors that threaten tigers, such as deforestation, human poaching, and human encroachment (Kinnaird et al. 2003, Kauppi et al. 2006, Carwardine et al. 2008). In addition, those countries with more endemic species listed as threatened, are less likely to have successful conservation mechanisms in place. Factors leading to the failing conservation of these other species are likely to be similar to factors leading to the failing conservation of tigers, such as the lack of education, lack of capacity, and lack of funding.

Tiger population trend was significantly modeled by school life expectancy and number of endemic threatened species (Table 12). Both education and number of other threatened species relate to other factors, such as wealth and capacity. Additionally, both variables can reveal the amount of concern for conservation compared to other issues such as development.

**Land Area within Tiger Conservation Landscapes**

India, Myanmar, Thailand, and Russia had the greatest amount of land area identified as TCLs. Human population growth rate and two education measures were significantly associated with the amount of TCL land area within each country (Table 14). Within the regression models, only literacy rate significantly contributed to the TCL land area (Table 14). Increased education levels promote greater concern for the environment, greater capacity for conservation efforts, and greater funding for conservation.

Countries with lower human population growth rates tended to have more land area in TCLs. Population growth rates decreased as per capita GDP increased (Table 3). Therefore, countries with lower population growth rates have more funding to supply to conservation and may be able to place more emphasis on conservation than other concerns.

Greater Class I TCL area was significantly correlated with greater urbanization, lower urban population growth rates, higher education, and lower poverty (Table 13). Higher urbanization and lower urban population growth rates were both significantly correlated with higher per capita GDP. This and overall lower poverty, as seen with overall TCL land area, promote increased and more successful conservation efforts. Greater education also promotes greater and more successful conservation as well.

**All Definitions of Success**

The seven countries identified as successful in the three approaches (tiger abundance, tiger population trend, and TCL land area) were India, Nepal, Malaysia, Thailand, Cambodia, Myanmar, and Russia. Only two, Russia and Thailand were identified as successful in all three approaches. India was identified as successful in two of the three approaches.

Russia and Thailand are likely to be successfully conserving tigers. Both were defined as successful under all three approaches and had higher quality measures of the factors associated with successful tiger conservation. Russia and Thailand have low measures of poverty and the highest measures of education of all tiger range states. Interestingly, measures of democracy for both countries are only average compared to the other range states, although Thailand is more democratic than Russia (Appendix A). Overall, Russia and Thailand seem to have successful tiger conservation efforts.

India was identified as successful for having a high amount of land area within TCLs and for having a high number of tigers. While the number of tigers and TCL land area were not significantly correlated for all countries (Pearson's r=0.190, p=0.535, n=13), India's success in both approaches may be correlated. India has considerably more tigers than any other country, is much larger than most range countries, and the majority of the country is within historical tiger range (Seidensticker et al. 1999). Therefore, being defined as successful in both approaches is likely related. In recent years, India's tiger population has been declining due to poaching (Johnson 2005). However, India has a high potential to successfully conserve tigers if specific issues, such as high poaching rates, can be solved (Kenney et al. 1995, Johnson 2005).

Malaysia was considered successful based on a large tiger population. Given that Malaysia does not have a large amount of land area within TCLs, this high population may suggest successful conservation or may suggest that Malaysia has naturally high tiger densities. Previous studies of tiger density within Malaysia indicate average or below average tiger densities (Azlan and Sharma 2006, Linkie et al. 2008). Additionally, Malaysia has a high GDP per capita and average to good measures of education and democracy (Appendix A). It seems likely that conservation efforts in Malaysia are having a positive impact on tiger populations.

Myanmar had the largest amount of land area in TCLs of all tiger range states. Additionally, all the TCLs in Myanmar are classified as Class I TCLs. Class I is the highest level and means the landscape has enough habitat to support at least 100 tigers, there is evidence of breeding within the landscape, threat levels within the habitat are moderate, and there are conservation measures in place for the landscape (Dinerstein et al. 2006). Myanmar's success in this approach may be a significant indicator of current or near future conservation success. However, democracy measures are the lowest of all tiger range states, which may be slowing tiger conservation efforts (Appendix A).

Cambodia was considered successful by one definition of success. However, the tiger estimates from the early 1990s are less reliable than for other countries due to political instability and subsequently lower levels of scientific study (Lanjouw et al. 1999, Roberts 2001). Therefore, while my calculations suggest a stable or increasing tiger population within Cambodia, this is unlikely to be true. Low democracy measures, lower education rates, and high poverty rates also suggest that Cambodia is not successfully conserving their tiger population (Appendix A).

Nepal was also only considered successful in one approach, the trend in tiger population. Tiger populations within Nepal are believed to be increasing although Nepal meets none of the other measures identified as promoting successful tiger conservation (Baillie et al. 2005, Wildlife Conservation Society et al. 2006, UNDP 2007, UNESCAP 2008, CIA 2009, Seidensticker et al. in press). Among tiger range states, Nepal has the lowest per capita GDP, the second shortest school life expectancy, the third lowest literacy rate, and the third highest population growth rate (Appendix A). Significantly, Nepal scores better for democracy measures. Nepal has the seventh best democracy index score, the third best civil liberties score, the fourth best political rights score, and the fourth best press freedom rank (Appendix A). Comparatively, Nepal is more democratic than poverty and education measures would suggest. This may be enough to promote successful tiger conservation within the country. For example, Nepal has a successful program of community involvement to expand tiger habitat beyond protected areas into buffer zones (Dinerstein et al. 2006). Nevertheless, Nepal also has significant outside support for their tiger conservation efforts. A considerable amount of tiger research has been conducted and non-governmental organizations (NGOs) have been very active within Nepal (Tamang 1982, Mishra et al. 1987, Smith 1993, Sharma 1995, Shrestha and Kattle 1996, Dinerstein et al. 2006).

China and Indonesia were not considered successful under any definition of success. However, measures of the factors identified as associated with successful tiger conservation suggest that these countries may require less effort to improve their conservation. China has a higher, and growing, GDP per capita than most tiger range states and has high education measures. However, democracy and other measures of social freedom are low (Appendix A). If local participation and political openness could be increased and corruption could be decreased, China may have the capacity in place to successfully conserve their tiger populations. Meanwhile, Indonesia has high democracy measures, comparatively high education measures, and, within range states, average poverty measures (Appendix A). These measures suggest that Indonesia could successfully conserve tigers. Nevertheless, tiger populations are declining (Budaiwan 1989, Tilson et al. 1997, Linkie et al. 2003). Deforestation due to land conversion is occurring rapidly in Indonesia and political priority seems to be on development, as opposed to tiger conservation (Budaiwan 1989, Nyhus 1999, Kinnaird et al. 2003).

Given which countries are likely to be successfully conserving tigers and which are not, some subspecies are more threatened with extinction than others. The Siberian tiger, found mostly in Russia (Seidensticker et al. 2008), is unlikely to go extinct. The future of the Siberian tiger would be even stronger if conservation in China improved. Both the Bengal tiger and the Indochinese tiger would be expected to survive in some areas as each is found in one country that is likely to be successfully conserving tigers currently (Seidensticker et al. 2008). However, it would be imprudent to rely on one country and one section of the population to continue a subspecies (Dinerstein et al. 2006). Within the ranges of both subspecies are one or two countries that could be or could in the near future be successfully conserving tigers. With increased conservation effort within those countries (India, Myanmar, and Malaysia), the future of the Bengal and Indochinese tiger would improve. The Sumatran tiger has the bleakest future as it is only found in Indonesia (Seidensticker et al. 2008), which at the moment is unlikely to be conserving their tigers successfully. To preserve this subspecies, conservation effort should be increased.

Variables identified as significantly contributing to successful tiger conservation under any approach were democracy index, press freedom rank, civil liberties score, political rights score, military spending, forest area, school life expectancy, literacy rate, population growth rate, and the number of endemic threatened species. While many of these variables were believed to impact conservation, to my knowledge previous studies have only found forest area and population growth rate had significant impacts on conservation (Forester and Machlis 1996, O'Brien and Kinnaird 2003, Cardillo et al. 2004, Araujo and Rahbek 2007, Pejchar et al. 2007) . Various measures of education contributed to multiple approaches for defining successful conservation. These education parameters are higher when per capita GDP was greater. Higher per capita GDP was also associated with lower population growth rate (Table 3). Overall, countries that were successful at conserving tigers had more education, higher levels of democracy, and lower poverty levels. These countries have a higher capacity for local support and involvement in conservation efforts, greater funding for conservation efforts, and improved scientific and technical basis for conservation efforts. In addition, countries with effective tiger conservation tended to be more successful at conserving other species.

**Implications for Wider Conservation**

Given that successful tiger conservation was significantly correlated with the number of endemic species that are threatened or endangered (Table 12), factors that impact tiger conservation are likely similar to factors that impact the successful conservation of other species. Democracy measures, poverty measures, and education measures significantly associated with tiger conservation. Education levels and poverty levels were significantly linked (Table 3). Conservation efforts are more likely to be successful as education increases and thus knowledge and capacity increase. Additionally, as poverty decreases, the ability for local people and national governments to shift priorities from basic needs or development to environmental and conservation needs provides a greater arena for conservation success.

Conservation efforts are also more likely to be successful within democratic and more open societies. Notably, we see in Nepal that conservation can be successful in a country with low education and high poverty indicators, but with a higher level of democracy. While this is unlikely to be the norm, and may require outside conservation assistance, it is an important indicator that an open society and community involvement facilitate conservation.

It would seem that one way to improve tiger conservation and conservation generally would be to promote education, poverty eradication, and freer societies. Methods of improving sustainable economic development and increasing educational capacity may need to be developed. Capacity for local participation in conservation processes may also need to be increased.

## Future Research

This study was not comprehensive. Many socioeconomic variables identified through a literature review as possible factors impacting tiger numbers and tiger conservation were not explored in this analysis (Table 2). Specifically, I believe factors such as anti-poaching efforts, interagency cooperation, and local support for conservation efforts are likely important contributors to successful or unsuccessful tiger conservation (Weber and Rabinowitz 1996, Karanth and Nichols 1998, Berger 2006, Dinerstein et al. 2006, Naidoo and Ricketts 2006). However, no country-wide data were available for these variables or many others. Country-wide data were used in all analyses conducted in this study and using data based on one study or one area would introduce new uncertainties into the analysis. Therefore all variables without country-wide data were excluded from this analysis.

Furthermore, while education, lower poverty, and democracy are associated with countries that have experienced successful tiger conservation, methods to improve these indicators need to be clarified. There is no simple way in which to promote democracy within tiger range states. Additionally, efforts to improve poverty levels or education levels have been underway for decades, with a varied history of success (The World Bank 2007, International Monetary Fund 2008). Moreover, while these indicators are associated with successful tiger conservation, they do not guarantee it. Specific tiger range nations need to make the commitment to provide resources, manpower, and political will to conservation efforts. However, tiger conservation effort and funding has been focused almost solely on biological criteria and descriptions of current distribution. Measures of democracy, education, and poverty do seem to be important for tiger conservation success. Conservation efforts should, thus, be broadened out to include these drivers. Future policy strategies to improve the measures of democracy, education, and development need to be explored, although they could not be investigated within this study.

The mechanisms for how the identified variables, democracy, education, and poverty, actually impact tiger conservation efforts also need to be studied. This study did not explore the direct or causal relationship between tiger conservation and the various biological and socioeconomic variables. Given that the variables identified are not just issues localized to specific protected areas or specific countries, tiger conservation organizations should consider them macro issues. Research and funding should follow accordingly.

Biodiversity conservation globally is likely to be associated with similar drivers. The focus of conservation efforts for all species needs to be drawn back from the specific biological factors to also explore the underlying causes for biodiversity loss. These broader impacts are less likely to be species specific, so efforts to address them could support overall species conservation. Conservation funding and effort is limited. Addressing the root causes of species loss will improve cost-effectiveness and will improve the impact of more biologically focused conservation projects.

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## APPENDIX A: COUNTRY CHARACTERISTICS

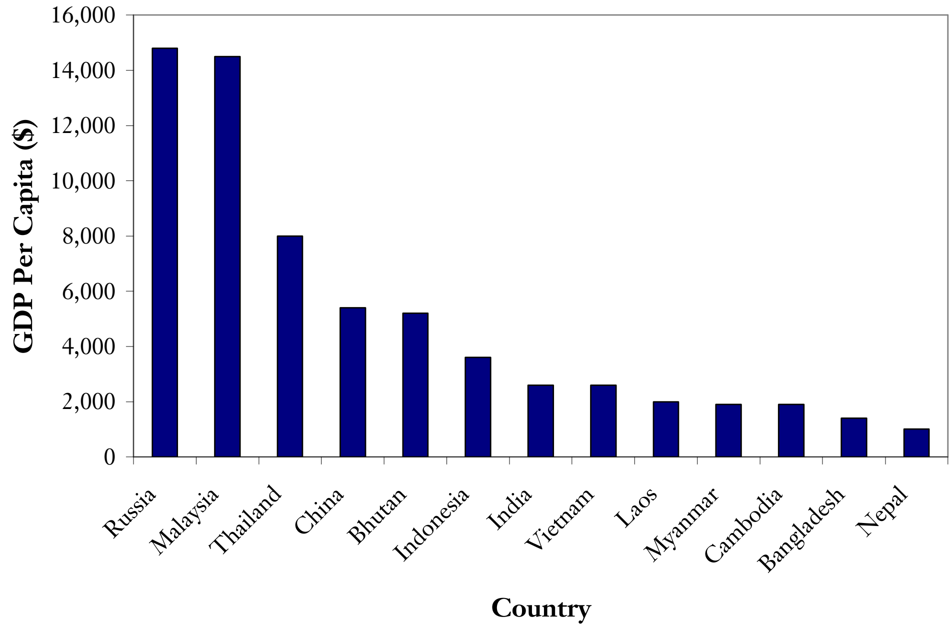


Figure A. GDP per capita for each tiger range state, ordered from highest to lowest (CIA 2009).

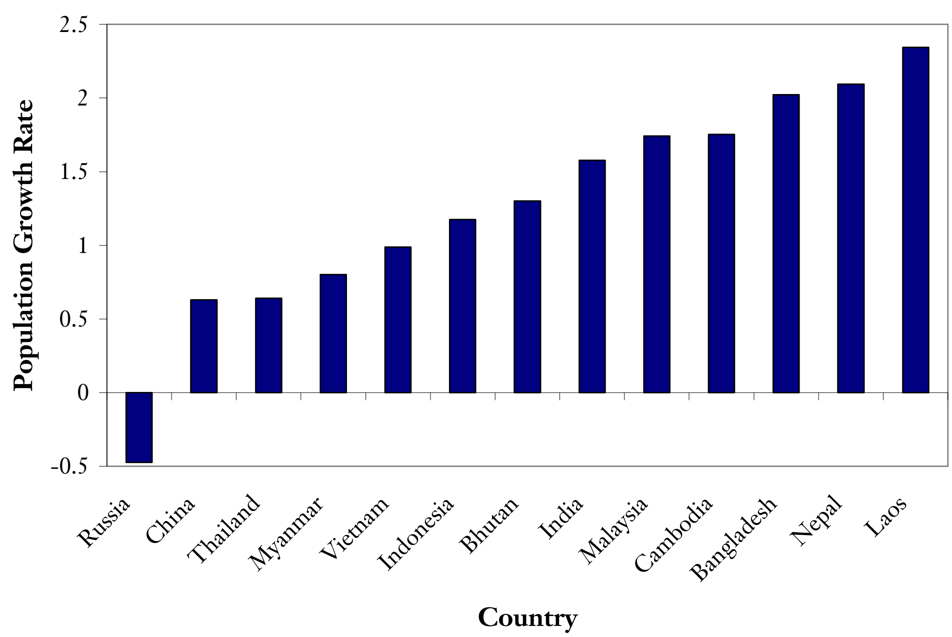


Figure B. Population growth rate for each tiger range state, ordered from lowest to highest (CIA 2009).

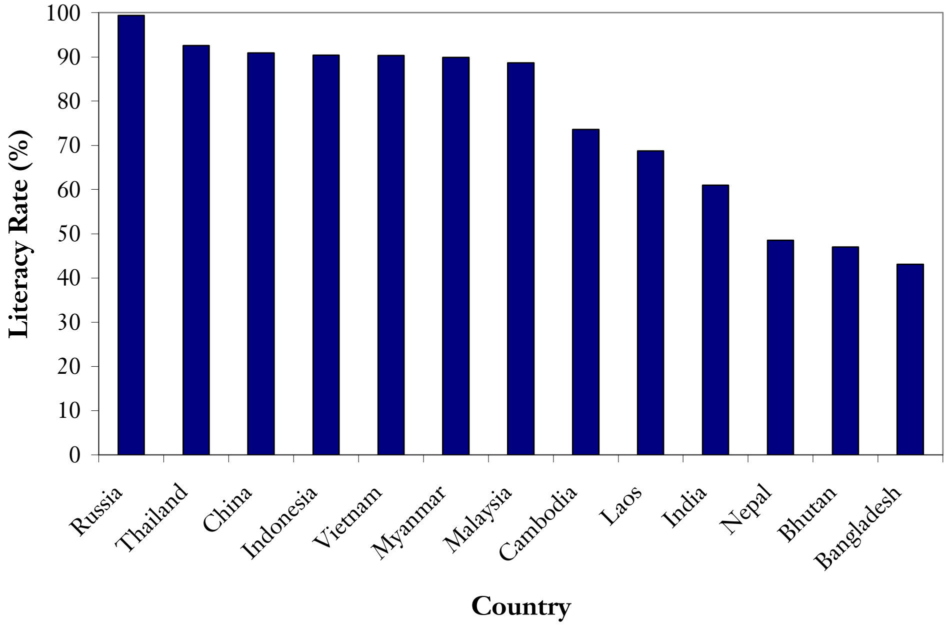


Figure C. Literacy rate (percent of total population) for each tiger range state, ordered from highest to lowest (CIA 2009).

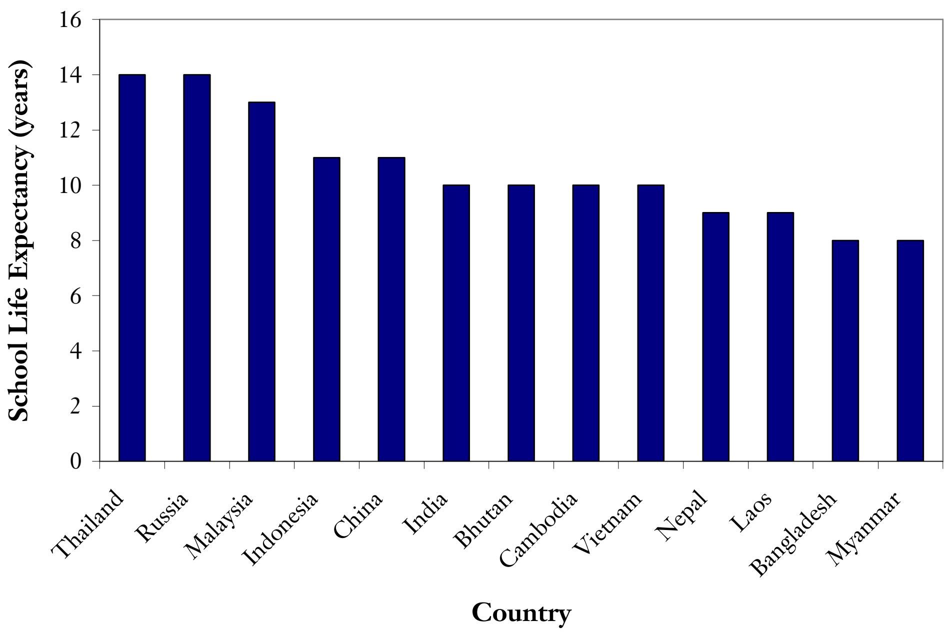


Figure D. School life expectancy (the number years an average citizen spends in school) for each tiger range state, ordered from highest to lowest (CIA 2009).

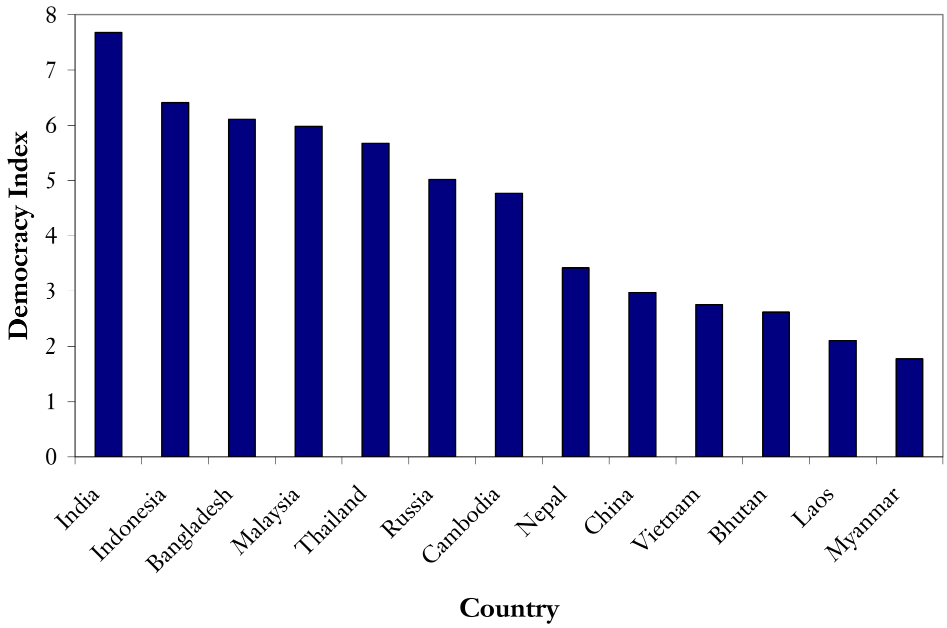


Figure E. Democracy index scores for each tiger range state ordered from most democratic to least democratic (Kekic 2007).

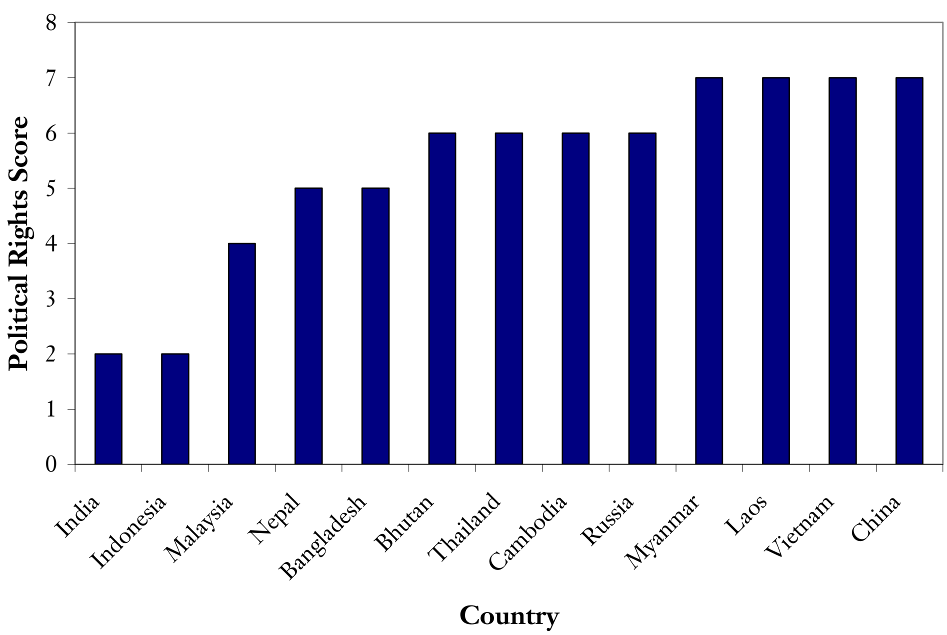


Figure F. Political rights score for each tiger range state ordered from the highest level of political rights to the lowest (World Audit 2008).

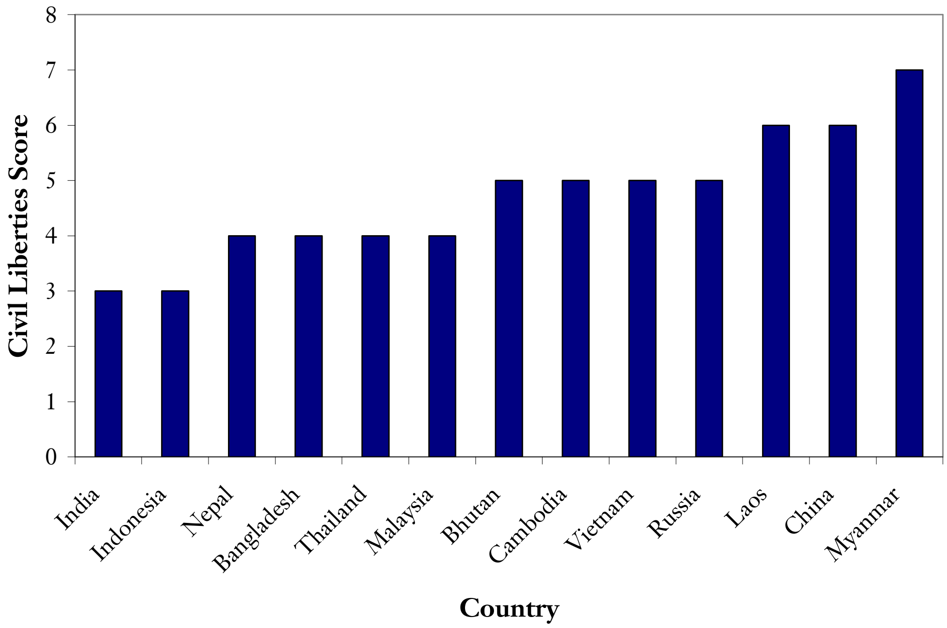


Figure G. Civil liberties score for each tiger range state ordered from the most civil liberties to the least (World Audit 2008).

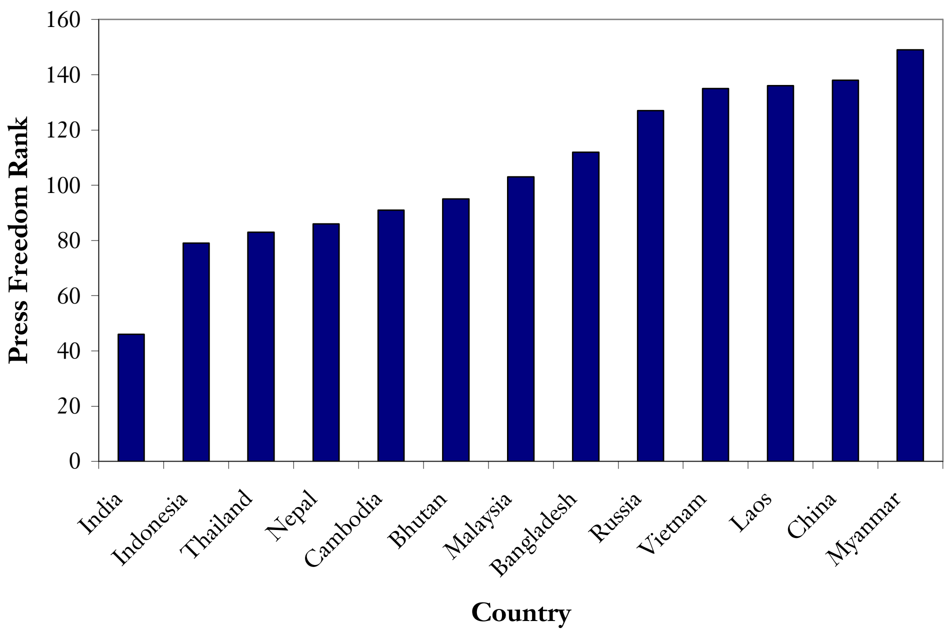


Figure H. Press freedom rank for each tiger range state ordered from the highest level of press freedom to the lowest (World Audit 2008).