Elizabeth Cohan April 13th, 2012

Road Construction and Amur Tigers (*Panthera tigris altaica)* in the Russian Far East

Introduction

The Amur tiger (*Panthera tigris altaica*), also known as the Siberian tiger, is an endangered species in the Russian Far East that has experienced a sharp population decline during the past century (Tian et al. 2011, 3166). Roads may be one of the primary factors for the dramatic decline of tiger population because the species most sensitive to roads tend to be large carnivores that rely on large movement ranges and have low reproductive rates (Fahrig and Rytwinski 2009, 1 and Tian et al. 2011, 3166). Tigers (*Panthera tigris*) are an example of such fragile large carnivores; as a result there are only six of nine tiger subspecies remaining in the wild to date (Kerley et al. 2002, 98 and Tian et al. 2011, 3166). Once found in Russia, China, Mongolia, and Korea, Amur tigers are one of the six remaining subspecies now found exclusively in the Russian Far East (Tian et al. 2011, 3166) (Fig. 1A). According to census data, there are about 400 adult individuals left in the wild, officially making Amur tigers an endangered species (Kerley et al. 2002, 98 and Miquelle et al. 2005). While many regions, such as the Sikhote-Alin State Biosphere *zapovednik* in the Russian Far East, are highly protected lands with minimal human disturbances, Amur tigers still suffer from the direct effects of roads in this region (Kerley et al. 2002, 99). In addition, increased road construction in the Primorsky Krai and Khabarovsk Krai regions of Russia beginning in the early 90s resulted in a road network extending well into the Russian Far East allowing for easier access to once uninhabited land (Fig. 1B). Despite increasing concerns about tiger conservation and the push for mass road construction, research linking roads and tigers is lacking. The purpose of this study is to create the link between road construction and Amur tigers in the Russian Far East through data analysis from two general categories: transportation and Amur tiger population. I review transportation and Amur tiger population data compiled before analyzing the relationship between the two. This study is important to aid in the creation of efficient conservation strategies for Amur tigers and to prevent their imminent extinction.

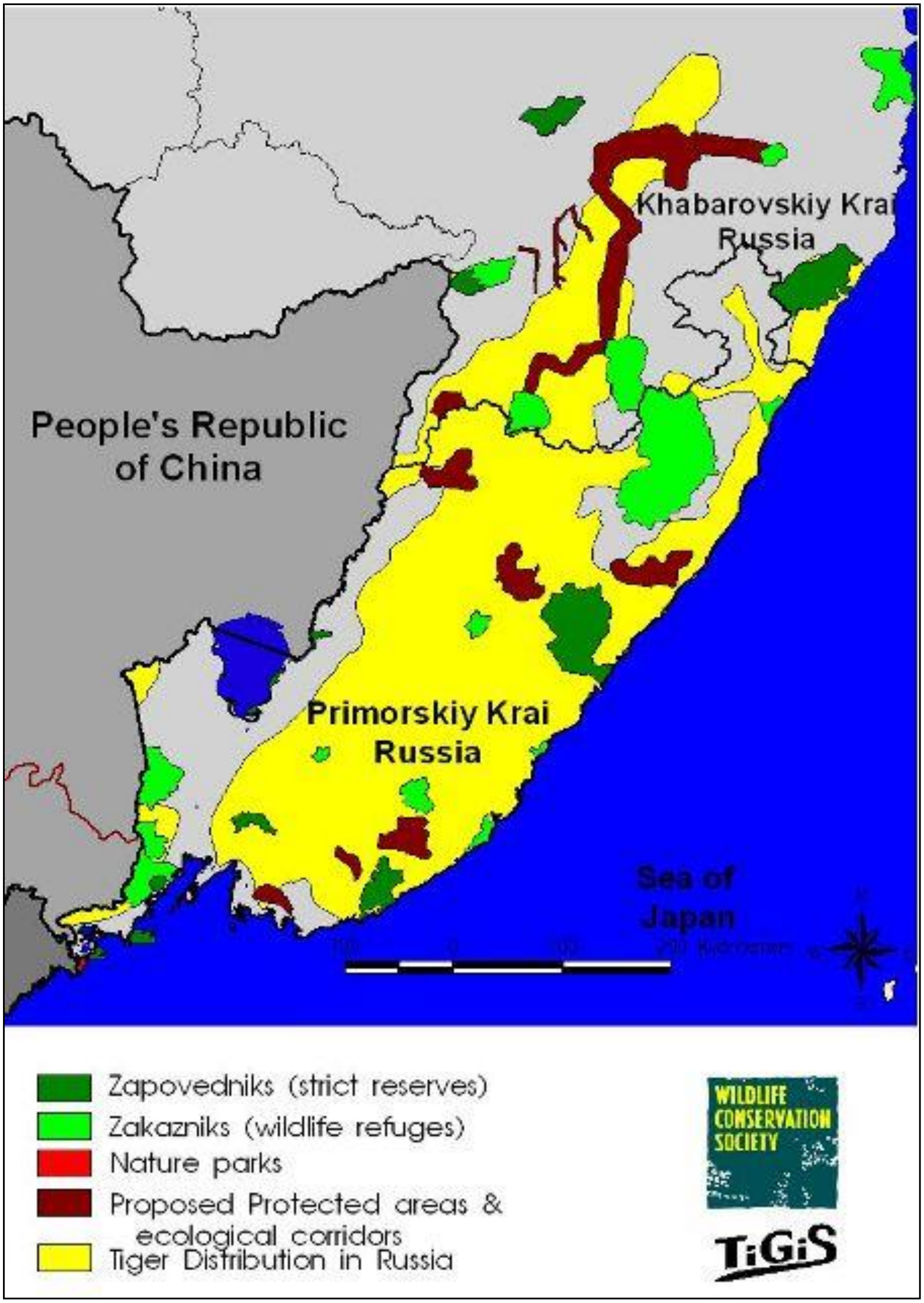


Figure 1A: Distribution of Amur tigers in the Russian Far East (yellow).
Source: http://www.wcsrussia.org/en-us/wildlife/amurtigers/ecology.aspx, accessed online April 10th, 2012.

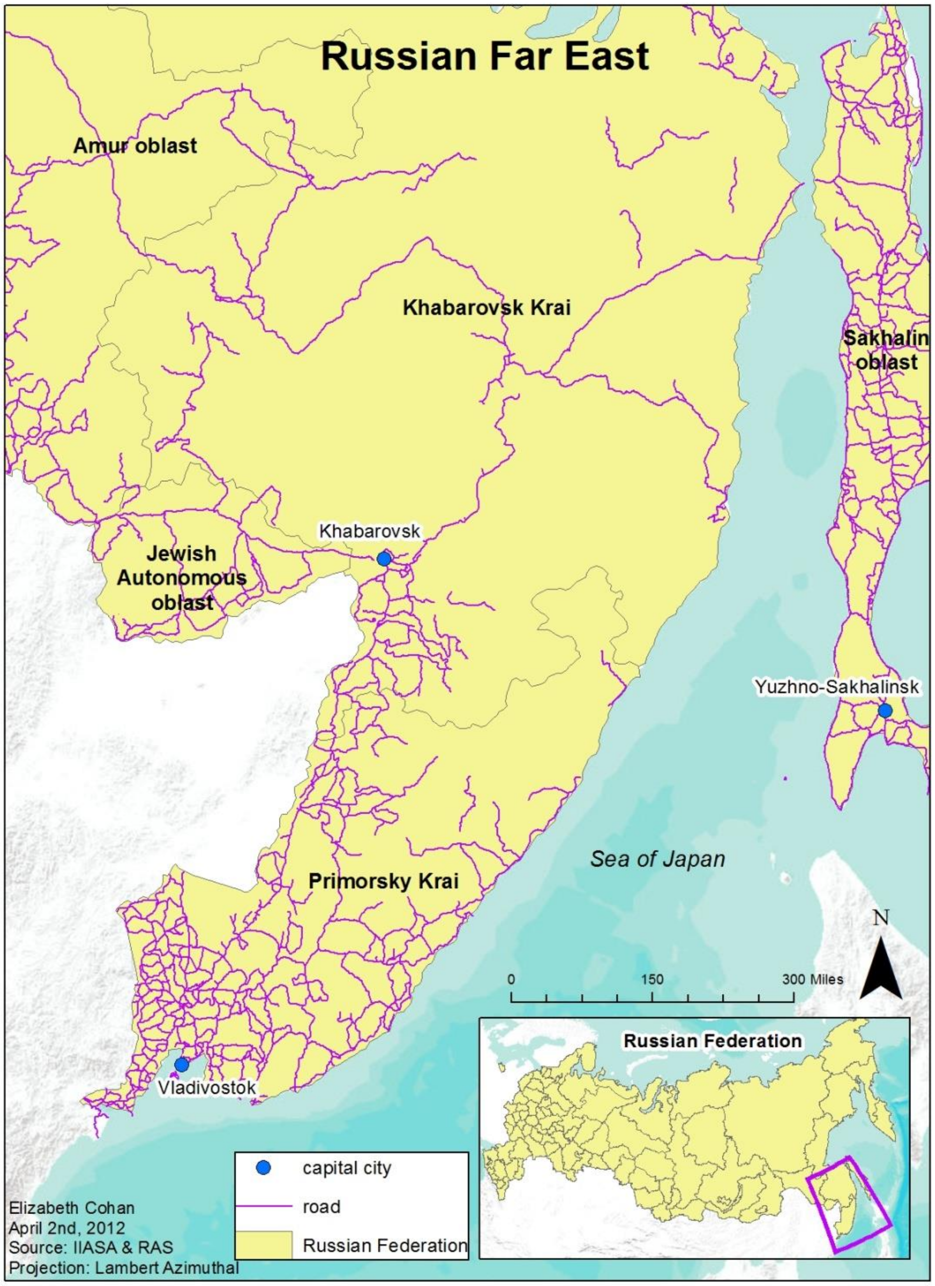


Figure 1B: Road network in the southern region of the Russian Far East.
Data source: International Institute for Applied Systems Analysis 2002.

Background

Over the past decade, awareness of the impending extinction of Amur tigers have increased in the scientific community and the 20th century decline of tiger populations is now well established (Alasaad et al. 2011, 723 and Goodrich et al. 2010, 738). Thus, the Amur tiger has been the subject for many long-term field studies since the early 1990s (Carroll and Miquelle 2006, 1057). Goodrich et al. (2008) and other researchers provide data on Amur tiger mortality, however, the causality is linked to poaching or logging while ignoring road impacts (Goodrich et al. 2008, 323). Goodrich et al.(2008) examined causes of mortality and survival rates for Amur tigers in the Sikhote-Alin Biosphere *zapovednik*. This is one of the largest protected areas within Amur tiger range yet still proves to be a dangerous habitat (Goodrich et al. 2008, 327 and Kerley et al. 2002, 99). Goodrich et al. (2008) radio tracked Amur tigers from 1992 and 2005 and found human-caused mortalities resulted in 83 percent of tiger deaths with vehicle collisions attributing 12.5 percent to this number. In their long-term data set, Goodrich et al. (2008) showed that 8 percent of tiger deaths were related to vehicle crashes based on reports from 1976 and 2001. This research group recognizes that if the road construction trend continues to increase, there will be an increase in road caused mortalities of Amur tigers; however, their report does not focus on mortalities due to roads as a primary factor (Goodrich et al. 2008, 325). Goodrich et al. (2008) attributes the increase in Amur tiger mortalities mainly to poaching and ignores the immense impact that road construction presents for these animals.

Along with mortality, many studies of Amur tigers focus on the spatial distribution and home ranges of Amur tigers using remote tracking methods, such as Rozhnov et al. (2011), Goodrich et al. (2010), and Carroll and Miquelle (2006). These spatial studies of Amur tigers are helpful in creating effective conservation strategies because researchers can illustrate how much protected wildlife area is in use (Goodrich et al. 2010, 741 and Rozhnov et al. 2011, 835). Studies of home range sizes are important because they are the basis for calculations and estimations of population size (Rozhnov et al. 2011, 843). Goodrich et al. (2010) found that male home ranges in the Russian Far East were 3.6 times larger than those of females and female Amur tigers maintained exclusive home ranges. This means that females were more likely to stay within their original home range despite increased human interactions such as road construction (Goodrich et al. 2010, 841). Therefore, if a female Amur tiger has a home range near a road she will not leave, resulting in an increased probability of mortality for her and her offspring. This is validated by studies that show Amur tigers living near primary roads have increased mortality rates than those living in areas without roads (Kerley at al. 2002, 98). Carroll and Miquelle (2006) and Rozhnov et al. (2011) emphasize the importance of understanding Amur tiger range in order to introduce alternative conservation strategies. As Carroll and Miquelle (2006) argue, the spatial distribution of these animals along with the current proportions of the actual protected areas appears to be helpful when studying the population viability. Their results illustrate that while the Sikhote-Alin *zapovednik* is a protected reserve, these tigers tend to wander outside the ranges into unprotected areas containing landscapes with increased road construction leading to an increase in vehicle collisions and tiger mortality. Carroll and Miquelle (2006) also found that tiger populations are very vulnerable to small increases in mortality rate. Thus, road construction, which is not mentioned in their study, could be very problematic because it can change Amur tiger populations as described by Kerley et al. (2002). Spatial studies of Amur tiger populations prove to be helpful when discussing conservation strategies but are not the answer to solving Amur tiger endangerment and creating more efficient conservation plans because they lack knowledge of road construction.

The spatial distribution of Amur tigers relies heavily on how the habitat itself is changing. Cushman and Wallin (2000) report on the changing landscape in the Russian Far East and point out that this area has one of the highest densities of endangered species, including Amur tigers. This study focuses largely on how the forested area has changed over time. For example, from 1972 to 1992 the total non-forest area of this region increased from 70,640 ha to 171, 592 ha (Cushman and Wallin 2000, 653) . More importantly, Cushman and Wallin (2000) discuss at the end of their paper that road building has increased in this area, causing more wildfires, attributing to 80 percent of total landscape change. The impact of road building and reduced forest cover has significant impacts on the viability of Amur tigers in the coniferous forests of the Russian Far East. Studies about land cover change and the spatial distribution of tigers prove to be helpful when discussing conservation strategies but are incomplete without knowledge of road construction.

Goodrich et al. (2008), Rozhnov et al. (2011), and Cushman and Wallin (2000) study Amur tigers from various perspectives such as mortality, spatial distribution, and land cover change, respectively. However, information and scientific studies regarding the impact of roads specifically on Amur tigers are scarce (Fahrig and Rytwinski 2009, 2). Fahrig and Rytwinski

(2002) construct a complete review of studies focusing on effects of roads on other animal populations over the past ten years. While few studies have been conducted on many different species, including bears, wolves, and cougars, the Amur tiger is only found in one of these studies and Fahrig and Rytwinski (2002) suggest that more research on the impact of roads is necessary. Also, while roads have become an increasing concern among conservationists, many studies are not focused on roads as the primary factor in impacting population levels (Fahrig and Rytwinski 2009, 2). This has resulted in few studies reflecting the relationship between road construction and Amur tiger populations.

To my knowledge, Kerley et al. (2002) is the first and only study that looks at the direct relationship between road presence and Amur tigers in the Russian Far East. Kerley et al. (2002) illustrate the detrimental effects of primary and secondary roads on the survival of Amur Tigers. They found that over the course of eight years, primary roads significantly increased the rate of mortality on Amur Tigers compared to roadless areas (Kerley et al. 2002, 106). Kerley et al. (2002) make the point that Amur tiger conservation in Russia must include the prevention of road construction and the closing of unnecessary roads. By doing this, the increasing illegal logging activities will decrease and ultimately allow Amur tigers to live in the *zapovednik* with less human disturbance (Kerley et al. 2002, 106). Roads facilitate vehicle collisions and road-related deaths and should therefore be strictly regulated or destroyed to conserve the remaining Amur tigers and prevent extinction. While Kerley et al. (2002) illustrate the impact of roads on Amur tigers, all tigers in their data set were ultimately killed by poachers. Furthermore, this study only looked at the impact of existing roads and not the impact of future or past road construction on levels of Amur tiger populations. Therefore, the relationship between road construction rates and population level changes over time in this area is unknown. Changes in road construction rates in Russia are important to understand because the Russian Far East contains the last of the Amur tigers (Kerley et al. 2002, 98).

Fahrig and Rytwinski et al. (2002) discuss various studies that have used a road ecology approach towards studying the relationship between wildlife populations and roads. As previously mentioned, Kerley et al. (2002) is the only known research group to use this perspective in order to evaluate Amur tiger responses to roads in the Russian Far East. Therefore, a road ecology framework is appropriate to use for a necessary study on the impact of road construction on Amur tiger populations throughout time. Road ecology is defined as “the interaction of organisms and the environment linked to roads and vehicles…the relationship between the natural environment and the road system" (Forman et al. 2003, 7). Forman et al. (2003) breaks down this definition by defining a road as a path for vehicles and ecology as the relationship between organisms and the natural environment (Forman et al. 2003, 7). In the world's ever expanding transportation industry, roads have led to a network built upon natural landscapes (Fahrig and Rytwinski, 2). Forman et al (2003) describes road networks as "superimposed on mountains, valleys, plains, and rivers teeming with natural flows". Over the past ten years, researchers have become interested in the relationship between the land and roads which are intertwined in an uneasy embrace, an interest which has led to the increasing emergence of road ecology (Forman et al. 1998 , xiii and Fahrig and Rytwinski 2009, 2).

Road ecology is an interdisciplinary approach to study the environment and acts as an umbrella over many different perspectives (Forman et al. 2003, 3). Road ecologists study various types of roads including trans-continental highways, logging roads, and even bike paths (Forman et al. 2003, 7). Furthermore, roads are labeled with many different names; some road ecologists may use road or roadway while others decide on road corridor (Forman et al. 2003, 7). Together these roads form road networks that act as a web stretching out over the land like tree roots (Forman et al. 2003, 7). Due to the interdisciplinary nature of road ecology, many different fields are combined into one. Such fields employ professionals including engineers, transportation planners, environmental consultants, economists, biologists, chemists, policymakers, mathematicians, conservationists, statisticians and many others (Forman et al. 2003, xiv). Out of all these road ecology fields, I am going to discuss two perspectives that best describe the framework used for my study of Amur tigers. As I will discuss in the following paragraphs, a transportation perspective combined with a conservation approach will create a new combination of ideas in order to best understand the state of Amur tigers in the Russian Far East.

The road ecology framework rests heavily on understanding the evolution of transportation and fluctuations of road density, which is the average total road length per unit area of landscape (Forman et al. 2003, 9). Kerley et al. (2002) and Mech et al. (1988) studied the effect of road density and the existence of roads on specific species in remote areas. Mech et al. (1988) focused on the distribution of the wolf (*Canis lupus*) in Minnesota, USA where mean road density was 0.36 km/km^2. Their results suggest wolves do not inhabit areas where road density rises above a certain threshold. The impact of roads on animal wildlife is also found in a study by Kerley et al (2002) on the effect of primary and secondary roads versus road less areas on Amur tigers in the Russian Far East. Their research found Amur tigers negatively affected by the presence of roads and none of the tigers survived in areas with primary roads as opposed to road less areas. Mech et al (1988) and Kerley et al (2002) both used a road ecology framework but focused on the effect of road density or road existence on wildlife. The effect of road density on species populations is important because this sheds light onto how transportation planning can impact surrounding wildlife. States are requiring new transportation plans and policies because the current road system in most countries reflects a "pre-ecological era" where engineers constructed roads during a time when society did not acknowledge ecological consequences (Forman 1998, iii). Forman points out that this has created a number of bottlenecks in populations, which disrupts natural processes and population sizes (Forman 1998, iii).

From a conservation perspective, increased road construction and road density over the past decade has not come without widespread environmental damage (Forman et al. 2003, 3 and Fahrig and Rytwinski 2009, 2). Therefore, the impact of roads on the environment, ranging from overhunting to invasive species development, must be understood to create effective conservation strategies for endangered species (Kerley et al. 2002, 98 and Forman et al. 2003, 15). Conservation and population biologists have recently become concerned about the effects of roads on animal populations because roads increase mortality and present a major threat for many species (Jaeger and Fahrig 2004, 1652). A study by Jaeger and Fahrig (2004) on how to reduce road related deaths states that populations of black bears in Canada have been declining since 1994, with 36 percent of deaths attributed to road related mortalities (Jaeger and Fahrig 2004, 1652). A similar study by Van der Zee et al. (1992) found the decline of badger (*Meles meles*) population in the Netherlands can be attributed to the road network and traffic increase. Van der Zee et al. (1992) emphasize the importance of knowing the cause of decline in order to preserve this already threatened species. Knowledge of how roads effect populations of wildlife may help prevent extinction of endangered species such as the Amur tiger.

Amur tiger conservation efforts lack research on the direct link between road construction rates over time and tiger population dynamics preventing an interdisciplinary approach to conservation strategies. Past research focuses on mortality, spatial distribution, and landscape change, but ignore road construction as a primary effecter (Tian et al. 2011, 3166). Knowledge of road construction and Amur tiger population levels are little to nonexistent and yet extremely necessary to prevent extinction. The most appropriate perspective to effectively study two different variables such as roads and tigers is an interdisciplinary road ecology approach that utilizes road construction information and Amur tiger populations throughout time. As previously discussed, studies reflecting Amur tigers and roads are lacking in the scientific community. Thus, a current review of the state of road construction and Amur tigers in the Russian Far East is needed. I bridge the gap between road construction and Amur tiger populations by studying trends of these variables throughout time. The use of an interdisciplinary road ecology framework allows for a new approach for transportation planners and conservationists alike to create new strategies that comply with the needs of society as well as the environment to save Amur tigers from extinction (Fig. 2).

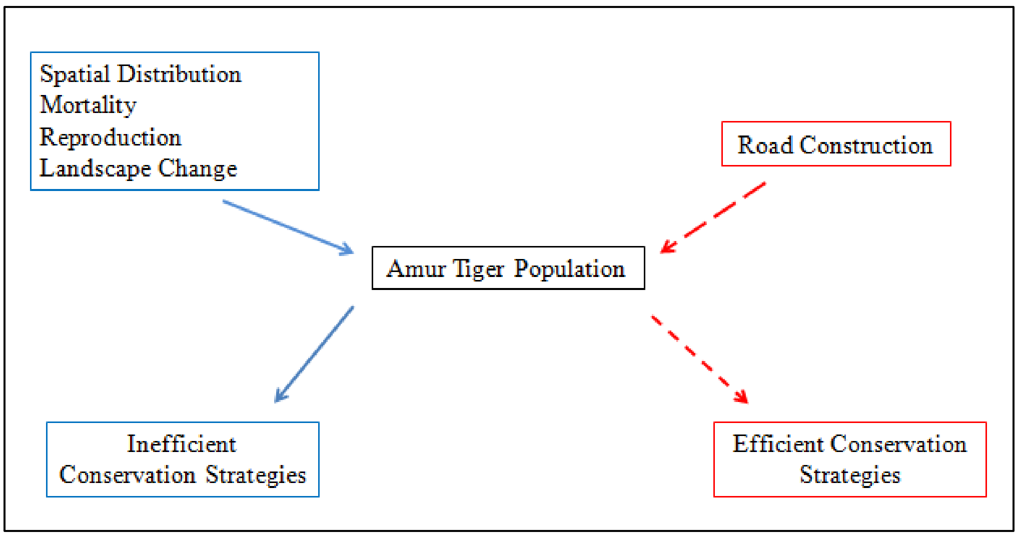


Figure 2: Diagram representing current research areas (blue) relating to Amur tiger population leading to inefficient conservation strategies. Red represents road construction research needed in relation to Amur tiger populations to create efficient and improved conservation plans.

Figure 3: Location of last remaining Amur tiger habitat in the Russian Far East.
Source: http://www.wildlifearchives.com/images/animals/siberian-tiger-map.gif, accessed on March 30th, 2012.

Methods

My methodology seeks to analyze the relationship between road construction and tiger populations since the early 90s by synthesizing data from two general categories: transportation and Amur tiger population. The transportation data includes information pertaining to road construction and road density from the Russian Federal State Statistics Service, International Institute for Applied Systems Analysis (IIASA), Russian Federal Highway Agency, Ministry of Transport of the Russian Federation, and previous studies. While analyzing these websites, I collected data specific to the change of road density or length of roads over time in order to show the growth of the Russian road network. Interim reports from the IIASA helped to establish variables pertaining to roads for the Russian Far East regions specifically while the Federal Highway Agency website verifies the government's plan to massively increase road construction and the road network to the Russian Far East.

The second category of data is information on Amur tiger populations in the Russian Far East, which is the current location of the last of these tigers (Fig. 3). Census data is found in a report named "Numbers, Distribution, and Habitat Status of the Amur Tiger in the Russian Far East: 'Express Report'" conducted by Matyushkin et al. (1996) under the United States Agency for International Development (USAID) Russian Far East Environmental Policy and Technology Project. Data also is analyzed from a census named "A Monitoring Program for the Amur Tiger Thirteenth-Year Report: 1998-2010" (Miquelle et al. 2010). This census represents a collaborative effort among numerous environmental groups and members of the Russian Federation including experts from the Wildlife Conservation Society, World Wildlife Fund and the Russian Academy of Sciences. A census that also provided helpful data is "A Survey of Amur (Siberian) Tigers in the Russian Far East, 2004-2005"conducted by Miquelle et al. (2005). Census data provided a historical background as well as an updated status on Amur tiger populations in the Russian Far East to help understand population fluctuations.

Throughout my research, the Russian language barrier was one of the major difficulties I encountered. For example, the Russian Federal Highway has an English and Russian version of their website. Unfortunately, the English version contains significantly less information than the Russian version. Fortunately, Dr. Yvonne Howell, an associate professor at the University of Richmond in Russian and International Studies, helped translate graphs, website pages, and Russian government documents to overcome this challenge. Overcoming the language barrier challenge proved to me the information gap existing across countries which creates problems of inaccessible data that is unavailable to a citizen outside the Russian Federation.

Analysis

In this section I will review the transportation and Amur tiger population data compiled before analyzing the relationship between the two. The first category of data I will review focuses on road construction and road density in Russia and the Russian Far East. A change in the social-economic status of the Russian Federation in the 1990s greatly impacted road construction and transportation planners. (Miquelle et al 2005). The economic opening caused an expansion of growth in the Russian Far East which resulted in an extended road network reaching Russia's eastern most regions (Federal Highway Agency 2012a) (Fig. 4). Much road construction is focused on the current state of roads that are deteriorating and in need of repair (Federal Highway Agency 2012b) (Fig. 4). Many news postings show images of road construction in various areas. One article focuses on the continued effort to build more roads in the Russian Far East (Federal Highway Agency 2012b). In this article, the Federal Highway Agency website claims construction workers move 15000 cubed meters of dirt daily. Also found on the Federal Highway Agency's website is a graph depicting a six fold growth in the federal road network in Russia over a ten year period (Federal Highway Agency 2012a) (Fig. 5). This graph helps visualize the rate of road construction that has drastically increased since the early 2000s.

Figure 4: *Development of Road Network in Accordance with Federal Program "Development of Transport System in Russia", 2010- 2015.* Illustrates extensive existing road network (red) and future repair plans (green and purple) for Russia. **Translated by Dr. Yvonne Howell*
Source: Federal Highway Agency 2012a.

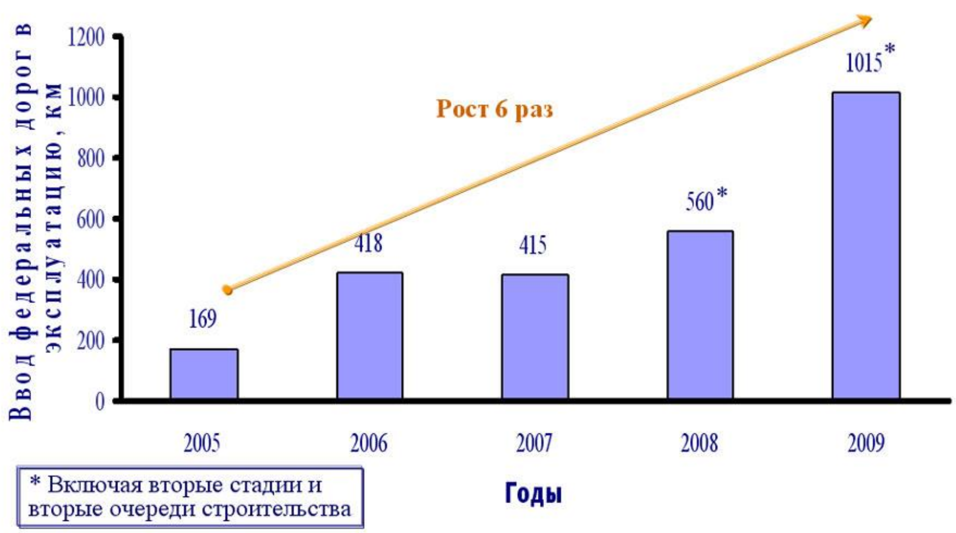


Figure 5: Introduction of federal roads from 2005 to 2009 in Russia (km). Trend line title reads "6 fold growth"(orange).
Source: Federal Highway Agency 2012a. **Translated by Dr. Yvonne Howell*

In addition to the impressive road network in Russia, data from the Federal State Statistics Service shows an upward trend in the amount of total motor roads existing in Russia due to new construction. Over the course of seventeen years from 1992 to 2009, the length of roads in Russia expanded from 902 to 983 (km per 1000 square km) (Federal State Statistics Service 2011a) (Fig. 6). Therefore, road construction has increased 9 percent when compared to data in 1992 versus 2009. The dip that occurred in 2005 can be explained by instability within the Russian Government delaying construction jobs. Arkadiy Lyubarev wrote in the Russian Analytical Digest that legislators passed more radical amendments during 2005 than those of the preceding ten years combined (Lyubarev 2011). The radical increase of amendments illustrates the instability of the Russian government explaining a decreased amount of total road length in 2005. Other indicators of road network growth include changes of road density throughout the past decade. According to the Federal State Statistics Service for the Russian Federation, road density for public roads increased by 21 percent in nine years, expanding from 31.2 to 37.8 (km per 1000 square km) (Federal State Statistics Service 2010b) (Fig. 7). At a meeting conducted by the Russian Prime Minister, Vladimir Putin talks about the subject of Russian road construction. Putin comments “massive road construction has been launched…for the first time in its history, Russia’s territory from the Far East to Kaliningrad is linked by a single road network” (Government of the Russian Federation 2011). Putin vows to continue increasing road construction and road repairs in order to fix current inadequate infrastructure.

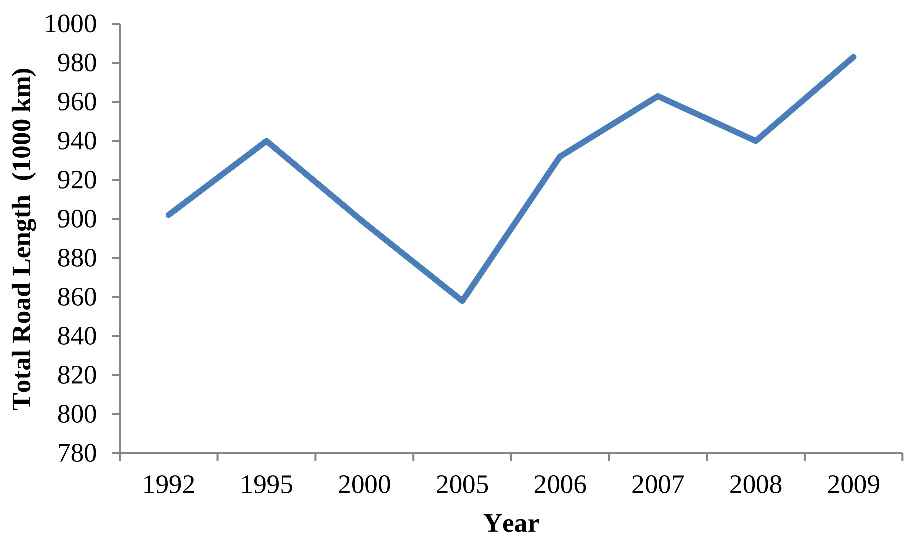


Figure 6: Length of total motor roads in Russia from 1992 to 2009.
Source: Federal State Statistics Service 2011a.

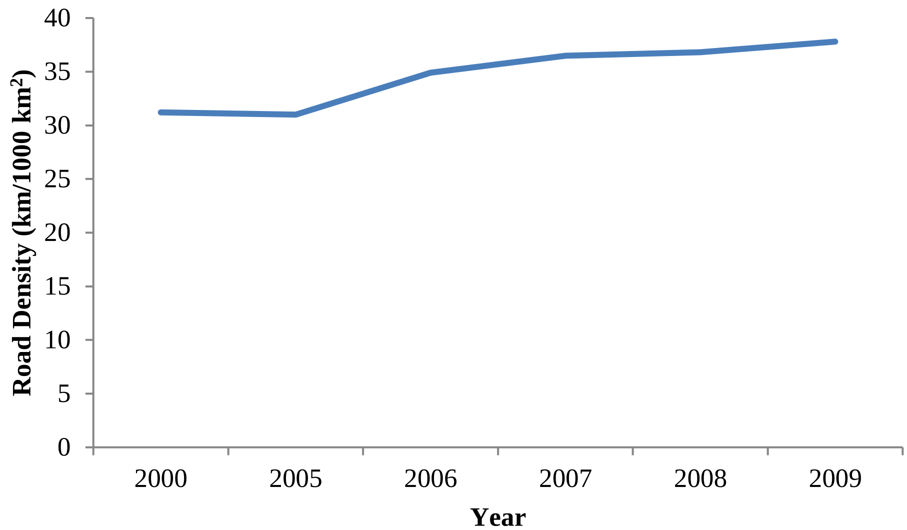


Figure 7: Increase of road density in Russia, 2000-2009.
Source: Federal State Statistics Service 2010b.

Not only has the length of roads and road density increased in Russia as a whole, but also specifically in the Russian Far East. An IIASA interim report on road construction in Russia claimed that the road density was 0.04 km/km^2 in 1994 (Nilsson et al. 2002). As can be seen in figure 8, this number increased to 0.146 km/km^2 little over a decade later according to reports by Viittanen and Ollonqvist (2007). This Far East comparison shows Russian efforts of regional transport expansion expressed through the Federal Highway Agency have succeeded. Increased road expansion from European Russia to the Russian Far East has expanded a web stretching throughout the entire country.

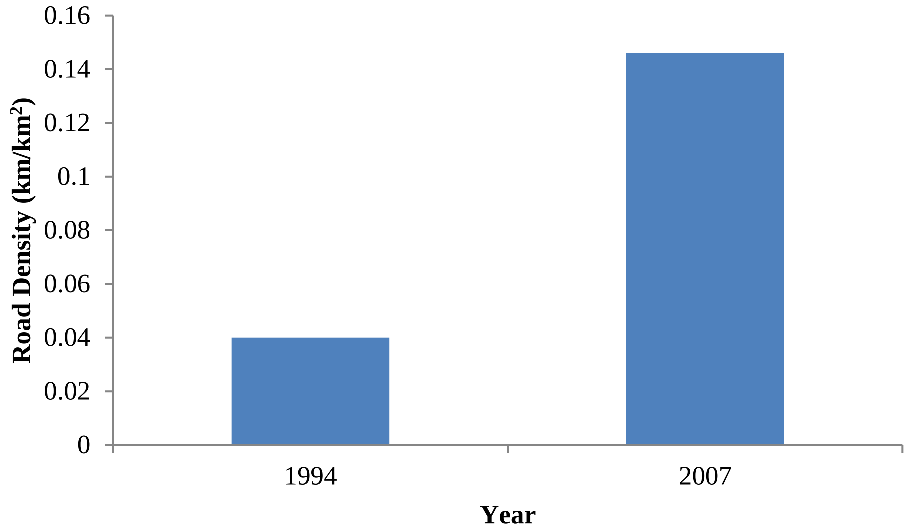


Figure 8: Comparison of road density in the Russian Far East in 1994 and 2007.
Source: Nilsson et al. 2002 and Viitanen and Ollonqvist 2011.

The next category of data focuses on Amur tiger population. The story of these endangered animals begins during the start of the 20th century. In the early 1900s, Russian laws were less strict allowing poachers and loggers to destroy the environment and kill countless tigers; it was not until 1947 when the Russian Government made tiger hunting illegal (Miquelle et al. 2005, 1). This was a necessary change due to the fact that only about 20-30 Amur tigers remained living in the Russian Far East during the time (Miquelle et al. 2005, 4). The Amur tiger was suddenly in the spotlight after people around the world began to acknowledge the eminent extinction of these animals. This caused an emergence of conservation strategies and programs to save the tiger (Miquelle et al. 2005 4). Based on previous surveys conducted, data suggests Amur tigers began to make a recovery in population numbers during the mid 20th century. Figure 9 shows the increasing number of Amur tigers in two regions of the Russian Far East from previous studies compiled by Miquelle et al. (2005). In addition, census data collected by Miquelle et al. (2005) suggests that from 1996 to 2005, the Amur tiger population achieved a stable population state. The 1996 census by Matyushkin et al. (1996) found 415 to 476 Amur tigers in the Russian Far East while Miquelle et al. (2005) found 428 to 502 Amur tigers in the Russian Far East. There is a ten year gap in censuses because 1996 was the last time researchers conducted a full range survey on Amur tigers (Miquelle et al. 2005, 2). According to the "Strategy for Preservation of the Amur tiger in Russia", Russia is only required to conduct a full range survey every five to ten years (Miquelle et al. 2005, 4). Before Miquelle et al. (2005), the last Amur tiger survey was conducted in 1996, explaining the need for her survey in 2005 (Miquelle et al. 2005, 4). However, conducting censuses decades apart does not accurately depict the trend in population fluctuations found in other censuses such as one conducted by Miquelle et al. (2010) over the course of thirteen years.

Year	Primorski Krai	Khabarovski Krai	Total	Source of Information
1940	20	No data	20-30	Kaplanov 1947
1952	40-45	No data		Kuzentsov, 1952
1954	48	No data		Kuzentsov, 1954
1957	35	23	58	Bromley, 1957; Florov, 1957
1959	55-65	35	90-100	Abramov, 1962
1965	70	No data		Kudzin, 1966
1970	129-131	20	149-151	Yudakov & Nikolaev, 1973; Kazarinov, 1979
1976			160-170	Bromley, 1977; Kucherenko, 1977
1979	172-195	34	206-229	Pikunov et al., 1983; Kazarinov, 1979
1985	200-210	68-69	240-250	Pikunov, 1990
1986	No data	91		Kazarinov, 1986
1989	275-295	No data		Mesheryakov, 1989
1990	No data	64	349	Mesheryakov, Kucherenko, 1990
1993	No data	54-56		Dunishenko, 1993
1994	No data	57-58		Dunishenko et al..1994
1996	351-405	64-71	415-476	Matyushkin et al., 1996

Figure 9: Recovery of Amur tiger population compiled from previous studies, 1940-1996. Source: Miquelle et al. 2005, 6.

Evidence from Matyushkin et al. (1996) and Miquelle et al. (2005) suggests the Amur tiger population has stabilized since the early 1900s. However, a thirteen year monitoring program conducted in accordance with the Russian National Strategy for Tiger Conservation from 1998-2010 suggests that Amur tiger population is decreasing (Miquelle et al. 2010). The monitoring program mentions that stable Amur tiger populations found in other surveys were not conducted on a regular basis and therefore lack a full range survey producing inefficient and unreliable results (Miquelle et al 2010, 2). In contrast, the monitoring program from 1998-2010 strived to use a methodology to produce reliable and effective data on Amur tiger abundance in the Russian Far East (Miquelle et al 2010, 6). From 1998 to 2010, the number of Amur tigers decreased from 102 to 80 tigers across sixteen site assessments, approximately 18 percent of suitable tiger habitat (Miquelle et al. 2010, 8) (Fig. 10). This is a 22 percent decline and the census emphasizes no results from monitoring sites showed an increase in tiger numbers (Miquelle et al 2010, 2). As figure 10 shows, numbers of tigers increased in 2010 compared to 2009, but the report by Miquelle et al. (2010) explains this slight recovery was largely expected due to several reasons. The expected rebound occurred due to record snows in the Russian Far East in 2009 reducing counts of both tigers and prey and the fact that other sites reported unusually few tigers as well (Miquelle et al. 2010, 24). Despite what seems to be a slight recovery in numbers from 2009 to 2010, their report emphasizes the overall outlook is still not favorable for Amur tigers and significant negative trends are evident (Miquelle et al. 2010, 24).

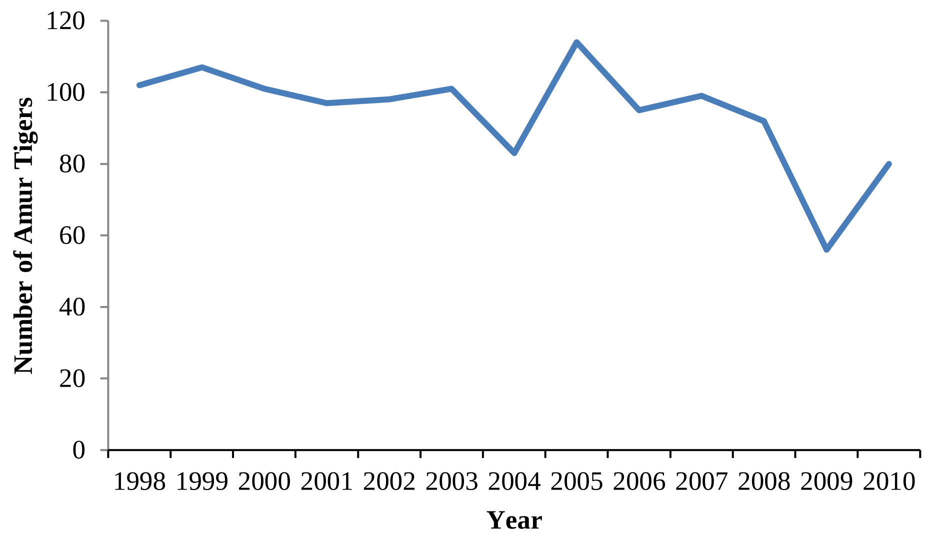
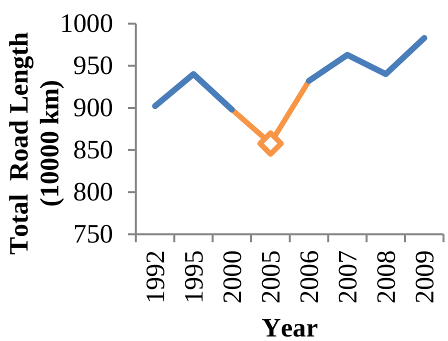


Figure 10: Decrease of Amur tiger population from 1998-2010 during Amur Tiger Monitoring Program in the Russian Far East.
Source: Miquelle et al. 2010.

(a)



(b)

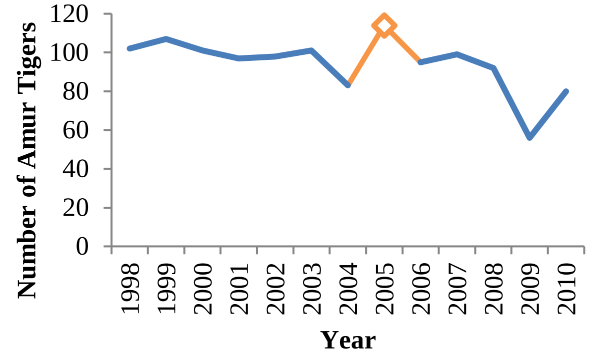


Figure 11A and 11B: (a) Comparison of total road length (10000 km) to (b) number of Amur tigers in 2005 (orange).
Source: Miquelle et al. 2010 and Federal State Statistics Service 2011a.

Data from various sources suggests road construction in the Russian Far East has increased over the past decade. This is around the same time the recovery of Amur tiger populations seems to have slowed or stopped. When comparing road construction to number of Amur tigers in figure 11A and 11B, the length of total motor roads experienced a drop while Amur tiger numbers simultaneously experienced a spike in 2005. This suggests an inverse relationship. In addition, as figure 12 shows, Amur tiger populations decreased from 114 to 56 tigers across sixteen monitoring sites according to a complete survey by Miquelle et al. from 2005-2009 (2010). This represents more than a 50 percent decrease in population numbers. Figure 12 also shows the increase in total road length increased from 85.8 to 98.3 (10000 km) according to the Russian Federal State Statistic Service from 2005-2009 (Federal State Statistic Service 2011a). This represents about a 15 percent increase in roads across Russia. Therefore, data suggests an inverse relationship between road construction and Amur tiger populations.

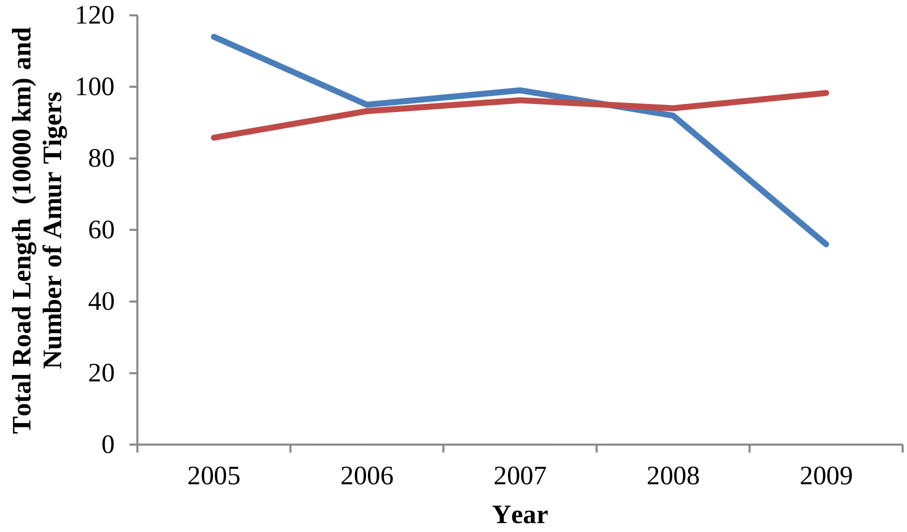


Figure 12: Decrease of Amur tiger population (blue) and increase of length of total motor roads in Russia (red) (10000 km), 2005-2009.
Source: Miquelle et al. 2010 and Federal State Statistics Service 2011a.

The Russian government acknowledges the impact of roads on tigers in a document named "Strategy for the Preservation of the Amur Tiger in the Russian Federation" (Ministry of Natural Resources and Environment 2010). The document notes the appearance of Amur tiger population stability in the late 1990s which has since changed and begun to decline.

> В настоящее время по сравнению с 1990-ми гг. ситуация с состоянием популяции амурского тигра изменилась: выпали из ареала малооблесенные равнинные территории, подвергшиеся интенсивному сельскохозяйственному освоению; усилилось разобщение популяционных группировок Сихотэ-Алиня и Восточно-Манчжурских гор, которые в ближайшее десятилетие могут стать полностью изолированными; наметилась тенденция снижения численности тигра. Изменились и социально-экономические условия в России, что потребовало разработки новой редакции Стратегии сохранения амурского тигра в Российской Федерации.
>
> *Today, however, in comparison to the late 1990s, the situation has changed: the tigers have left the less forested territories that came under more agricultural cultivation; their isolation in a few places has increased; and a tendency towards a new decline in population numbers has been noted. The social-economic conditions in Russia have changed, which requires that we come up with a new strategy for protecting the Amur tigers in the Russian Federation.*
> **Translated by Dr. Yvonne Howell**

This document shows evidence that the Russian government understands these tigers are no longer recovering their population levels but are in need for new strategies of protection. This report goes on to explain the destructive nature of road networks which facilitate increasing numbers of hunters, fishers, and loggers into critical habitat area.

> Осуществление сплошных рубок лесов сопровождается строительством широкой сети лесных дорог для доставки оборудования на вахты лесорубов и вывоза леса. В результате угодья становятся доступными для широких масс населения, которые посещают их для сбора дикоросов, охоты и рыбалки. Лесными дорогами охотно пользуются и амурские тигры, в результате чего нередко попадают под выстрелы автобраконьеров. Усугубляет ситуацию тот факт, что тигры, в первую очередь самцы, при столкновениях с людьми нередко теряют осторожность и появляются совершенно открыто. Таким образом, расширение дорожной сети резко повышает риск гибели тигров. Кроме того, расширение и улучшение дорожной сети способствует доступу в угодья большого числа охотников зимой, в наиболее критический для животных период. В некоторых участках на юге Приморского края численность охотников, занимающихся в угодьях добычей копытных животных, такова, что не оставляет тиграм шанса остаться незамеченными и не быть вспугнутыми.
>
> *The Amur tigers are most negatively affected in the areas where the logging industry is most intensive. In these areas, the tigers are under constant pressure all year long. Clear cutting the forests necessitates the construction of an extensive network of roads, in order to supply the logging sites with equipment, and transport the lumber out. As a result, these areas become accessible to everyone, including hunters, fishers, and others. Tigers are not at all adverse to using the forest roads, and in this way, they become victims of incidental poachers. This situation is exacerbated by the fact that tigers on the roads, especially the males, often lose their caution and appear in the open. People shoot at them. Therefore, the expansion of the road networks sharply increases the risk of death for the tigers. In addition, the expansion and improvement of the road network has allowed more hunters to move in during the winter months, the most critical period of the tiger's annual cycle. In some parts of the south Primorsky region, the number of hunters who occupy the forested lands while hunting for wild sheep is so great, that the tigers cannot avoid them, which again increases the risk of human-tiger encounters.* **Translated by Dr. Yvonne Howell**

The "Strategy for the Preservation of Amur Tigers" explains the expansion of the road network is a critical danger to Amur tigers. The results of this study have shown road expansion is indeed coinciding with a decrease in Amur tiger numbers. From this study I hypothesize that increasing road construction in Russia and the Russian Far East negatively impacts endangered Amur tiger population levels representing an inverse relationship.

Conclusion

The primary motivation for my study is the increasing endangerment of Amur tigers in the Russian Far East. I conclude that increasing road construction in Russia negatively impacts endangered Amur tiger population levels. Evidence is strong to suggest an inverse relationship. My methodology analyzed the relationship between road construction and tiger populations since the early 90s by synthesizing data from two general categories: transportation and Amur tiger population. I reviewed the transportation and Amur tiger population data compiled before analyzing the relationship between the two. In the first category, I reviewed road construction fluctuations through data found on the Russian Federal Highway Agency and Russian Federal State Statistics Service websites. Data suggests a great increase in road construction and road density over the course of the last decade. In the second category, I reviewed three different sets of census data from Matyushkin et al. (1996), Miquelle et al. (2005), and Miquelle et al. (2010) to study Amur tiger population fluctuations throughout time. I found the tiger population was in a stable recovery since the early 1900s but has experienced a decrease as seen by Miquelle et al. (2010) during the last decade. My study of the relationship between roads and Amur tigers in the Russian Far East reveals the increasing trend of road construction throughout Russia and the decreasing trend of Amur tiger populations. Future research is needed to further understand this relationship to improve transportation plans with minimal Amur tiger disturbance. To my knowledge, Kerley et al. (2002) is the first study to acknowledge the harm roads present for endangered Amur tiger populations and the first study to mention the direct impact of roads. Therefore, there is a clear need for more research in this area.

The road—tiger relationship is imperative to understand through a road ecology framework that is interdisciplinary in order to underscore contradictory policies within the Russian government. Russian policymakers support programs like the "Development of Transport System of Russian Federation" and plan to spend more than $285 billion dollars to double the rate of road building and cars (Ministry of Transport of Russian Federation 2009 and The Guardian 2011). At the same time, the Russian government supports projects such as the "Amur Tiger Monitoring Program" and the "Strategy of the Preservation of Amur Tigers" (Wildlife Conservation Society 2011 and Ministry of Natural Resources and Environment 2010). My study illustrates how these are conflicting policies, creating inefficient methods of both road construction and the preservation of endangered Amur tigers.

Collaboration among transportation planners and conservationists is necessary to save the last of the Amur tigers. Researchers from around the world must bridge the information gap between countries. This will prevent the language barrier that stops the flow of vital information about efficient strategies to protect our wildlife from the worldwide increase of road construction. While the problem of conflicts between roads and wildlife cannot be simply solved, in the long run we must question if society is willing to make changes in order to prevent further degradation and stop the increasing amount of roads in an ever expanding anthropocentric world (Forman et al. 2003, xvi).

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I pledge that I have neither received nor given unauthorized assistance during the completion of this work: Elizabeth Cohan