Impacts of Climate Change on Wildlife Conservation in the Samiria River Basin of the Pacaya-Samiria National Reserve, Peru

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Introduction

Climate changes are occurring globally at ever greater intensities. While the debate on climate change continues there are increasing examples of abnormal climatic events on every continent, including South America. The frequency and intensity of rainfall have caused an increase in the number of floods and droughts reported throughout tropical Latin America (DFID 2010).Glaciers have receded in the Andes Mountains and there has been a greater intensity and frequency of tropical storms and hurricanes (McMullen 2009).

Climate changes in South America are impacting environmental services, plant and animal distributions and diversity, and the food production, water availability, and socio-economics of rural and urban people (Schneider y Root 2002, DFID 2010). Entire regions of Latin America are being affected by climate change, similar to other continents. South American countries are taking actions and many governments have put climate change on the political agenda.

Peru has been at the forefront of climate change in South America. Rapid glacier retreat in the tropical Andes is at an intensity that has not occurred for over 1,000 years and changing climate is causing altitudinal shifts in ecosystems, including plant communities and animal distributions in the highlands of Peru (Matzen 2010). The repercussions of these climate changes are impacting the production systems and the rural people. Strategies for adaptation and mitigation have been developed and tested in the Peruvian Andes.

There has been less attention to climate change in the Peruvian Amazon (Cáceres 2010, GOREL 2011). Results from long term research presented in this report clearly show that the Peruvian Amazon is undergoing dramatic impacts from climate change in the lowland flooded forest ecosystems. Over the past five years the greater intensity of flooding and the occasional drought have impacted the biodiversity and the local people, resulting in population changes of wildlife and resource use changes of indigenous communities.

This report examines the impact of climate change on wildlife and people in the flooded forests of the Peruvian Amazon. The major findings over the past 8 years have demonstrated the impact of climate change on wildlife species in flooded forests of the Peruvian Amazon and the need for conservation actions. Results have continued to show the importance of incorporating local people in reserve management through community based sustainable resource useof the principal livelihood products of fish and bush meat. However, results have shown how climate change is impacting sustainability of subsistence resource uses. This highlights the importance of involving local communities in incentive based conservation as a mechanism for ecosystem management and how this can help mitigate impacts of climate change on local people through improving livelihoods.

During the late 1990´s and first ten years of the 21st century studies on climate change in the Amazon focused on dieback of the rainforest and its conversion to savanna habitat (Cook &Vizy 2008, Fearnside 2004). Climate models predicted that with warmer temperatures the Amazon would experience decreased rainfall resulting in greater fire risk and in turn savannas of the cerrado overtaking the Amazon (Malhi 2008). Deforestation along the southern rim would accelerate these changes (Killeen &Solorzano 2008). Intensive droughts of 2005 and 2010 supported these predictions (Zeng et al. 2008, Asner&Alencar 2010). Concern about Amazon dieback is multiple, since it impacts biodiversity, livelihoods and shrinks size of the Amazon carbon

sink (Betts et al. 2008). Indeed, the Amazon basin is the largest terrestrial carbon sink on Earth (Cowling &Shin 2008).

More recently better climate models show a more complex scenario of climate change in the Amazon. Models using the IPCC-AR4 predict the western Amazon basin will actually become wetter with greater flooding during the high water season, and extreme conditions becoming more frequent (Cook et al. 2012, Langerwisch et al. 2012). These models also predict that extreme drought during the low water season will occur, but with a lower probability than intensive flooding (Cook et al. 2012). In contrast, these models predict that the southern Amazon will become drier, but to a lesser extent then was predicted by previous models (Cook et al. 2012).

The empirical evidence from western Amazonia, where the project is working, concurs with more recent models. Each year the Amazon River goes through seasonal changes between the flooding period from December to June and the low water period between July to November (Junk et al. 1989). However, these normal seasonal changes are now becoming more intense. In 2009, the Amazon River was at a record high, flooding huge areas of Amazonian forests. In 2010 the water levels of the Amazon River were at record lows resulting in extreme dry conditions and drought. More recently in 2011, high water exceeded those of 2009. In 2012 the water level flooded with greater intensity than in previous years and became a new record high. The low water season was also relative intensive, but did not exceed previous records. In 2013 the water level was again at unusually high levels, but not quite as intensive as 2012. The consecutive intensive recent flooding and the occasional intensive drought concur with the IPCC-AR4 models (Cook et al. 2012, Langerwisch et al. 2012). However, these models predicted that intensive events would only occur during the end of the 21st century, when in fact they are already occurring in the second decade.

The research presented in this report analyses the impact of the recent climatic fluctuations of drought and intensive inundations on the wildlife and people. These recent climate fluctuations are in accordance with the IPCC-AR4 models on climate change in western Amazonia. The concordance between the recent climate fluctuations and the IPCC-AR4 models allows for an analysis of what is likely to happen in the future if the models are correct. Therefore, when the statement "impacts of recent climate change" is used in this report, it refers to the impact of recent climate fluctuations in accordance with the IPCC-AR4 models and what is predicted to happen in the future under longer-term climate changes.

The evidence of impacts of recent climate change presented in this report use correlations between the observed intensive inundations and drought that have occurred over the past five years, 2009-2013, and changes in wildlife populations. The previous three year period, 2006-2008, had more average climate conditions and trends in wildlife populations are compared between the two sets of years, those with more normal conditions and those with greater climate fluctuations. We realize that the cause and effect relationships of correlations need to be treated with caution. But, at the same time, the most obvious variable that changed between the two sets of years was the difference in climate fluctuations.

The confidence that observed changes in wildlife populations are actually a result of recent climate change is greater if different wildlife species or assemblages of species show the same trends. A similar repeated observation in different species suggests that the cause and effect relationships between animal populations and recent climate changes are probably accurate.

Research on wildlife populations is being conducted on river dolphins, primates, fish, caimans, macaws, deer, peccaries, tapirs, jaguars, giant river otters, wading birds, game birdsand other species to understand how ever increasing climatic changes are impacting their ecology, behavior and populations. The research team is also working with the local Indian communities to see how the changes are affecting their fishing and bushmeat hunting that they depend on for their daily livelihood.

Wildlife of the Samiria River lives in an ecosystem that is driven by large seasonal fluctuations occurring between high and low water seasons. The ecology of aquatic and terrestrial wildlife revolves around these seasonal changes in water level (Aquino et al. 2001).Ecological conditions of long periods of flooding, up to 6 months, are very harsh on much of the floral and faunal community(Junk &Piedade 1997). Many plant species cannot withstand long periods of inundation and diversity of plants in the heavily flooded areas is lower than lightly and non-flooded levees (De Simone et al. 2002). Likewise, terrestrial wildlife (deer, peccaries, rodents and tapir) must seek out floodplain islands or levees during high water seasons, which have increased competition and predation pressures (Bodmer 1990, Junk & Da Silva 1997). Even arboreal wildlife is impacted by flooding, since many fruit trees are quite seasonal in flooded forests, resulting in seasons with low food production (Ayres 1986).

Aquatic wildlife is equally affected by large seasonal inundations. During the flooded periods fish enter water laden forests and feed on the abundance of vegetative and animal production, especially abundant fruits, invertebrates and other living organisms trapped in the annual floods (Junk et al. 1997). Indeed, many tree species fruit during this season and rely on the fish as their primary means of seed dispersal (Goulding 1980). During the flooded period many fish populations reproduce within the inundated forests (Ortega &Hidalgo2008). Other aquatic wildlife have a more difficult time during floods, such as dolphins, giant river otter and other fish predators, since their prey is more sparsely distributed throughout the large expanses of flooded forests. When waters recede during dry months, fish populations become condensed in the reduced lakes, rivers and channels with ever increasing competition and predation. During this period many fish populations migrate out of smaller rivers and into larger rivers (Granado-Lorencio et al. 2007). Dolphins, wading birds and other fish predators have an abundance of prey during the low water season and even follow fish migrations down rivers and channels.

People who live in flooded forests also have adapted to seasonal changes in both use of natural resources and their agriculture (Goulding et al. 1996). During high water seasons fishing is more difficult, since fish are dispersed throughout inundated forests. However, during this period hunting becomes easier with the large bushmeat species, such as deer, peccaries and tapir being trapped on levees (Bodmer et al. 1998). In contrast, during low water seasons bush meat species become difficult to hunt as they range throughout the entire forests, and the fish become easy prey being trapped in reduced water bodies of lakes, channels and rivers (Tejerina-Garro et al. 1998)). Local indigenous people of floodplain forests alter their hunting and fishing accordingly, with a greater emphasis on hunting during high water seasons and a greater focus on fishing during low water seasons (Bodmer et al. 1998).

The normal cycles in the Amazon forests are now being disrupted by extreme flooding and drought events of recent years. Flooded forests are particularly important at understanding impacts of climate change in the Amazon, since the aquatic and terrestrial interface between high and low water seasons makes this habitat sensitive to greater seasonal variations (Hamilton et al.

2002). Water level change is a robust measure of climate fluctuation, since variations are on a weekly, or even monthly basis as the waters raise and recede. This is unlike temperature and rainfall, which can have dramatic daily fluctuations resulting in large standard deviations (Wittmann et al. 2004).

The project is using a set of key wildlife species to evaluate conservation strategies and impact of climate change on species and local people of the Samiria River basin in the Pacaya-Samiria National Reserve. These species groups include the following:

1) River dolphins were used as indicator species of the aquatic systems.
2) Macaws were used as indicators of the arboreal forest fruit production.
3) Primate populations were monitored to evaluate arboreal mammals.
4) Ungulates and rodents are important bush meat species and were used to examine how climate change is impacting sustainability of hunting.
5) Carnivores, marsupials and edentates were used to monitor non-bush meat mammals.
6) Giant river otters and manatees were monitored to evaluate the recovery of vulnerable species.
7) Game bird populations were monitored to evaluate large bodied forest birds.
8) Caiman populations were monitored to evaluate the recovery of black caiman populations.
9) The abundance and age structure of fish were monitored to determine the status of fish populations and local fisheries.
10) The livelihoods of local Cocama people were evaluated under the current climate change conditions.

The Pacaya-Samiria National Reserve extends over an area of 2,080,000 ha in the Department of Loreto, Peru. The study areas of the Samiria River basin included 1) the complex hyrdoscape of the mouth with its lakes, channels and river. This area was also classified as the commonly hunted zone and is where the local Cocama villages are situated. 2) The mid-section of the Samiria River basin is located in the region of PV2 Tachcocha and Huistolake and stream and was classified as the occasionally hunted zone. 3) The upper section of the basin between PV3 Hungurari and PV4 Pithecia, which was classified as the infrequently hunted zone (Figure 1 Map).

Major Habitat Types and Flood Levels

The general habitat types and flood levels in the Samiria River basin can be divided into six broad categories, including riverine forests, open understory forests, levee forests, liana forests, tree fall gaps and aguaje palm swamps.

The riverine forests of the Samiria basin are characterized by a blanket of vegetation that covers the river edge vegetation. Compared to the Marañon or Amazonas River, the Samiria River has slower currents caused by the vegetation slowing the flow rate as water moves through the flooded forests. In addition the quantity of water in the Samiria is much less than the larger rivers. Thus, the physical force of water flow, which includes both flow rate and water quantity, is much less than larger rivers and this results in less erosion of river banks and a more stable riverine habitat. This stability allows the riverine forests to produce a thickly covered blanket of vegetation, since the open river results in direct sun light and high plant productivity through photosynthesis. Understory plants behind the blanket of vegetation is often sparse due to the shaded conditions.

There can be considerable variation in the flood levels of riverine forests, ranging from deeply flooded areas (2m) to non-flooded riverine habitat. The deeply flooded areas have a more open understory behind the blanket of vegetation, since the floods result in die off of sapling plants that become completely inundated during the high water season.

The open understory flooded forests are characterized by mature emergent trees and a sparse understory. During the flooded period the majority of saplings are killed by the inundations, since they become completely submerged underwater. Very few saplings reach a height that enables them to survive the annual floods. When the floods recede the understory is quite bare and open. Towards the end of the dry season a considerable number of saplings have grown, only to be eliminated when the floods return. The older trees of this habitat are tall emergent individuals often reaching over 30m in height. The annual floods during a normal year are around 1 – 1.5 m deep.

The levee habitats are non-flooded habitats during normal years. Levees have the greatest diversity of plant species in the flooded forests and resemble the terra firme non-flooded forests both in species composition and physical structure. Levee forests have large emergent trees with canopies over 30m in height. The understory vegetation is quite dense and resembles that of terra firme forests. During normal years these forests do not flood, however, during the recent intensive floods many levee forests become inundated up to 1 m deep. Levee habitats provide refuge for terrestrial wildlife during the high water season. During peak flooding in the mid-section of the Samiria non-flooded levees only account for around 4% of the total area. However, during recent intensively flooded years this drops to 2%, and during the historic flood levels of 2012 non-flooded levees only made up 1% of the total area.

Liana forests are characterized by a low, broken canopy with dense understory vines and sparse sapling growth. These forests are low lying areas that flood intensively. Liana forests are remnants of old oxbow lakes and channels that have become filled with sediments. They have low plant diversity, since the long duration of flooding limits species composition. The canopy usually ranges from 10-20m in height and varies greatly. Annual flooding can be up to 8 months and during the peak flooding the water depth ranges from 2 to 3+ m in normal years.

Tree falls can occur in any of the flooded forest habitats. Tree canopies are often attached with lianas and when one tree falls it often pulls down neighboring individuals. The soft alluvial soil of flooded forests results in tree falls caused by wind blow, especially after tropical storm winds. Vegetative growth is rapid in tree fall gaps and they are categorized as recent gaps (1-2 years), mid-aged gaps (3-4 years), and older gaps (5+ years).

Aguaje palm swamps are forests dominated by the Mauritiaflexuosa palm tree. This habitat is characterized by peat-like water filled soil in backswamp areas. The understory is sparse and dominated by young aguaje palms. Species diversity is low, but wildlife food is great when the aguaje fruit is in production. Aguaje palm swamps vary greatly in size, from small swamps of one to several hectares, to larger swamps that can be several kilometers squared. Annual flooding is around 1.5 – 2 m deep during normal years, and the water filled conditions remain throughout the dry season.

Recent Climate Change and Water Level

Water level is a reliable measure of climate change for several reasons. Water level has a gradual increase and decrease in the upper Amazon and is a steady measurement, unlike temperature or rainfall which can vary greatly even on a daily basis. Water level in the upper Amazon is similar over very large areas and in not site specific, in contrast to rainfall which can vary significantly even at sites in close proximity. Water level is also very easy to measure and records have been taken in the Amazon for over 100 years, so long term trends are available. Lastly, water level has both direct and indirect impacts on wildlife and the flooded forests are where this impact is the greatest and can be measured easiest (Bodmer et al. 2011).

Water levels during the flooded and dry seasons were at normal levels between 2006 and 2008 and did not exceed long term variations. In contrast in 2009, the Amazon River was at a record high, flooding huge areas of Amazonian forests. In 2010 the water levels of the Amazon River were at record lows resulting in extreme dry conditions and drought. More recently in 2011, high water exceeded those of 2009. In 2012 the water level flooded with greater intensity than in previous years and became a new record high. In 2013 water levels were again unusually high, but slightly less than 2012 (Figure 2).

Water levels were recorded from the SENAMHI y Coast Guard Stations of San Reyes, Rio Marañon and Iquitos, respectively. The San Reyes station is in the vicinity of the Samiria River. Both the San Reyes and Iquitos stations had very tight concordance. For the analysis years were categorized as 1) Normal, 2) Drought, and 3) Intensive floods, as follows:

2006: normal

2007: normal

2008: normal

2009: intensive floods

2010: drought

2011: intensive floods

2012: intensive floods

2013: intensive floods

Wildlife Monitoring

Animal populations fluctuate in natural environments from extrinsic and intrinsic variables. Extrinsic factors are those outside the species and can include a variety of variables, including physical conditions (such as droughts and floods) and human activities (such as resource use and pollution). Intrinsic variables include the biological factors such as interspecific and intraspecific competition, predation, parasites and diseases. Population fluctuations in vertebrate wildlife species are usually observed over multi year periods and analyses require long term effort.

Monitoring of wildlife is the acquisition of population data over numerous years with short term studies being 1-2 years, medium term studies being 3-5 years and longer term studies being 6+ years. Data can be collected during specific seasons or throughout the year, and analyses can compare results between years, different sites and seasons. Monitoring populations is essential to many conservation strategies, since it provides information on whether conservation efforts are being successful in terms of wildlife populations. Wildlife monitoring also provides information on the impact of threats, such as habitat destruction, overexploitation, pollution and climate change.

The two major types of wildlife monitoring include density and abundance analysis. Density analysis yields the actual population size in terms of individuals per unit area, which for larger vertebrates is individuals per kilometer squared (ind/km2). Abundance analysis provides information on the trends in populations against some standard variable. Some common variables include time, distance and unit effort. Sample size is very important for determining the statistical confidence in population trends and determining if fluctuations are significant. For many species this requires large data sets and extensive fieldwork.

Methods

Terrestrial mammals and game birds
Line censuses along transect trails were used to conduct terrestrial mammal and game bird censuses. Census trails between 2-5 km in length were surveyed repeatedly. Information registered on a census includes: day, site, species, number of individuals, and perpendicular distance from the individual to the transect line, habitat, time, distance travelled and weather conditions.

The method assumes that all the animals that are on the center of the line transect (0 m perpendicular distance) will be observed. The technique is based on the notion that observers do not see all the animals that are off the center of the line, and that the probability of sighting an animal depends on the distance of the animal from the line. Animals closer to the line have a higher probability of being seen than animals further from the line. The perpendicular distance of all solitary animals sighted, or the first animal sighted in a social species were recorded (Buckland *et al.* 1993). The DISTANCE estimation calculates the animals that you did not see, and includes these animals in the density estimate.

The method relies on measuring the perpendicular distance of animals before they move as a consequence of seeing the observer. That means observers must try and see the animal before they sight the observer. It also means observers must measure the perpendicular distance of the first sighting. If animals move because of the observer than the estimate will be biased. With the DISTANCE program trails do not have to be straight, but the perpendicular distances must be measured at the correct angle of the center line. The perpendicular distance will be measured directly from the point of first sighting (Buckland *et al.* 1993).

The method assumes that animals are independently dispersed throughout the habitat. Since individual animals within a social group are not independent, but move dependent upon one another, animal groups in social species must be considered as the sampling unit. Thus, DISTANCE will calculate the density of animal groups (Buckland *et al.* 1993).

The equipment used for line transects included: a map of the area, a compass, data sheets, pens and binoculars. Trails were not placed with any pre-determined knowledge of the distribution of the animals. Censuses were done using small groups of three or four observers. Transects were walked slowly and quietly (500-1,000 m/hr) between 7am and 3pm.

Census information was analysed using DISTANCE software (Thomas *et al*. 2002). This program is regularly used in calculating individual or group densities (Buckland *et al*. 1993) and can estimate densities if the distribution of sightings within a transect line forms a clear probability function. When the number of sightings is deemed insufficient to determine a probability function, the method known as 'fixed width' was used to estimate the densities.

Camera Traps
Digital camera traps with heat/motion sensors were used to photograph ungulates, rodents, cats, armadillos and other terrestrial species. Twenty paired StealthCam passive infrared camera trap stations were set over an area of *c.* 50 km2 and distributed across habitat types. Detection histories were constructed for each species using capture rates. Trails were used to place camera traps throughout each sampling area. Cameras were checked once a week for batteries and to download pictures (Pittet 2012).

Censuses of caimans
To assess the population and ecology of caiman species in the ecosystem it is necessary to gain an understanding of their population size. Aquatic transects were used traveling upstream or downstream on the main river and in nearby channels or lakes. A GPS was used to determine the distance surveyed each night. All caimans seen were identified to the species level as best as possible and size of the caiman and location were noted. These data, along with data collected from captured caimans, were used to analyze the caiman population size. Caiman surveys and captures were conducted from a small boat fitted with a 15-horsepower engine. Caimans were located by their eye reflections using a 12-volt spotlight and approached to a distance where the engine was silenced and the boat paddled closer.

Noosing was used to capture caimans. The noose was made of a long pole about 2 m in length with a loop of rope that can be pulled tight over the caiman's neck. The caimans were secured with rope tied around the jaw behind the nostrils and around the neck. Total body length was measured from the tip of the snout to the tip of the tail, while head length was measured from the tip of the snout to the posterior edge of the orbital (the vent). The sex was also determined. Weight of the caiman was recorded in kilograms. A measuring tape and weighing scales was used (Swan 2012).

The population abundance of each species was calculated using the formula N/L, where N= the number of individuals and L= the distance travelled in kilometers. The results indicate the number of individuals per kilometer.

Censuses of macaws
Point counts were used to monitor macaws. Between eight and nine points was established in each sampling unit separated by 500m. A GPS was used to measure the distance between points. Fifteen minutes was spent at each point. Censuses were carried out twice a day in the morning (5:30-9:00h) and afternoon (16:00-18:30).The censuses usually lasted longer in the morning than in the afternoon.

Within the 15-min counts, all macaw species either perched or flying were noted. The distances of the birds from the observer were estimated where possible. A motorized boat was used to travel to each point. Abundance data were calculated in each sampling zone. This was done by adding the total number of sightings and dividing this number by the number of points. Thus, abundance is expressed as the number of individuals per point.

Censuses of dolphins

Dolphin censuses were carried out at both sites. Five kilometers was travelled daily from 9:30 to 13:00 h along the center of the river using a boat. Information collected included: species, group size, group composition, behavior (travelling, fishing, playing), time, and any additional observations.

Data were analyzed using fixed width:

Where:

$$D = \frac{N}{AL}$$

        D= Density
        N= Number of individuals
        A= River width
        L= Distance travelled

Aquatic surveys were used to census dolphins. A GPS (Global Positioning System) was used to determine the length of each aquatic census. Dolphin transects usually take three to four hours to complete depending on the speed at which the river is flowing.

A motorized boat was used to carry out the census. Any dolphins seen coming to the surface for air, swimming with their heads above water, sunbathing or swimming just below the surface of the water (i.e. no deeper than 5 cm) were recorded. Care was taken not to double count any dolphin sightings. Behavioral information on the dolphin activity was also recorded along with the size class of each dolphin sighting. For each transect the weather conditions and the start and finish times were recorded.

Censuses of fish

During the censuses green gill nets of 3.5'' were used in lakes and channels with weak currents and white gill nets in the river. Fishing points were located on shores or banks where there is aquatic vegetation or shrubs, although meanders are the preferred areas. Individuals were identified, measured and weighed. Catch per unit effort was calculated by the number of individuals per species caught and the effort spent fishing at each zone.

Habitats were also compared (lake, channel, river) and diversity indices were used. Productivity of fish was shown in terms of catch per unit effort, using the 'biomass captured per effort' method. The CPUE method is a robust indicator over time for the level of abundance, density and pressure fishing in a given zone (Hinton & Maunder 2004).The length-frequency analysis helps to predict biological impacts of fisheries. A harvest focused on juveniles, for example, causes greater impact than a harvest of adult fish not in their breeding period.

Giant River Otter

Censuses were conducted for two months intervals. Sample counts were used to compare relative abundance between censuses rather than absolute counts which would have required identification of all individuals. Censuses were conducted by boat, scanning with binoculars and listening for otter calls. We recorded group sizes and locations using a handheld Global Position System (GPS), which we also used to calculate the length of each transect. Double counting was avoided by keeping a constant boat speed and where possible by identifying groups by the unique throat markings of individuals. The total length of each transect was recorded, along with the width and type of the body of water (Recharte& Bodmer 2009).

Sample sizes

Large sample sizes are needed to have confidence in the results and the study has had increasing sample sizes over the years. Sample sizes for 2013 included 930 km of terrestrial transects, 922 km of dolphin transects, 838 km of caiman transects, 968 macaw points, 372 fishing hours, 367 km of wading bird transects and 1010 camera trap days.

Wildlife Impacted by Droughts

The Amazon basin has experienced two recent drought events over the past decade. In 2005 there was a severe drought that was particularly strong in the western and south-western Amazon. At the time it was reported as being a one-in-100-year event. Subsequently, in 2010, just 5 years later, an even more severe drought occurred that was widespread throughout the Amazon (Cook et al. 2012). Thus, over a period of 5 years the Amazon basin experienced two droughts of magnitudes not reported in 100 years of recorded water level history.

Predictions of recent climate change models using the IPCC-AR4 method predict that western Amazonia will experience severe occasional droughts as a consequence of climate change (Cook et al. 2012, Langerwisch et al. 2012). Results of the research presented in the following sections show the impacts of the 2010 drought on wildlife populations of the Samiria River basin. These results provide an indication of what will happen if drought events continue to happen in the Amazon basin as a consequence of global climate change.

Flooded forests of the Pacaya-Samiria National Reserve have a predictable annual cycle of high water and low water seasons. The low water season usually begins in June as the rains in the Andean foothills subside. Water levels begin to recede and continue fall through July and August with the lowest water levels usually occurring in September. In normal dry season years the Samiria River depth varies around 4 – 8 meters. Many fish species reproduce in the flooded forests during the high water season with large fish migrations occurring as water resides in the dry season. Annual movements of dolphins towards the river mouth are observed and large flocks of migratory cormorants and egrets congregate along the lower Samiria River to feed on the migratory fish. Caimans retreat from the smaller steams and flooded areas and abound along the river banks and river turtles lay their eggs in the abundant sand beaches.

During drought years the conditions in the Samiria River basin became extreme. Water levels fell to such an extent that in many sections there was less than a meter of depth. Shores expanded well into the river and stagnant flow resulted in algae blooms. Dolphins had limited areas to fish

and were restricted to the surface. Streams, channels and lakes dried out to mere pools of water. Dead fish abounded in the water and shores. Animal carcasses became frequent with flocks of vultures eating the carrion, including dead dolphins, manatees, caimans, and wading birds. The hot stagnant air had a smell of rot and decay. Local people complained about the water and stomach illness became common among the villages. Occasional afternoon rain storms helped to alleviate the conditions, but only for short periods, until the river began to rise again.

The following sections show how the dolphins, wading birds, fish and caimans are negatively impacted by drought conditions. All of these species depend on the aquatic ecosystem, which in drought years dries out and affects populations of wildlife that live and feed in the river, channels and lakes.

Dolphins

Pink river (*Iniageoffrensis*) and grey river dolphins (*Sotaliafluviatilis*) were used as indicator species for the aquatic hydroscape. These species are appropriate as indicator species because 1) they are top predators of the hydroscape, 2) they are not intentionally killed by people due to strong taboos, 3) they can move in and out of river systems over short periods of time, and 4) they are easy to count and observe. The dolphin's ability to move widely means that changes in dolphin populations within a river system will be caused more by dolphins leaving an area or immigrating into an area rather than a result of mortality or reproduction. Thus, if a hyrdoscape is going through negative changes, such as pollution or overfishing, dolphin numbers will decrease rapidly. Likewise, if a river system becomes healthier than surrounding hydroscopes dolphin numbers would increase from dolphins moving into the area.

Results from this research show some important consequences of the extreme variations in water levels that have been occurring over the past several years on the dolphin populations. Extreme variations in water levels are having a clear impact on the dolphins with drought resulting in lower numbers and floods resulting in healthier numbers. However, these changes are not immediate with changes in dolphin numbers lasting for several years after an extreme low water level event. This impact began during the initial record high waters of 2009 and has continued through the drought of 2010 and high waters of 2011, 2012 and 2013.

The populations of pink river dolphins between 2006-2013 was consistently greater than the grey river dolphin (Z(U)=5.9492, P=0.0001). Overall, pink river dolphins had an average density of 3.22 +0.76ind/km2 and grey river dolphins 1.43 +0.43 ind/km2. Both the pink and grey river dolphins use the length of the Samiria River differently throughout the year, with the dolphins moving up and down the river depending on the season. Therefore, the analysis of population changes over the years only used data from the August – September period, which corresponds to the annual low water season. During the low water season dolphins use river habitats to a much greater extent, whereas in the high water season dolphins are using lakes and channels more than river habitats. The greater use of river habitats by dolphins during the low water season also makes multi-year comparisons more robust by focusing on dry season data.

Using results from 2006-2013, pink river dolphins decreased in density in the SamiriaRiver between 2007 and 2011, began to increase in 2012, and in 2013 showed an even greater increase in numbers (Figure 3a). The population of pink river dolphins has always been greatest at the mouth of the Samiria River, compared to mid and upper sections. However, at the mouth of the

Samiria River pink river dolphins decreased from the drought of 2010 and have only recently increased in 2012 and 2013 following three years of heavy flooding. In 2011 pink river dolphins at the mouth were at a low of 2.36±0.75 ind/km, compared to 3.76±1.00 ind/km in 2012 and 3.77 ±0.79ind/km in 2013.

The drought in 2010 had a significant impact on dolphin populations. The extreme low water conditions of 2010 resulted in lower dolphin numbers throughout the Samiria River. Overall, the pink river dolphin numbers decreased by 47% and the grey river dolphin by 49% in September and October 2010.Results from 2011 show that the pink river dolphin did not recover fully from the drought, and populations continued to decrease despite higher water levels in 2011. It was only in 2012 and 2013 that the pink river dolphin increased in numbers. The negative impact of a drought appears to have lasted two years, and positive growth following consecutive high floods also appears to have a multi-year lag time.

This same trend was seen in the mid-section of the Samiria River. The pink river dolphin has decreased in population since the greater variations in water level began. In 2011, the pink river dolphin was at a low of 1.02±0.93 ind/km following the drought of 2010 and only began to increase in 2012 with 2.62±1.41 ind/km, and a further increase in2013 of 2.68 ±0.74 ind/km. Similar to the mouth, the drought had a two year negative impact and positive growth from consecutive flooding occurred after two years.

The grey river dolphin has also been impacted by the extreme climatic variations in water level since they began in 2009, but to a lesser extent than the pink river dolphin. The grey river dolphin has always had smaller populations at the mouth of the Samiria River than the pink river dolphin. The grey river dolphin population initially decreased at the mouth of the Samiria River in 2009 and the lower numbers have been consistent through to 2012 and an increase in numbers in 2013. In 2013 the grey river dolphin was 1.68 ±0.63ind/km at the mouth compared to the average of 1.90 ind/km and the peak in 2006 of 3.28 ±1.35 (Figure 3b).

In the mid-section of the Samiria River the grey river dolphin was increasing between 2006 to 2008 and then decreased in 2009 at the beginning of the greater climatic variations in water level. The lower numbers of grey river dolphins have been relatively constant between 2009 and2013. In 2012, the grey river dolphin was rather low with 0.59±0.073 ind/km at the mid-section of the Samiria River and has increased in 2013 to 1.18 ±0.36 ind/km compared to the average of 1.32ind/km and the peak in 2008 of 2.61±0.61 ind/km.

Demographics of pink river dolphins have changed since greater variations in water level have been observed in the Samiria River. In 2008, prior to the water level changes pink river dolphins had an average composition along the river of 93.5% adults and 6.5% juveniles and young. In 2011, after three years of greater variations in water level and decreasing pink river dolphin populations the demography consisted of 85.9% adults and 14.1% juveniles and young. In 2012 it appears that the pink river dolphin is reproducing even greater with 66.25% adults and 33.75% juveniles and young. In 2013 the proportion of young and juvenile pink river dolphin increased even greater with 46% of the population being either young or juveniles. The increase in juveniles and young indicates a pink river dolphin population starting to recover from perturbations, which is commonly observed in mammalian systems. The larger and more stable population prior to the water level variations shows an adult dominated population with less reproduction. As the adult population decreased between 2009 and 2011 the reproduction of individuals has increased and

the demographics show a greater percentage of juvenile and young individuals, which is now reflected in increasing populations.

Demographics of grey river dolphins have also changed since greater variations in water level have been observed in the Samiria River. The demographic changes in grey river dolphins have been less intensive than the pink river dolphins, which mirrors the population declines that have been greater in the pink than the grey river dolphins. In 2008, prior to the water level changes the grey river dolphin had an average composition along the river of 91.4% adults and 8.6% juveniles and young. In 2011, the demography consisted of 85.8% adults and 14.2% juveniles and young, and in 2012 there were 77.9% adults and 22.1% juveniles and young. In 2013 the proportion of young and juvenile grey river dolphin increased further with 42% of the population being young or juveniles. Similar to the pink river dolphin, the increase in juveniles and young grey river dolphin indicates a population starting to recover from perturbations. The reproduction of grey river dolphins has increased as the populations have been declining from greater water level variations that have impacted the dolphins.

Changes in dolphins numbers is directly related to the fish populations. This relationship has to do with several variables. During intensive floods fish populations have greater reproduction due to better and longer access to flooded forests. However, during intensive floods fish are less dense due the increase in water volume, making fishing by dolphins more difficult. This would explain the initial decrease in dolphin numbers during the onset of more flooded years after 2009. Droughts have immediate impacts on fish numbers and result in rapid decreases. This explains the impact of droughts on the dolphin numbers in 2010 which lasted until 2011. With two consecutive years of high floods the fish population has increased with a corresponding increase of dolphins in 2012, especially pink river dolphins. Results show that pink river dolphin populations are correlated to the abundance of red piranha and that grey river dolphin populations are correlated to the abundance of white piranha. Both red and white piranha species were negatively impacted by the drought in 2010 and have shown signs of recovery in 2012 and 2013 (see section on fish results).

Manatee

Manatee (*Trichechusinunguis*) populations along the Samiria River have been relatively stable over the years. This species was occasionally hunted by local people in the 1990´s, but hunting decreased substantially during the 21st century. The manatees are now facing a new threat from the greater variations in water level. Previous to 2010, no manatees were ever recorded dying from natural causes. During the drought of 2010 there were two manatee individuals found dead from natural causes. It was presumed that the manatees died from starvation, since the water levels were so excessively low that the floating vegetation that they feed on was grounded and out of reach from the animals. The Samiria River basin continues to be a stronghold for the species in Loreto, but further extreme droughts will likely result in additional mortality.

Results of the research conducted in the Samiria River show that populations of both species of dolphins and the manatee are negatively impacted by droughts and respond positively to high water years. The aquatic nature of these species makes them susceptible to dry outs of rivers, lakes and channels when droughts occur. It takes the dolphin population two years to recover when droughts are followed by consecutive high water years. If climate change persists and drought conditions re-occur the dolphin and manatee populations will be impacted. The frequency of droughts will be critical. If they occur more frequently than the dolphin and manatee

populations might not have time to recover and species numbers will be severely impacted. However, if droughts continue to be interspersed by at least two consecutive high water years dolphin and manatee populations are likely to persist.

Wading Birds

Wading birds were used as indicators of the fish production in the Samiria River basin. Fish reproduce in the flooded forests of the Samiria basin during the high water season. Young fish then migrate out of the Samiria during low waters of the dry season. Each year flocks of Neotropical cormorants (*Phalacrocoraxbrasilianus)* and great egrets (*Ardeaalba)*migrate to and congregate at the mouth of the Samiria River to feed on fish swimming out of the basin between the months of August to November. In addition, non-migratory wading birds are also seen in greater abundances, including wattled jacana (*Jacana jacana)*, cocoi heron (*Ardeacocoa)* and snowy egret (*Egrettathula).*

Fish feeding aquatic birds depend on the large fish production of the flooded forests. Climate change will impact fish production negatively during droughts and positively during high water years. Fluctuations in aquatic birds should reflect changing fish populations and should be a good indicator of the impacts of climate change in flooded forest ecosystems. This section examines how aquatic bird populations responded to the recent climate changes, as a consequence of drought and high water conditions.

Wading birds along the Samiria River were classified into five assemblages according to their annual use of the river and changes in abundances.

Group 1: These are the species that show marked seasonal migrations during the dry season.
Group 2 & 3: These are the species that show variations in their abundances over the year, but not in relation to the dry season.
Group 4 & 5: These are the resident species that show little annual fluctuations in their abundances along the Samiria.

The species composition of wading birds differed along the Samiria River. Overall the wading bird abundance was greatest at the mouth of the river, with a considerably lower abundance at the mid-section and even lower numbers in the upper reaches of the river. At the mouth *Phalacrocoraxbrasilianus* dominated, followed by *Ardeaalba* and *Jacana jacana*. In the mid-section the most abundant wading bird was *Ardeaalba,* followed by*Phalacrocoraxbrasilianus* and *Ardea cocoa*. In the upper reaches *Ardeaalba* was agin the dominant species followed by *Ardea cocoa* and then *Phalacrocoraxbrasilianus*.

There was a strong correlation between abundance of wading birds and fish populations in the Samiria River basin. Overall abundance of all species of wading birds are correlated to abundance of fish populations. Abundance of *Ardeaalba*and *Phalacrocoraxbrasilianus*correlated with overall fish abundance. Therefore, wading bird species are a good measure of overall fish production.

Greater variations in water level have impacted wading bird populations. Abundances of the two dominant species, *Phalacrocoraxbrasilianus* and *Ardeaalba*, at the mouth of the Samiria River were relatively constant between 2006 to 2010, and even had a slight increasing trend over the

years. However, the drought of 2010 resulted in significantly lower numbers of *Phalacrocoraxbrasilianus* (X^2=125.41, gl=5, P<0.0001) and *Ardeaalba* (X^2=11.098, gl=4, P=0.0495) during the 2011 low water season. The drought resulted in high fish mortality and decreased wading bird numbers concur with a decrease fish production during 2011. This also correlates with the impact of water level variations on fish populations and decrease in dolphin numbers.

In 2012 there was a significant recovery of wading bird populations with numbers approaching the peak years of 2009-2010. Then in 2013 the wading bird population showed a divergent trend, with extremely high numbers ofNeotropical cormorants (*Phalacrocoraxbrasilianus)* at the mouth, more than double of previous years (X^2 = 691.055, gl = 7, P = < 0.0001)(Figure 4). In contrast, the numbers of great egrets (*Ardeaalba)* decreased at the mouth (X^2 = 37.437, gl = 7, P = < 0.0001), but they had high numbers in the mid-section of the Samiria. In total, including both the mid-section and mouth wading bird numbers were considerably higher in 2013 than in previous years. The consistent high water seasons of 2011, 2012 and 2013 appears to have triggered a greater reproduction in the fish population that was reflected in 2013 in a greater wading bird population.

Biomass of Fish Consumed by Aquatic Birds

The biomass consumed by aquatic birds at the mouth of the Samiria River was calculated using the two most abundant species, Neotropical cormorants(*Phalacrocoraxbrasilianus)* and great egrets *(Ardeaalba)*. The total number of birds was estimated by using 40 km of shoreline at the mouth of the Samiria River, the duration of the birds at the mouth and the kg of fish consumed by individual birds.

The results from the monitoring surveys showed that the large aquatic bird migrations of Neotropical cormorants and great egrets were from mid-August to mid-October, covering a period of 3 months or approximately 90 days. The average number of Neotropical cormorants during this period was 243 ind/km. The population at the mouth of the Samiria River using 40 km of shoreline was estimated at 9,720 individuals. The average number of great egrets during this same period was 48 ind/km, which yielded 1,920 individuals.

Aquatic birds consume approximately their body weight in fish daily. Neotropical cormorants weigh between 1-1.5 kg and great egrets between 0.7-1.2 kg. The estimated biomass consumed by the aquatic birds was rounded to 1 kg of fish per day.

Using the above values the estimated fish biomass consumed per day by Neotropical cormorants was 9,720 kg or 9.72 tons of fish. The estimated fish biomass consumed by great egrets was estimated at 1,920 kg or 1.92 tons of fish. Together, the two species of aquatic birds were estimated to consume 11.64 tons of fish daily at the mouth of the Samiria River, which yielded 1,047.6 tons of fish during the 90 days of residence.

Aquatic birds have clearly been impacted by recent climate fluctuations. During the drought of 2010 the populations of Neotropical cormorants and great egrets decreased, which was observed by significantly lower numbers in the year following the drought. Their populations recovered after two consecutive years of high water levels, and in 2013 had greater numbers than in previous years. The population fluctuations of the aquatic birds are a good indicator of the fish abundance and the impact of climate change on fish populations. Fish numbers and biomass drive

the aquatic wildlife system and when their population falls due to drought conditions repercussions are seen in much of the aquatic diversity. Fish numbers rebound after consecutive years of high water levels due to high reproductive productivity in the inundated flooded forests. Increases in fish numbers during high water levels are reflected in higher numbers of aquatic birds.

The fluctuations in aquatic bird populations during the recent climate changes is a good indication of what will happen if climate change continues in the Amazon basin. During droughts aquatic bird populations will suffer as a consequence of smaller fish populations. Similar to the dolphins, the impact of droughts on aquatic birds will depend on the frequency, with greater numbers of droughts having a more profound negative impact. If droughts become too frequent aquatic bird population will not have enough time to recover and their numbers will decrease. High water levels are good for aquatic bird populations and the consecutive high water levels of recent years have resulted in large numbers of aquatic birds. If droughts are interspersed by two or more consecutive high water years then aquatic bird populations should persist at healthy numbers.

Fish

Fish are the major component of aquatic diversity and biomass in flooded forests of Amazonia. During the annual high water season over 90% of the Pacaya-Samiria National reserve becomes inundated. Many fish species enter the flooded forests during the floods that span over an area of 20,000 km2. There are abundant food resources for the fish in flooded forests including a variety of food types on the submerged forest floor, insects, spiders, millipedes and other animal foods on the trunks, leaves and branches of flooded vegetation, and fruits that fall from the canopy. When fish feed on the abundant resources their body condition increases. Fish then breed in the flooded forests in large numbers. In effect, the Pacaya-Samiria National Reserve becomes an inland sea for fisheries reproduction. When the water recedes the fish production migrates out of the forest and into the lakes, channels and rivers with a large proportion leaving the reserve for the major rivers. The reserve is by far the largest flooded forest in the region and yields the largest fish production, supplying fish to the major rivers of the Rio Amazonas, Marañon and Ucayali.

Changes in the dynamics of the water level will impact fish reproduction and mortality and cause changes in their populations. Drought conditions result in lower fish reproduction and greater fish mortality. In contrast, high water levels result in greater reproduction and lower morality. Changes in fish populations impact other wildlife species and people who depend on the fisheries, including local villagers and the commercial fisheries. This section examines how climate change resulting in drought conditions impacted fish populations and how high water levels are needed for consecutive years to recover the populations.

Fish populations in the Samiria River have been impacted by the greater variations in water level. This impact was evident in 2011, following the drought of 2010. The abundance of fish remained stable, but the size of abundant species decreased indicating a demographic change in the populations. It appears that changes in fish population impacted dolphin and wading bird populations. Fish numbers and demographics do better in high water years when fish can enter flooded forests for longer periods and exploit the abundance of food. Many fish species reproduce in the flooded forest habitats and high water years usually result in greater reproductive rates.

Fish abundance was calculated using CPUE (catch per unit effort) and showed differences along the Samiria River basin. The greatest abundance of fish was in the mid-sectionof the Samiria, followed by the lower section and lastly the upper section ($F_{2,14}$=4.1786, P=0.037). The fish populations along the Samiria River basin showed an increase in numbers after 2007, then a dip in biomass after the 2010 drought and a recovery in 2012. In 2013, both the biomass and individuals have begun to increase to a new high in the Samiria River basin (b = 0.6498, t = 1.9884, p = 0.0938)(Figure 5).

Differences were seen in the fish composition between the low water and high water seasons along the Samiria River basin. In the mid-section *Liposarcuspardalis* dominated the CPUE in both seasons. However, in the low water season *Hoplerythrinusunitaeniatus* was the next most abundant species followed by *Pygocentrusnattereri* . During the high water season in the mid-sectionof the river *Pygocentrusnattereri* was the second most abundant species, followed by *Serrasalmusrhombeus*. In the upper reaches of the Samiria River the most abundant species during the low water season were *Hoplerythrinusunitaeniatus, Liposarcuspardalis*and*Pygocentrusnattereri*, respectively. In contrast during the high water season the most abundant species were*Liposarcuspardalis, Chaetobranchusflavesens, and Mylossomaduriventrus,* respectively. Abundances between the two seasons showed that dominant fish species differed, reflecting a change in the community structure of the fish populations.

Demography used size structure to evaluate the general health of the populations and analyses were done on *Astronotusocellatus, Liposarcuspardalis, Prochilodusnigricans, Pygocentrusnattereri*and*Serrasalmusrhombeus*. All of the species, except *Prochilodusnigricans* showed a significant decrease in size classes in 2011, reflecting degradation in the health of the populations following the drought of 2010. Populations show a recovery in 2012 and 2013 following the record high waters.

Astronotusocellatus"acarahuazu"
The demography of *Astronotusocellatus* has been impacted by the variations in water level. During the years 2007, 2008, the size of the largest catch of *Astronotusocellatus* ranged was 17 - 19 cm in length. In 2010 the size of the largest catch increased to 19-21 cm. In 2011, the size of the largest catch declined dramatically to 11-13 cm (Kolmogorov-Smirnov (K-S), P>0.05) and in 2012 after intensive flooding the age structure shows signs of recovery with the largest catch being 13-15 cm. In 2013 the demographics had even larger size classes, showing a healthier population with the largest size class being 21-23 cm.

Liposarcuspardalis"carachama"
The demography of *Liposarcuspardalis*has shown some signs ofimpact from the greater variations in water level. The largest size catch of *Liposarcuspardalis*over the years 2007-2010 has been in the range of 22-25 cm in length. In 2011 the largest size catch dropped to 19-22 cm, which was also the size in 2008 (K-S, P<0.01). After the high waters of 2011 and 2012 age of the largest catch has shown signs of recovery with an increasein the 22-25 cm catch. In 2013 the demographics had even larger size classes, showing a healthier population with increase in the 25-28 cm size classes.

Prochilodusnigricans"**boquichico**"
The demography of *Prochilodusnigricans*has not shown any impacts from the water level variations.The largest size catch in the years 2007, 2008 and 2010 was 18-21 cm in length, while the largest size catch in 2009 and 2011 was 21-24 cm, and in 2012 it was 15-17 cm (K-S, P<0.05). In 2013 the demographics had even larger size classes, showing a healthier population with the largest size class being 18-21 cm.

Pygocentrusnattereri"**pirañaroja**"
The demography of *Pygocentrusnattereri*has been impacted by the variations in water level. The largest size catch of *Pygocentrusnattereri*over the years 2007-2010 has been in the range of 14-16 cm cm in length. In 2011 the largest size catch dropped to 12-14 cm and had increases in the smaller 8-12 cm catches. In 2012 *Pygocentrusnattereri* shows signs of recovery with increases in the 12-14 cm catches and decreases in the 8-12 cm catches (K-S, P<0.05). In 2013 the demographics had even larger size classes, showing a healthier population with the largest size class being 14-16cm.

Serrasalmusrhombeus"**pirañablanca**"
The demography of *Serrasalmusrhmbeus* has been impacted by the variations in water level. En el The largest size catch of *Serrasalmusrhombeus* over the years 2007-2010 has been in the range of 13-15 cm in length. In 2011 the largest size catch dropped to 9-11 cm, and had increase catches in the smaller sizes of 7-9 cm. In 2012, *Serrasalmusrhmbeus* has shown signs of recovery with the largest catch size being13-14 cm (K-S, P<0.05). This was the only species analyzed that showed a decrease in age structure in 2013 with the largest size class decreasing to 10-12 cm.

Similar population trends were seen with the aquatic species of fish, dolphins and wading birds during the recent climate fluctuations. The populations of fish, dolphins and wading birds all declined during and immediately following the drought and then recovered after two years of intensive flooding. Since fish, dolphins and wading birds all showed the same trends we can have greater confidence that the recent climate changes of drought and intensive floods were the cause of the fluctuations in their populations. This similar repeated observation in different species suggests that the cause and effect relationships between fish, dolphins and wading bird populations and recent climate changes are probably an accurate conclusion.

Caimans

Caimans are long lived species that have adapted to the Amazonian ecosystem over millennium. They live on the aquatic-terrestrial interface and adapt to both the annual dry and wet seasons of the flooded forests. The evolutionary history of caimans has been in the drier and wetter cycles of Amazonian history. These factors make the caimans resistant to many fluctuations. However, during the drought conditions the spectacled or common caiman showed signs of population change. This section examines how the caiman populations responded to the recent climate changes in the flooded forests.

Three species of caimans occur in the Pacaya-Samiria National Reserve, black caiman (*Caiman niger*), spectacled caiman (*Caiman crocodylus*) and smooth fronted caiman (*Paleosuchustrigonatus*). Black caiman were intensively overhunted during the 1950's – 1970's and

havebeen recovering in the Samiria River over the past decades. The caimans have not shown any lasting impacts from recent climate change events. However, during the drought of 2010 there were short term impacts on the spectacled caiman population.

The spectacled caiman appeared to be impacted by the extreme low water levels, whereas the black caiman appeared to be less affected. The spectacled caiman had an overall lower abundance in the Samiria River during the drought than their six year average with the upper section having 56% fewer, the mid-section having 27% fewer, and the lower section having 40% fewer. It appears that the drop was due to spectacled caimans moving to more isolated habitats, because after the drought the caiman populations returned to the more stable numbers. The black caiman abundances were similar and did not show general declines, with the upriver section having very similar numbers to previous years, the mid-sectionhaving slightly fewer and the lower section having greater numbers than previous years.

The abundance of caiman varies along the Samiria River. The spectacled caiman (*Caiman crocodilus*) was the most abundant species along the Samiria River and in 2013 had greater numbers in the mid-section 0.80 $\pm$0.17 ind./km and lower at the mouth 0.12 $\pm$0.08 ind./km (H=4.82, gl=2, *P*=0.09). Black caiman (*Melanosuchusniger*) had greater numbers in the mid-section 1.26 $\pm$0.23 ind./km and least abundant at the mouth 0.16 $\pm$0.11 ind./km (H=4.95, gl=2, *P*=0.084). The smooth fronted caiman (*Paleosuchustrigonatus*) was the rarest species along the Samiria River with similar abundances between all three sections of the river ranging between 0.09 $\pm$0.03 ind./km at the mid-section and 0.002 ind./km at the mouth (H=1.004, gl=2, P=0.61).

The population of black caiman showed a trend towards increasing numbers after the extensive overexploitation of the 1950´s to 1970´s (H=28.42, gl=9, p=0.0014). More recently, between 2006-2013 the black caiman has had a more stable abundance (b=1.5086, t=0.3016, p=0.7070)(Figure 6a). The spectacled caiman population decreased significantly when black caiman began to recover (b=-3.346, t=-5.3279, P=0.0007), but have been relatively stable since 2006 (b=-1.2199, t=-0.2331, p=0.8223)(Figure 6b). The numbers in 2013 have remained stable. The smooth fronted caiman has had a relatively stable population over the years along the Samiria River and numbers in 2013 were also consistent with previous years.

The habitat use of the caiman also differed in the Samiria according to the species. The common caiman had the greatest abundance in the river habitat, followed by the lake habitat and was least abundant in the channels. The black caiman showed a similar pattern and had the greatest abundance in the river habitat and similar abundances in lakes and channels. The smooth fronted caiman was only found in the river habitat.

There was a relationship between the black caiman, common caiman and the white piranha (*Serrasalmus*rhombeus). The greater the densities of white piranha the more abuandant the caiman species, indicating the correlation between food resources and caiman numbers.A reverse trend was found with the smooth fronted caiman.

Caimans have adapted over millennium to the changing conditions of Amazonia. Yet, the spectacled or common caiman was still impacted by the drought of 2010. Numbers of common caiman recovered rapidly indicating an adaptive response to climate fluctuations. Caiman species have considerable overlap in their diet and habitat use, which suggests competition during periods of scarcity. The drought conditions reduced the aquatic-terrestrial interface habitat, thus forcing

the caimans into smaller areas and increasing the likelihood of competition. Indeed, it could have been this increased competition that resulted in a decrease in common caiman numbers during the drought. During high water levels the aquatic-terrestrial interface habitat is much greater and the likelihood of competition is significantly lower. Caimans are fast reproducing species with large clutch sizes and populations can rebound rapidly from perturbations. This fast reproduction is likely to have allowed the common caiman to increase its population rapidly after the drought.

The preceding sections have shown how dolphins, aquatic birds, fish and caimans were negatively impacted by the historic drought of 2010. All of these species have recovered after several consecutive years of high water levels. Recent models predict that climate change in western Amazonia will result in generally wetter conditions with greater flooding interspersed with occasional droughts. This is precisely what has happened over the past five years, which shows what will happen if the climate change models are accurate. The recent impacts of climate fluctuations also show what will happen if more intensive and frequent droughts occur.

If droughts become more frequent much of the aquatic diversity will be negatively impacted. Fish dominate the biomass and numbers in the flooded forest aquatic system. Droughts will decimate fish populations and in turn a large number of other species that rely on fish for food, including the local people. However, if droughts are interspersed by consecutive years of flooding the fish and other aquatic species will have a chance to recover during the high water years.

The intensive floods of recent years have been more frequent then the droughts in western Amazonia. These frequent higher than normal floods have been positive for aquatic species. However, terrestrial species have been impacted negatively by the historic high water levels. The negative effects of intensive floods caused by climate fluctuations will be examined In the following sections.

Wildlife Impacted by Intensive Flooding

The first models of climate change in the Amazon predicted that conditions would become drier and droughts would be more frequent (Nobre et al. 1991, Phillips 2009). When more information became available and were incorporated in the IPCC-AR4 models they showed that the Amazon basin was not homogenous with regard to climate change and regions would differ. The IPCC-AR4models predict that western Amazonia will generally become wetter with greater flooding, interspersed by occasional droughts(Cook et al. 2012, Langerwischet al. 2012).

The southern Atlantic has a major influence on these wetter conditions, since evaporation of the hot summer waters of the southern Atlantic ocean follow a wind pattern that brings them over northern South America, down the foothills of the Andean mountains and then over the Pantanal region and finally westwards over the southern Atlantic forests of Brazil. When the weather cycles hit the foothills of the Andes precipitation is heavy and prolonged. These intensive a prolonged rains feed the tributary streams and rivers that flow into the Amazon basin, raising the water levels and causing floodplains to become inundated. The climate change models predict hotter conditions in the southern Atlantic producing greater evaporation and in turn heavier and more prolonged rains in the Andean foothills. Thus, models predict the wetter conditions to become greater in both the level of flooding and the length of the flooded season (Cook et al. 2012, Langerwischet al. 2012).

The recent climate changes observed in the Peruvian Amazon concur precisely with the IPCC-AR4models. Since 2009 there have been consistently greater flooding during the high water and the flooded season has become longer. Unusually high water levels were recorded in 2009, 2011, 2012 and 2013 with 2012 being a one in one hundred year event. It is estimated that around 18% of the northern Peruvian Amazon has water surface during the flooded periods, including flooded forests, rivers, lakes and channels, and the Pacaya-Samiria National Reserve being the largest flooded forest of this region.

The Samiria River basin has experienced greater levels of flooding since the onset of climate change events that began in 2009. During normal years the basin has a water surface of around 96%.This has increased to 98% during the recent intensive floods and was approximately 99% during the historic flood of 2012. Non-flooded levee forests are important refuge for the larger ground dwelling terrestrial wildlife. During peak flooding these habitats are scarce and animals are forced on ever smaller spaces. Competition for food increases in herbivorous species and the body condition of animals decrease. Mortality from weak conditions prevails. Predators, such as the large felids, have abundant prey concentrated on the levees and mortality from predation increases.

When the waters begin to raise ground dwelling mammals, such as peccaries, deer, tapir, paca, agouti, armadillos, giant anteaters, jaguars, pumas and ocelots, move towards the levee forests to take refuge during peak flooding. During the historic flood of 2012 many levees became flooded and animals had to find alternative high ground. Deer, anteaters, paca, agouti among other species were seen swimming in vain to find dry land. Many individuals drowned becoming exhausted from searching for a levee. Water was flooding almost every section of the basin with frequent day-long rains made the whole environment drenched with water. Floating logs and tree trunks were filled with ants, spiders and other terrestrial insects, frogs clung to trees and terrestrial birds hopped among the lower branches. Even the arboreal animals, such as primates, macaws, and sloths, were wet and sluggish from the continual rains. When the floods began to recede the forests regained its land and the animals that survived once again spread out to their old haunts.

The following sections will examine impacts of the intensive flooding on wildlife during recent climate changes. Results show how the terrestrial ground dwelling mammals have suffered from the recent floods and how many populations have become decimated from the climate change.

Ungulates

Ungulates have been impacted by greater climatic variations in water level between 2009and 2013. Ungulates in the Samiria River basin include the white-lipped and collared peccary (*Tayassupecari and Tayassutajacu*), red brocket deer (*Mazamaamericana*) and lowland tapir (*Tapirusterrestris*). Overall density of ungulates estimated from line transects has decreased significantly since water level variations began (b=-0.9505, t=-3.8605, p=0.0119). Peak density of 3.93 ind/km2 occurred in 2009 after years of relatively stable water levels and then decreased in 2010 to 1.03 ind/km2 and again in 2011 to 0.65 ind/km2. In 2012 and 2013 there were very few ungulates sighted on transects (Figure 7).

Camera traps showed similar results to line transects. 3,335 camera trap days were used to calculate camera capture rates in the Samiria River basin in 2009, 2011 and 2013. Capture rate is per animal at a camera station and multiple photos during a visitation are only counted as one event. Peccary herds are registered as events, not as individuals. In 2009, capture rates of ungulates were 142.69 captures per 1,000 trap days compared to 77.18 captures in 2011 and 40.59 in 2013, resulting in a 47% decrease since 2011 and a 72% decrease since 2009.

Ecological conditions of long periods of flooding in varzea forests of the Samiria River, up to 6 months, can be very harsh on the ungulate community. Ground dwelling mammals must seek out levees during the high water season, which result in increased competition and predation pressures. These normal seasonal conditions have been more intense during the exceptionally high waters of 2009 to 2013. Initially, higher ungulate densities were recorded during 2009, as the stable populations were forced onto ever decreasing levees. In 2010, the initial impact of high waters of 2009 was observed, with decreasing ungulate densities. Record high waters of 2011 and 2012 surmounted those of 2009 and resulted in an even greater decrease of ungulates, which continued in 2013.

Results from camera traps show that the greater extremes in high water are resulting in greater percentages of emaciated ungulates. Camera traps set in 2009 did not record any emaciated individuals of ungulates. In drastic contrast, Camera traps set in 2011 recorded significant percentages of emaciated individuals, including lowland tapir: 3% (4 pictures out of 127 pictures), collared peccary: 12% (5 pictures out of 41 pictures), and white-lipped peccary: 10% (7 pictures out of 71 pictures). The emaciation is due to the smaller levee size resulting in less food availability and greater intra and inter specific competition.

White-lipped peccary (*Tayassupecari*) have been impacted dramatically by intensive floods of recent years. The species had a peak in its population in the Samiria River basin in 2009 with 3.64 ind/km2 which declined dramatically in 2010 to 0.88 ind/km2 and still further in 2011 to 0.59 ind/km2 (G= 26.25, gl=5, P=0.0001). No white lipped peccary were sighted on line transects in 2012 and 2013. They still occur in the Samiria River basin, but at greatly reduced numbers. White-lipped peccary had a greater density in the infrequently and occasional hunted zones and a significantly lower density in the frequently hunted zone. All three zones have shown decreases in white-lipped peccary density. Results from camera traps concur with line transects, and capture rates in 2011 were 9.86 herds per 1000 trap-days, 56% lower than in 2009. In 2013 there were no white-lipped peccary recorded on camera traps.

Collared peccay (*Tayassutajacu*) have been impacted equally as intensively as white-lipped peccary by intensive floods occurring in western Amazonia. Collared peccary had a peak in population in the Samiria River basin in 2008 with 0.23 ind/km2, which declined dramatically in 2010 to 0.05 ind/km2 and still further in 2011, 2012 and 2013 where no individuals were sighted on the line transects (b=-2.6493, t=-2.6189, P=0.0471). Collared peccary still occur in the Samiria River basin, but at much lower numbers than in the past. Camera traps concur with line transect results, and capture rates in 2011 were 29.02 herds per 1000 trap days, 51% lower than in 2009. There were no collared peccary observed on camera traps in 2013.

Red brocket deer (*Mazamaamericana*) were faring slightly better until the historically high floods of 2012, which caused their population to fall. Density of red brocket deer was relatively constant in the Samiria River basin between 2004 to 2010, but in 2011 red brocket deer density dropped to

0.04 ind/km2 and in 2012 and 2013 no red brocket deer were sighted on the transects (b=-14.82, t=-3.2686, P=0.0170). Camera trap results agree with the transects. In 2009 there were 36.36 captures per 1000 trap days and by 2011 the capture rate fell to 19.15, or a 42% decrease. The red brocket deer showed a large decrease in 2013 with a camera trap capture rate of 3.96 captures per 1000 camera trap days, with a 79% decrease since 2011 and a89% decrease since 2009.

Lowland tapir (*Tapirusterrestris*) arenot showing the same levels of impacts from climate change as the other ungulate species and are maintaining their populations. Camera traps capture tapirs with better accuracy than sightings on line transects. In 2009 camera trap capture rates for tapir were 22.73 captures per 1000 camera days and in 2011 capture rates fell slightly to 19.15 captures resulting in a 16% decrease, which was much less than other ungulate species. In 2013tapir had a capture rate of 36.63, which is the greatest capture rate. Over the years, tapir have been sighted most frequently in the occasionally hunted zone, followed by the infrequently hunted zone, and sighted least in the commonly hunted zone. The commonly hunted zone has always had very low populations of lowland tapir.

There are two reasons that might explain why tapirs have been able to withstand the intensive floods compared to other ungulate species. One explanation is the more folivorous diet of tapirs, compared to peccaries and brocket deer that feed primarily on fruits and seeds (Bodmer 1989).The competition for fruits and seeds on floodplain levees is likely to be very intense, resulting in greater mortality of peccaries and brocket from starvation. The much greater body size of lowland tapir and their post-gastric digestive system permits the tapir to meet its metabolic energy demands from the low quality leaves of the forest understory. Tapir are able to eat large quantities of low quality food and digest the cellulose with post-gastric fermentation. This adaptation allows them to feed to vegetative food that the peccaries and deer are unable to eat, and in turn gives the tapir a survival advantage on the floodplain levees.

The second reason why tapir populations have not declined from the recent intensive floods is their ability to largely overcome the natural predators. The large body size of tapirs helps them overcome predation by jaguars and pumas. In contrast, peccaries and brocket deer are common prey species. When animals are confined to the small floodplain levees predators have higher densities of prey and it becomes easier for them to capture food. Thus, populations of peccaries and brocket deer have become decimated, whilst the tapir populations have remained intact, since they are rarely eaten by the large feline predators.

Recent climate change events in the Amazon basin have had a dramatic impact on the ungulate populations in the flooded forests. The consecutive and intensive high water levels have reduced non-flooded levees during peak periods. This has resulted in ungulates being forced onto smaller spaces leading to fewer food resources available for the animals and greater interspecific and intraspecific competition. As a consequence, body condition of ungulates deteriorated with signs of emaciation and in turn greater mortality. In addition, the concentration of ungulates on smaller levees has resulted in greater predator pressure, since ungulates are less dispersed and therefore easier prey.

Camera traps indicate that there is still a residual population of ungulates in the Samiria River basin. Lowland tapir populations have remained stable, while peccaries and brocket deer populations have crashed. Ungulates can recover if the consistently high waters cease. However, if the intensive high water levels persist than ungulate populations will remain small. Small

populations are more prone to local die off and ungulate species could become extirpated from flooded forests. The forest structure is also likely to undergo changes if ungulate populations remain small, which in turn will impact other components of the flooded forest biodiversity.

TerrestrialRodents

Theterrestrial rodent species surveyed included black agouti (*Dasyproctafuliginosa*) and paca (*Agouti paca*). Climatic variations in water level have impacted these species with both terrestrial transects and camera traps showing similar results.

Black agouti (*Dasyproctafuliginosa*) densities calculated from terrestrial transects were relatively constant in the Samiria River basin between 2006 and 2012 (G= 0.8392, gl=7, P= 0.997). Density of black agouti peaked in 2009 with 0.93 ind/km2 and decreased slightly with a density in 2012 of 0.39 ind/km2. In 2013, however, the black agouti has shown a dramatic decrease in their population with a transect density of 0.10 ind/km2. Camera trap results showed an even more dramatic decrease of black agouti in 2013. Capture rates in 2009 were 445.45 captures per 1000 trap days compared to a capture rate in 2011 of 239.11 captures or a 46% decrease. However, in 2013 there were no black agoutis captured on camera traps.

It is unclear why the agouti population crashed in 2013. One explanation might be from increased predator pressure on the floodplain levees. Ocelots regularly prey on agouti and the ocelot populations have remained healthy. Aqouti become more vulnerable to predation when they are concentrated in the floodplain levees and the observed decrease in their population may reflect increased consumption of agouti by ocelots.

Pacas (*Aguotipaca*) are terrestrial nocturnal species and were only observed on camera traps. Results of capture rates showed a decrease in their population following recent flood events. In 2009 paca had a capture rate of 113.64 captures per 1000 camera days, which fell to 45.59 captures in 2011 resulting in a 60% decrease in their abundance. In 2013 the capture rate of paca fell to 21.78individuals per 1000 camera days, with a 52% decrease since 2011 and an 81% decrease since 2009.

Terrestrial Edentates

Giant anteaters (*Myrmecophagatrydactila*) were only sighted occasionally on terrestrial transects. However, giant anteaterswere recorded on camera traps, which showed impacts of intensive floods. Capture rates in 2009 were 22.72 captures per 1000 trap days and in 2011 were 8.70 captures with a decrease in abundance of 62%. In 2013 capture rates fell to 4.95 individuals per 1000 camera days, with a 43% decrease since 2011 and an 78% decrease since 2009. Giant anteaters are large terrestrial animals and similar to ungulates they have declined as a result of recent inundations.

Dasypusspp. arenocturnal species and were only recorded on camera traps. Armadillo species were impacted by intensive floods and populations declined as a result of the recent climatic events. Capture rates in 2009 were 127.27 captures per 1000 trap days and in 2011 the rateswere 31.34 captures, resulting in a decrease in abundance by 75%. In 2013 capture rates fell to 4.95 individuals per 1000 camera days, with an 84% decrease since 2011 and a 96% decrease since 2009. Flooded forests are not preferred habitat of armadillos, since the borrowing habits and

proximity of ground water often result in borrows becoming inundated. Indeed, a study of borrow placement by the project showed that armadillos in the Samiria River basin often prefer elevated mounds made by leaf cutter ants, which are usually found on higher ground. In contrast, in non-flooded altura forests there is no relationship between armadillos and leaf cutter ants.

Giant armadillos (*Priodontesmaximus*) are large terrestrial species predominantly active at night. They are only very rarely seen on terrestrial transects, but haveon occasion been recorded on camera traps. There were no records on the 2009 cameras and only 9 events on the 2011 cameras yielding a capture rate of 5.22 captures per 1000 camera trap days. In 2013 no giant armadillos were captured on the camera traps. The small sample size does not allow for an analysis of their population trends; however, the prediction is a declining giant anteater population in line with other large terrestrial mammals and smaller armadillos.

The physical effects of more intensive flooding since the onset of climate change events have had a direct and significant impact on the ground dwelling mammals, Populations of peccaries, brocket deer, tapir, paca, agouti, armadillos and giant anteaters have all decreased, some substantially. The natural history of these animals restricts them to the forest floor and they must find refuge on the small levees during peak flooding. Mortality has increased as levee size has decreased.

Because all of these species showed the same trends in their populations we can have greater confidence that the historically high water levels of the recent climate change were the cause of the population declines. The similar repeated observation in all of the terrestrial mammal species strongly suggests that the cause and effect relationships between the decline in terrestrial mammal populations and recent climate changes are probably accurate.

The reduction in the populations of the ground dwelling mammals will have longer term impacts on the forest structure, since these species are important seed dispersers, seed predators and soil diggers. Changes in forest structure will in turn impact a wide range of the biodiversity including the arboreal species.

Arboreal wildlife species and semi arboreal species can escape the direct physical consequences of the greater flooding. Any species that can climb, even at low heights, can survive the floods without having to retreat to levees. Populations of these arboreal animals have not shown a direct impact from recent flooding and their populations have remained healthy. The next section will examine the populations of species that have not been directly impacted by the recent climate change events.

Wildlife not Impacted by Recent Climate Change

Recent climate events have impacted the aquatic wildlife during droughts and ground dwelling wildlife during intensive floods. Animal species that have arboreal or semi arboreal habits can escape the physical effects of flooding and their ability to ascend trees makes them better adapted to the intensive inundations caused by climate change. Wildlife species such as birds, frogs, snakes, lizards, bats, primates, sloths and semi arboreal mammals are all able to avoid the direct impact of flooding.

Climate events will produce longer term changes to the forest structure and plant diversity. The physical effects of more intensive inundations will impact the plant community, especially with the survival rates of saplings that often have die offs when submerged for extended periods. Likewise, the impact of drought conditions causes higher mortality in certain plant groups, such as palms. Plant community structure will also change from the reduced populations of ground dwelling mammals who have important roles of seed dispersal and seed predation in the ecosystem.

The longer term changes in the plant community will likely have impacts on the arboreal and semi arboreal wildlife species. However, the recent climate change events have only occurred over the past five years, and the indirect impacts of plant community changes have not yet been observed. These impacts will be more subtle than the direct physical impacts of flooding and droughts and in turn more difficult to determine.

Another group of species that can generally overcome the impacts of recent climate events are species that have both terrestrial and aquatic habits, such as giant river otter and amphibians. These species can survive both inundations and dry conditions and are also well adapted to the changing environment.

The following sections will examine species that have not yet shown obvious impacts from the recent physical effects of climate changes, either the droughts or flooding.

Macaws

Macaw populations were used as indicator species of the terrestrial forest landscape. These species are appropriate as indicator species because 1) they are frugivores that rely on forest fruits, 2) they are not killed by people, 3) they can move in and out of the forest areas over short periods of time, and 4) they are easy to count and observe.

Macaws did not show impacts from the recent climate change. Their arboreal habits allowed them to escape the direct physical impacts of flooding. Macaws are able to move between fruits sites and also overcome changes in fruit production, caused either by droughts or inundations. Over the longer term there macaws might be impacted by changes in the forest structure and seasonality and abundance of fruits.

The macaws in the Samiria River include the chestnut-fronted macaw (*Araseverus)*, blue & yellow macaw (*Araararauna),* red-bellied macaw (*Orthopsitacamanilata)* and scarlet and red & green macaws (*Aramacao/chloroptera)*.

Overall the abundance of macaws in the Samiria River during 2013, as in previous years, differs between species (H = 9.667, gl = 3, P = 0.0216). The most common species was the red-bellied macaw (*Orthopsitacamanilata)*9.12 ± 4.95ind/point, followed by the blue & yellow macaw (*Araararauna)* 4.52 ± 1.08ind/point and chestnut-fronted macaw (*Araseverus)*1.13 ± 0.51ind/point. The scarlet and red & green macaws (*Aramacao/chloroptera)* are least common and together only had an abundance of 0.21 ± 0.10 ind/point.

Along the length of the Samiria River macaw numbers in total were relatively constant and ranged between 8-12 ind/point. However, the composition of the macaws varied considerably between

the mouth, mid-sectionand upper reaches of the Samiria River. At the mouth of the river the numbers were dominated by the red-bellied macaw, with low numbers of blue& yellow and chestnut-fronted macaws. There were no sightings of the scarlet and red & green macaws at the mouth. In the mid-sectionof the river the numbers were again dominated by the red-bellied macaw, but the blue & yellow macaw had greater numbers, and the chestnut-fronted lower numbers. In the upper reaches of the river the three common macaws, red-bellied, blue & yellow and chestnut-fronted all had similar numbers. The scarlet and red & green macaws were present in the mid and upper sections, but with very low numbers.

In general the macaws have been increasing in the Samiria River basin over the period of greater variations in water level and do not appear to have been impacted negatively by the greater climatic variations. Overall, the macaw populations have been stable between 2009 to 2013 (Figure 8). The macaws are not directly impacted by water level variations due to their arboreal habits. Therefore, health of the forest appears to have been maintained since the greater climatic variations took effect in 2009. The population variations over the years in the different sections of the basin (mouth, mid-sectionand upper reaches), for the most part conform to overall annual variations.

The red-bellied macaw population has increased since 2009 in the Samiria River basin (H=19.97, gl=8, P=0.010). This species has gone through cyclical population booms and bursts in the basin. Between 2006-2007 there were high population numbers of the red-bellied macaw. Then between 2008-2009 the population was low. In 2010 the red-bellied macaw began to increase and in 2011 it was at its highest population level recorded thus far in the Samiria basin, and with a slight decrease in population in 2012 and 2013.

The chestnut-fronted macaw is also cyclical in the Samiria River basin. This species had relatively low number until 2009, when its population increased significantly. In 2010, 2011, 2012 and 2013 the population of chestnut-fronted macaw has been declining (H=15.64, gl=8, P=0.047). It appears that the chestnut-fronted and red-bellied macaws are in direct competition, both over the years and at specific sites. Total numbers of the two species are relatively constant, however, at times one species or the other will dominate either annually throughout the basin or specifically at a given site.

The blue & yellow macaw has been relatively constant in numbers in the Samiria basin since 2003 with some annual fluctuations ($F_{8,18}$=3.55, P=0.0122). The greater variations in water level have not obviously impacted the blue & yellow macaw numbers, though its population did peak in 2009 and again increased in 2011 with a slight decline in 2012 and a slight increase in 2013.

The sample sizes of the scarlet and red & green macaw are small and the variations do not show any significant trends along the Samiria River basin between 2006 to 2013 (H=6.17, gl=8, P=0.6282).

Popultions of chestnut fronted and red-bellied macaws might be in direct competition. In years when red-bellied macaws are high, chestnut fronted are lower, and vice-a-versa. A significant LotkaVolterra relation can be seen between the two species, with the red-bellied macaw having greater populations in the latter years, including 2012. This relationship might be a result of red-bellied macaws having a greater competitive advantage due to changes in the fruiting patterns.

The macaw species have had some variance between years, but overall have remained at healthy populations. Their arboreal nature allows them to overcome the direct physical impacts of flooding and population variations are due more to fruiting and competition between the species, especially between the chestnut fronted and red-bellied macaws.

Macaws rely on fruit production and their populations will fluctuate as fruiting conditions change. It is unclear why the populations of red-bellied macaws have increased and those of chestnut fronted have decreased. This might be due to some changes in the fruiting pattern of the flooded forests caused by the recent climate change, giving and advantage for the red-bellied macaws. If the climate events continue the populations of macaws might be impacted due to long term changes in fruiting of flooded forest trees.

Primates

All of the primate species of the Peruvian Amazon are arboreal species that live in the middle story and canopy of the forest. Therefore, they are not directly impacted by the physical inundations and are better adapted to the recent climate changes than the ground dwelling mammals. The primates that do best in the flooded forests are those species that can vary their diets between fruit and other food sources, and do not rely solely on fruit productions, since the fruiting in the flooded forests is more variable than terra firme non-flooded forests.

The most common diurnal species of primates in the flooded forests of the Samiria River basin are *Lagothrixpoeppigii* "choro", *Alouattaseniculus* "coto", *Cebusapella* "machín negro", *Pitheciamonachus* "huapo negro", *Saimiriboliviensis* "frailecito". *Saguinusfuscicollis* "pichico boca blanca" y *Cebusalbifrons* "machín blanco".

Results of the censuses conducted between 2006-2013 showed that overall densities and biomass of primates differed between the three zones, with the occasionally hunted zone having the highest density of mammals, followed by the infrequently hunted zone, and lastly the commonly hunted zone (X^2= 91.264, gl= 2, P< 0.0001). Primates dominated the density and biomass of mammals in all three zones (X^2= 397.89, gl= 2, P= 0.0001) with the infrequently hunted zone have the greatest density, followed by the occasionally hunted zone and the lowest density of primates being in the commonly hunted zone. *Saimiribolviensis, Cebusapella, Alouattaseniculus,* and *Saguinusfuscicollis,* had the greatest density in the infrequently hunted zone. *Saimiriboliviensis* dominated the occasionally hunted zone followed by *Saguinusfuscicollis, Cebusapella,* and *Alouattaseniculus. Saimiribolviensis* was also the dominant species in the commonly hunted zone followed by *Saguinusfuscicollis, Cebusapella, Alouattaseniculus,* and *Pitheciamonachus*.

Populations of primates along the Samiria River have not shown any obvious impacts from the greater variations in water level that began in 2009 and continued through 2013 ($F_{5,12}$=0.84, P= 0.54). The overall density of primates was similar between 2006 to 2013 with a overall density in 2013 of 92.29 $\pm$30.76 ind/km2 (Figure 9). Primate populations increased after 2000 from overhunting in the 1990´s and by 2006 primate densities were relatively stable. Unlike ground dwelling mammals and dolphins, the arboreal primates inhabit the environment above the physical influences of the changing water level. Many primate species rely on fruits as their major food, and similar to macaws, primates have maintained stable populations that reflect a constant fruit production in the forests.

Densities of woolly monkeys (*Lagothrixpoeppigii*) have remained relatively constant between 2004 and 2013 (b = -0.4505, t = -1.9734, p = 0.0958). Woolly monkey density in 2013 was 3.22 ind/km2. Over all years, woolly monkey density differed between the zones and was greatest in the infrequently hunted zone, followed by the occasionally hunted zone and least in the commonly hunted zone (Kruskal-Wallis= 13.67, gl=2, P= 0.0011). The multi-year fluctuations between 2006 and 2013 show the infrequently and occasionally hunted zones to have similar densities of woolly monkeys. The commonly hunted zone had a greater increase in woolly monkey density between 2006 and 2011.

The howler monkey (*Alouattaseniculus*) densities have shown fluctuations in the Samiria River, with a declining population between 2006 to 2008 (X^2 = 28.873, gl = 9, P = 0.0007)and then an increasing and stable population between 2008 to 2013 (b = -1.3052, t = -1.6668, p = 0.14). Howler monkey density in 2013 was 10.63 ind/km2. Over all years, the density of howler monkey differed between the hunting zones and was greatest in the infrequently hunted zone, followed by the occasionally hunted zone and least in the commonly hunted zone ($F_{2,15}$=4.40, P=0.0307). The greatest increase in howler monkey density since 2006 was in the commonly hunted zone.

The brown capuchin monkey (*Cebusapella*) densities have been relatively constant in the Samiria River basin between 2004 and 2013 (X^2=7.63, gl=7, P= 0.36). In 2013, the brown capuchin monkey density was 12.32 ind/km2. Over all years, the density of brown capuchin was similar between all three zones, with a slightly lower density in the commonly hunted zone ($F_{2,15}$= 2.2108, P=0.1428). The greatest increase in brown capuchin density has been in the infrequently hunted zone.

The monk saki monkey (*Pitheciamonachus*) densities have been relatively constant in the Samiria River basin between 2004 and 2012 (G= 0.8704, P = 0.56) with a drip in density in 2008 and a stable population through to 2013. In 2013 the saki monkey density was 2.96 ind/km2. Whilst the sample variation shows no significant difference in density of monk saki monkey between the hunting zones, the species does show a greater density in the commonly hunted zone (H=2.6584, P=0.2647). Monk saki monkeys were hunted in the past, but wildlife management in the Samiria River basin has resulted in this species having a healthy density in the zone with heaviest subsistence hunting.

The squirrel monkey (*Saimiriboliviensis*) densities have had increases and dips between 2004 and 2013 (X^2=50.892, gl=7, P<0.0001) with the 2013 density being relatively average for the species over the years at 49.23 ind/km2. Over all years, the density of squirrel monkey was similar between all three hunting zones ($F_{2,20}$= 1.5144, P=0.2432). There was a dip in 2011 and the density of squirrel monkey has been stable in 2012 and 2013.

The saddled back tamarin (*Saguinusfuscicollis*) densities have been relatively constant in the Samiria River basin between 2004 and 2013 (X^2=11.272, gl=8, P= 0.1867). In 2013 the saddled back tamarin density was 11.89 ind/km2. Over all years, the density of saddled back tamarin was very similar between the hunting zones, with a slightly lower density in the commonly hunted zone ($F_{2,20}$= 0.0274, P=0.9737). The commonly hunted zone has also seen the greatest increase in the density of saddled back tamarins between 2009 through to 2012, and is now at a peak population.

The white capuchin monkey (*Cebusalbifrons*) is a rarer species in the Samiria River basin and densities have been relatively constant between 2004 and 2011, with a dip in 2012 and 2013 (G= 6.0307, gl=8, P= 0.6438). In 2013 the white capuchin density was 0.97 ind/km2. Over all years, the

density of white capuchin monkey was similar between all three hunting zones ($F_{2,20}$=0.3683, P=0.7012), but has considerable variation due to the small sample sizes.

Several lotka-volterra competitive interactions were observed with the primates. The woolly monkey and howler monkey appear to be competing in the Samiria River. In areas with high woolly monkey density there is low howler monkey density, and vice versa. In general howler monkeys had a greater density than woolly monkeys, however the densities of both species have been relatively stable over the years since 2004, indicating that the competitive interactions appear stable.

In contrast, the squirrel monkey and brown capuchin monkey often form interspecific associations. Thus, the densities of squirrel monkeys and brown capuchin monkeys had a positive correlation with greater density of squirrel monkey also having greater density of brown capuchin.

This section has shown that the primates have so far fared well during the recent climate events in the flooded forests of the Samiria River. Densities of primates have been relative stable along the river basin. The arboreal habits of the primates have allowed them to escape the physical effects of intensive inundations. Over the longer term populations of primates will probably changes as the forest structure and diversity of plants change as a consequence of climate change. Whilst these changes might be currently occurring, they are likely to be too subtle to notice. However, if climate change events continue it is likely that the primates will be impacted by floral variations.

There are a range of other arboreal and semi-arboreal mammals that like primates can also escape the intensive floods. The next section examines other arboreal and semi-arboreal mammal populations during the recent climate change events.

OtherAborealMammals

Las ardillas (*Sciurusspadiceus*), la tamandua (*Tamanduatetradactyla*), el perezoso de tres dedos (*Bradypusvariegatus*) y el zorro común (*Didelphismarsupialis*) no han mostrado efectos en sus poblaciones en las recientes variaciones de cambio climático. Estas especies son arborícolas y no están afectados directamente por los eventos de inundaciones físicos extremas de los últimos años, y similar a las otras especies de la fauna arbórea, como primates, estas poblaciones se han mantenido estables.

Amazon squirrel (*Sciurusspadiceus/igniventris*) densities have shown an overall stable population in the Samiria River basin between 2004 and 2013 (G=4.8109, gl=7, P= 0.683) with a peak in 2009 of 11.27 ind/km2 a decreasing tendency between 2010 and 2012 and an increase in 2013 at a density 8.82 $\pm$0.14 ind/km2. Camera trap results showed a decreasing trend with a capture rate in 2009 of 72.72 captures per 1000 trap days, 2011 had 52.80, and 2013 had 26.90. The Amazon squirrel has not shown significant changes in density as a result of the recent climate changes, whilst transects have shown an increase, camera traps showed a decrease. The habits of the squirrels are predominantly arboreal and similar to the primates are not directly impacted by the physical flooding and indicating healthy fruit production.

Tamandua (*Tamanduatetradactyla*) densities have been relatively constant in the Samiria River basin between 2004 and 2013 with a low point in 2009 and 2010, followed by higher densities in 2011, 2012 and 2013 (G=1.5145, gl=5, 0.9114). Density of tamandua in 2013 was 0.40 ind/km2. Tamdandua have shown an increase in camera trap captures over the years. There were no individuals captured on the cameras in 2009. In 2011 tamandua had a capture rate of 1.16 and in 2013 the capture rate was 6.90. Density of tamandua was relatively similar in all three zones ($F_{2,17}$=0.6125, P= 0.2275). The tamandua are both arboreal and terrestrial and they feed on ants and termites, which indicates that ant and termite populations have not presumably been impacted during the recent climate changes.

Three toed sloth (*Bradypusvariegatus*) densities have been consistently constant in the Samiria River basin between 2008 and 2013 (G= 0.8321, gl=6, P= 0.9912). In 2013 the density was higher than previous years at 1.02 +0.30 ind/km2. The density of three toed sloth has been relatively similar between all three zones (H=0.0241, gl=2, P= 0.988). The sloths are folivores and their arboreal habitats have not been directly impacted by the recent high water levels.

The common opossums (*Didelphismarsupialis*) are nocturnal species that were recorded frequently on camera traps, but not during terrestrial transects conducted during daylight hours. The 2009 camera trapping sessions recorded a capture rate of common opossum at 131.81 captures per 1000 trap days compared to 169.47 captures in 2011 and 111.90 in 2013, with relatively similar abundances and no indications of declines caused by floods. The common opossums live both on the ground and in trees of the lower understory of the forests and can survive above water during times of intensive flooding, which explains its stable population.

Similar to the primates, other arboreal and semi-arboreal mammals can overcome the direct physical effects of intensive floods by ascending into the forest. Their populations have remained relatively stable over the past years and have not decreased as a result of recent intensive inundations.

Ground dwelling predatory mammals have also not shown signs of being impacted by the recent climate change events, however, for a very different reason. The following section examines why carnivorous mammals have not yet been impacted by the intensive inundations, whilst the ground dwelling herbivores and insectivores have been impacted.

Carnivores

The carnivores and marsupials analyzed from terrestrial transect and camera trap results included coati (*Nasuanasua*), tyra (*Eirabarbara*), ocelot (*Leoparduspardalis*), jaguar (Pantheraonca) and puma (*Puma concolor*). Other species sighted with sample sizes too small for population analysis included crab eating raccoon (*Procyoncancrivorous*), jaguarundi (*Felisyaguaroundi*) and margay (*Feliswiedii*). The scansorial species did not show any clear impact from the recent climate change events since they are both ground dwelling and arboreal. The arboreal habits allow these species to overcome the physical impacts of recent extreme floods and included the coati, tyra and common opossum.

Coati (*Nasuanasua*) densities have varied with dips and peaks in the Samiria River basin between 2006 and 2013 (G= 10.5981, gl=7, P= 0.1571) and in 2013 were at relatively high densities of 4.08

+0.27 ind/km2. Coati were rarely captured on camera traps and sample sizes were too small for analysis. Over the years the coati populations have been similar between all three hunting zones (H=1.3581, gl= 2, P= 0.5071). Coati use both terrestrial and arboreal habitats and feed predominately on larger insects that move up the trees during floods and in turn allow the coati to overcome the intensive flooding events and maintain healthy populations.

Tyra (*Eirabarbara*) densities have varied in the Samiria River basin between 2006 and 2012 but have been consistently increasing since a low point in 2009 (G=1.4836, gl=6, P=0.9606) and density in 2013 were at 0.27 ind/km2. Densities of tyra were similar between all three hunting zones (H=5.526, gl= 2, P= 0.631). Results from the camera traps agree with line transects. In 2009 no tyra were captured on the cameras, in 2011 camera traps had a capture rate of 6.96 tyra per 1000 camera trap days, and in 2013 they had a capture rate of 5.94. Tyra often feed in the lower and middle story of the forest, which allows individuals to overcome periods of extensive flooding and maintain a healthy population during intensive floods.

Jaguar (*Pantheraonca*), puma (*Puma concolor*), and ocelot (*Leoparduspardalis*) were recorded on camera traps. The responses of terrestrial predators to the intensive flooding should be different than terrestrial herbivores (ungulates and rodents), since predators can find a higher density of prey trapped on floodplain levees during inundations, which would actually make it easier for them to find prey. In contrast, herbivores have much greater competition of food and lower body conditions as animals are pushed ever tighter on the smaller and smaller levees as waters rise. Thus, herbivores would suffer mortality both from increased predation and greater competition of food, whilst predators would have an easier time capturing prey.

Ocelots (*Leoparduspardalis*) were recorded in considerable numbers on camera traps. In accordance with the predictions, ocelot abundance has not been impacted by the recent intensive floods. In 2009 ocelot abundance had a capture rate of 9.09 ocelots per 1000 camera trap days. In 2011 the capture rate increased to 54.55 captures and on the small sample of traps placed in 2012 capture rate remained strong at 41.26. In 2013 the capture rate on camera traps was 19.80 individuals per 1000 camera trap days. Ocelots can be individually identified by their pelt marking, which makes it possible to use capture-recapture methods to estimate density. There were an estimated 12 individual ocelots captured on the camera traps distributed over an area approximately 20km2, which yielded a density of 0.6 ind/km2 (Pittet 2012).

Jaguars were only recorded on camera traps. In 2009 there were on jaguars recorded on the camera traps. In 2011 the capture rates of jaguar on camera traps was 12.18 captures per 1000 camera trap days and in 2013 the capture rate was 4.90. Pumas were also only recorded on camera traps. In 2009 there were no pumas recorded on the camera traps. In 2011 the capture rates of puma on camera traps was 12.18 captures per 1000 camera trap days and in 2013 the capture rate was similar at 14.85. These capture rates indicate sizeable abundances of both species and would suggest that both jaguar and puma have not been impacted by the climate changes of greater water level variations. This concurs with the prediction that predators are less vulnerable to the intensive floods than herbivorous species.

Giant river otter (*Pteronurabrasiliensis*) density have been increasing steadily in the Samiria River basin and the continued population growth does not appear to be impacted by recent climate change variations in water level. Giant otters are endemic to South America and had a marked decline due to excessive pelt hunting during the 1940's to 1970's with many pollutions becoming

extirpated. By the end of the 1970s, giant otters were nearly extinct. Studies of giant otter are a high priority for the IUCN and long-term conservation efforts for this critically endangered flagship species are needed. Today, giant otters are beginning to show a recovery in population size in many areas of their former range in the Amazon, including the Samiria River basin. Sightings of giant river otter have increased substantially in the Samiria River basin over the years.

Densities of giant river otter along terrestrial and aquatic transects have been increasing though the years. Between 2005 and 2007 there were no giant river otter observed on the transects. In 2008 density was calculated at 0.05 ind/km2, in 2009 it increased to 0.44 ind/km2, in 2010 it was 0.77 ind/km2, in 2011 it was 1.02 in/km2, in 2012 it increased slightly further to 1.12 ind/km2 and in 2013 increased to 2.05 ind/km2 (Figure 10).

Group size of otters also appears to be larger and more stable as the population grows. One otter group on the upper Samiria River was followed for a month. The group consisted of 5 individuals, one adult female, one adult male, one juvenile female, and two sub adults, one being a male and the other unconfirmed. All of the otters were individually identified by their throat markings and their behavior recorded. On one occasion the otter group was observed in aggressive interaction with a pink river dolphin. The group swam towards the dolphin and aggressively splashed, and in turn the dolphin swam aggressively towards the otters once they retreated. This went on for several minutes until the otters retreated.

The carnivores have not yet shown signs of being impacted by the recent climate changes. There are several different reasons why these species have overcome the effects of intensive floods and droughts. The terrestrial carnivores, including the jaguar, puma, and ocelot, are ground dwelling mammals that retreat to levees during intensive inundations. However, they have not shown any impact from the physical effects of flooding, unlike the other ground dwelling mammals such as ungulates and rodents that have been significantly impacted. It appears that the ungulates and rodents have been impacted by the intensive floods, because of increased competition for food and increased predator pressure as the animals are forced onto smaller levees. The jaguar, puma and ocelot actually have the reverse situation, since smaller levees results in greater concentration of prey species (ungulates and rodents), thus making it easier for these predators to obtain prey. The carnivores can therefore maintain healthy populations, because they do not lack food on the levees, but actually have more food resources.

The predator-prey lotka-volterra models predict cyclical populations between prey and predator populations are caused by a lag time. When prey populations grow, predators have more food and their populations begin to expand. Then, when predator populations are large the result is a shrinking of the prey population due to increased prey mortality from the large predator population. A small prey population causes the predator population to shrink due to increased competition. A small predator population results in the growth of the prey population as a result of decreased mortality, and the cycle begins again.

The longer term impacts of climate change should result in a decrease in the ground dwelling carnivores as predicted by the cyclical populations of prey and predators in the lotka-volterra model. As the ungulate and rodent populations become ever smaller due to a reduction in levee size from increased flooding, there should be a point where the carnivores have fewer prey causing a drop in predator numbers. However, current prey numbers appear to be large enough to maintain healthy jaguar, puma and ocelot populations.

The semi arboreal habits of coati and tyras allow these carnivore species to overcome the direct physical effects of flooding. These predators are able to ascend trees during intensive inundations and maintain healthy populations, similar to the oter semi arboreal mammals.

The giant river otter has not shown signs of being impacted by either droughts or floods. Giant river otter populations were decimated during the professional pelt hunting period between the 1950's to early 1970's when massive numbers of giant river otter skins were sold to the international market. Giant river otter numbers have increased over the years, but populations are still relatively small.   The aquatic-terrestrial habits of the giant river otter have helped the species overcome the impacts of recent climate events. During droughts the otters can survive more on dry land, whereas the otters have a more aquatic existence during intensive floods. The aquatic-terrestrial nature of giant river otters has allowed them to overcome the physical effects of recent climate change events.

Game Birds

The game birds have been able to overcome the recent climate change events, since they are able to wait out the periods of intensive flooding in the forests. All of the game bird species can take flight; even so many species are not good flyers. As long as the birds can stay above the inundation they are able to maintain healthy populations during the intensive inundations.

Game birds surveyed along terrestrial transects included tinamous species (*Tinamus* spp.), razor-billed curassow (*Mitutuberosum*), Spix's guan (*Penelope jacquacu*), and blue-throated piping guan (*Pipilecumanensis*). There were no obvious impacts on the density of game birds from greater variations in water level. Similar to macaws, primates and other arboreal wildlife, game birds are able to overcome the physical flooding. Overall numbers of game birds was relatively similar between the hunting zones with a trend towards greater numbers in the infrequently hunted zone, followed by the occasionally hunted zone and least in the commonly hunted zone ($F_{2,17}$=2.3146, P=0.1278). The density of game birds in 2013 was around the long term average for all three hunting zones.

Density of tinamous in the Samiria River has gone through dips and peaks between 2004 to 2012 with no significant long term trends (G=4.3755, gl=6, P= 0.626) and an average density at 4.39 ind/km2. Densities in 2011, 2012 and 2013 were towards the lower end, at 2.40, 2.01, and 2.00 ind/km2, respectively. The transects show a healthy and stable population of tinamous and no indication of the species impacted by climate change variations in water level. The tinamous density was similar in all three hunting zones ($F_{2,15}$= 0.8311, P=0.542).

The razor-billed curassow was observed both on line transects and on camera traps. Densities have been relatively constant between 2004 and 2013 (G=1.3613, gl=6, P=0.9682).Density of razor-billed curassow was 0.20 ind/km2 in 2012 and 0.17 ind/km2 in 2013. Camera traps recorded an encounter rate in 2009 of 22.72 events per 1000 camera trap days, in 2011 there were 8.70 eventsand in 2013 the capture rate was 9.90. The results do not show any signs of razor-billed curassow being impacted by climate change events, whilst camera trap encounters fell somewhat, transect densities have increased slightly. The infrequently hunted zone had the greatest density of razor-billed curassow, followed by the occasionally hunted zone. There were no sightings of this species in the commonly hunted zone.

The Spix's guan has gone through some peaks and dips in numbers on transects between 2004-2013, but overall has had a relatively stable population (G = 11.7878, gl = 7, P = 0.1078) with 2013 density at 0.36 ind/km2.. This indicates that the species has not been impacted by the climatic fluctuations in water level. Spix´sguan were not recorded on camera traps. The density of Spix's guan was relatively similar between the hunting zones with a trend towards higher density in the infrequently hunted zone, followed by the occasionally hunted zone, and least in the commonly hunted zone (H=1.6494, gl=2, P=0.4383).

Blue-throated piping guan had a relatively stable population between 2006 to 2013 (G = 7.6775, gl = 7, P = 0.3619). The 2013 density was higher than the mean at 0.88 ind/km2, up from 2012. Results indicated that blue-throated piping guan has not been impacted by recent water level variations. Blue-throated piping guans were not recorded on camera traps. The infrequently hunted zone had the greatest density, followed by the occasionally hunted zone. There were no sightings of this species in the commonly hunted zone.

All of the game bird species have maintained healthy populations during the recent climate changes. Their ability to fly has allowed them to ascend to the forest and stay above the intensive inundations. Indeed, most of the species that have not shown impacts from climate change are forest dwelling animals that have arboreal or semi-arboreal habits, including macaws, primates, other semi-arboreal mammals, and game birds.

Forest dwelling species are not impacted by the direct effects of droughts, since their terrestrial life is outside the aquatic environments. However, terrestrial wildlife might be indirectly impacted by droughts if forest structure changes over the long term from the intensive dry conditions. Droughts have not been a consistent consequence of climate change in western Amazonia. Thus, drought should generally not impact forest dwelling species.

In contrast, the more frequent intensive flooding will have a direct impact on terrestrial forest species if they cannot ascend to the middle story or canopy of the forest. However, those species that can climb or fly above the ground have a clear advantage during intensive inundations, since the floods do not directly impact their survival. Over the longer term these species might be impacted by climate change due to changes in the diversity and structure of the plant community. Direct effects of intensive flooding on plants and changes in the dispersal and predation of seeds by ground dwelling wildlife will likely result in changes in the plant community and in turn will cause changes in the composition and availability of food resources for arboreal and semi-arboreal wildlife. Some species may fare better, whilst other worse as the long term impacts of climate change alters forest structure and diversity.

Ground dwelling carnivores have so far overcome the effects of intensive floods for a completely different reason. The jaguar, puma and ocelot actually have had access to a greater density of prey species and in turn more food. Density of common prey species, such as ungulates and rodents have increase as the levees have become smaller, thus making it easier for the carnivores to capture food resources. On the other hand, giant river otter have over the impacts of droughts and intensive floods, because they can survive both on land and in water by having an aquatic-terrestrial existence.

The people who live in the flooded forests of Amazonia rely on subsistence resources from the forest, especially fish and to a lesser extent bushmeat. The Cocama indigenous people have lived

in the Samiria River basin since pre Colombian times. They are involved in sustainable management and are helping to conserve the vast flooded forests of the PacayaSamiria National Reserve. However, their livelihoods are now being impacted by the recent climate change events. The following section looks at the impact of climate change on the local Cocama people of the Samiria River and discusses the overall impact of climate change on wildlife and people.

Impact of Climate Change on Indigenous Cocama People

Indigenous people are very vulnerable to the impacts of climate change. Throughout the world indigenous people are being affected by change climatic conditions, because of their close association with nature and the natural environment (Macchi 2008). Many indigenous societies rely on bushmeat and fish for their protein, the soils and water for their agriculture, and they often live in marginal areas making their villages and livelihoods vulnerable to changes in weather conditions (IPMPCC 2011).

The impact of climate change on indigenous people is occurring around the world in the Arctic and sub-Arctic, in both northern and southern hemispheres and in the Andes and Amazon (IPMPCC 2011). Indigenous peoples have become actively involved with climate change issues, both in their daily lives and in social and political agendas on local, national and international levels (Macchi 2008). In Peru indigenous peoples are being affected by glacial melt downs and changing altitudinal weather conditions in the Andes (Gonzales 2011). In the Amazon indigenous peoples are being impacted by the droughts and intensive floods.

Indigenous cultures are adapted well to changes in the natural world where they live. This helps them overcome the annual and multi-year changes cause by weather, such as storms, fires, winters, droughts and floods. However, these weather conditions are becoming more extreme due to the effects of climate change and indigenous people are often being inflicted by more extreme conditions making their livelihoods more difficult. Indigenous people must find new ways to adapt to climate changes. As natural resources and agricultural conditions change they must find alternative foods, both in the natural environment and agricultural landscape.

Indigenous people who live in the Amazonian flooded forests have been confronted in recent years by extreme floods and occasional droughts. Cocama indigenous people live in the Samiria River basin and have been directly impacted by the physical effects of floods and droughts, and indirectly impacted by changes in the fish and bushmeat populations. The following section will examine the impacts of climate change on the indigenous people of the flooded forests, especially in relation to their natural resource use and management.

Cocama Indigenous People

The greater variations in water level caused by recent climate change events is beginning to have an impact on the sustainability of resource use by the local Cocama Indians who use the Samiria River as their traditional area. The Cocama live in the flooded forests and have adapted to the seasonal fluctuations in the use of natural resources. During high water fishing is more difficult, since the fish are dispersed throughout the inundated forests. However, during this period hunting

usually becomes easier with the large bushmeat species, such as deer, peccaries and tapir being trapped on the levees. However, the recent climate change events have resulted in a decline in bush meat species, resulting in both fewer animals to hunt and hunting becoming less sustainable. The Cocama now have to rely more on fishing during the high water season, when fish are more difficult to catch. The size of commonly used fish decreased after the drought, which means that people had to capture greater numbers to maintain the same protein intake. This requires greater effort and less sustainable fisheries, since more fish need to be captured. More recently, the fish population has recovered resulting in a more sustainable fishery.

The sustainability of bush meat hunting by the Cocama in the Samiria River basin was evaluated using stock'recuitment analysis. The stock-recruitment model is based on density-dependent population models that use maximum sustained yield estimates (MSY) and carrying capacity (K). Most species of tropical wildlife that are hunted are K-selected species and should therefore have density-dependent recruitment. In turn, sustainable harvests of tropical wildlife populations will depend on relationships between rate of recruitment and population size. The stock-recruitment model predicts the riskiness of harvests for different populations sizes. A species population in a hunted area can be compared to a predicted K and MSY. This is accomplished by comparing the density of the hunted population (N) to an estimated K as N/K. Harvesting species at the MSY is a risky management strategy and should be avoided. Similarly, harvesting species with small base populations (to the left of MSY) is a risky management strategy and should be avoided. Harvesting species with large base populations (to the right of MSY), on the other hand, is a safe management strategy that can be used for long-term sustainable use of a species. In the Samiria River basin densities of mammals in nonhunted areas were used to estimate K. MSY was set at 60% of K for peccaries, deer, and large rodents and 80% of K for lowland tapir and primates.

The sustainability of bush meat hunting has decreased significantly since the climatic changes in water level variation began in 2009. The hunting pressure has not increased, but declined since 2000. The changes in the sustainability appear to be due to the impact that climate change is having on bush meat species. In 2000, the only species that was hunted with a risk in sustainability was the lowland tapir. Collared peccary, white-lipped peccary, red brocket deer and black agouti were all hunted safely. The conservation actions that were implemented through community based wildlife management have resulted in a healthier tapir population, and by 2009-2010 the tapir was hunted safely in terms of sustainable use. However, other bush meat species have declined since the climatic variations began. The first species to be impacted was the collared peccary and in 2009-2010 the hunting of collared peccary became risky. The other bush meat species were hunted safely in 2009-2010. By 2011 the impact of climatic change on the sustainability of hunting became evident, with collared peccary, white-lipped peccary, red brocket deer and black agouti all becoming risky in terms of hunting sustainability. The only species that remained as safe was the lowland tapir, because of a reduction in hunting pressure by the Cocama as a result of conservation and sustainable use actions. In 2013 the sustainability of bushmeat hunting is even more extreme, due to the reductions in the populations of peccaries, brocket deer, paca, and agouti caused by the consecutive intensive flooding.

The local Cocama have changed their bushmeat use over the past few years as hunting has become more difficult due to climate change events. Hunting has become less common and hunters who do still go out are less successful. Hunters state that "it is no longer worthwhile going hunting, there are no longer game animals."

However, families still have a desire to eat bushmeat at times. Men now travel to the non-flooded upland forests of the Chambira and Tigre Rivers and trade fish for bushmeat. The non-flooded forests still have healthy populations of bushmeat species, such as peccary, deer, paca and agouti, since they are not affected by physical flooding. Instead of hunting the Cocama of the flooded forests trade their abundant fish for scarce bushmeat, thus providing their families with red meat on occasion.

Fishing has been productive during the high water years and was only reduced during and immediately after the drought. The Cocama people have always relied more on the fish production of the flooded forests, than on bushmeat. However, the impact of climate variation has now changed the Cocama to become almost entirely reliant on fish, which during high water years is fine.

The drought years, however, have high fish mortality and a decrease in fish populations immediately following the dry conditions. Fish populations generally recover relatively quickly, and two years after the drought of 2010 fish populations recovered. The decrease in fish populations have not have a notable effect on the local people, because the massive fish production of the Samiria River still results in sustainable fish harvests during drought events.

The total annual harvest of fish by the Cocama communities at the mouth of the Samiria River is approximately 1,735 tons, or 4.7 tons a day on average (Kirkland 2013). People reported fishing and consuming at least 23 different species. The most important species were the black prochilodus*(Prochilodusnigricans)*. Other important species include the common pleco (*Liposarcuspardalis*), the golden wolf fish (*Hoplerythrinusunitaeniatus*), the hard-bellied silver dollar (*Mylossomaduriventre*) and the wolf fish (*Hopliasmalabaricus*). During the low water season wading birds are consuming approximately 10 tons a day or 1,000 tons over the 100 days they remain at the mouth of the Samiria River. At the mouth of the Samiria River the local people and game birds combined are harvesting around 2,735 tons of fish annually or on average 7.5 tons per day. In comparison, the city of Iquitos has an average daily fish landing of 10 tons/day.

Fish production is not constant throughout the year with fishing returns being higher in the low water season than during high water. Fish enter the PacayaSamiria reserve at the beginning of the high water season and many species breed in the flooded forests, exploiting the rich food availability spanning over 20,000 km2 of inundated forests. When the waters begin to recede many fish migrate out of the Samiria River basin into the larger Marañon and Amazonas Rivers. During the low water season the CPUE of Cocama fishermen at the mouth of the Samiria is about double of the CPUE during the high water season ($H_{(2)} = 33.29$, $p < 0.01$).

In the past when game animals were more abundant the Cocama hunted more during the high water season and fished more during the low water season. During high water fish are dispersed throughout the vast flooded forests, which make fishing more difficult, reflected by the lower CPUE. However, during the high water season game animals such as peccary, brocket deer, paca and agouti are concentrated on levees. The reverse goes for the low water season when the Cocama fished more and hunted less. During low water fish are more concentrated in the lakes, channels and rivers, which makes fishing easy. During the low water season the forest floor is dry and the larger game species can range throughout the reserve, making hunting more difficult.

Climate change events are causing the local Cocama to change their traditional resource use patterns. The people now rarely hunt, since the levees are currently at a great distance from the village. Instead, the Cocama of the Samiria must now fish in the high water season when fish are more dispersed and fish returns are much lower. Fortunately, fish numbers are overall very high in the Samiria River basin and can support the increased fish returns. Local people state that during the high water they must fish for longer periods to meet the daily fish intake of their families (Kirkland 2013).

The local people of the flooded forests live in seasonal habitats that change from low water to high water annually. Climate changes are causing the high water seasons to have more intensive inundations interspersed with occasional droughts during the low water season. The Cocama people have been adapting to the wildlife changes caused by climate variations by hunting less, fishing more in the high water season than in the past and trading fish for bushmeat with communities living in the non-flooded upland forests of nearby rivers.

The recent climate change has also impacted the agriculture, water quality and living conditions. The higher water levels of recent years have impacted the agriculture of the Cocama people. The traditional agriculture in the flooded forests revolves around the flooded and dry seasons and crops are planted to maximize the period when soils are dry. The greater floods have resulted in shorter growing seasons of annual crops such as manioc, corn and rice and die off of longer term crops such as plantains on grown on levees, which in the past did not flood. When the Cocama of the flooded forests lack agricultural products due to climate events they will trade fish production for plantains, manioc, rice and corn with communities in the upland non-flooded forests. Similar to a lack of bushmeat, fish production is used to obtain other food products that have become rare due to intensive inundations caused by climate change.

During the droughts water quality becomes a major concern for the communities og the flooded forests. Water becomes stagnant and fish mortality can be great. Rotten fish left by wading birds is a constant issue and decomposition in the stagnant water causes the water to rot. In addition, a heavy rain can cause upwelling during the low water period. The hot sunny conditions heats up the surface water. When a cold heavy rain hits the surface the water at the bottom of the rivers, channels and lakes has a higher temperature and moves to the surface as the surface water moves to the bottom. The bottom water has much less oxygen and many fish die from the anoxic conditions. This coupled with the stagnant water amplifies the water rot. Local people rely on the river water for cooking, bathing and washing. The rotten water makes these activities difficult and increases the incidence of stomach and skin illnesses.

Likewise, the intensive floods cause hardship in the living conditions of the Cocama people. The intensive floods the villages and local people retreat to the attic of their houses, since the lower levels of most houses becomes flooded. There is no land in the villages and everyone must go by canoe. Children go to school in canoes, authorities go by canoe to meetings, family and social visits are done in canoes, and some people even eat their dinner from their table in a canoe; the legs of the table being underwater. While the Cocama are accustomed to these conditions, the intensity of flooding has made living conditions worse and more difficult.

Climate change is impacting the Cocama of the flooded forest on many different levels of their livelihoods. They are adapting to these changes, but their standard of life has become more difficult. The massive fish production of the flooded forests has allowed them to trade fish for

bushmeat and agricultural products that have become scarcer due to the intensive inundations. The effects of water rot during droughts and intensive floods have resulted in harsher living conditions. If climate events continue or become even more severe the Cocama people will need to find new ways to adapt.

Conclusion: Climate Change and Wildlife

The Peruvian Amazon was on a downward slope of destruction between the 1950's to 1980´s with unregulated extractive activities, including extensive timer extraction, uncontrolled commercial fisheries, commercial bushmeat hunting and commercial pelt hunting, among others. In the early 1980´s it was predicted that at that rate of destruction there would be no Amazon forests left by the year 2010. Fortunately, that prediction did not happen and today the Peruvian Amazon is still generally intact. Indeed, in many areas the Peruvian Amazon is actually healthier now than it was in the early 1980's. The reason is that during the 1980's, 1990's and 2010's people took action to stop much of the destruction and conserve the Amazon. Local people defended their traditional lands and created co-managed community conservation areas that allow them to continue their traditional livelihoods (Little 1994). Protected areas incorporated the indigenous people in co-management and implement conservation strategies (Robinson y Redford 1994). Government policies were implemented to regulate extractive activities and help biodiversity conservation (Robinson 1993). Institutions, NGO's and government departments worked together to help conserve the Amazon. Of course things are not prfect and there are still many challenges and threats that need to be confronted. But, overall conservation has made significant progress in the Peruvian Amazon.

The conservation efforts of local people have been particularly notable and community-based conservation efforts have been a major driving force for many of the conservation successes in the Peruvian Amazon (Bodmer y Puertas 2000). The Cocama people of the flooded forests have been involved with co-management conservation strategies and are helping to conserve the PacayaSamiria National Reserve. Climate change is now impacting the Cocama people and they will need to adapt to more intensive flooding, occasional droughts and changes in their agriculture, fishing and hunting.

The impacts of recent climate change presented in the previous sections have clearly shown the effects on wildlife and the Cocama people. The long term monitoring research on a wide range of wildlife groups conducted in the Samiria River basin has been important to understand the climate change impacts. The monitoring research required the selection of indicator and resource use species in both aquatic and terrestrial habitats, development of robust standard methodologies, and the dedication of researchers, students and volunteers. Institutional support from the PacayaSamiria Reserve Authority, NGO´s and universities has also been very important to continue the reseach over the long-term. The final section will present an overview of the results and discuss them in terms of climate change and conservation.

Conservation activities produce the best results when professionals, institutions, local communities and reserve authorities work together. The monitoring activities conducted by the expeditions helped to collect information on a variety of wildlife populations, which is helping determine whether the current climate change variations in water level are impacting the wildlife and people of the Samiria River basin (Bodmer et al. 2012).

Water level is a reliable measure of climate change for several reasons. Water level has a gradual increase and decrease in the upper Amazon and is a steady measurement, unlike temperature or rainfall which can vary greatly even on a daily basis. Water level in the upper Amazon is similar over very large areas and in not site specific, in contrast to rainfall which can vary significantly even at sites in close proximity. Water level is also very easy to measure and records have been taken in the Amazon for over 100 years, so long term trends are available. Lastly, water level has both direct and indirect impacts on wildlife and the flooded forests are where this impact is the greatest and can be measured easiest (Bodmer et al. 2011).

The drought of 2010 negatively impacted much of the aquatic wildlife, including dolphins, wading birds, fish and the specktecaled caiman. In contrast, consecutive years of intensive flooding have positive impacts on many aquatic species and populations increase under these conditions.

The variation in water level is impacting the dolphins. The drought of 2010 caused many dolphins to leave the Samiria River. In addition, the annual sighting of dead pink river dolphins floating down the Samiria is usually 1 or 2 individuals. However, during the drought there were 6 dead pink dolphins seen along the Samiria and the number of sightings of dead individuals is only a proportion of the actual mortality. Sightings of dead grey dolphins are much rarer. Mortality in manatees was also seen in 2010 for the first time presumably due to a lack of access to their major food resource, the floating vegetation, which was high and dry and out of their reach.

Major food resources for the dolphins are piranha fish and there are good correlations between the abundance of piranha and dolphins, both pink and grey. Results showed that piranhas are one of the fish species that have been impacted by recent climate changes in water level. The age structure of the two most abundant species decreased during the drought indicating deterioration in the demography of the species. In turn, it is likely that the decrease in fish size was impacting the food resources of the dolphins, reflected in the declining dolphin abundances. In 2012, following two years of high water levels, both the dolphin and fish showed signs of recovery, and in 2013 after yet another year of intensive flooding the dolphin populations have returned to healthy population levels.

The greater proportion of young dolphins in the Samiria may be a population response to the lower populations following the drought. Density dependent mechanisms would predict a younger demography after a perturbation in the population. The younger dolphin population may also lead to a recover in dolphin numbers and a growing population in the coming years, if conditions of climate change stabilize.

Wading bird populations also showed an impact from the drought. The great egret and Neotropical cormorant seasonally migrate in large numbers to the mouth of the Samiria River as the fish fry move out of the flooded forests. It is common to sight over 7,000 Neotropical cormorants and 2,000 great egrets during a single transect at the mouth during the low water season. In 2011, there were significantly fewer wading birds at the mouth, and many cormorants and egrets were seen searching for fish on the Marañon River and the mid-section of the Samiria River. It appears that numbers of fish fry were lower and birds had to look for food in other areas than their usual dry season feeding waters. Similar to dolphins, it appears to be the impact on the fish populations that caused declines in observed numbers of wading birds after the drought. Wading bird numbers recovered in 2012 after two high water seasons, reflecting a recovery in fish

populations. In 2013 the wading bird numbers increased even further with a doubling of the Neotropicalcormorant population.

Fish populations were impacted by the drought during the low water season of 2010 and consequences were seen during 2011. Fish mortality during the drought was substantial both because of the lack of deep water and anoxic conditions. Water depth was only a foot or so deep in many lakes, channels and the river, which also caused greater competition, predation and movement out of the Samiria River into the larger Marañon and Amazon Rivers. The production of fish during the 2011 high water season was likely reduced substantially because of the adult mortality from the drought. Indeed, in 2012 after two consecutive high water years fish populations show recovery in demography and numbers. Fish populations usually rebound quite rapidly from poor conditions, which appear to be the case in 2012. In 2013, fish populations have recovered even further with greater numbers and larger size classes.

The speckled caiman was impacted by the drought of 2010. Their population declined following the drought, but umbers of common caiman recovered rapidly indicating an adaptive response to climate fluctuations. There were no signs of black and smooth-fronted caimans being impacted by the drought. Caiman food resources are very broad, including insects in young individuals and fish, mammals, reptiles and birds in adults. This diverse array of food resources was overall not impacted by the water level changes and may have helped the speckled caiman population recover and helped the black and smooth-fronted caimans have stable numbers.

Ground dwelling species, such as the ungulates and other terrestrial mammals, have been impacted severely by the consecutive intensive flooding caused by recent climate changes in water levels of flooded forests. Terrestrialungulates,rodents and edentates, including peccaries, brocket deer, paca, agouti, giant anteater and armadillos have been impacted by the greater variations in water level. These ground dwelling species are impacted by the high water levels that reduce the availability of dry ground during the high water season. There are multiplier effects that are causing the ground dwelling mammals to decline under these conditions. With less dry land during extreme floods the food availability decreases, since food resources are directly proportional to the amount of dry land. Thus, the carry capacity also declines and both inter and intra specific competition increases. The camera traps set during the high water season in 2011 clearly showed the consequences of this reduced food availability and increased competition, with many peccaries, deer and tapir showing signs of emaciation.

Ungulates populations also become more vulnerable to predation when they are restricted to floodplain levees during high water. Predators such as jaguars and pumas seek out the levees and prey on the ungulates. It would be expected that the predators would actually do better during these extreme floods seen in recent years, and camera trap results confirmed this prediction. Interestingly, the lowland tapir, the largest of the ground dwelling mammals has not shown signs of population declines from the camera traps. One explanation is that the tapir is an uncommon prey species because of its large body size and defensive canine teeth. Another explanation is its more diversified diet of leaves and other herbivorous foods, whereas peccaries, deer, agouti and paca rely on fruits and seeds as their major food source.

Species that can live in the arboreal or semi-arboreal habitats are not directly impacted by the flooding and can overcome the physical effects of the inundations. These species feed on arboreal food resources, such as fruits, leaves, insects or other prey and have not been affected by recent

climatic changes in water level. Wildlife groups such as macaws, primates, arboreal edentates and tree dwelling carnivores inhabit the forest above the physical impacts of flooding. It also appears that the forest fruit production has not been effected by the water level variations, and some groups that depend on fruits have increased, while others have remained stable. Likewise, the insects and other arboreal prey resources are still in abundance, since they move vertically up the trees during floods. This was reflected by a stable population of arboreal edentates and carnivores.

However, longer term impacts on the arboreal species are likely to happen as the diversity and structure of the forests changes as a consequence of climate events. Direct physical impacts from flooding and droughts, and changes in seed dispersal and predation will result in alterations in the forests. These changes will result in niche and food differences for the wildlife and in turn impact arboreal animal populations.

The ground dwelling carnivores, such as jaguars, pumas and ocelot, have also maintained healthy populations during the recent intensive floods. The common prey species of ground dwelling carnivores include peccaries, deer, agouti, paca and other terrestrial wildlife. These common prey species become concentrated on the floodplain levees during high water, thus making them easy prey for the carnivores and helping to maintain healthy populations of jaguars, puma and ocelot. However, lotka-volterra models predict that their populations will be impacted as the prey numbers decrease.

The giant river otter populations have also shown no signs of impact from water level changes. Giant river otter are still in a growth phase from the massive overexploitation that occurred between the 1950´s and 1970´s. There populations are still well below the carrying capacity and it is likely that the decrease in their preferred fish was not drastic enough to impact the steady growth of their population. The otters use both the aquatic and terrestrial habitats and can switch between them during extreme water level variations.

The evidence of impacts of recent climate change presented in this report use correlations between the observed intensive inundations and drought that have occurred over the past five years, 2009-2013, and changes in wildlife populations. The previous three year period, 2006-2008, had more average climate conditions and trends in wildlife populations are compared between the two sets of years, those with more normal conditions and those with greater climate fluctuations. We realize that the cause and effect relationships of correlations need to be treated with caution. But, at the same time, the most obvious variable that changed between the two sets of years was the difference in climate fluctuations.

The confidence that observed changes in wildlife populations are actually a result of recent climate change is greater if different wildlife species or assemblages of species show the same trends. A similar repeated observation in different species suggests that the cause and effect relationships between animal populations and recent climate changes are probably accurate. For example, the aquatic assemblages of fish, dolphins and wading birds all showed the same trends. The populations of all three assemblages declined during and immediately following the drought. All three assemblages then recovered after two years of intensive flooding and have continued to recover in 2013 after another year of intensive floods. Since fish, dolphins and wading birds all showed the same trends we can have greater confidence that the drought and intensive floods were the cause of the changes in the populations. Similarly, all of the terrestrial ground dwelling

mammals, including peccaries, brocket deer, paca, agouti, armadillo, and giant anteater showed declines in their populations following consecutive years of extreme flooding. Because all of these species showed the same trends in their populations we can have greater confidence that the historically high water levels were the cause of the population declines.

Local Cocama Indigenous people are being impacted by the greater water level variations of recent years for multiple reasons. The bush meat hunting has decreased substantially from the declining ungulate and rodent populations, and has become less sustainable as a result of the climate changes. People now rely more on fish during high waters, which were traditionally the period of bush meat hunting. However, fish become dispersed in the flooded forests during inundations and are more difficult to capture than in the low water season when they are restricted to lakes, channels and rivers. During the drought fish also became rarer after a time and in 2011 the size of many common species has become smaller and people had to capture more fish for the same level of protein. Floodplain agriculture has also been impacted by the intensive floods, with growing seasons becoming shorter as the high water rises earlier. Crops have to be harvested before they become fully mature or left to die from the flooding.

Conservation strategies need to be found that help the local people overcome the impacts of their traditional resources uses by the climatic conditions. Incentive based conservation is likely to be one strategy that helps local people overcome the declining resource uses. The lessons learnt from community based conservation in the PacayaSamiria and other sites are helping form a larger and more robust conservation strategy for the Amazon basin. Economic incentives that act as catalysts to help local people implement community-based conservation are needed, not economic alternatives. The local people in the Amazon have an economic strategy based on hunting, fishing, non-timber plant products and small scale agriculture. This is the basis of their economy. These activities can be done in a sustainable manner that helps conserve species, forests, ecosystems and local cultures, or they can be done in a non-sustainable way that results in overexploitation of species, destruction of forests and degradation of their ecosystem and cultures. What are needed are economic incentives that help communities convert unsustainable practices to sustainable practices.

The turtle certification program being developed in the Samiria River basin will help secure added income from the sale of pet turtles, and communities will become recognized as responsible environmentally sensitive communities that are helping to save the Amazon rainforest. With an increasing number of communities becoming certified the program is enhancing the conservation of Amazon forests, providing added income for rural families and demonstrating the importance of the environmentally sensitive consumer as a driver for conservation of the Amazon rainforests.

The Pacaya-Samiria National Reserve has gone through major shifts in its management policies over the past decades, from an area of strict protection where local people were excluded from the reserve to an area where the local indigenous people participate with the reserve management (Bodmer et al. 2008). This drastic shift in conservation policy has led to a reduction in hunting pressure and an increase in wildlife populations (Bodmer &Puertas 2007). When the park administration changed and the reserve began to incorporate the local communities in the management of the area, attitudes of the local people also changed (Puertas et al. 2000). Local management groups were given areas to manage and were no longer considered poachers. They were able to use a limited amount of resources legally and with reserve administration approval.

Many of the local people changed their attitude towards the reserve and began to see the long-term benefits of the reserve for their future. The reserve became part of their future plans and there was increasing interest in getting involved with the reserve. Many local people can now see the socio-economic benefits of the reserve and are helping to conserve the area. Hunting has decreased substantially, both due to the poachers now becoming mangers, and because the local people are keeping the other poachers out of their management areas (Bodmer et al. 2008).

The impacts of climate change now present another challenge for the reserve and the local people living in the area. New threats are becoming obvious from the greater variations in water level, both in terms of droughts and intensive flooding. It is very fortunate that the reserve authority and local people are now working together, since it will take a collaborative and combined effort to overcome the physical nature of climate change impacts. Unfortunately, it is the greater human population that is responsible for these impacts from carbon emissions and economic development, not local unsustainable uses as in the past.
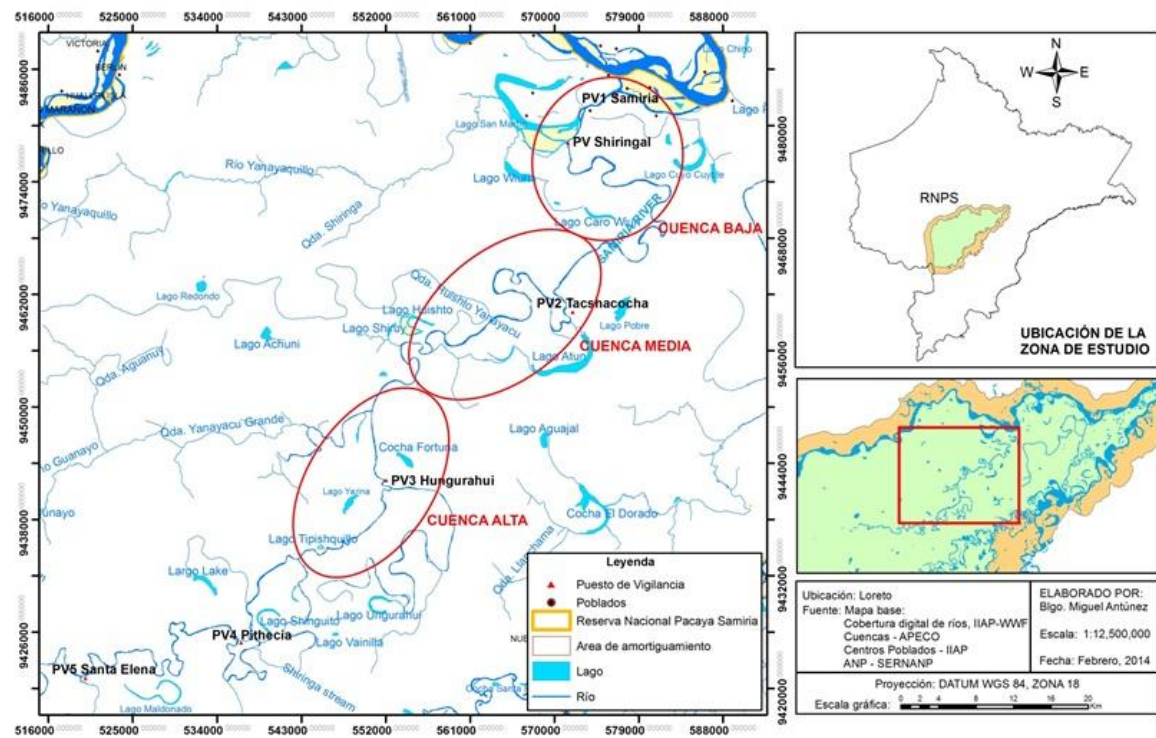
Figure 1. Map of the Samiria River basin showing the study areas at the mouth (Cuenca Baja), mid-section (Cusenca Media) and upper section (Cuenca Alta).
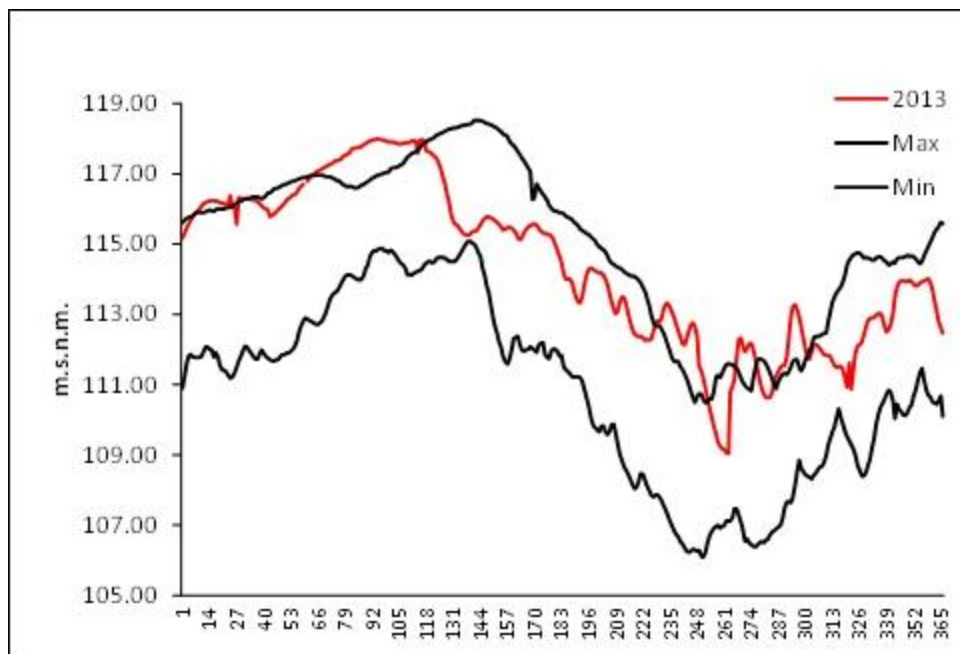
Figure 2. Water levels during 2013 in the vicinity of the Samiria River (red line). Black lines depict long term maximum and minimum water levels.
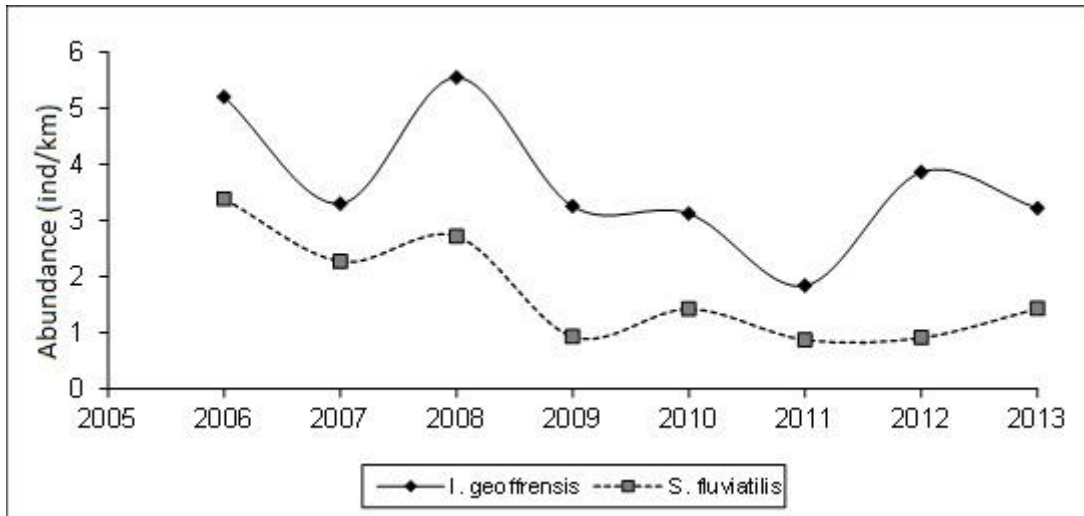
Figure 3. Overall abundance of pink river dolphins (*I. geoffrensis*) and grey river dolphins (*S. fluviatilis*) in the Samiria river between 2006 and 2013.
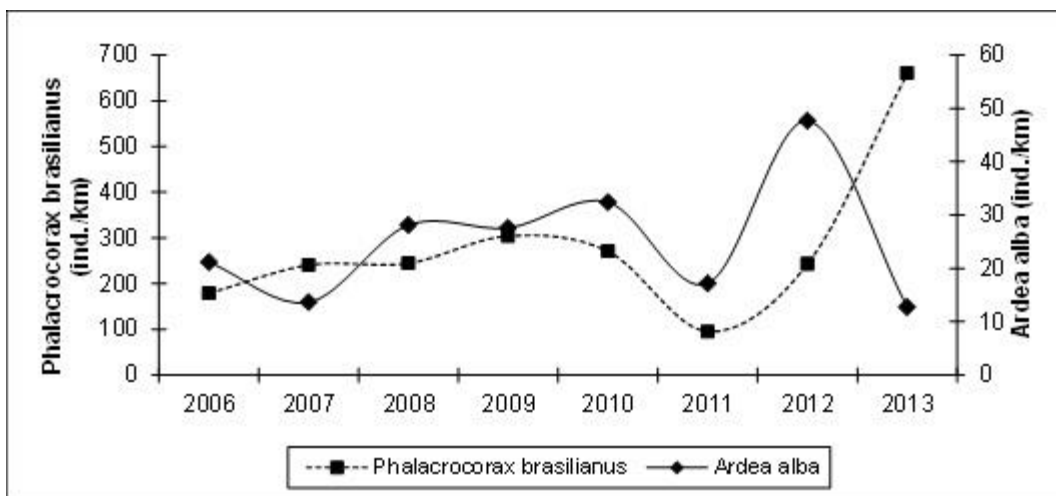

Figure 4. Abundance of Neotropical cormorants (*Phalacrocoraxbrasilianus)* and great egrets (*Ardeaalba)* at the mouth of the Samiria River between 2006 and 2013.
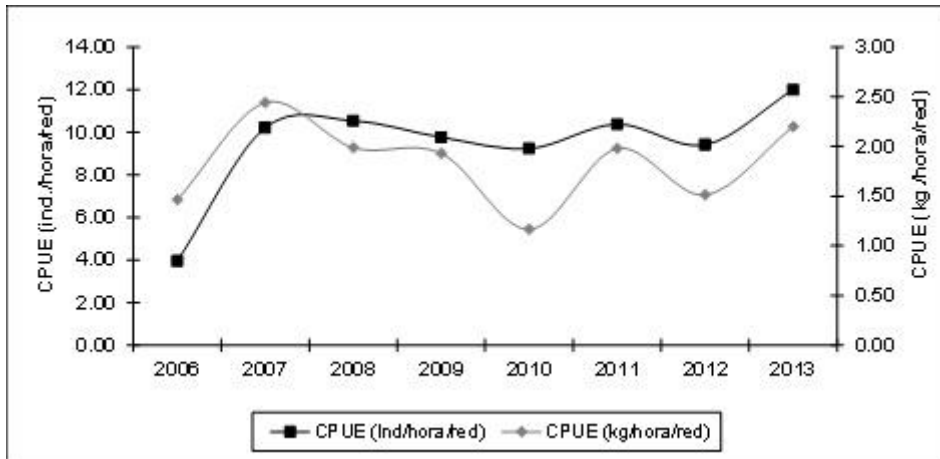
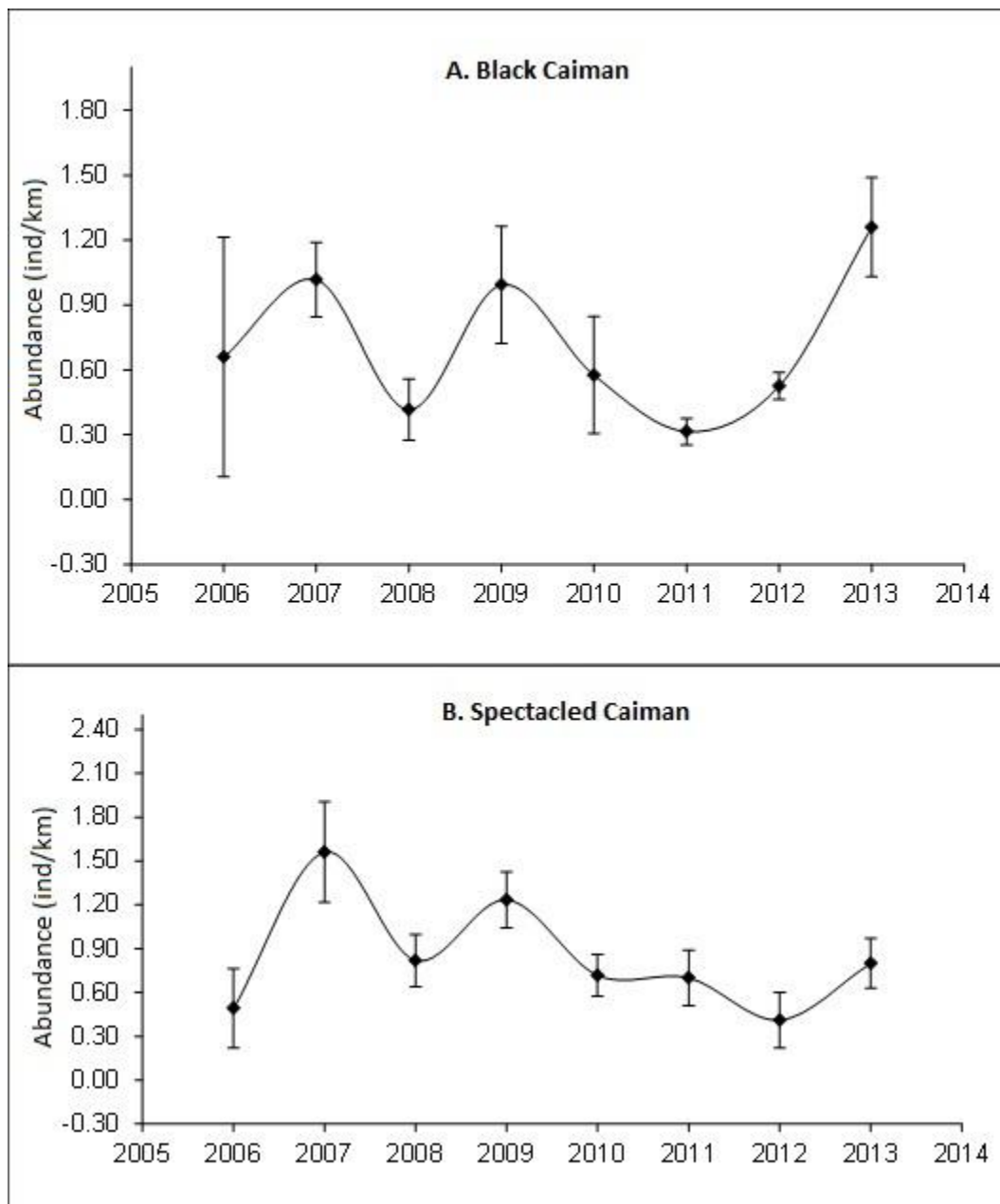Figure 5. Overall Catch per Unit Effort (CPUE) of fish in the Samiria River between 2006 and 2013, depicted in both individuals (ind/hora/red) and biomass (kg/hora/red).

Figure 6. Overall abundance of a) black caiman and b) spectacled caiman in the Samiria River between 2006 and 2013.
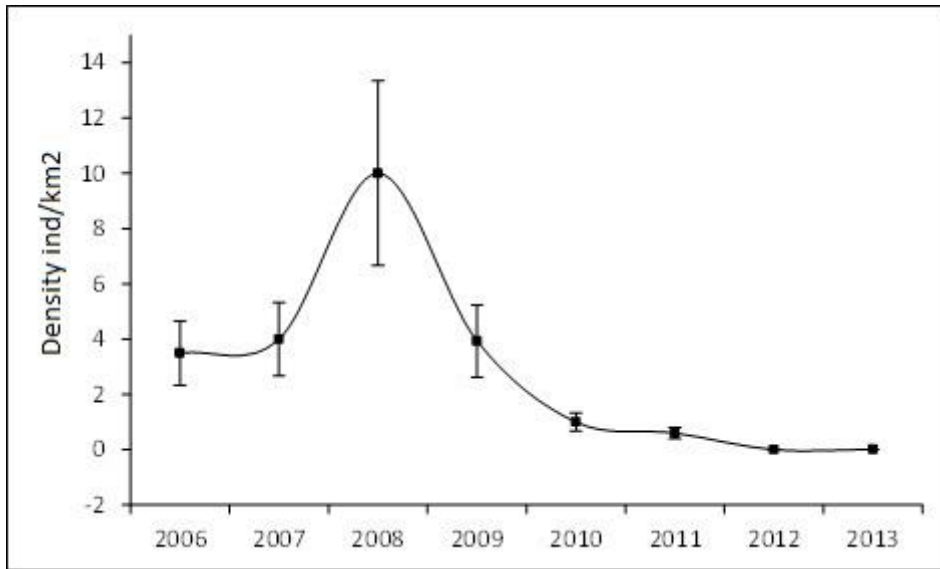
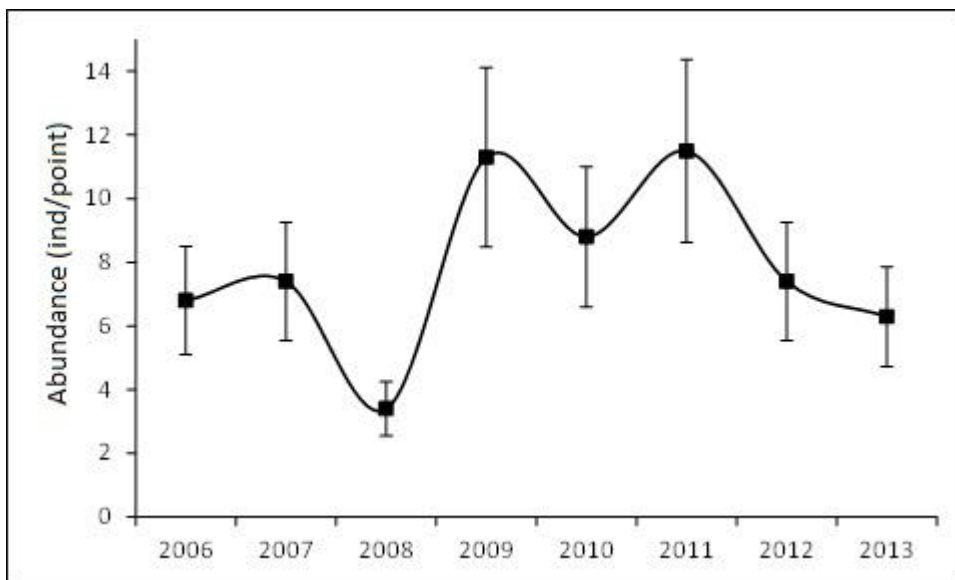Figure 7. Overall density of ungulates in the Samiria River basin between 2006 and 2013.

Figure 8. Overall abundance of macaws in the Samiria River basin between 2006 and 2013.
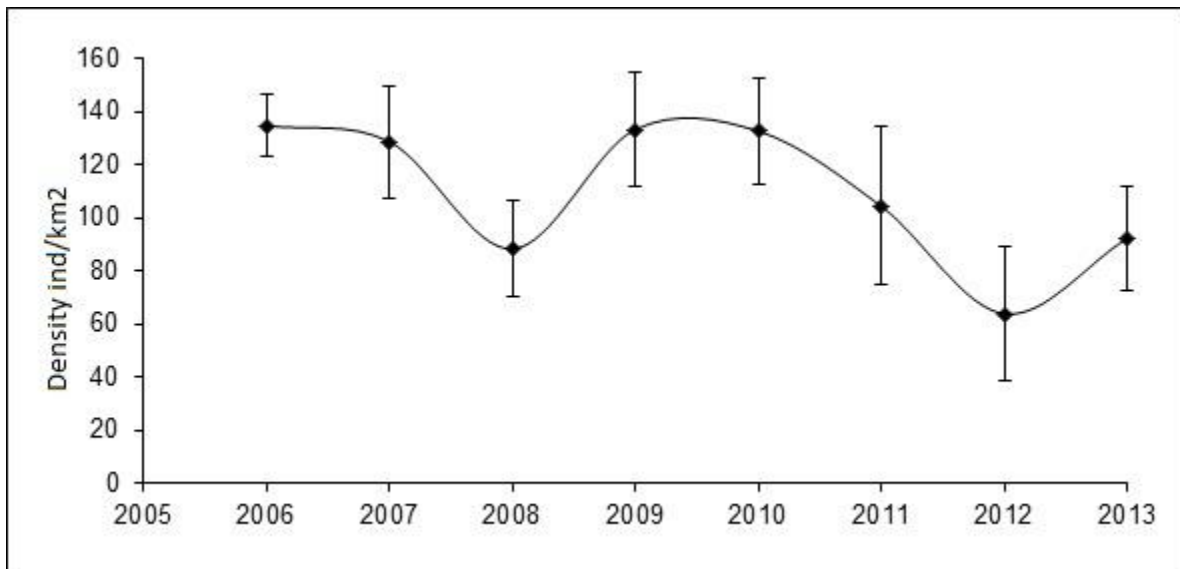
Figure 9. Overall density of primates in the Samiria River basin between 2006 and 2013.
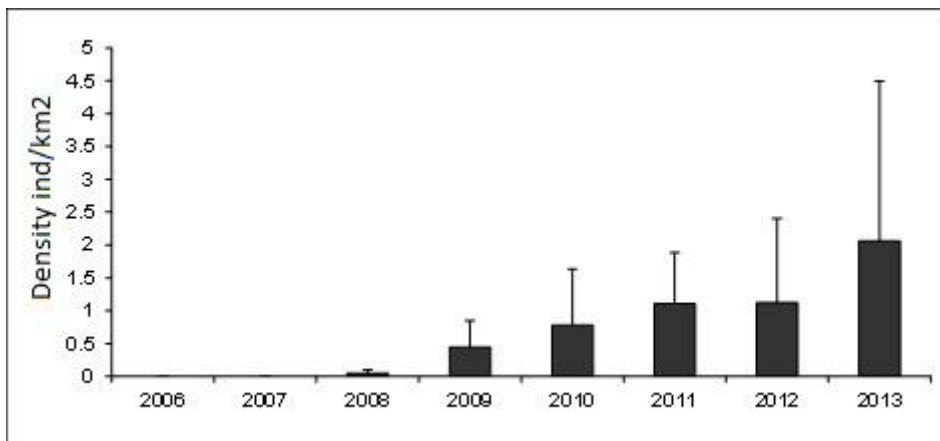

Figure 10. Overall density of giant river otter in the Samiria River between 2006 and 2013.

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