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

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Abstract

The Amazon basin is going through dramatic climate changes that will impact the largest rainforest on Earth. 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, the high water exceeded those of 2009 and continuing in 2012. 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. However, these normal seasonal changes are now becoming more intense, which is impacting the wildlife and local people.

Research on wildlife populations is being conducted in the Samiria River basin to understand how the ever increasing climatic changes are impacting the ecology, behavior and populations of aquatic and terrestrial species. The team is also working with the local Cocama Indian communities and the reserve authority to see how the climate changes are affecting fishing, bushmeat hunting and conservation strategies. Results show that pink and grey river dolphins and wading birds have declined as a consequence of the negative impact that climate changes has had on fish populations. The ground dwelling ungulates, including peccaries, deer and tapir, have decreased from the intensive flooding that has restricted access to dry land during high waters, resulting in food shortage and greater competition. Species that live above the physical flooding such as primates and macaws have not shown impacts from the climate changes due to their arboreal habits and the maintenance of healthy fruit production of the forest. Caimans and giant river otters have also not shown impacts from the recent water level variations.

The local Cocama people living in and around the reserve have been impacted both directly and indirectly by the extreme conditions. Bush meat from the preferred ungulates has become uncommon and people now must rely on fishing during the flooded period when fish are scarce due to them moving into flooded forests. The drought in 2010 resulted in lower fisheries production during what should have been a peak fishing period. The reserve authority and this project are working on finding economic alternatives through incentive based conservation strategies as a means of offsetting the negative impacts from the ongoing climate change.

Introduction

The Amazonian forests of Loreto, Peru are situated in the western Amazon basin and harbor some of the greatest mammalian, avian, floral and fish diversity on Earth. Indeed, these forests are one of the last remaining true wilderness areas left on the planet. However, these vast expanses of pristine forest will only remain intact if conservation programs are successfully implemented. Wildlife conservation in Loreto must incorporate landscape features (in terms of major habitat types of both flooded and upland forests), the biology of landscape species and the socio-economics of the rural people.

Research and conservation activities should use an interdisciplinary approach to find a balance between the needs of the indigenous people and the conservation of the animals and plants. For example, some animals like the primates, jaguars, manatees and tapirs are very vulnerable to hunting and their populations can rapidly be depleted by overhunting. Other animals are more appropriate as a source of meat for local people, such as peccaries, deer and large rodents. This project is helping to conserve wildlife, not only for saving the biodiversity of the Amazon, but also as a means of helping the poor indigenous people who rely on these resources for their food and shelter . The project is working together with the local people, because they are the true guardians of the forest, and information provided by this research can help the indigenous people make appropriate decisions on how best to save the Amazon. The Amazon has been abused in the past, through deforestation for timber, overhunting of animals and overfishing. Local people are taking actions in places like the Pacaya-Samiria Reserve, which is an examples of how things are changing; it is an example of how conservation can work in collaboration with local people, governments and NGO's.

The Amazon basin is going through dramatic climate changes that will impact the largest rainforest on Earth. In 2009, the Amazon river was at a historic high, flooding huge areas of Amazonian forests. In 2010 the water levels of the Amazon River were at a historic low resulting in extreme dry conditions and drought. More recently in 2011, the high water was again at historic highs which are continuing in 2012. 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. However, these normal seasonal changes are now becoming more intense, which is impacting the wildlife and local people.

Research on wildlife populations is being conducted on the river dolphins, primates, fish, caimans, macaws, deer, peccaries, tapirs, jaguars, giant river otters, and other species to understand how the ever increasing climatic changes are impacting their ecology, behaviour 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.

The wildlife of the Samiria River lives in an ecosystem that is driven by the large seasonal fluctuations occurring between high and low water seasons. The ecology of the aquatic and terrestrial wildlife revolves around these seasonal changes in water level.

The ecological conditions of long periods of flooding, up to 6 months, are very harsh on much of the floral and faunal community. Many plant species cannot withstand the long periods of inundation and the diversity of plants in the heavily flooded areas is lower than lightly and non-flooded levees. Likewise, the terrestrial wildlife (deer, peccaries, rodents and tapir) must seek out floodplain islands or levees during the high water season, which have increased competition and predation pressures. Even the arboreal wildlife is impacted by the flooding, since many of the fruit trees are quite seasonal in the flooded forests, resulting in seasons with low food production.

The aquatic wildlife is equally affected by the large seasonal inundations. During the flooded periods the fish enter the water laden forests and feed on the abundance of vegetative and animal production, especially the abundance of fruits, invertebrates and other living organisms trapped in the annual floods. Indeed, many tree species fruit during this season and rely on the fish as their primary means of seed dispersal. During the flooded period many fish populations reproduce within the inundated forests. Other aquatic wildlife have a more difficult time during the floods, such as the dolphins, giant river otter and other fish predators, since their prey is more sparsely distributed throughout the large expanses of the flooded forests. When the waters recede during the 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 the smaller rivers and into the larger rivers. The dolphins and other fish predators have an abundance of prey during the low water season and even follow the fish migrations down the rivers and channels.

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

The normal cycles in the Amazon forests are now being disrupted by the extreme flooding and drought events that are occurring. The flooded forests are particularly important at understanding the 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.

Results from this research show some important consequences of the extreme variations in water levels that have been occurring over the past several years.

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.

1) River dolphins were used as indicator species of the impact of climate change on aquatic systems.
2) Macaws were used as indicators of the impact of climate change on arboreal forest fruit production.
3) Primate populations were monitored to determine the impact of climate change on arboreal mammals.
4) Ungulates and rodents are important bush meat species and were used to examine how climate change is impacting the sustainability of hunting.
5) Carnivores, giant river otters and manatees were monitored to evaluate the recovery of vulnerable species under the climate change conditions.
6) Game bird populations were monitored to determine their conservation status and impact from climate change.
7) Caiman populations were monitored to evaluate the recovery of black caiman populations and the impact from climate change.
8) River turtles are part of a head-starting conservation programme in the Samiria River basin and can provide economic incentives under climate change conditions.
9) The abundance and age structure of fish were monitored to determine the impact of climate change on 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 reserve is dominated by white water flooded forests, known in Amazonia as Varzea forests. The wildlife of the Samiria River lives in an ecosystem that is characterised by large seasonal fluctuations occurring between the high water and low water seasons. The ecology of the aquatic and terrestrial wildlife revolves around these seasonal changes in water level. 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 Huisto lake and stream and was classifies 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 (Map 1: Appendix).

Methods

Terrestrial mammals and game birds

Line censuses along transect trails were used to conduct terrestrial mammal and game bird censuses. Censues 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 programme 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 dependant 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 were analyzed using DISTANCE software (Thomas *et al*. 2002). This programme 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.

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.

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 kilometres. The results indicate the number of individuals per kilometre.

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 kilometres was travelled daily from 9:00 to 14:00 h along the centre of the river using a boat. Information collected included: species, group size, group composition, behaviour (travelling, fishing, playing), time, and any additional observations.

Data were analysed using fixed width:

$$D = \frac{N}{2AL}$$

Where:

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

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

Censuses were carried out at both sites. 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 (Queiroz 2000). 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.

Sample sizes

Large sample sizes are needed to have confidence in the results and the study has had increasing sample sizes over the years, with 2010 and 2011 have the greatest number of surveys conducted. In 2011 the samples sizes for surveys were Terrestrial transects 1136 km, Dolphin surveys 1959 km, Caiman surveys 834 km, Macaw points 1498 points, Hours fishing 494 hours, and Wading bird surveys 552 km.

Results

River dolphins

The pink river dolphin (*Inia geoffrensis*) and the grey river dolphin (*Sotalia fluviatilis*) 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 intentially 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, the dolphin numbers in the system will be observed 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.

The pink and grey river dolphins are an important part of the aquatic ecosystem in the Samiria River. The research is using these species as general indicators of the aquatic system. The local Cocama Indians have very strong taboos against killing dolphins and they have great respect, especially for the pink river dolphin.

The extreme variations in water levels are having a clear impact on the dolphins. This impact began during the initial record high waters of 2009 and has continued through the drought of 2010 and the high waters of 2011. The populations of pink river dolphins during 2011 was consistently greater than the grey river dolphin (Z(U)=3.0707, P=0.0021), as in previous years. Overall, pink river dolphins had an average density of 2.07±1.08 ind/km2 and grey river dolphins 1.05±0.98 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 the dolphins use the river habitats to a much greater extent, whereas in the high water season the dolphins are using the lakes and channels more than the river habitats. The greater use of river habitats by the dolphins during the low water season also makes the multi-year comparisons more robust by focusing on the dry season data.

Using results between 2006-2011, the pink river dolphin has had a continual decrease in its density in the Samiria River since the extreme climatic changes began in 2009. The population of pink river dolphin has always been greatest at the mouth of the Samiria River, compared to the mid and upper sections. However, at the mouth of the Samiria River pink river dolphins have been decreasing since the drought of 2010. In 2011 the pink river dolphins at the mouth were 2.36±0.75 ind/km, compared to the average of 5.36 ind/km and the peak in 2009 of 7.31 ±2.15 ind/km (Figure 1a).

The drought in 2010 had a significant impact on the 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. The dolphins left their habitats in the Samiria River to find refuge in the larger channels of the Amazon. The drought ended in late October 2010 and in January and February 2011 both the pink and grey dolphins continued to be consistently lower (between 60-70% fewer sightings) than the same months in 2010. By March 2011 both species began to return to the Samiria river. The results from 2011 show that the pink river dolphin has not recovered fully from the drought, and populations continued to decrease despite the higher water levels in 2011.

In the mid section of the Samiria River the pink river dolphin has also shown a decreasing 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 compared to the average of 2.55 ind/km and the peak during 2007 of 3.79±1.23 in/km. The deceases in pink river dolphins in the mid section began during the first extreme high water levels in 2009 and have continued to decrease through to 2011.

Pink river dolphins in the upper section of the Samiria River have not shown decreases in populations, though there is a downward non significant trend. In 2011 the pink river dolphins in the upper section of the Samiria River were 2.34±1.06 ind/km with an annual average of 2.99 ind/km and a peak in 2006 of 3.91 ±0.40 ind/km.

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 2011. In 2011 the grey river dolphin was 1.49±0.43 ind/km compared to the average of 1.90 ind/km and the peak in 2006 of 3.28 ±1.35 (Figure 1b).

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 to 2011. In 2011, the grey river dolphin was 0.75±0.63 at the mid section of the Samiria River compared to the average of 1.32 ind/km and the peak in 2008 of 2.61±0.61 ind/km.

The grey river dolphin has had relatively stable numbers in the upper section of the Samiria River between 2006 to 2010, but decreased in numbers in 2011. In 2011, the grey river dolphin was at 1.01±1.07 ind/km in the upper section of the Samiria River compared to the annual average of 2.44 ind/km and the peak in 2010 of 3.29 ±2.33 ind/km.

The demographics of the 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 the pink river dolphin 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. 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 has decreased between 2009 and 2011 the reproduction of individuals has increased and the demographics show a greater percentage of juvenile and young individuals.

The demographics of the grey river dolphins have also changed since greater variations in water level have been observed in the Samiria River. The demographic changes in the 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. 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 the grey river dolphins has increased as the populations have been declining from greater water level variations that have impacted the dolphins between 2009 to 2011.

The decreases in dolphins numbers is directly related to the fish populations. The fish were also impacted by the extreme variations in water levels of the Samiria River. Results have shown that the pink river dolphin populations are correlated to the abundance of red piranha and that the grey river dolphin populations are correlated to the abundance of white piranha. Both the red and white piranha species have been negatively impacted by the climatic variations in water level in 2011 (see section on fish results) and this corresponds with the declining dolphin populations.

Macaws

The 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.

The macaws in the Samiria River include the chestnut-fronted macaw (*Ara severus)*, blue & yellow macaw (*Ara ararauna),* red-bellied macaw (*Orthopsitaca manilata)* and scarlet and red & green macaws (*Ara macao/chloroptera)*.

Overall the abundance of macaws in the Samiria River during 2011, as in previous years, differs between species (H=7.69, gl=3, P=0.0528). The most common species was the red-bellied macaw

(*Orthopsitaca manilata)* 19.08±2.93 ind/point, followed by the blue & yellow macaw (*Ara ararauna)* 8.32±0.93 and chestnut-fronted macaw (*Ara severus)* 5.75±1.40 ind/point. The scarlet and red & green macaws (*Ara macao/chloroptera)* are least common and together only had an abundance of 0.06±0.02 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 section and 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 section of 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. In contrast, the macaw populations are actually doing better over the past few years. The macaws are not directly impacted by water level variations due to their arboreal habits. Therefore, health of the forest appears has 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 section and upper reaches), for the most part conform with the overall annual variations (Figure 2).

The chestnut-fronted macaw 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 chestnut-fronted macaw. Then between 2008-2009 the population was low. In 2010 the chestnut-fronted macaw began to increase and in 2011 it was at its highest population level recorded thus far in the Samiria basin.

The red-bellied macaw population is also cyclical in the Samiria River basin. This species had relatively low number until 2009, when its population increased significantly. In 2010 and 2011 the population of red-bellied 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 steadily increasing 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.

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 (H=6.17, gl=8, P=0.6282).

Wading birds

The 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. The young fish then migrate out of the Samiria during low waters of the dry season. Each year flocks of Neotropical cormorants *Phalacrocorax brasilianus* and great egrets *Ardea alba* migrate to and congregate at the mouth of the Samiria River to feed on the 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 *Ardea cocoi* and snowy egret *Egretta thula*.

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 *Phalacrocorax brasilianus* dominated, followed by *Ardea alba* and *Jacana jacana*. In the mid section the most abundant wading bird was *Ardea alba,* followed by *Phalacrocorax brasilianus* and *Ardea cocoa*. In the upper reaches *Ardea alba* was agin the dominant species followed by *Ardea cocoa* and then *Phalacrocorax brasilianus*.

There was a strong correlation between the abundance of wading birds and fish populations in the Samiria River basin. Overall the abundance of all species of wading birds are correlated to the abundance of fish populations. The abundance of *Ardea alba* and *Phalacrocorax brasilianus* correlated with the overall fish abundance. Therefore the wading bird species are a good measure of overall fish production.

The greater variations in water level have impacted the wading bird populations. The abundances of the two dominant wading birds, *Phalacrocorax brasilianus* and *Ardea alba*, 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 *Phalacrocorax brasilianus* (X^2=125.41, gl=5, P<0.0001) and *Ardea alba* (X^2=11.098, gl=4, P=0.0495) during the 2011 low water season (Figure 3). The drought resulted in high fish mortality and the decreased wading bird numbers concur with a decrease fish production during 2011. This also correlates with the impact of water level variations on the fish populations and the decrease in dolphin numbers (see fish and dolphin sections).

Over the years the annual migration of wading birds to the mouth of the Samiria River has been relatively constant with similar numbers of *Ardea alba* and *Phalacrocorax brasilianus* retruning during the dry season, except for the decline observed in 2011. It is unclear where these species migrate during the other season, but it appears to be outside the Samiria river basin since they are not sighted in these numbers in other sections of the Samiria.

Primates

Primates and other mammals were surveyed in the Samiria River to evaluate the success of wildlife management by the reserve and the participation of community based involvement. The Samiria was divided into three zones according to the wildlife use plans, including 1) a zone used commonly for subsistence hunting of the local Cocama indigenous people, 2) a zone occasionally used for subsistence hunting, and 3) a zone infrequently used for subsistence hunting.

Results of the censuses conducted during 2011 showed that the overall densities and biomass of mammals 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.

Saimiri bolviensis, Cebus apella, Alouatta seniculus, and *Saguinus fuscicollis,* had the greatest density in the infrequently hunted zone. *Saimiri boliviensis* dominated the occasionally hunted zone followed by *Saguinus fuscicollis, Cebus apella,* and *Alouatta seniculus. Saimiri bolviensis* was also the dominante species in the commonly hunted zone followed by *Saguinus fuscicollis, Cebus apella, Alouatta seniculus,* and *Pithecia monachus*.

The 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 2011 ($F_{5,12}$=0.843, *P*= 0.5455). The primate populations increased after 2000 from overhunting in the 1990´s and by 2006 primate densities were relatively stable. Unlike the ground dwelling mammals and dolphins, the arboreal primates inhabit the environment above the physical influences of the changing water level. Many of the primate species rely on fruits as their major food, and similar to the macaws, the primates have maintained stable populations that reflect a constant fruit production in the forests.

The densities of woolly monkeys (*Lagothrix poeppigii*) have remained relatively constant between 2004 and 2011 (X^2=6.538, gl=7, P= 0.4785)(Figure 4a). 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 2009 show the infrequently and occasionally hunted zones to have similar densities of woolly monkeys. The commonly hunted zone has seen a greater increase in woolly monkey density between 2006 and 2011.

The howler monkey (*Alouatta seniculus*) densities have shown fluctuations in the Samiria River, with a declining population between 2004 to 2008 and then an increasing population between 2008 to 2011 (X^2=17.01, gl=7, P= 0.0173)(Figure 4b). 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 (*Cebus apella*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (X^2=7.63, gl=7, P= 0.3657)(Figure 4c). 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 (*Pithecia monachus*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (X^2=9.784, gl=7, P=0.2012)(Figure 4d) with a drip in density in 2008 and a steadily increasing population through to 2011. 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 the greatest density in the zone with heaviest subsistence hunting.

The squirrel monkey (*Saimiri boliviensis*) densities have had increases and dips between 2004 and 2011 (X^2= 43.132, gl=7, P<0.0001)(Figure 4e) with the 2011 density being relatively average for the species over the years. 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 in the density of squirrel monkey in the commonly hunted zone, but this is unlikely due to hunting since the species is really taken by hunters due to its small size. It is more likely due to competition from the increase in the larger primate species.

The saddled back tamarin (*Saguinus fuscicollis*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (X^2=10.577, gl=7, P= 0.1582)(Figure 4f). 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 beteen 2009 through to 2011.

The white capuchin monkey (*Cebus albifrons*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (G=2.359, gl=7, P=0.9373). Over all years, the density of white capuchin monkey was similar between all three hunting zones ($F_{2,20=}$0.3683, P=0.7012). There has been a dip in the white capuchin monkey in the commonly hunyed zone and a slight increase in the occasional hunted zone.

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 .

Ungulates

Unlike the primates, the ungulates have been impacted by the greater climatic variations in water level between 2009 to 2011. The ungulates in the Samiria River basin include the white-lipped and collared peccary (*Tayassu pecari and Tayassu tajacu*), red brocket deer (*Mazama americana*) and lowland tapir (*Tapirus terrestris*). The overall density of ungulates has decreased significantly since the water level variations began (b=-0.9505, t=-3.8605, P=0.0119). The recent 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.

The ecological conditions of long periods of flooding in the varzea forests of the Samiria River, up to 6 months, can be very harsh on the ungulate community. Ground dwelling mammals must seek out floodplain islands or levees during the high water season, which have increased competition and predation pressures. These normal seasonal conditions have been more intense during the exceptionally high waters of 2009 to 2011, and now continuing in 2012. 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. The record high waters of 2011 surmounted those of 2009 and resulted in an even greater decrease of ungulates.

Results from the camera traps are showing that the greater extremes in high water are resulting in greater percentages of emaciated ungulates. The camera traps set in 2009 did not record any emaciated individuals of ungulates. In drastic contrast, the 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)(Figure 5). The emaciation is due to the smaller levee size resulting in less food availability and greater intra and inter specific competition.

The white-lipped peccary (*Tayassu pecari*) has been impacted dramatically by the climatic variations in water level. The species had a peak in its population in the Samiria River basin in 2009 with 3.64 ind/km2 which the 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)(Figure 5a). The 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 dramatic decreases in white-lipped peccary density.

The collared peccay (*Tayassu tajacu*) has been impacted even more intensively than the white-lipped peccary by the climatic changes occurring in the Amazon. Collared peccary had a peak in its 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 where 0 individuals were sighted (b=-2.6493, t=-2.6189, P=0.0471)(Figure 5b). Over the years, the collared peccary had a greater density in the infrequently hunted zone than the occasional and frequently hunted zones. The infrequently hunted zone has larger and higher levees that would help explain the species preference for this area. All three zones have shown dramatic decreases in collared peccary density. The collared peccary generally does not have as large populations in the flooded forests as in the non-flooded forests and the varzea could be considered as a marginal habitat for the species. The increasing level of flooding since 2009 has caused this species to become very rare in the flooded forests of the Samiria River basin.

Of all of the ungulate species, the red brocket deer (*Mazama americana*) has fared slightly better during the recent climatic changes. The density of red brocket deer has been relatively constant in the Samiria River basin between 2004 to 2010, but in 2011 red brocket deer density dropped to its lowest level recorded in the basin, 0.04 ind/km2 (b=-14.82, t=-3.2686, P=0.0170)(Figure 5c). Over the years, the density of red brocket deer was similar in the infrequently hunted zone and the occasionally hunted zone and none were recorded in the commonly hunted zone. The commonly hunted zone has always had very low populations of red brocket deer.

The lowland tapir (*Tapirus terrestris*) is also showing impacts from the climate change. In 2010 the results showed a large increase in tapir sightings, which in 2011 dropped to a very low number. Tapir sightings are generally rare and the variation in 2010 may have reflected tapir having greater movements as they searched for levees. In 2011, results likely reflect the actual low numbers and a decline from the recent average (Figure 5d). 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.

Rodents

The rodent species surveyed included black agouti (*Dasyprocta fuliginosa*) and Amazon squirrel (*Sciurus spadiceus/igniventris*). The climatic variations in water level have not obviously impacted these species and the densities are relatively similar as in previous years.

The black agouti (*Dasyprocta fuliginosa*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (G=0.6102, gl=6, P=0.9912)(Figure 6a). The black agouti occurs in all three hunting zones with a greater density in the infrequently hunted zone, followed by the occasionally hunted zone and least in the commonly hunted zone. The small body size of the black agouti (around 5 kg) allows individuals to survive on small forest levees during intensive flooding, which is not possible for the larger ungulate species. This has presumably allowed the black agouti numbers to be maintained during the recent variations in water level.

The Amazon squirrel (*Sciurus spadiceus/igniventris*) densities have shown an overall stable population in the Samiria River basin between 2004 and 2011 (X^2=3.72, gl=6, P=0.36a)(Figure 6b) with the density in 2011 reflecting the long term average. The population of Amazon squirrel was similar between all three hunting zones ($F_{2,17}$=1.4175, P= 0.2675). The Amazon squirrel has not shown any changes in density as a result of the recent climate changes. 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.

Edentates

The two edentate species surveyed included the tamandua (*Tamandua tetradactyla*) and three toed sloth (*Bradypus variegatus*). These species have not shown impacts in the populations over the recent climate change variations. Both species are arboreal and are not directly impacted by the extreme physical flooding events of recent years, and similar to the other arboreal wildlife species the populations of edentates has been stable.

The tamandua (*Tamandua tetradactyla*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (G=0.6972, gl=6, P=9946)(Figure 6c) with 2011 density actually being at a peak. The density of tamandua was relatively similar in all three zones ($F_{2,17}$=0.6125, P= 0.2275). The tamandua feeds on ants and termites and indicates that ant and termite populations have not presumably been impacted during the recent climate changes.

The three toed sloth (*Bradypus variegatus*) densities have been relatively constant in the Samiria River basin between 2004 and 2011, with a peak during 2006-2007 and a stable population since 2008 (G=1.26, gl=6, P=0.9737)(Figure 6d). 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.

Carnivores

The carnivores analyzed from transect results included coati (*Nasua nasua*) and tyra (*Eira barbara*). These species did not show any clear impact from the recent climate change events. Both species are scansorial being both ground dwelling and arboreal. The arboreal habits allow these species to overcome the physical impacts of the recent extreme floods.

The coati (*Nasua nasua*) densities have varied between dips and peaks in the Samiria River basin between 2004 and 2011 (G=11.07, gl=5, P=0.09)(Figure 6e) and in 2011 were around the long term average density, and up from 2010. Over the years the coati populations have been similar between all three hunting zones (H=1.3581, gl= 2, P= 0.5071). The coati feeds predominately on larger insects that move up the trees during floods and in turn allow the coati to overcome the intensive flooding events.

The tyra (*Eira barbara*) densities have been relatively constant in the Samiria River basin between 2004 and 2011 (G=1.4836, gl=6, P=0.9606)(Figure 6f) with density in 2011 reflecting the long term average. The density of tyra was similar between all three hunting zones (H=5.526, gl= 2, P= 0.631). The tyra often feeds in the lower and middle story of the forest, which allows individuals to overcome the periods of extensive flooding.

Jaguar (*Panthera onca*), puma (*Puma concolor*), ocelot (*Leopardus pardalis*), jaguarundi (*Felis yaguaroundi*) and margay (*Felis wiedii*) were recorded on camera traps. 28 jaguar photos were recorded of 7 different individuals, 31 puma photos with 7 different individual, 96 photos of ocelot with an estimated 40 individual, 7 photos of jaguarundi and one photo of a margay.

The jaguar, puma and ocelot appeared to be impacted by the variations in climate change, especially during the extensive flooding. In 2009, camera traps did not record any individuals of these species in poor condition. In contrast, the camera traps in 2011 showed that 14 % of the jaguars were in poor condition, and 30% of the pumas (Photo in appendix). The results concur with the reduced densities of prey species in 2011, especially the collared and white-lipped peccary.

Gaint River Otter

The giant river otter (*Pteronura brasiliensis*) density have been increasing steadily in the Samiria River basin and the continued population growth does not appear to be impacted by the recent climate change variations in water level. The giant otter is endemic to South America and has shown 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, the giant otter was 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, the giant otter is beginning to show a slow recovery in population size in many areas of its former range in the Amazon, including the Samiria River basin. The sightings of giant river otter have increased substantially in the Samiria River basin over the years.

The density of giant river otter along terrestrial transects has been increasing though the years. Between 2005 and 2007 there were no giant river otter observed on the terrestrial transects. In 2008 the 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 and in 2011 increased further to 1.02 in/km2 (Figure 7).

The group size of otters also appears to 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.

Manatee

The manatee (*Trichechus inunguis*) population along the Samiria River has 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 the extreme further extreme droughts will likely result in further mortality..

Game birds

The game birds surveyed along terrestrial transects included tinamous species (*Tinamus* spp.),razor-billed curassow (*Mitu tuberosum*), Spix's guan (*Penelope jacquacu*), and blue-throated pipin guan (*Pipile cumanensis*). There was no obvious impact on the density of game birds from the greater variations in water level. Similar to the macaws, primates and other arboreal wildlife, the game birds are able to overcome the physical flooding. The 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 2011 was around the long term average for all three hunting zones.

The density of tinamous in the Samiria River has gone through dips and peaks between 2004 to 2011 with no significant long term trends (b=0.522, t=0.1106, 6354)(Figure 8a) with density in 2011 at the lower end. The tinamous density was similar in all three hunting zones ($F_{2,15}$= 0.8311, P=0.542). The density of tinamous decreased in the commonly hunted zone in 2010 and 2011 (G=13.6439, gl=4, P=0.0085).

The razor-billed curassow is generally a rare species in the Amazon and has overall low numbers in the Samiria. The densities have been relatively constant over the years from 2004 to 2011 (H=3.22, gl=5, P=0.67)(Figure 8b). 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 its numbers between 2004-2011, but overall has had a relatively stable population (H=3.9415, gl=5, P=0.5579)(Figure 8c). 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).

The blue-throated pipin guan increased in the Samiria in 2009, and has had a relatively large and stable population since then (H=3.342, gl=6, P=0.7649)(Figure 8d). 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.

Fish

The fish populations in the Samiria River have been impacted by the greater variations in water level. This impact has become evident in 2011. The abundance of fish has remained stable, but the size of the abundant species has decreased significantly indicating a demographic change in the populations. It appears that the changes in fish population are in turn impacting the dolphin and wading bird populations.

The 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 section of 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, at which point the populations abundance has remained relatively stable (X^2= 3.53, gl=5, P= 0.6181).

Differences were seen in the fish composition between the low water and high water seasons along the Samiria River basin. In the mid section *Liposarcus pardalis* dominated the CPUE in both seasons. However, in the low water season *Hoplerythrinus unitaeniatus* was the next most abundant species followed by *Pygocentrus nattereri* . During the high water season in the mid section of the river

Pygocentrus nattereri was the second most abundant species, followed by *Serrasalmus rhombeus*. In the upper reaches of the Samiria River the most abundant species during the low water season were *Hoplerythrinus unitaeniatus, Liposarcus pardalis* and *Pygocentrus nattereri*, respectively. In contrast during the high water season the most abundant species were *Liposarcus pardalis, Chaetobranchus flavesens, and Mylossoma duriventrus,* 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 *Astronotus ocellatus, Liposarcus pardalis, Prochilodus nigricans, Pygocentrus nattereri* and *Serrasalmus rhombeus*. All of the species, except *Prochilodus nigricans* showed a significant decrease in size classes in 2011, reflecting degradation in the health of the populations.

Astronotus ocellatus **"acarahuazu"**
The demography of *Astronotus ocellatus* has been impacted by the variations in water level. During the years 2007, 2008, the size o f the largest catch of *Astronotus ocellatus* 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)(Figure 9a).

Liposarcus pardalis **"carachama"**
The demography of *Liposarcus pardalis* has shown some signs of impact from the greater variations in water level. The largest size catch of *Liposarcus pardalis* 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)(Figure 9b).

Prochilodus nigricans **"boquichico"**
The demography of *Prochilodus nigricans* 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 (K-S, P<0.05)(Figure 9c).

Pygocentrus nattereri **"piraña roja"**
The demography of *Pygocentrus nattereri* has been impacted by the variations in water level. En el The largest size catch of *Pygocentrus nattereri* 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, which was also the size in 2008 (K-S, P<0.05)(Figure 9d).

Serrasalmus rhombeus **"piraña blanca"**
The demography of *Serrasalmus rhmbeus* has been impacted by the variations in water level. En el The largest size catch of *Serrasalmus rhombeus* over the years 2007-2010 has been in the range of 13-15 cm cm in length. In 2011 the largest size catch dropped to 9-11 cm, which was also the size in 2009 (K-S, P<0.05)(Figure 9e).

Caimans

Three species of caimans occur in the Pacaya-Samiria National Reserve, the black caiman (*Caiman niger*), the spectacled caiman (*Caiman crocodylus*) and the smooth fronted caiman (*Paleosuchus trigonatus*). The black caiman was intensively overhunted during the 1950's – 1970's and has been recovering in the Samiria river over the past decades. The caimans have not shown any lasting impacts from the recent climate change events. However, during the drought of 2010 there were short term impacts on the common 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 more similar and did not show general declines, with the upriver section having very similar numbers to previous years, the mid section having 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 had greater numbers in the upper Samiria 1.06±1.02 ind./km, followed by the mid section 0.67±0.43 ind./km and lowest at the mouth 0.082±0.051 ind./km (H=4.82, gl=2, *P*=0.09). Black caiman (*Melanosuchus niger*) was the second most abundant species and had greater numbers in the mid section 0.42±0.18 ind./km, followed by the upper reaches 0.28±0.19 ind./km and least abundant at the mouth 0.42±0.18 ind./km (H=4.95, gl=2, *P*=0.084). The smooth fronted caiman (*Paleosuchus trigonatus*) was the rarest species along the Samiria River with similar abundances between all three sections of the river ranging between 0.02±0.02 ind./km - 0.04±0.04 ind./km (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 2006-2011 the black caiman has had a more stable abundance (b=1.5086, t=0.3016, P=0.7070)(Figure 10a).

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 10b). The smooth fronted caiman has had a relatively stable population over the years along the Samiria River.

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 the lake habitat 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.

River turtle certification

The Pacaya-Samiria National Reserve has implemented a turtle conservation program based on head starting for a number of years, where eggs of Yellow-spotted Amazon River Turtle (*Podocnemis unifilis*) and Giant Amazonian River Turtle (*Podocnemis expansa*) have been removed from their wild nests, replanted at guard stations, hatched, and released back into the river. This conservation strategy has been set up to overcome the intensive poaching of turtle eggs during the laying season. River turtle numbers are recovering along the Samiria river basin as a result of the head starting program.

The project has begun a turtle certification program through a sub grant from USAID and WCS. The turtle certification programme is a mechanism to consolidate the turtle headstarting program using the local, regional and international trade in turtle egg products and live young turtles for exportation. Under certification local communities and management groups implement conservation activities in the reserve. Local communities and management groups only become certified if they manage aquatic and terrestrial resources for conservation.

Peru has been a party of CITES since 1974 and the Amazonian river turtles were placed on Appendix II of CITES. The certification programme helps implement a system to guarantee that the turtle capture and exploitation of eggs and live young turtles for exportation has a non-detriment impact on turtle populations, in accordance with Peru's responsibility to the CITES convention.

The turtle certification programme is a mechanism to add value to the turtle headstarting program in communities that help conserve the reserve, through a process that certifies those communities that meet the standards of certification. Certification of the turtle trade benefit rural families with low income, and the trade has all the requirements for seeking certification. Numerous economically disadvantaged rural families would benefit from the added value from turtle trade certification and certification would encourage rural families to convert unsustainable resource uses to more sustainable practices. Thus, the turtle certification programme brings economic benefits to rural families, improving their living standards, and at the same time helps conserve wildlife and provide incentives for the conservation of Amazon rainforests.

The major impact of turtle certification is its role as a catalyst for community involvement in wildlife conservation. Communities that manage their wildlife sustainably would participate in the certification programme and in turn, would be able to secure added income from the sale of the young turtles, and be recognised as responsible environmentally sensitive communities that are helping to save the Amazon rainforest. These incentives would help communities convert unsustainable practices to more sustainable uses. Implementing a certification programme for turtles in the Pacaya-Samiria National Reserve of the Peruvian Amazon will require participation of the major direct stakeholders, including the management groups and rural communities who harvest turtles meat and eggs for consumption and sale in the market of Nauta and Iquitos; indirect stakeholders including minor traders who buy the turtle eggs from rural communities; major traders who buy the young turtles for export.

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 is also decreasing, which means that people have to capture greater numbers to maintain the same protein intake. This requires greater effort and a less sustainable fisheries, since more fish need to be captured.

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 in the 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.

Conclusions from this Year's Research

Conservation activities produce the best results when professionals, institutions, local communities and the reserve authorities work together. The monitoring activities conducted by the Earthwatch expedition 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.

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 in site 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.

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 likely only a proportion of the actual mortality. Sightings of dead grey dolphins are much rarer. Mortalty in manatees was also seen in 2011 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.

One of the major food resources for the dolphins are the piranha fish and there are good correlations between the abundance of piranha and dolphins, both pink and grey. The results from 2011 show that piranhas are one of the fish species that have been impacted by the recent climate changes in water level. The age structure of the two most abundant species has decreased indicating a deterioration in the demography of the species. In turn, it is likely that the decrease in fish size is impacting the food resources of the dolphins and is reflected in the declining dolphin abundances.

The greater proportion of young dolphins in the Samiria may be a population response to the declining populations. 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 are also showing an impact from the climate changes in water level. The great egret and Neotropical cormorant seasonally migrate in large numbers to the mouth of the Samiria River as the fish frie 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 Maranon River and the mid section of the Samiria River. It appears that the number of fish frie were lower and the birds had to look for food in other areas than the usual dry season feeding waters. Similar to the dolphins, it appears to be the impact on the fish populations that is causing the decline in observed numbers of wading birds.

The fish populations were probably impacted the greatest by the drought during the low water season of 2010 and the consequences were seen during 2011. Fish mortality during the drought were substantial both because of the lack of deep water and the 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 Maranon 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. Fish populations usually rebound quite rapidly from poor conditions, if the conditions do not persist. In 2011 there was a short strong low water season, but not in any way as severe as the drought of 2010. Thus, the fish populations might rebound in 2012. Further drought will have a negative impact on fish populations and in turn impact the dolphins, wading birds and other aquatic wildlife dependant on fish resources.

The terrestrial ungulates, including peccaries, brocket deer and lowland tapir, are also being 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 ungulates 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 any both inter and tra 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, however, the camera trap results are showing the opposite and the jaguars and pumas also showed signs of emaciation during the high water of 2011.

It is likely that the prey species have been reduced over several years of high water and the decline in prey density is impacting the larger predators. In addition, the poor condition of the ungulate prey means there is less good quality meat, and more skin and bones.

Species that rely on arboreal food resources, such as fruits, leaves, insects or other prey have not been effected by the climatic changes in water level. Wildlife groups such as macaws, primates, arboreal edentates and 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 the fruits have actually increased, such as the chestnut-fronted and blue & yellow macaws, while others have remained stable, such as the primates. Likewise, the insects and other arboreal prey resources are still in abundance reflected by a stable population of arboreal edentates and carnivores.

The giant river otter and caiman populations have also show no signs of impact from the 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. Likewise, the caimans food resources are very broad, including insects in young individuals and fish, mammals, reptiles and birds in adults. This diverse array of food resouces was overall not impacted by the water level changes and the caiman populations have remained stable.

The 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 population, and has become less unsustainable 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 fhey are restricted to the lakes, channels and rivers. During the drought fish also became rarer after a time and in 2011 the size many common species has become smaller and people now have to capture more fish for the same level of protein. Floodplainagriculture has also been impacted by the intensive floods, with growing seasons becoming shorter as the high water raises earlier. Crops have to be harvested before 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 Pacaya Samiria 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.

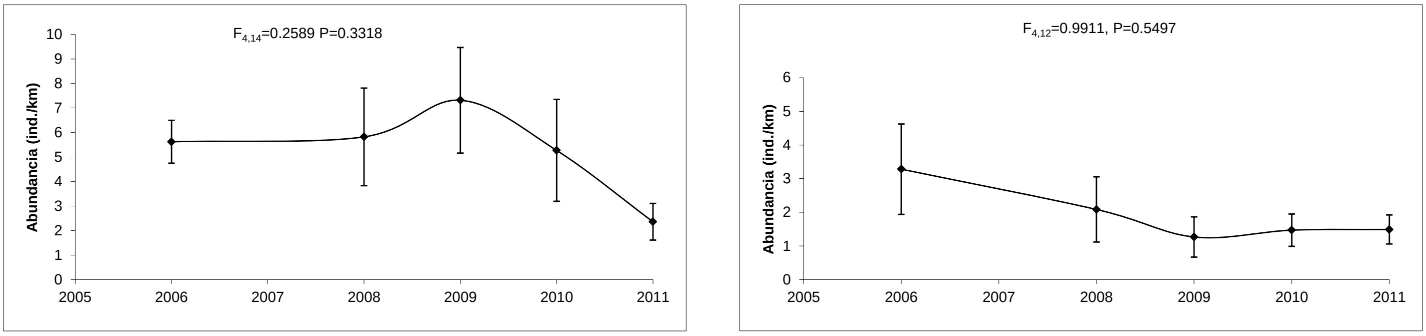
The turtle certification program being developed in the Samiria River basin will help secure added income from the sale the pet turtles, and communities will become recognized as responsible environmentally sensitive communities that are helping to save the Amazon rainforest. With an increasing number 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.

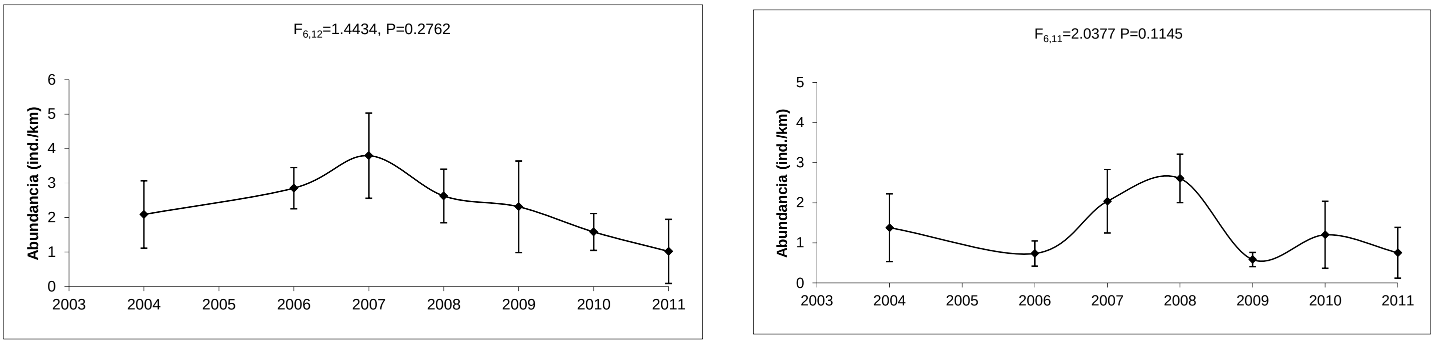
The Pacaya-Samiria National Reserve has gone through a major shifts in its management policies over the past decades, from an area of strict protection where local people were excluded from the reserve to an area where the local indigenous people participate with the reserve management. This drastic 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 themselves 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.

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.

Pink River Dolphin Mouth Grey River Dolphin



Mid section



Upper reaches

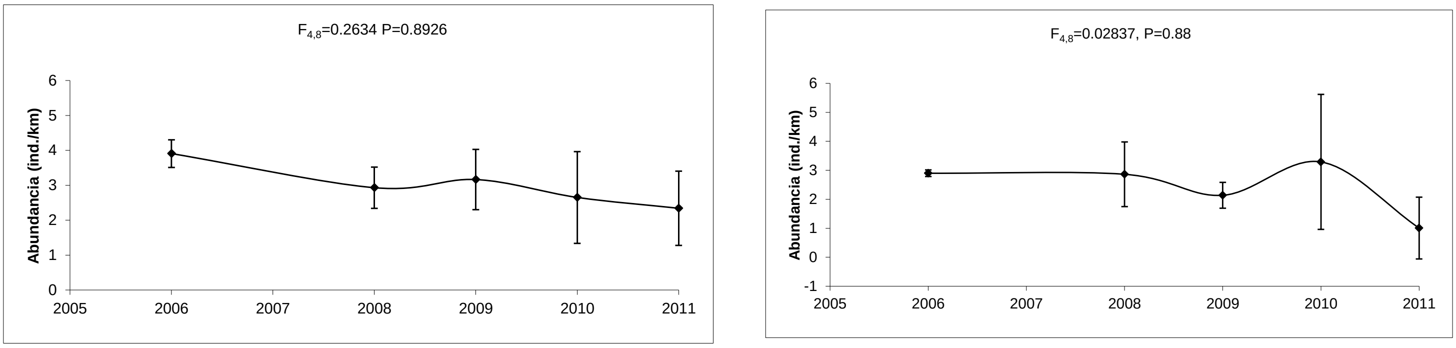
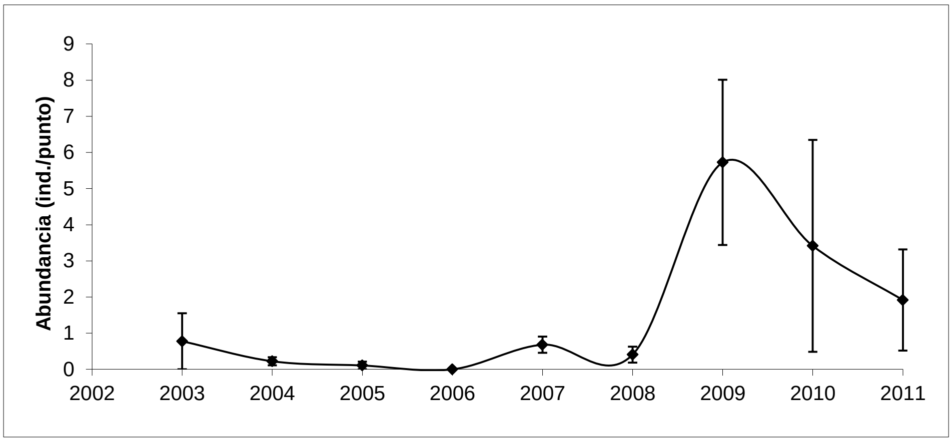
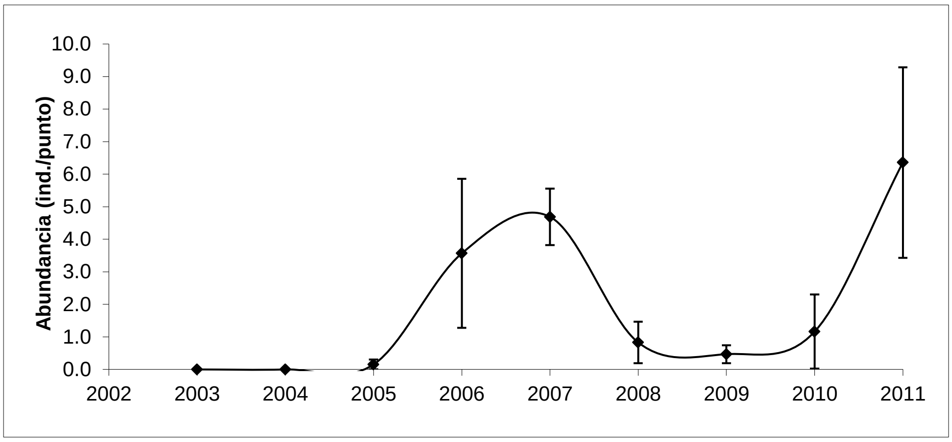


Figure 1. Abundance of pinkand grey river dolphins along the Samiria River between 2006-2011 at the mouth, mid section and upper reaches.

Chestnut-fronted macaw *Ara severus*



Red-bellied macaw *Orthopsittaca manilata*



Blue & yellow macaw *Ara ararauna*

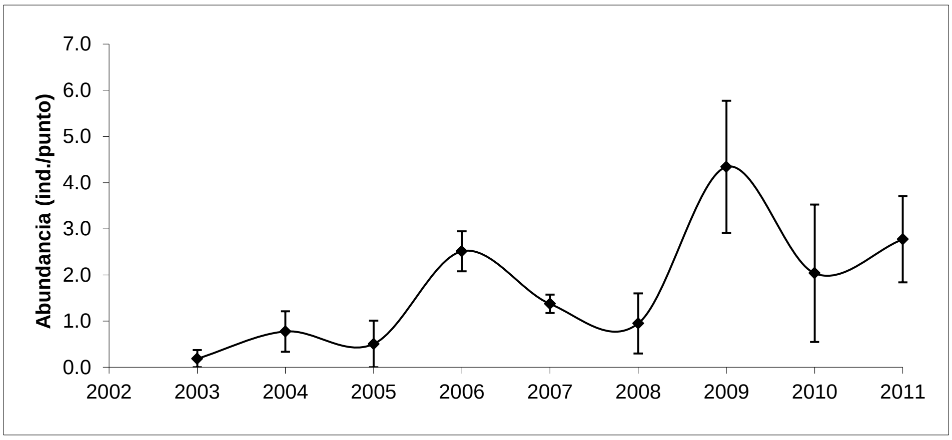
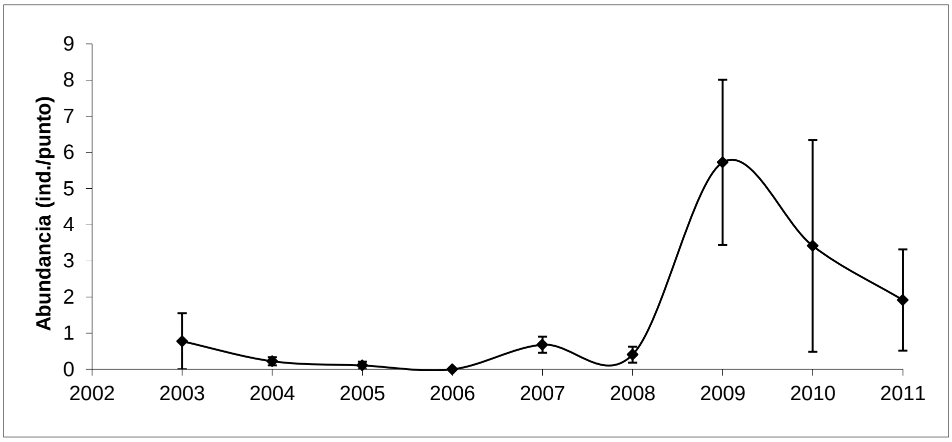
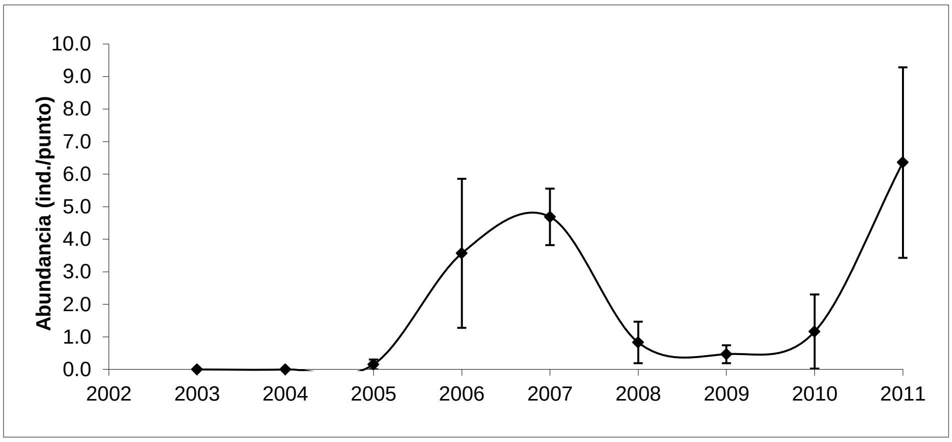


Figure 2. Abundance of macaws in the Samiria River basin between 2003-2011.

Chestnut-fronted macaw *Ara severus*



Red-bellied macaw *Orthopsittaca manilata*



Blue & yellow macaw *Ara ararauna*

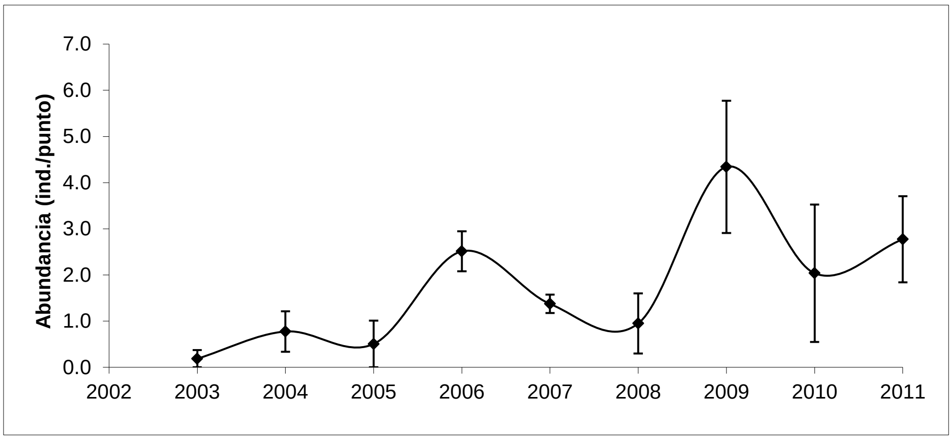


Figure 2. Abundance of macaws in the Samiria River basin between 2003-2011.

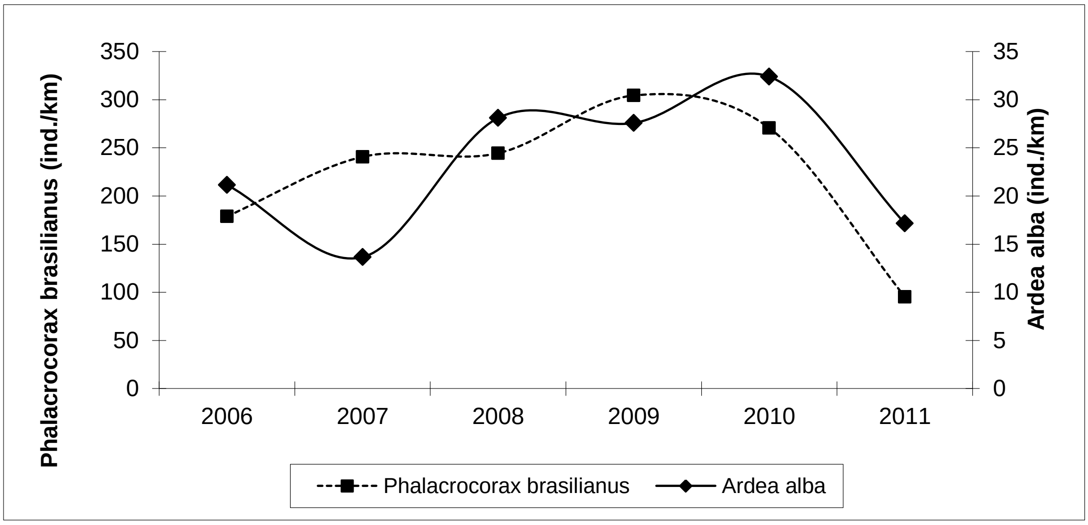
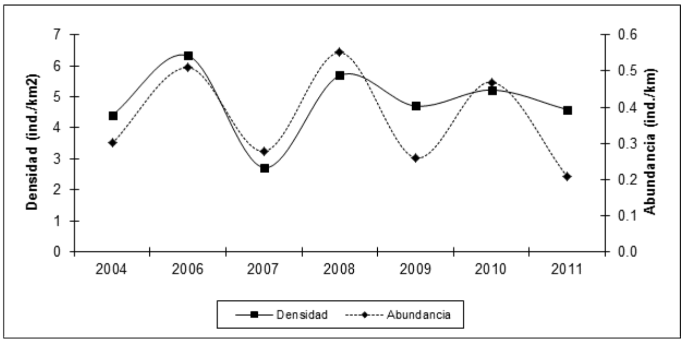
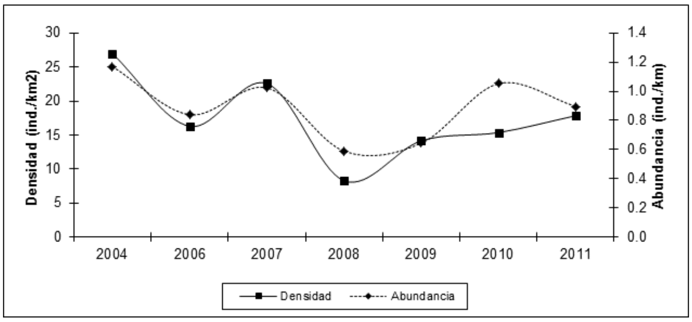


Figure 3. Abundance of *Phalacrocorax. brasilianus* and *Ardea alba* at the mouth of the Samiria River between 2006-2011 during the low water season.

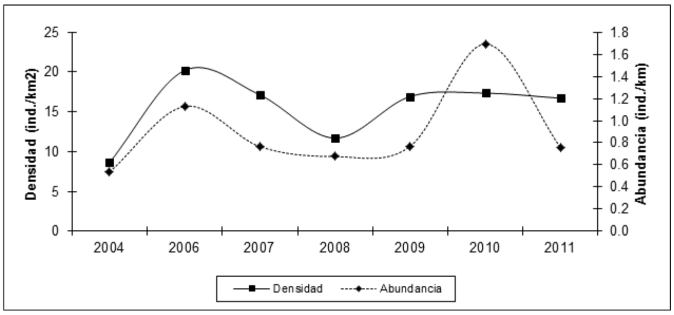
a) Woolly Monkey



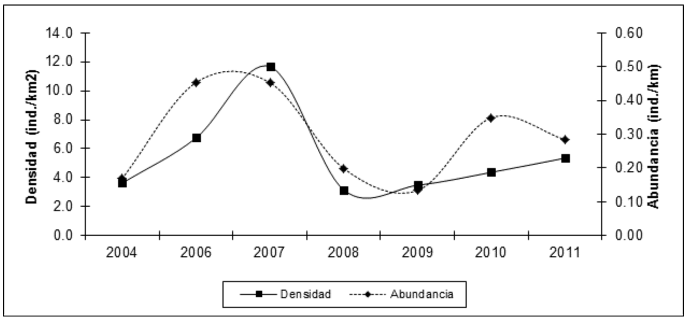
b) Howler Monkey



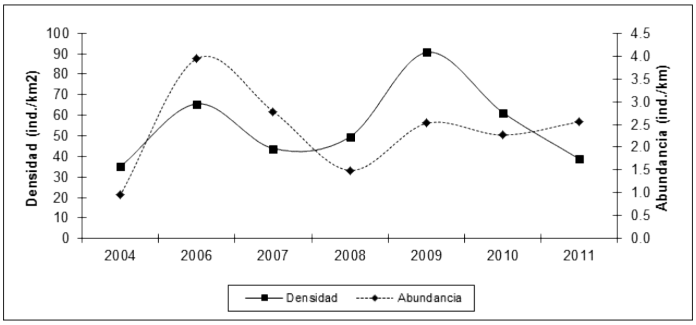
c) Brown Capuchin



d) Saki Monkey



e) Squirrel Monkey



f) Saddled-back Tamarin

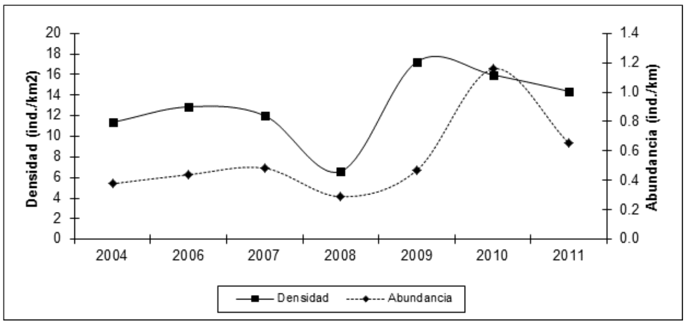
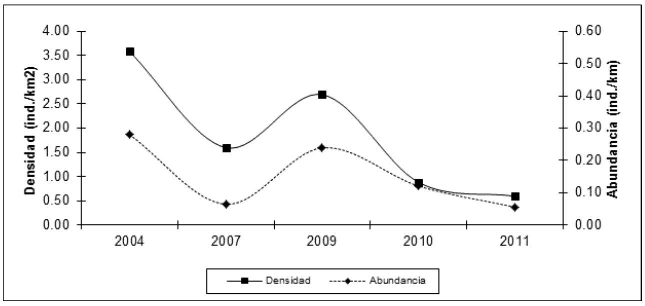
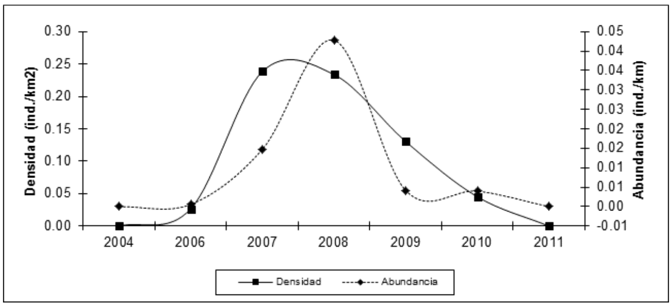


Figure 4. Density and abundance of primate species between 2004 to 2011 in the Samiria River basin.

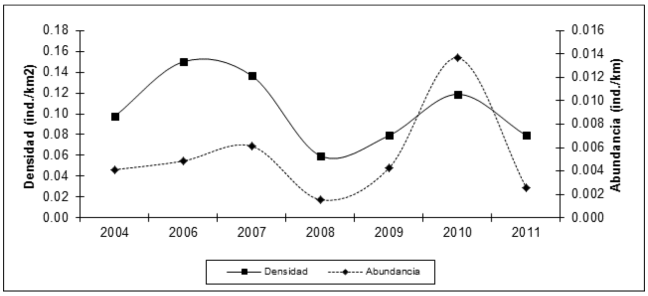
a) White-lipped Peccary



b) Collared Peccary



c) Red Brocket Deer



d) Lowland tapir

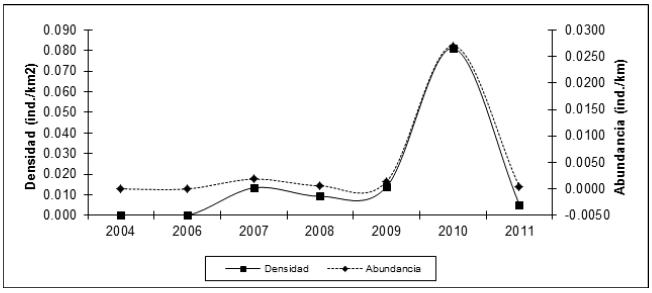


Figure 5. Density and abundance of ungulate species between 2004 to 2011 in the Samiria River basin and photos of emaciated tapir and white-lipped peccary in 2011.

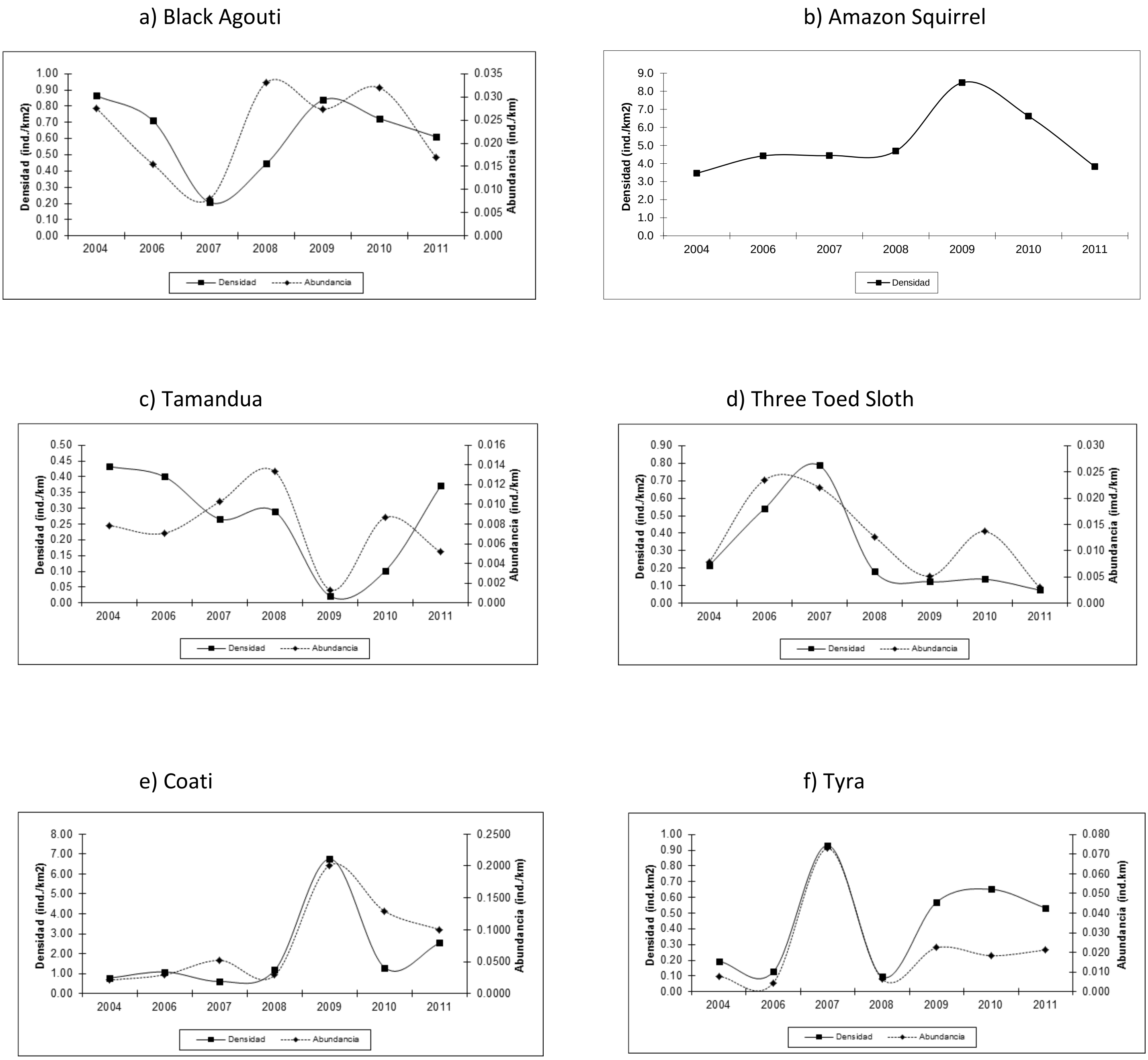


Figure 6. Density and abundance of rodent, edentate and carnivore species between 2004 to 2011 in the Samiria River basin.

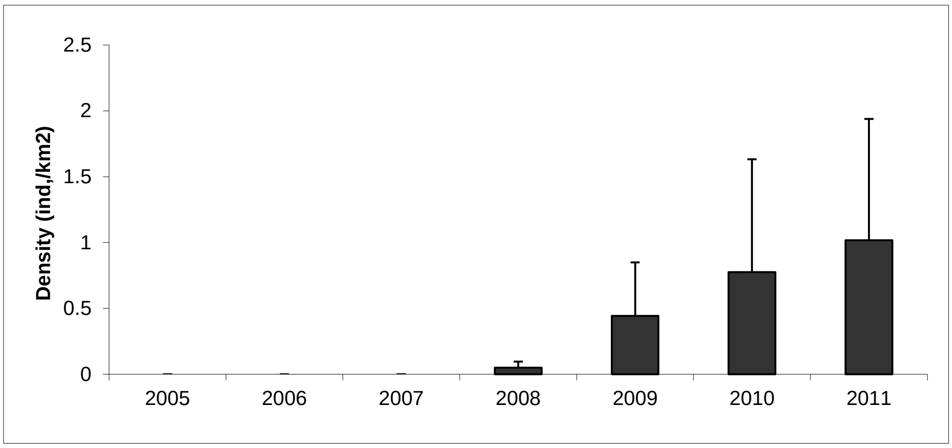
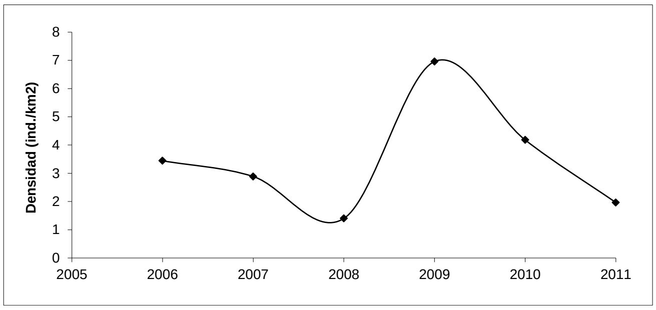
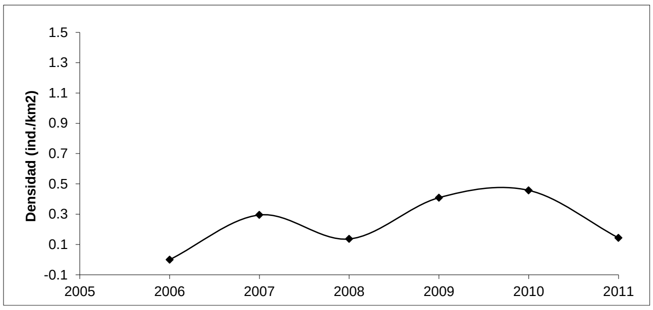


Figure 7. Density of giant river otter along the Samiria River.

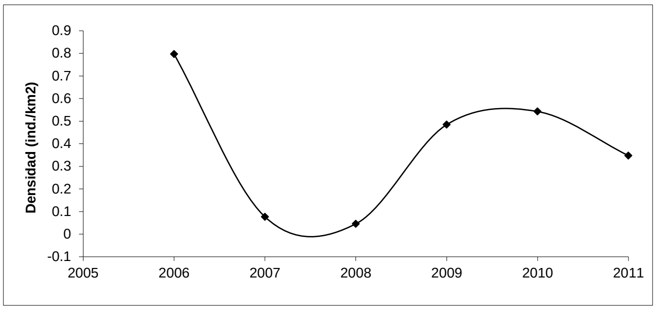
a) Tinamous



b) Razor-billed Curassow



c) Spix's Guan



d) Blue-throated Pipin Guan

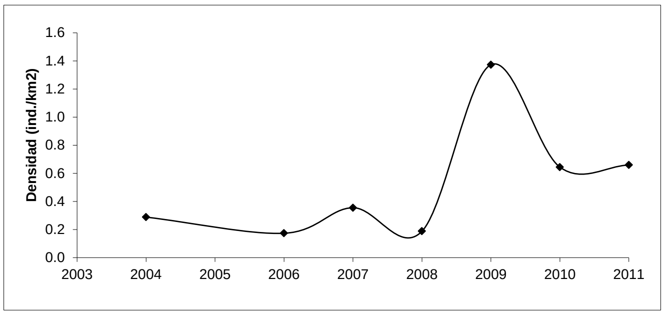


Figure 8. Density of game bird species between 2004 to 2011 in the Samiria River basin.

a) *Astronotus ocellatus* b) *Liposarcus pardalis* c) *Prochilodus nigricans* d) *Pygocentr*

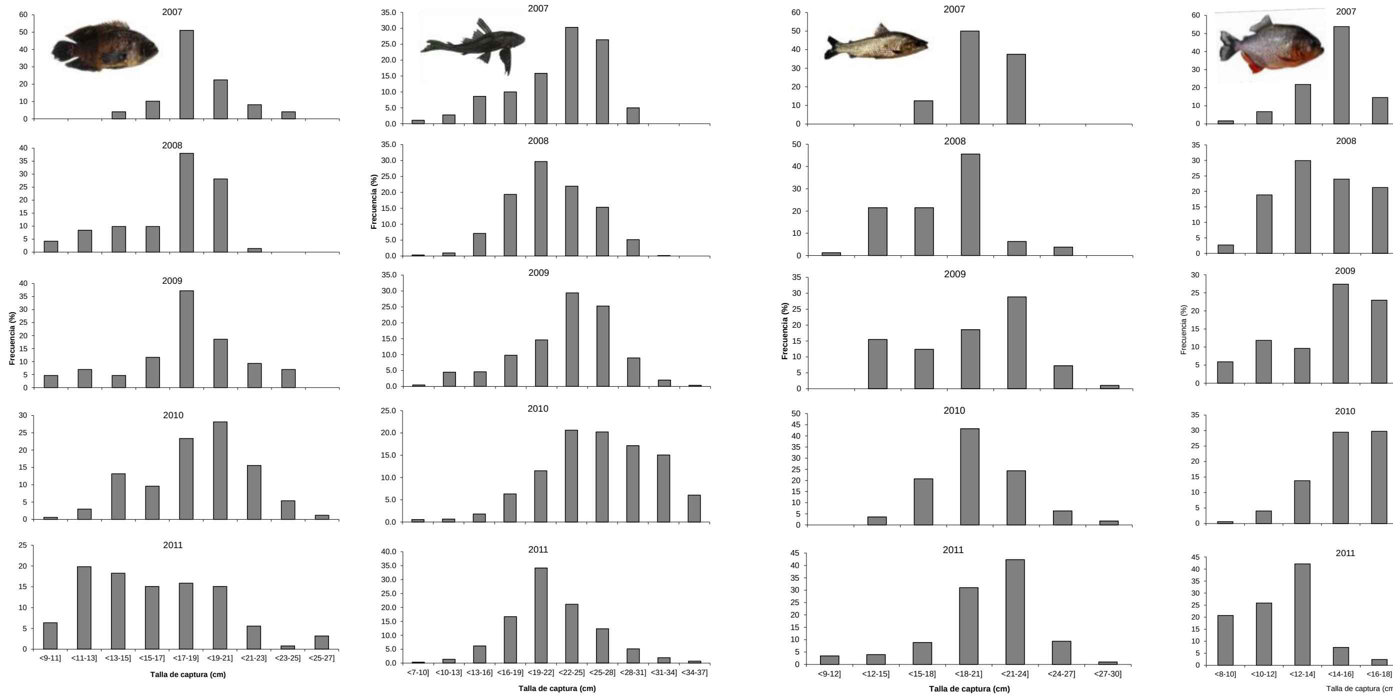


Figure 9. Size classes of common fish species between 2007 to 2011 in th

a) *Astronotus ocellatus* b) *Liposarcus pardalis* c) *Prochilodus nigricans* d) *Pygocentrus nattereri* e) *Serrasalmus rhombeus*

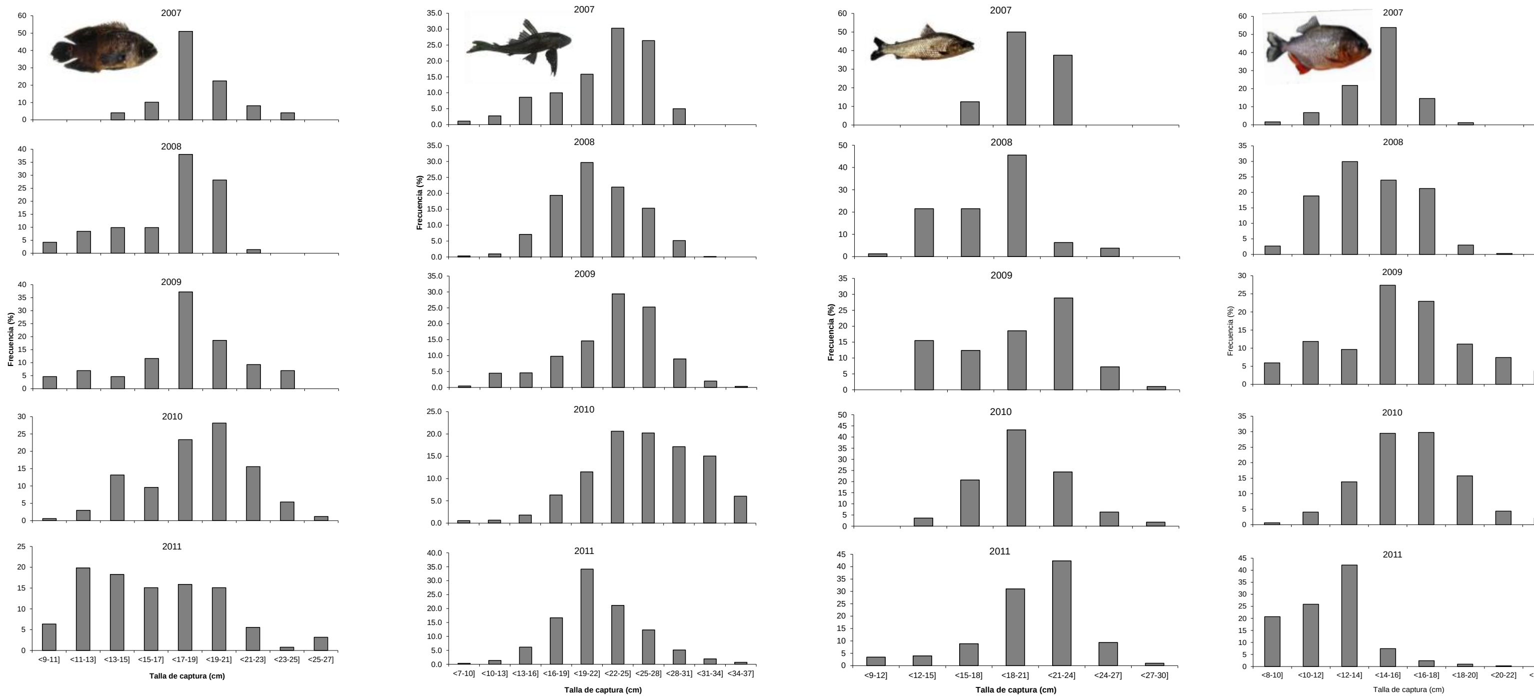
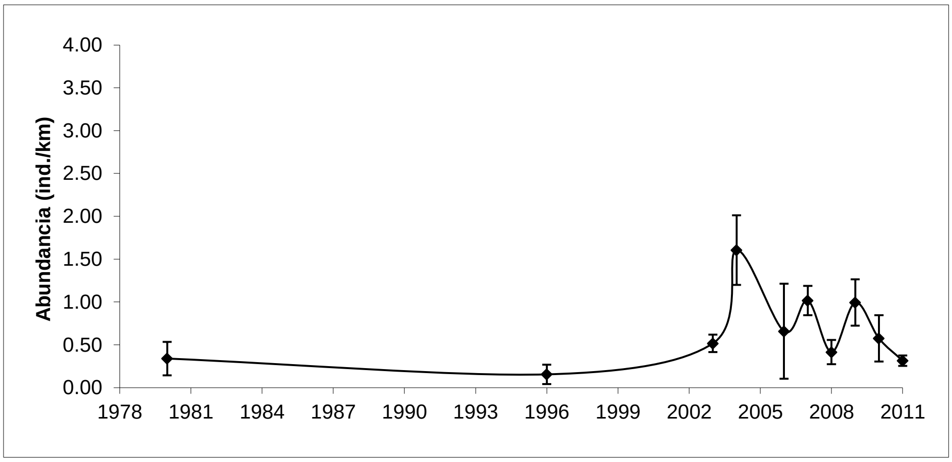


Figure 9. Size classes of common fish species between 2007 to 2011 in the Samiria River.

a) Black Caiman



b) Spectacled Caiman

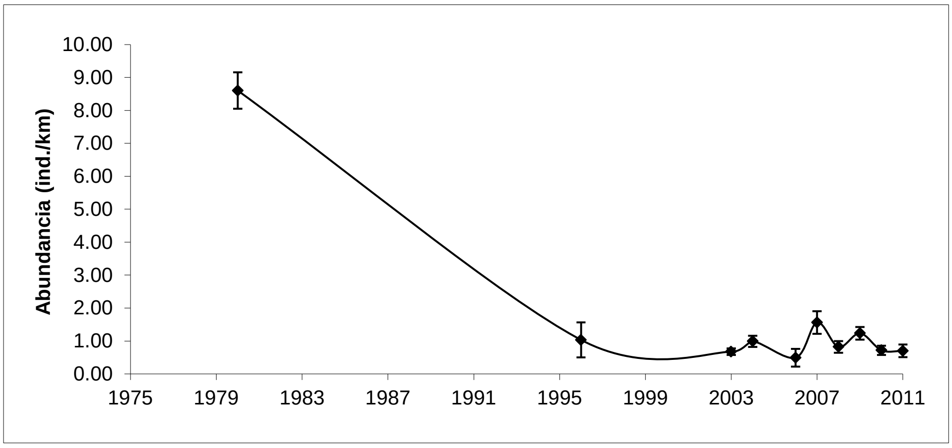


Figure 10. Long term changes in the black spectacled caiman populations in the Samiria River.