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Documenting Aguaje Palm Swamp Area and Conditions in the Peruvian Amazon

Malinda Van Sledright

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by

Malinda Van Sledright

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Malinda Van Sledright, M.A.

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Mauritia flexuosa is the most widespread and economically important palm in western Amazonia and is known as aguaje in Peru. It is found mostly in "aguajales," but little is known about the size and spatial distribution of these permanently wet oligarchic forests. Aguaje is dioecious; only the female trees produce the coveted fruit, and cutting them down leaves a preponderance of unproductive male palms. There exists a consensus in the literature that levels of damage to aguajales is related to distance from settlements where extractors reside. However, no studies exist which show this relationship. By mapping 24 aguajales and conducting forest censuses in the Area de Conservación Regional Comunal Tamshiyacu Tahuayo (ACRCTT) the findings suggest that accessibility rather than distance determines levels of damage. Additionally, plot inventories were taken within the swamps to obtain the female/male ratio. Mean female/male ratio was 0.33; well under the control plot ratio of 0.72. This imbalance has implications for local and government conservation plans in the area.

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CHAPTER 1

INTRODUCTION

Statement of the Problem

The Amazon and the surrounding rainforest contain many resources used by the local inhabitants for survival and economic gain. Palm fruits are just one example of many non-timber forest products extracted daily and used in the local economy. One such palm species is known as aguaje (*Mauritia flexuosa*) in Peru and buriti in Brazil. Aguaje is found throughout the Amazon basin, mostly in swamps or permanently wet areas known as '"aguajales" and in flood plain environments (Henderson et al. 1997, Santos 2005). To the people of Amazonia, it is probably the most useful palm and is considered by them to be the "tree of life" (Hiraoka 1999).

Fruit from the palm in the Peruvian Amazon is sold by many families (Penn 1994, Bodmer et al. 1997, Carrera 2000, Santos 2005). In northeastern Peru, the aguaje fruit is brought to the markets in the city of Iquitos, capital of Loreto province, to sell either as raw fruit or for use in ice cream and cold drinks. Women, selling the fruit products, can be seen on many street corners. During the 1980s, at least fifteen tons of this fruit were consumed daily, and the fruit is considered a necessity for many residents of the city (Padoch 1988, Vásquez and Gentry 1989). Because of this need, during the off season from August to September, the price of aguaje increased four-fold, which is more than any other palm fruit (*ibid*). Since then, demand has increased to over 20 tons daily in Iquitos alone, and it is estimated that some 5000 people in this urban center rely on aguaje for at least part if not all of their income (Del Castillo et al. 2006).

In the forest, aguaje palms can grow up to 35-40 meters tall and the fruit grows near the top of the palm on racemes (Fig 1) (Santos 2005).

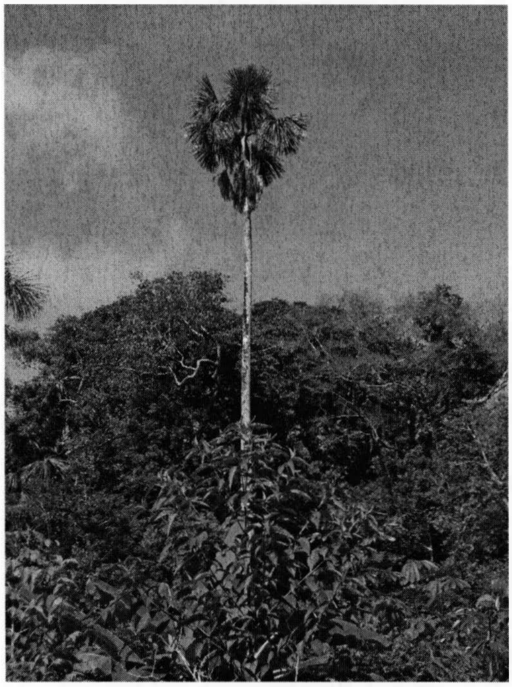

Figure 1. Aguaje palm in forest
Source: Author

A typical palm has from three to six racemes with 800 to 1000 fruits on each of these (Fig 2) (*ibid*). The palm has a hard and slippery stem that make climbing to collect the fruit extremely difficult. Aguaje harvesters will often lean a pole up against the side of shorter palms to shinny up and reach the fruit, but even this can be dangerous and they risk being stung by insects in the crown of the tree (Coomes 1992). Climbing devices have been largely ineffective (Bodmer et al. 1997), and there is a tradition of destructive harvesting for many species of wild fruit trees in this region of the Amazon because of market demands for their fruit (Vásquez and Gentry 1989). The primary method of harvest is cutting the palm down; as a result, the species is being genetically and economically depleted for future generations (Carrera 2000). Because aguaje is dioecious and the fruit grows only on the female trees, cutting them down leaves behind large stands of unproductive male trees (Kahn and Henderson 1999). This in turn decreases the fruit production and could ultimately lead to the extinction of the aguajales on which so many families rely (Vásquez and Gentry 1989, Carrera 2000).

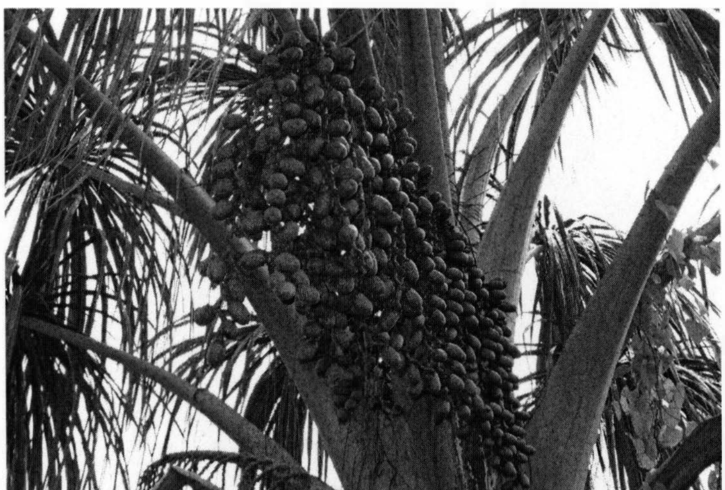

Figure 2. Raceme containing green aguaje
Source: Author

Maintaining current data on how many palms have been cut down and how far the damage extends into the interior of the forest is difficult and daunting because of the remoteness of the palm swamps and permanently wet conditions within the swamps. A current state of damage needs to be recognized to assess how severe extraction has been and is currently and exactly what areas may need to be restored or left to regenerate.

The tropical rainforest is a very delicate ecosystem that needs all of its parts to function as a whole. When one part of the forest is overexploited, the ecological balance becomes disrupted. For example, many mammals rely on the fruit of the aguaje palm (Bodmer et al. 1990, Bodmer et al. 1997), and mammal populations as well as hunting economies will be affected by humans extracting the fruits.

This study examines the effects of humans on a unique ecosystem (the aguaje palm swamp) that is of great ecological value to Amazonian forests (Henderson et al. 1997) and of great economic value to residents of western Amazonia (Peters el al. 1989) and especially northeastern Peru (Padoch 1988, Vásquez and Gentry 1989, Bodmer et al. 1997, Barham et al. 1999, Del Castillo et al. 2006). The goal is to better understand human impacts to inform and give more attention to the ecosystem value and role of aguaje in regional conservation plans (RCF 2007). Along with saving the aguaje species, the study conducted could assist in management plans for wildlife populations, which the villagers also rely on for food and income.

Research Questions

This study analyzes the current spatial arrangement of aguajales and assesses the extent of aguaje extraction by the local people through inventories of the female/male ratio. The location of each studied aguajal is analyzed in relation to its' distance to the nearest village.

A study of aguaje palm density and extraction from individual swamps has never been done in the study area, although Bodmer (1994) stated that most swamps within a 10 km radius of the village of Chino were heavily damaged and one would have to travel outside a 25 km radius to find intact swamps. Bodmer (*ibid*) claims there is a negative relationship between the degree of damage to aguaje swamps and proximity to villages. This means that aguajales close to villages have a high degree of damage and as one travels further away from a village the degree of damage becomes less. Coomes (1995) made a similar statement about the village of Charo stating that all female palms within a 15 km distance from the village were eliminated. However, none of these statements have been supported with quantitative research. The design of this research was to discover if these statements and distant-dependent relationships were in fact true through mapping and collection of quantitative data and to determine the level of damage that these aguajales had indeed sustained. The data collected and results show that extraction and damage does not essentially follow a straight linear relationship, but other variables, especially access, in this type of environment, ultimately determines the level of damage inflicted on an aguajal.

Aguajales typically are found in three different landforms: floodplain, upland (non-flooding) and in the narrow transition zone between floodplain and uplands. The floodplain (várzea) forests of the region are often dominated in areas by a few woody species (oligarchic forests) at relatively high densities and can be highly productive (Peters et al. 1989, Kahn and Meija 1990, Kahn and Henderson 1999).

During the flood season of February to June, the water level in these aguajales can rise 4-6m. Since they are subject to flooding during parts of the year, the aguajales in the várzea are more accessible by fluvial means. The extractors can use the floodwaters to navigate (in canoes) close to or directly into the aguaje swamps for much easier extraction than walking requires. The less effort needed to transport the fruit, the more fruit that can be harvested. Also, the higher the water levels, the deeper extractors can effectively penetrate the aguajales.

The upland (terra firme) aguajales are located above the floodplain and are not subjected to the seasonal flooding. Although they remain out of the floodplain, they still contain standing water because they tend to grow in poorly drained depressions where water is collects. Because of these limiting factors, these aguajales tend to be smaller in area than both the floodplain and transition aguajales. Terra firme landscapes are the most extensive forest type in the Amazon region including eastern Peru (Peters et al. 1989, Henderson 1995). These areas contain high species diversity, mostly understory species (Kahn et al. 1988); hence the total area of aguaje swamps with their dense stands of trees may be less in várzea than in terra firme forests. Likewise, density of mature aguaje palms may be lower than in várzea. A study done by Phillips (1993) shows that although várzea have a lower diversity of woody species than terra firme forests in Peru, fruit production is often higher than in terra firme forests. This supports the concept of the highly productive oligarchic forests of western Amazonia in studies by Peters et al. (1989). Terra firme aguajales do not have high flood waters in them, but human effort to reach them often increases since fluvial transportation is not an option.

Transition zone aguajales occupy the zone where flooding meets non-flooding uplands. Portions of the swamps lie in both landforms, with the swamps draining into the floodplain.

Research Objectives

The primary objectives of this paper are to:

- Inventory population characteristics of aguaje in aguajales surrounding Chino, Peru
- Describe correlations among these characteristics
- Create model to estimate damage using population variable information collected in plot inventories
- Determine if there is a negative correlation between damage and distance from settlements in order to evaluate the statements made by Bodmer (1994) and Coomes (1995)

- Compare damage in typical aguajales with a managed control plot
- Compare damage levels and aguaje densities for the three landform types of aguajales in the region

The remaining chapters are as follows: Chapter Two considers the background literature of aguaje, discusses the study area and the control plot. Chapter Three reviews the materials and methods used in the study area. First, it explains the data collection techniques, and second the methods used in the analysis of the data. Chapter Four displays the results of the research objectives and the statistical tests. Chapter Five discusses these results in terms of damage to aguajales and the current state of these swamps. This chapter also draws conclusions about the spatial pattern of extraction and what it means for conservation in the area. This chapter also considers limitations of this study and suggestions for future studies.

CHAPTER 2

LITERATURE REVIEW

Biodiversity

Biological diversity is essential to human survival (Edwards and Abiardi 1998) not only for the resources that it provides, such as timber, and substitutes for depleting resources, but also ecological assets, such as cycling of nutrients for soil preservation and operation of the hydrological cycle (Folke et al. 1996). Forests, especially rainforests, are important sources of biodiversity and ecological services. They store carbon from the carbon dioxide in the atmosphere, thus lowering the amount of concentrated greenhouse gases that influence the global environment (Malhi et al. 1999, Kosugi et al. 2008). They contain species of flora that provide mankind with beneficial medicines and products, some known and others undiscovered, but all endemic to the moist, tropical environment (Ali and Jacobs 2007). Destroying these areas means loss of biodiversity and species with unknown consequences.

According to Moran (2005), humans do not yet understand how much biodiversity is necessary to sustain the ecosystems on which so much of the world depends. To better understand this relationship, the fundamental controls on biological diversity present in nature need to be examined. How much change can take place without damage to the services provided by ecosystems? How does conservation integrate with human uses? Much of the negative impact of humans on biodiversity is not intentional but rather the result of single actions, for example clearing land for agricultural development and food production, that have unintended consequences such as eliminating the species that lived in the forest that once stood. Creating structures that integrate sustainable natural systems with people, where each of the users needs are still provided, biodiversity is sustained, and extinction rates are reduced is a tough challenge for research, but that must succeed (*ibid*). This makes a strong statement about conducting more research, which is critical, especially in parts of the world where peoples' lives depend on the security and healthiness of the forest around them. Keeping these forests intact is also not just important to the people that live in the region but for the rest of the world from an environmental and ecological standpoint.

Peru's biodiversity is being threatened by human activities. To protect and conserve this area of the world it is important to research and collect data to gain understanding of the delicate relationship between forest and humans that use it for their survival. Many non-timber forest products are extracted out of the forest daily for economic gain. One of these non-timber forest products is aguaje.

Aguaje

So what are the characteristics of aguaje fruit and why is it so important? The fruit of the aguaje palm is relatively small in size, about 3.5 x

5cm, but can vary depending on where the aguaje originated (Fig 3). The outside is comprised of a dark red to brown pericarp consisting of many overlapping scales. The middle, or mesocarp, consists of a bright yellow to deep orange 3 mm thick layer, and is the only part that is consumed (Fig 4) (Padoch 1988). The mesocarp tends to be acidic and oily and high in Vitamin A. Darker fruit tends to be less acidic and is more preferred by consumers (*ibid*). The inside of the fruit contains a large seed, which makes up most of the weight and volume, and is discarded or crafted into figures to sell (*ibid*).

Figure 3. Aguaje fruit
Source: Author

Figure 4. Inside of aguaje fruit
Source: Author

Aguaje reaches the markets of Iquitos through boats that come in from all directions around the city. Because of the city's isolation, access by roads is limited so there is not much commercial business or exporting of goods because the high cost of fluvial movement of goods is too high (Pyhälä et al. 2006). The fruit is transported in 50-kg sacks, which contain about 1000 fruits. The average price for one of these sacks is about 25 soles (7 dollars), but the price can range from $1.50 for a 40 kg sack of poor quality, "green" fruit to $10-20 for high quality "shambo" aguaje (Padoch 1988, Penn and Neise 2004). "Shambo" is often hard to find. It is high quality aguaje that has a red, oily pulp, and is made into ice cream and drinks (Penn and Neise 2004). Aguaje usually ripens during June and July, so during the off season, aguaje can jump to 100 soles per sack, as the local people have a preference for consuming a few aguaje per day (Padoch 1988). It provides employment and income for many residents of the city of Iquitos, especially its poor and women.

The aguaje is mostly sold by women from small carts on many corners in the city. The fruit is sold in several forms: raw, about four to eight fruits with salt (after being soaked for a few hours and the outside scales removed and discarded), as aguajina (drink made with mashed mesocarp mixed with sugar), popsicles or as ice cream. The popsicles are usually sold by male street vendors with wheeled, insulated carts and can be found all across the city. Aguaje ice cream is manufactured and sold in small parlors along with ice cream made from other native fruit.

By growing aguaje on plantations or gardens, the trees do not grow as tall and the fruit can be harvested sustainably because by not having to cut the trees, they can produce fruit year after year (RCF 2007). Although it does take eight to ten years for the palm to start producing fruit, the tree will produce for 40 to 50 years creating a sustainable source of income. In these plantation trees, the fruit is suspended only about two to five meters from the ground because of lack of competition with other trees for sunlight, which causes these palms to grow shorter (*ibid*).

Because of intense competition for aguaje, harvesters cut down the palm before the fruit is ripe. This low quality fruit fetchs a minimal price in market and does not benefit either the forest or the harvester (Padoch 1988, RCF 2007).

Besides having an economic value, aguaje also has an important ecological value. Many large game animals (brocket deer, peccaries, and tapir) that require forest habitat, feed on the fruit that falls from these palms. Local people hunt these animals for food and if aguajales are damaged, the animals will be affected and may migrate to other parts of the forest (Bodmer 1990, Bodmer et al. 1997).

Many different species of primates also feed on the fruit of the aguaje palm, including the red uakari monkey. This primate is considered an endangered animal and the reserve that comprises the study area is the only protected area in Peru that it inhabits (Bodmer et al. 1997, RCF 2007). In total, 14 different species of primates have been observed in the reserve, the highest number reported in any protected area in Peru (Puertas and Bodmer 1993). During the study period, five different types of primates were observed feeding on aguaje high in palm fronds. These included black and white capuchins, mustached tamarins, black saki monkeys, and howler monkeys.

M. flexuosa has also been found to be a keystone species for the nesting habitat of parrots and macaws (González 2003, Brightsmith 2005). They use the fruit from the nearby live aguaje palms as food for themselves and their young. Blue-and-yellow macaws have been found to nest in the hollow trunks of dead *M. flexuosa* palms exclusively (Brightsmith and Bravo 2006). These birds have low reproductive rates and are under pressure from being hunted and captured for the pet trade industry (*ibid*). Parrots are a threatened species, so destructive uses of their habitat will reduce suitable nest cavities and ultimately have great impacts on the delicate ecosystem (Brightsmith 2005).

Although aguaje is an important economic non-timber forest product, on which many families rely for income, the human impacts of extraction are still not well understood and documented at the landscape level (Oliveira et al. 2007). The extraction and commercialization of aguaje fruits in Peru are discussed by geographers (Penn 1994, Coomes 1995, 1996, Coomes and Barham 1997), and there have been studies about the diversity of other palm species in Peru (Vormisto 2002). O'Neill et al. (2001) argues for conservation of the trees in the Peruvian Amazon, but there is little research on the spatial patterns currently experienced in the forest today.

Elements of the forest that are used for economic gains within a certain radius around the city of Iquitos make its way to the market. Iquitos is growing. The population, currently at 400,000, is expected to reach 500,000 by 2010. The pressure on local forests is likewise going to increase (Pyhälä et al 2006). In fact, it is estimated that aguaje sales in Iquitos now averages 20 tons of fruit per day (7300 tons annually), with fruit sales reaching 50 tons on some days (Nube 2006). Therefore, current data on the status of important economic non timber forest products, such as aguaje, in the nearby forest is more important than ever.

No actual counts or surveys have been done in the study area to determine how many aguaje palm trees are still intact or how far the damage to the palm swamps from extraction reaches into the forest (Bodmer 1994, Bodmer et al. 1997). Studies that have examined or mapped the spatial patterns of aguaje extraction or its cultivation in this vast region are lacking. The limited access to transportation makes relative location a key factor influencing the level of these activities (Kahn and Mejia 1990, Henderson 1995).

Information that has been gathered and produced about palms throughout the Amazon, such as ecological counts of species richness (Gentry 1988, Kahn and Mejia 1990) and distribution maps (Henderson 1995) are now outdated, limited to just a few small areas, and often inaccurate. Hiraoka (1999) states that ecological research about palms, especially ones that have been disturbed by humans because of economic reasons, are needed.

According to Henderson (1995), the lack of collections of Amazon palms hinders understanding the diversity. He states that the whole region of Amazonia is poorly collected in regards to palms. Although Henderson collected 500 specimens and examined approximately 6000 specimens in the greater Amazonian basin and created maps from these collections, this information is already 10 years old.

Study Area

The study area is located in and near the 322,500-hectare Reserva Comunal Tamshiyacu-Tahuayo (RCTT) in northeast Peru. The RCTT was created by the government of Loreto in 1991 from combined efforts of local communities and researchers who had been working in the area for more than a decade (Rapid Biological Inventories 2003). Recently the reserve was expanded to 420,000 ha and re-legislated as part of a decentralization process of the government of Peru. The name has also been changed to Area de Conservación Regional Comunal Tamshiyacu Tahuayo (ACRCTT).

The Reserve was created for many different reasons. These include the biological diversity found in the area, granting the local people legal title to the land to keep out commercial logging and hunting, and because their own hunting and harvesting practices are a risk to the natural resources of the forest (*ibid*). Community management practices, with limited government involvement, were integrated from the beginning of the reserve. The Amazon Conservation Fund (ACF), which later merged with the Rainforest Conservation Fund (RCF), a non-profit organization based in Chicago, Illinois, worked along with the local people to help them gain legal communal title of the land where these communities are located. They also worked on removing local squatters in the area who had illegally taken over community land to raise cattle (*ibid*). The majority of the rural people that inhabit the study area are referred to as "ribereños", a quasi-ethnic group of mestizo people of mixed Amerindian and European descent (Chibnik 1991). The combination comes from the mixture of the remnants of native populations with European and African racial and cultural elements left from the rubber boom (Miller et al. 2006).

After the reserve was in place, RCF's involvement has been as guardian to help promote and protect the reserve and to assist the local people with any cultural or agricultural needs. RCF also conducts and funds projects in Peru to conserve the rainforest. They also oversee and fund many programs within this reserve in order to educate and work with the local people on the need to maintain the biodiversity of the forests and to prevent the past "boom" and "bust" cycles that happened throughout the area (RCF 2007).

The economic cycle of "boom" and "bust" that happened throughout the Amazon region in the past affected the forests and surrounding area of the ACRCTT negatively from a resource perspective. Rubber extraction during the late 1800s and early 1900s drew an influx of people to the area to become part of this boom and make economic gains (Coomes 1995). The forests were altered as foreign investors claimed large tracts of land near Iquitos to extract the rubber that was in such demand in Europe (*ibid*). Eventually, as cheaper versions of rubber were discovered and produced elsewhere, the need and high prices for rubber greatly subsided. The forests were left depleted and the local people with very little economic gain (Padoch 1992). These immigrants from the rubber boom have since settled in the area and are still using the forest for resources and subsistence.

To help prevent these destructive cycles from repeating, efforts have been underway for years by non-profit organizations, including RCF, to help the local people grow trees in gardens instead of depleting the forests and eventually destroying these resources for good (RCF 2007). "Proyecto Aguaje" is one such project that the RCF oversees to guide the local people on how to use sustainable forest practices such as agroforestry (cultivating the trees in multiple specie gardens), by growing tree species of high ecological and economic value, including aguaje, instead of extracting them from the forest (*ibid*). By using sustainable practices with flora that have economic value, the local people will have resources available to them outside of the forest and on an annual basis.

According to Bodmer et al. (1997) there are 3 main zones of the ACRCTT. These are the permanent settlement, where villages are located; the subsistence use zone, where extraction of resources takes place by the local people; and the fully protected zone where no extraction can take place and people may not live. Preliminary studies suggest that the villagers have been extracting aguaje mainly from the subsistence use zone, and the settlement or buffer zone, north of the fully protected zone of the ACRCTT, but it is unclear what spatial patterns of aguaje extraction or cultivation exist (Bodmer et al. 1997).

The study area is characterized by floodplain along the Tahuayo River, considered a black water river, meaning it is stained dark by plant compounds, and mostly terra firme forests along the Quebrada Blanco River, a white water river, named so because of the large amount of silt causing its' lighter color. Mean monthly temperatures range between 26°and 28°C with annual precipitation measured between 2400-2800 mm (SENAHMI 1997).

The aguajales were surveyed along the Tahuayo and Quebrada Blanco Rivers. Located along the banks of the rivers is Chino along with other villages (Fig 5). Members of these villages extract aguaje from the nearby aguajales to sell in the markets of Iquitos. The local people need current data to gauge the actual fitness of the forest; otherwise they will view it as an endless supply of resources when in fact it is a much degraded version. The reserve was created in part because the local people knew their behavior was a risk to the forest. Having an actual count of the palms will help them to assess exactly what condition these aguajales are in and if management and conservation efforts will need to be reassessed for the reserve.

The control plots used in this study for comparison against the study plots were taken in the Pacaya-Samiria National Reserve (PSNR). It is located southwest of the ACRCTT (Fig 6). It is Peru's largest reserve, containing some 2,150,770 ha, and is comprised completely of floodplain (CDC 1994). The Marañon and Ucayali rivers make up its borders, which eventually join to form the Amazon River, although the reserve was named for the Pacaya and Samiria Rivers that flow through the middle of it. It was set aside as a reserve in 1940 and 1944 by the government to protect and manage aquatic fauna

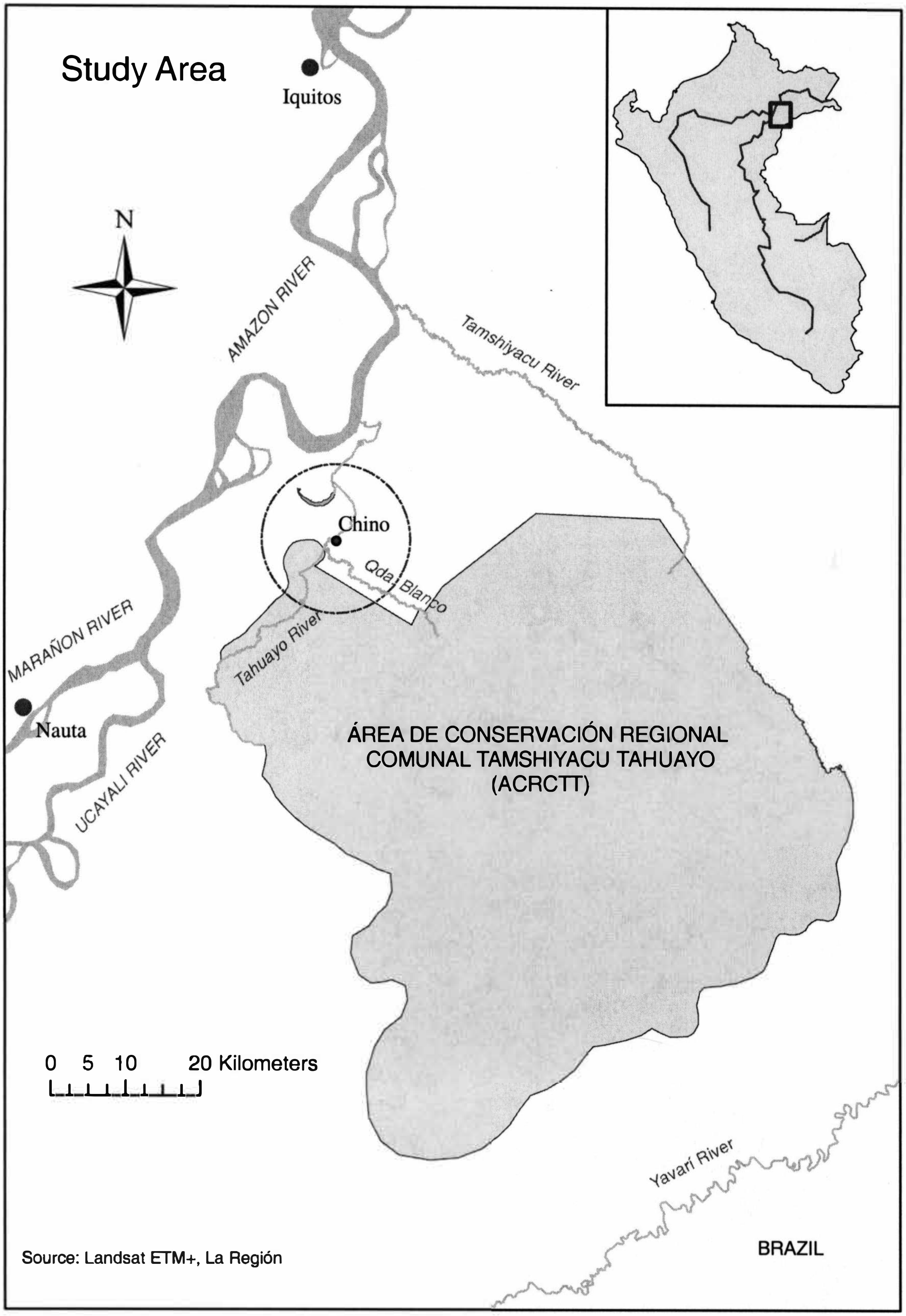

Figure 5. 10-km radius study area around Chino

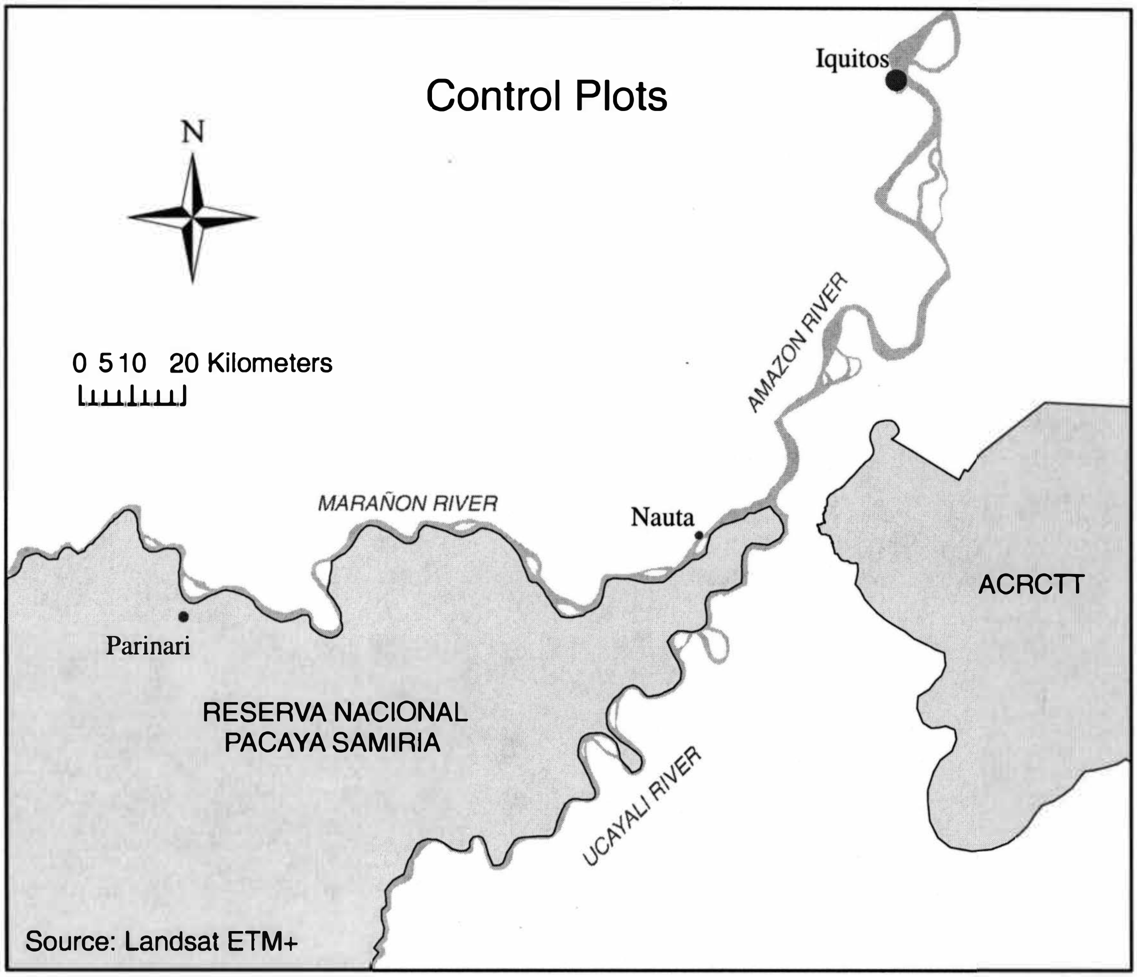

Figure 6. Area where control plots were taken

(COREPASA 1986). These aquatic species include the Amazonian manatee, giant river otter, the pink and gray dolphins, caimans, Amazon River turtle and the paiche; the largest fish of the Amazon. The first efforts of the reserve were to protect this fish species (*ibid*).

The management plan for the PSNR, named the Employment and Natural Resource Sustainability Project, or Pacaya-Samiria Project, was initiated in 1991 and is still ongoing in the area (Durand and McCaffrey 1999). The U.S. Agency for International Development (USAID) and The Nature

Conservancy (TNC) provide funding for the project. The Nature Conservancy (TNC), works closely with the Fundación Peruana para la Conservacion do la Naturaleza, or Pro Naturaleza, a nongovernmental organization (NGO) and the regional office of the Peruvian government that has jurisdiction over the PSNR, Instituto de Recursos Naturales (INRENA) located in Iquitos (*ibid*).

The Project was designed to create a balance between conserving the natural resources and protecting the delicate ecosystems, while developing economic growth in the area in a sustainable fashion. This dual relationship of the reserve is the central approach to any decisions made about the reserve and is the rudimentary idea behind how the reserve is managed.

Part of the uniqueness of the management in this area is the close involvement of the agencies involved with the local communities. By holding local meetings at various locations within reserve, the community input is integrated in the project. Also there is not just one central plan for the whole reserve, but is developed for each communities unique needs and expectations. Part of the project plans include using alternative ways of conserving natural resources and using technology for extraction of these resources in a sustainable fashion. In the case of aguaje in this region, the plan includes harvesting the fruit for sale but also leaving some behind for the game animals that feed on the fruit. It also includes using developed technology such as tree climbing devices to extract the fruit without having to cut down the palm.

One such device that has been designed is "the climber". This device is crafted from simple materials and makes use of a self propelled motion of the person to lift them up the trunk to the fruit located near the top (Fig 7). Great

Figure 7. Man demonstrating "the climber" device
Source: Author

skill is needed to do this and once the top of the palm has been reached, they can be subjected to bites and stings from bees, spiders and scorpions that live in the crown (Coomes 1992). Exhaustion can incur because of the physical exertion needed to climb and descend the trunk. Falls can result incurring serious injuries.

The area of the PSNR where the control plot inventories were taken was near the village of Parinari (Fig 6). The Flores brothers took over the aguajal management of this area in 1997. Three brothers and a father all work together to market and extract the aguaje. They have title to manage over 500 ha of aguaje that they manage. Emelton Flores, considered the number one innovator and promoter of "the climber" in this area, uses the device to climb the palms and extract aguaje without cutting down the palms. This managed area and the Flores family are well known among the community in Iquitos because of the work they do with the climber. Walking to the aguajal was very difficult, as it was wet and muddy, making accessibility and extraction more challenging. Since the area is under sustainable management, it served as a control plot for the study.

Pacaya-Samiria National Reserve is classified as a tropical moist forest that receives about 2000-3000 mm of precipitation annually (Durand and McCaffrey 1999). Mean monthly temperatures vary between 20° and 33°C and the climate is hot, humid and rainy (Rodriguez et al 1995). The water levels also vary along the rivers in this area between 8-10m. High water periods are between December-June with low water periods between July-November (Durand and McCaffrey 1999). In this area, aguaje ripens later in the year, August – October.

CHAPTER 3

DATA AND METHODS

This chapter is organized into two sections. The first section explains data collection and organization. The second section explains the quantitative analysis of the data with various statistical analyses to address the research objectives.

Data Collection

The aguajales that were chosen for this research are representative samples of these palm swamps in all three landforms (floodplain, transition and upland), each used by the inhabitants for extraction. The size of the aguajales and their location relative to transportation routes were gathered using a GPS.

Aguajal Perimeters

Field data on location and population characteristics of aguaje in numerous aguajales was collected in the study area. The data, including global positioning system (GPS) points and plot inventories, were collected in the study area between the dates of June 25, 2007 and July 31, 2007. A Garmin® eTrex Venture 2002 model was used to collect GPS points for the perimeters of the aguajales as it received the best reception under the canopy of the rainforest of several GPS units tested. The points were collected in decimal degrees with the settings set to WGS 1984.

To collect the points of the perimeters of the aguajales, local men were hired to guide and machete a path through the rainforest. Also assisting with the research were Gerardo Bertiz and Exiles Guerra, employees of the RCF, who had rapport with the local people, were experienced at navigating within the jungle and had experience with the local flora. Once an aguajal was reached by canoe, three groups were formed to cover as much area as possible in the limited daylight hours. Each group had a guide with a machete and a GPS system to collect perimeter points. The groups then set out in three different directions to collect the points and conduct plot inventories. The perimeter points, along with the inventory data, were hand written in field notebooks and later entered into a spreadsheet for organization. The aguajales were surveyed at a rate of about one per day, sometimes two if they were small in area and located close to each other.

There seemed to be a 'blackout' time in the middle of the afternoon (1-3pm) where it was nearly impossible for the GPS units to receive satellite signals. Whether this happened because of the canopy of the forest or the limited satellite coverage during certain times of the day could not be determined. This typically happened right in the middle of the aguajal during the middle of the day and was frustrating since sunlight only lasted until 6pm. A way to help compensate for the weak signal was to tie the GPS unit onto a long branch and hoist it up higher into the air. The receiver was periodically checked until it had received a signal and a coordinate point.

As a reference for the gathered points, Landsat 7 satellite images were obtained and downloaded from the University of Maryland Global Land Cover

Facility Website. Images include the city of Iquitos and the study area, precisely Path 006 and Row 063, and for the control plot area of Pacaya-Samiria, Path 007 and Row 063. The image date for the study area was May 31, 2001 and was chosen because it had the least interference from clouds. The date was before May 2003, when missing gaps appeared due to the damaged sensor onboard the Landsat 7 satellite. The image date for the control plot was August 21, 1999.

From the University of Maryland website, the images were downloaded as individual bands, namely one, two, three, four, five, and seven. Six was not used because it is the thermal band and is not needed to view the image. To view the image, the bands needed to be layered together to create one image and this was accomplished in the program ENVI 4.2 (ENvironment for Visualizing Images 2005), a remote sensing software created by Research Systems, Inc. The bands were stacked together and then exported as a GeoTiff (Tag Image File Format), a specific file format that is recognized and can be opened by ArcMap 9.2, a geographic information systems (GIS) software program, which assists with mapping and analysis of spatial data. ArcMap 9.2 was created by ESRI (Environmental Systems Research Institute 2006), a GIS company based in Redlands, CA.

The spreadsheet, containing the latitude and longitude in separate columns of all the perimeter points of each aguajal, was imported into ArcMap 9.2 as georeferenced points. These points were then connected together (digitized) to create polygons of the perimeters overlaid on top of the TIFF image of the study area. Once the perimeter was digitized in ArcMap 9.2, the area, in hectares, could be calculated for each of the 24 aguajales that were surveyed during the course of the research using the calculate tool in ArcMap 9.2.

Aguajal Inventories

Although the use of transect collection is widely used for ecological purposes, it did not fit in with the scope of this research. A male/female ratio per hectare was needed to analyze the overall health of each aguajal. By taking plot inventories of a known size, a ratio of density could be found per hectare.

For this study, population characteristics of aguaje were inventoried within each selected aguajal (Table 1). The number of palm swamps, aguaje palm density and abundance, and the number of palms cut for harvesting were recorded by conducting forest censuses. Because of the fast decomposition that occurs within the moist, warm tropical rainforest, trees tend to decay quickly and it is nearly impossible to compute felled palms older than seven years, thus the breakdown between recent and old felled females.

Plots were placed randomly throughout the aguajales, but at least one was taken at the front of the aguajal, where it was entered, and one along the back edge, farthest away from the access point, for comparison. Plots were 25 x 25 meters or 50 x 50 meters, but did vary in size depending on the individual aguajal, as some were less than 25 meters wide. This is typical in such research as Peters et al (1989) used plots between 0.1 and 1 hectare to establish density

Table 1. Characteristics of aguaje inventoried in each plot

Name	Number of Males	Number of Females	Trunked Juveniles	Juvenile-Large	Juvenile-Small	Seedlings	Felled-Old	Felled-Recent
Code	MHa	FHa	JuvTrunk	JuvL	JuvS	Seedlings	FelledOld	FelledRecent
Description	Male palms with dry racemes and no seedlings below	Female palms with fruiting racemes or seedlings underneath	Juveniles > 5 meters that have started producing a trunk but have unknown sex	Juveniles > 5 meters tall	Juveniles – 1-5 meters tall	< 1 meter tall	Cut aguaje palms – > 5 years	Cut aguaje palms – < 5 years

and yield over a series of years, and Kahn and de Castro (1985) collected data from 0.1 hectare plots. Plot inventories in this study varied between two to ten plots for each aguajal. The number of males and females of all plots taken within one aguajal were averaged to come up with one ratio per hectare per aguajal. 101 total plot inventories were taken during the time period. Four additional plots were taken in the Pacaya-Samiria reserve for use as a control plot for male/female ratio analysis against the plots collected in ACRCTT.

Analysis Methods

To conduct the analysis of the data collected in the plot inventories, all of the data was entered into a spreadsheet for easier management and organization. This spreadsheet was compatible with the program SPSS 15.0 (2006), a statistical and data management package, which was used for all of the statistical analysis in this paper.

Correlations and Regression

To determine if the variables of the population characteristics taken in each plot were associated or related to each other, correlations were conducted between all eight variables (Table 1). Correlations are a test of the strength of the relationship between two variables. This strength is represented by a Pearson's correlation coefficient, r, which ranges between +1 to -1 and measures the linear association whether positive or negative (Rogerson 2006). The coefficient is calculated by taking the mean value of the product of the deviations of two variables from their respective means (*ibid*). As the r - value reaches closer to +1 or -1, the strength of the linear relationship increases.

Researchers use regression analyses to create models to predict a dependent variable from sets of independent variables. These models are useful tools to help humans better understand the biological world. Regression analysis is a common method for assessing the relationship between the population variables. It can be used to evaluate the importance of the variables and the goodness of fit for a particular model (*ibid*).

Multiple regression analysis is used to study the relationship between a dependent variable and a set of independent variables (Rogerson 2006). Assumptions of regression are that the relationship between y and x is linear; the errors have a mean of zero and constant variance; the residuals are independent, meaning the value of one error is not affected by the value of another error; for each value of x, the errors have a normal distribution about the regression line; and independent variables are not correlated to each other (*ibid*). Researchers have used regression to model variables such as tree density and species richness (Bjorholm et al. 2005, Cao and Dean 2008, Kim 2008). Models of land use change and its effect of forest (Abdullah and Nakagoshi 2007) have been created to understand the reasons that people use certain palm trees (Byg et al. 2006).

In this research, a multiple regression was used to create a model using significant population variables to predict the damage inflicted on the aguajales by extraction. Damage was calculated by determining the ratio between female and male in each of the plots. The dependent variable in this case would be damage, while the independent variables would be variables that were significantly correlated to damage. The variables tested in the regression were six population variables (trunked juveniles, large juveniles, small juveniles, seedlings, old felled and recent felled), plus travel time needed to reach each aguajal by the extracting village broken down into time traveled by canoe (rounded to nearest ¼ of an hour), and time spent walking to reach the plot once the port was reached (rounded to nearest ¼ of an hour) and Euclidean distance (measured in meters between aguajal and nearest village). Stepwise variable selection was used during regression to evaluate each variable in a forward and backward procedure to test and re-check each variable to determine if they are still significant.

T-Test and ANOVA

T-tests were used to assess if the means of two groups were statistically different from each other. It was used in this paper to determine if the female/male ratio gathered in plots near the access point of an aguajal was statistically different than the ratio of plots in more inaccessible parts of the aguajal.

Using paired means, the ratio in the plot close to the entrance point was paired against the ratio in plots in the farthest end to determine if these were statistically different from each other. The seven floodplain aguajales were the only ones with enough area to have plots taken at the entrance and ones taken from the back, away from the access point, so these were the only aguajales used. Transition and upland aguajales are too small to have much difference in density between the plots.

Analysis of variance (ANOVA) tests were conducted in the same manner as t-tests, but they were used when there were more than two means to analyze. ANOVA assumes that observations between and within samples are random and independent, that the observations are normally distributed and that the population variances are equal (Rogerson 2006).

Since there are three different types of landforms that the aguajales are found in, ANOVA tests were conducted to determine if they are statistical different of each other. First, female/male ratios were averaged for each of the three landforms from all plots and then compared against the control plot ratio. Secondly, the three landforms were compared with each other for statistical differences in regards to male/female density to determine if there are natural differences in population characteristics among the types of aguajales. ANOVA tests have been used by other researchers to test for differences among plots and ecosystems (Barbosa and Fearnside 2004, Sankey 2008).

Differences in densities among different landforms have been discussed (Peters et al. 1989, Kahn and Meija 1990, Kahn and Henderson 1999), both female/male ratio and male/female densities were examined.

The variables seedlings, small juveniles, large juveniles, and trunked juveniles were averaged for each of the three landforms and then graphed to show how the numbers of individuals changed with age and time.

CHAPTER 4

RESULTS

In Chapter Four the results of Chapter Three are presented.

Data Collection

Aguajal Perimeters

24 aguajales were surveyed with GPS units and plot inventories (Fig 8). Since upland aguajales are so small in area, a second map focusing on the 13 upland aguajales surveyed was created for easier viewing (Fig 9). The aguajales are separated into three groups based on the landform in which they are located. The floodplain aguajales are largest in size, followed by transition and then upland, which are the smallest. Floodplain aguajales ranged in size from 7.99 ha to over 900 ha. Transitions ranged from 3.69 ha to 36.68 ha and upland ranged from 0.24 ha to 5.65 ha. Table 2 lists the names, size, landform, extracting village of each of the aguajales and populations of these villages.

Aguajal Inventories

101 plot inventories were taken within the 24 aguajales and two plot inventories were taken as control plots. Histograms of all eight population variables and distributions are displayed in Figures 10-13.

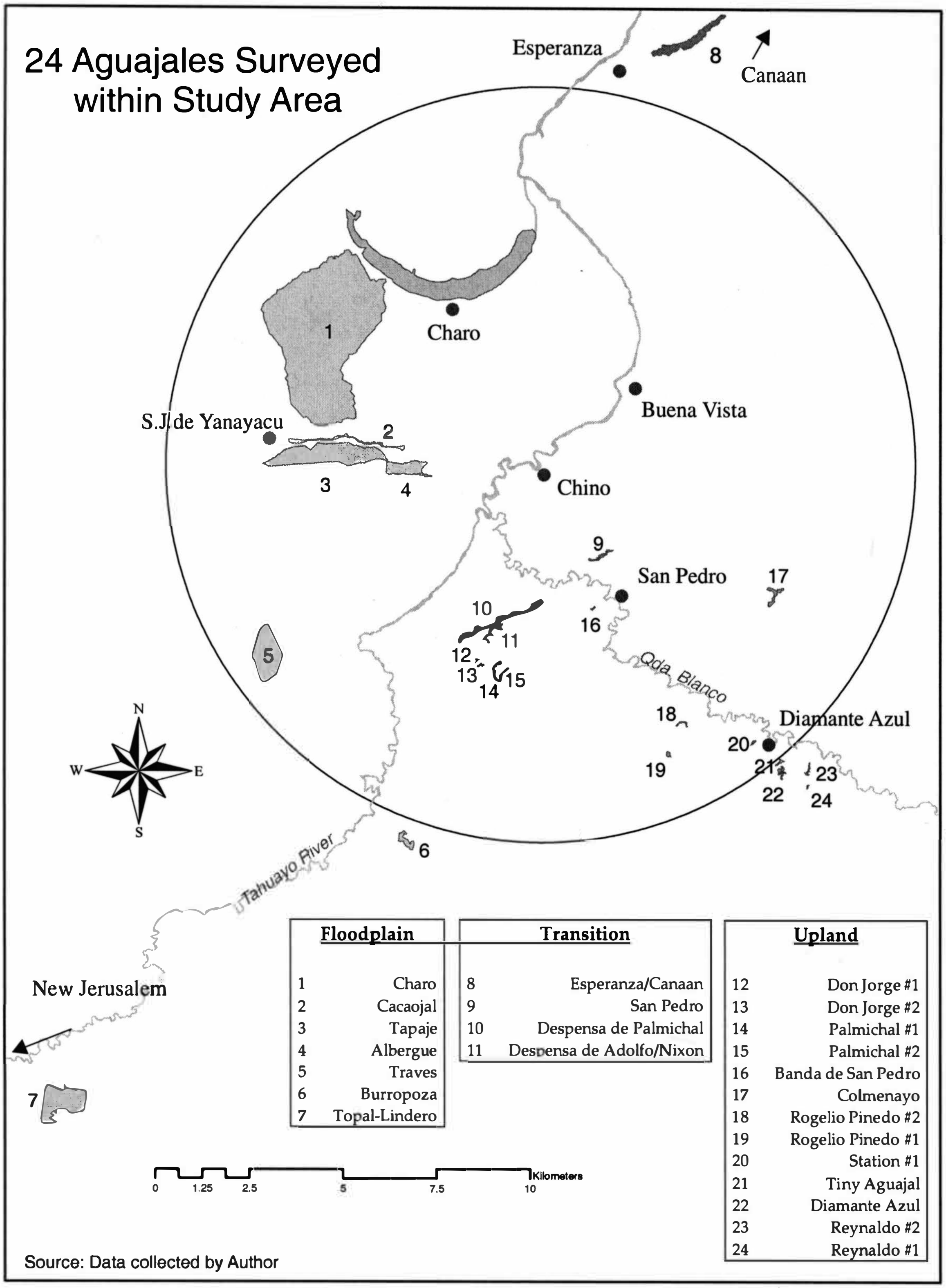

Figure 8. Map showing location of the 24 aguajales studied in the Área de Conservación Regional Comunal Tamshiyacu-Tahuayo (ACRCTT) in the Province of Loreto, Peru

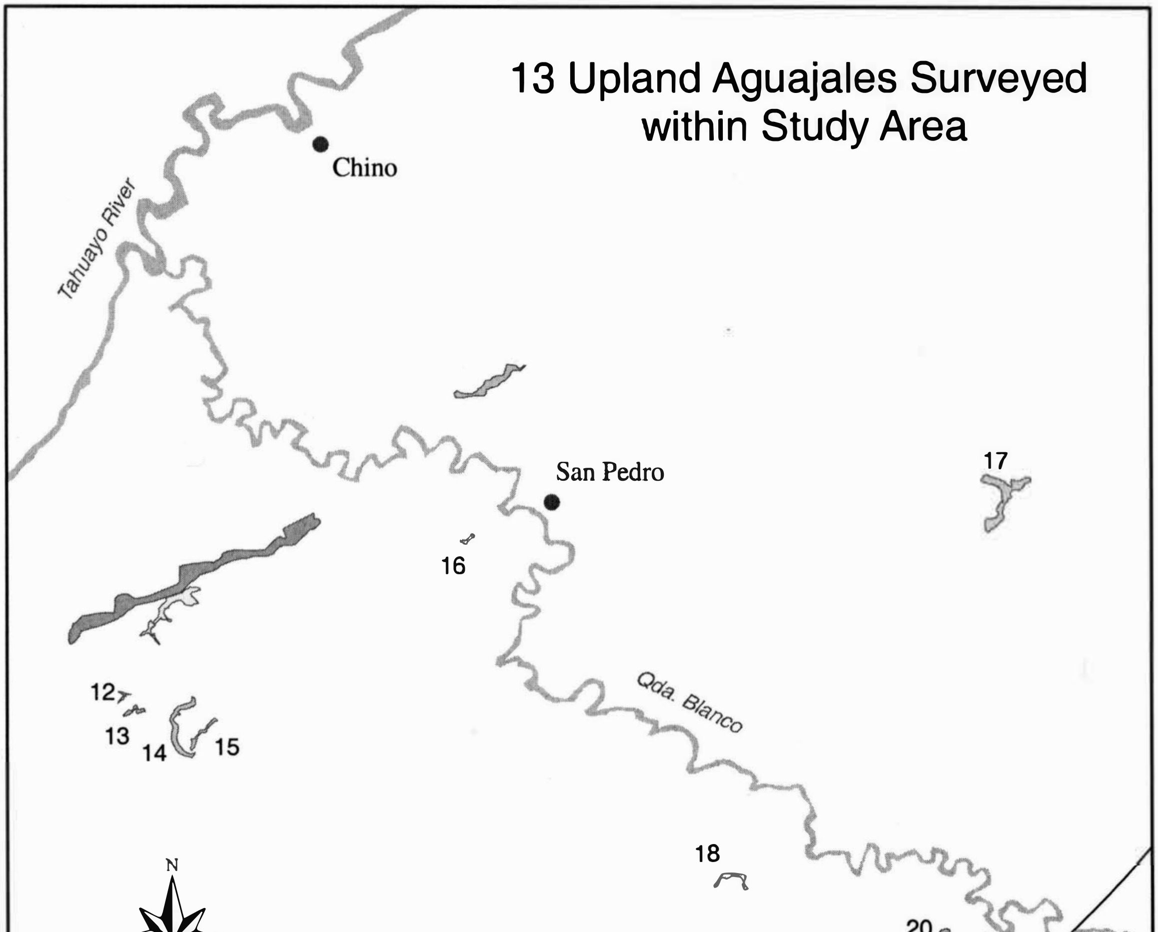

Figure 9. Map showing the 13 upland aguajales

Table 2. Names, sizes, landform, extracting villages and population data on all 24 aguajales

	Name	Size (Ha)	Landform	Extracting Village	Number of Families*^	Total Population*^
1	Charo	903.40	Floodplain	Charo	27	150
2	Cacaojal	15.35	Floodplain	Chino/ S.J. de Yanayacu	47 17	226 92
3	Tapaje	131.28	Floodplain	Chino		
4	Albergue	31.99	Floodplain	Chino		
5	Traves	75.88	Floodplain	Chino		
6	Burropoza	7.99	Floodplain	Chino/ Buena Vista	 37	 206
7	Topal-Lindero	76.65	Floodplain	Chino/ New Jerusalem	 18	 98
8	Esperanza/Canaan	36.68	Transition	Esperanza/ Canaan	55 8	300 46
9	San Pedro	3.69	Transition	San Pedro/ Chino	7	38
10	Despensa de Palmichal	23.94	Transition	Chino/ San Pedro		
11	Despensa de Adolfo/Nixon	4.38	Transition	Chino		
12	Don Jorge #1	0.24	Upland	Chino		
13	Don Jorge #2	0.62	Upland	Chino		
14	Palmichal #1	3.01	Upland	Chino		
15	Palmichal #2	0.91	Upland	Chino		
16	Banda de San Pedro	0.38	Upland	Chino/ San Pedro		

Table 2 - Continued

	Name	Size (Ha)	Landform	Extracting Village	Number of Families*^	Total Population*^
17	Colmenayo	5.65	Upland	San Pedro		
18	Rogelio Pinedo #2	1.03	Upland	Chino		
19	Rogelio Pinedo #1	1.03	Upland	Chino		
20	Station #1	0.59	Upland	Diamante Azul	13	70
21	Tiny Aguajal	1.15	Upland	Diamante Azul		
22	Diamante Azul	2.64	Upland	Diamante Azul		
23	Reynaldo #2	1.20	Upland	Diamante Azul		
24	Reynaldo #1	0.33	Upland	Diamante Azul		

* The number of families and total population for each village are listed at the first appearance of that village in the table

^ Source: Tafour, L. 2001. Distrito Iquitos: Capital Iquitos. *Kanatari* 900:131-152.

Arévalo, E. 2001. Distrito Fernando Lores: Capital Tamshiyacu. *Kanatari* 900:3-11.

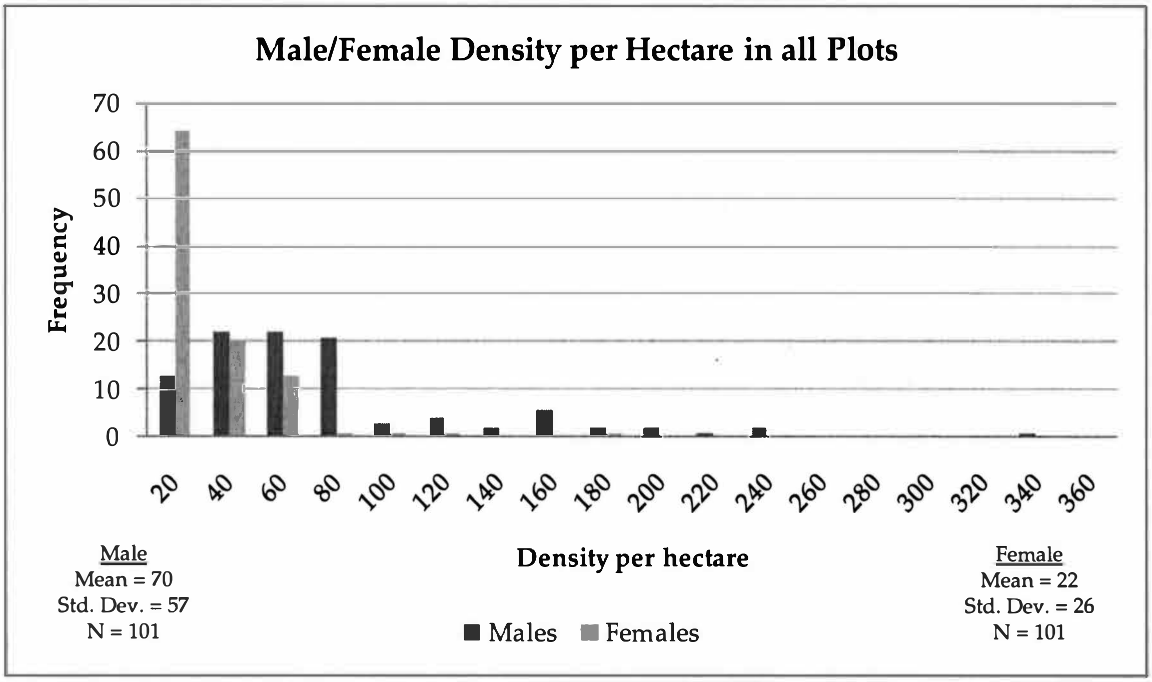

Figure 10. Histogram of male/female density per hectare

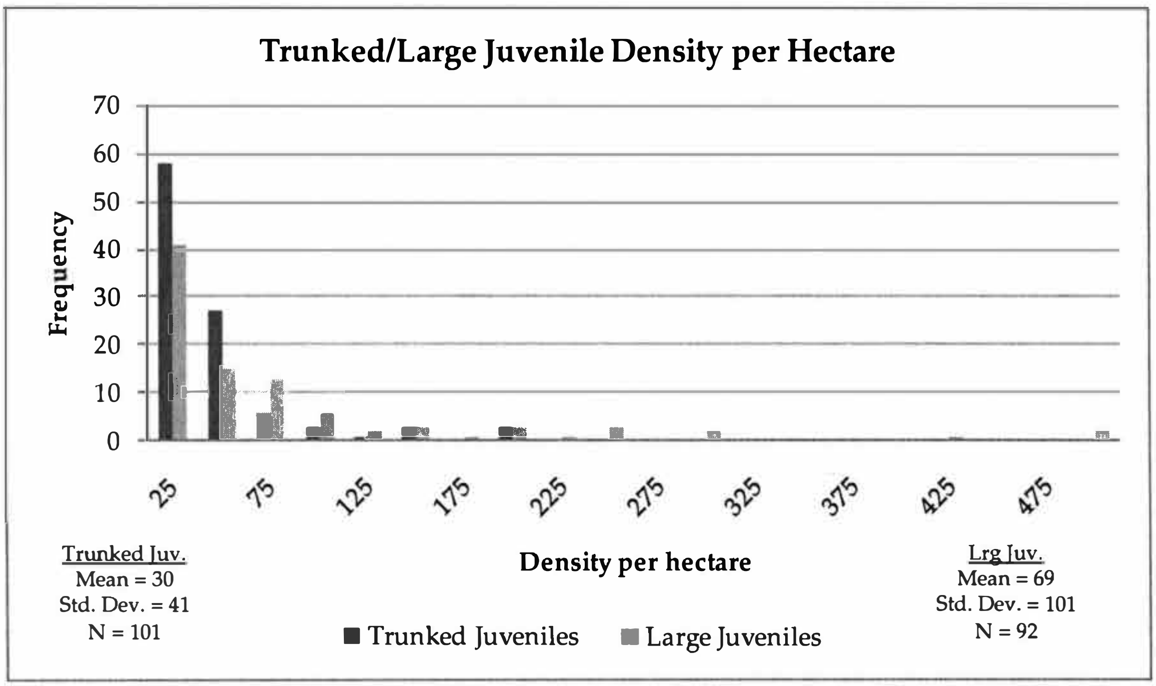

Figure 11. Histogram of trunked/large juvenile density per hectare

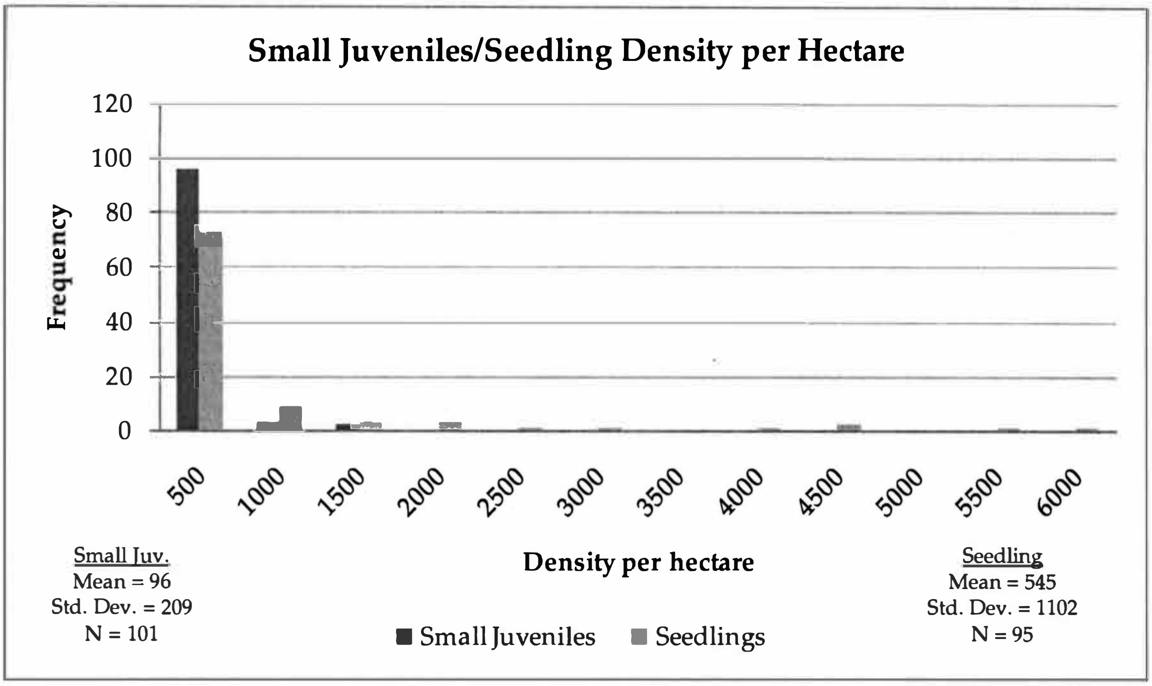

Figure 12. Histogram of small juvenile/seedling density per hectare

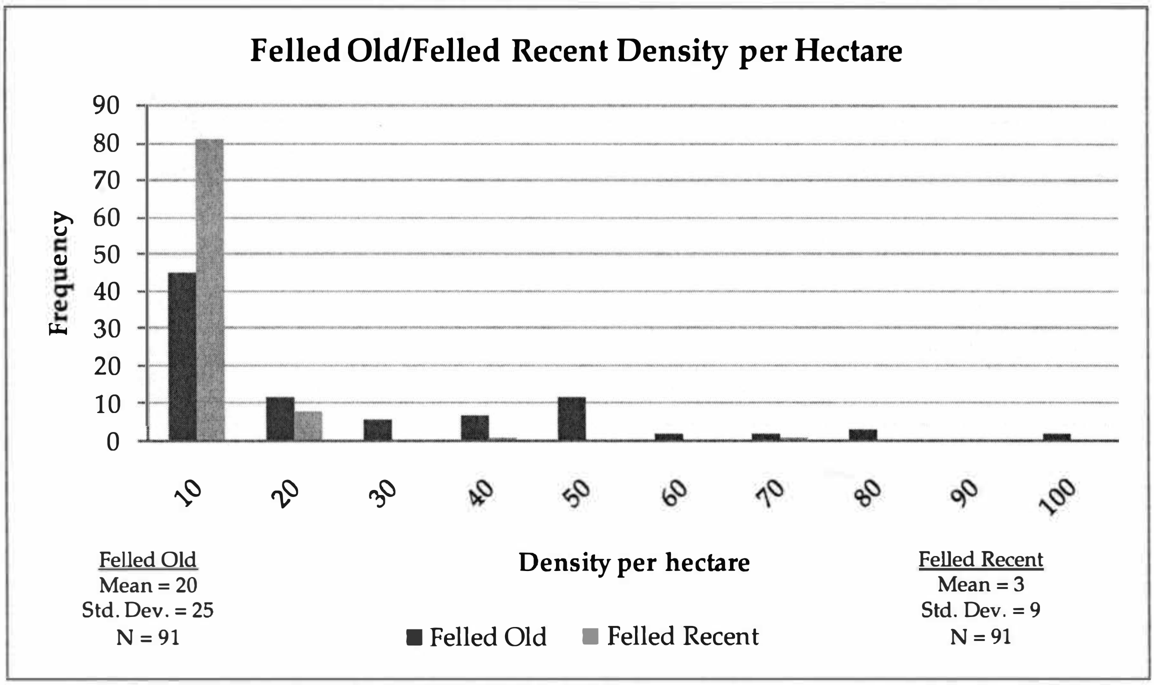

Figure 13. Histogram of felled old/felled recent density per hectare

The histogram of male and female density show that male palm density is higher than that of female density in the aguajales surveyed, especially in the density of 50 palms per ha and higher (Fig 10). Over half of the plots contained a female density less than 20 palms per hectare and female density greatly trails off after 60 palms per hectare. Female density overall is very low; the mean was only 22 palms per hectare, while the mean for male density was 70 palms per hectare, well below the total density found by other researchers; 138 mature palms per hectare (Peters et al. 1989) and 167 mature palms per hectare (Kahn and de Granville 1992). This is a 0.33 ratio of female to male density, whereas intact swamps have a ratio closer to 1.

The majority of the plots contained a density of trunked and large juveniles less than 75 palms per hectare and no plots contained trunked juvenile density over 200 palms per hectare (Fig 11). The majority of the plots contained 500 or less palms per hectare of small juveniles and seedlings with while plots contained a higher density of seedlings causing the mean to be higher than small juveniles (Fig 12). The results among the immature palms; trunked juveniles, large and small juveniles and seedlings indicated that the mean density per hectare increased as the size decreased. The means are 30 trunked juveniles per hectare, 69 large juveniles per hectare, 96 small juveniles per hectare and 545 seedlings per hectare (Fig 11 & 12). Most of the plots contained 50 or less trunked juveniles per hectare, while the majority of plots contained 500 or less seedlings per hectare, although individual plots had a density of up to 6000 seedlings per hectare.

Upon viewing the histogram of old and recent felled female trees (Fig 13), it is apparent that fewer trees have been cut within the last five years. Only 13 of the 91 plots surveyed contained recently felled females and the mean was less than 3 per hectare. Many more plots contained a higher number of trees that were cut longer than five years ago and at higher densities. The mean was around 20 per hectare.

The variation of the sample sizes amongst the population variables is due to tough conditions under which the data was collected. Intense heat, insects (many types of mosquitoes and sweat bees), and difficult footing were just some of the many features that the rainforest offered during data compilation.

Analysis Methods

Correlations and Regression

To detect the statistical significance of the relationships between the eight population variables, a significant correlation test was performed on all population variables. The variables that were significantly related to each other are shown in Table 3. Not all variables had significant correlations with each other and even the ones that did were not very strong (r values around 0.300 or 0.400). Male population density and female population density are significantly correlated with each other. Female population density is significantly correlated only with male density, but males are also with trunked juveniles.

Table 3. Significant correlation values between all population characteristics

Variable	n	Correlated Variable	*r* -value
Males	101	Females	0.434**
		Trunked Juveniles	0.219*
Trunked Juveniles	101	Large Juveniles	0.472**
		Small Juveniles	0.429**
		Seedlings	0.335**
		Felled Old	0.377**
Large Juveniles	92	Small Juveniles	0.618**
		Seedlings	0.463**
		Felled Old	0.383**
Small Juveniles	101	Seedlings	0.447**
		Felled Old	0.362**
Seedlings	95	Felled Recent	0.203*

** 0.01 significant level
* 0.05 significant level

Trunked juveniles are related to large and small juveniles, seedlings and old felled females (Table 3). The strongest correlation between variables were between large and small juveniles (r = 0.618). Large juveniles are also related to seedlings (r = 0.463). Large juveniles and trunked juveniles are correlated with old felled females with similar strength (r = 0.383, r = 0.377, respectively). Small juveniles are related to seedlings, and also to old felled females. Each of the three immature palms (trunked, large and small juveniles) are all significantly related to seedlings. Recent felled females were only found to be significant to seedlings.

A model was constructed to predict damage (measured as ratio between female and male density) using the variables seedlings, recently felled females and travel time divided between time spent canoeing to reach the aguajal and time spent walking within the aguajal. Out of the eight variables tested these were the ones that had significant correlations with damage. Approximately 34 percent ($p = 0.048$) of the total variance of damage in each plot can be explained by these four variables (Table 4).

Table 4. Standardized coefficients of variables used in the regression model

Population Variable	**Standardized Coefficients ($p = 0.048$, $R^2 = 0.341$)**
Seedlings	0.373
Felled Recent	-0.189
Canoe	0.224
Walking	0.371

The regression indicated that seedlings are the greatest predictor for damage. Lower seedling counts indicated a lower ratio of female to male aguaje, meaning more damage. Very close behind seedlings is the amount of time spent walking. The less time spent walking meant a lower ratio or more damage. Canoe time also impacted the level of damage along with recent felled females. The more females recently cut meant a higher level of damage or lower ratio.

In a regression model, the independent and dependent variables are not assumed to be normally distributed although the residuals are required to be. To test the assumption that the residuals are normally distributed, a histogram of the residuals is graphed to illustrate their distribution. For the model created in this research, the residuals are reasonably normally distributed (Fig. 14).

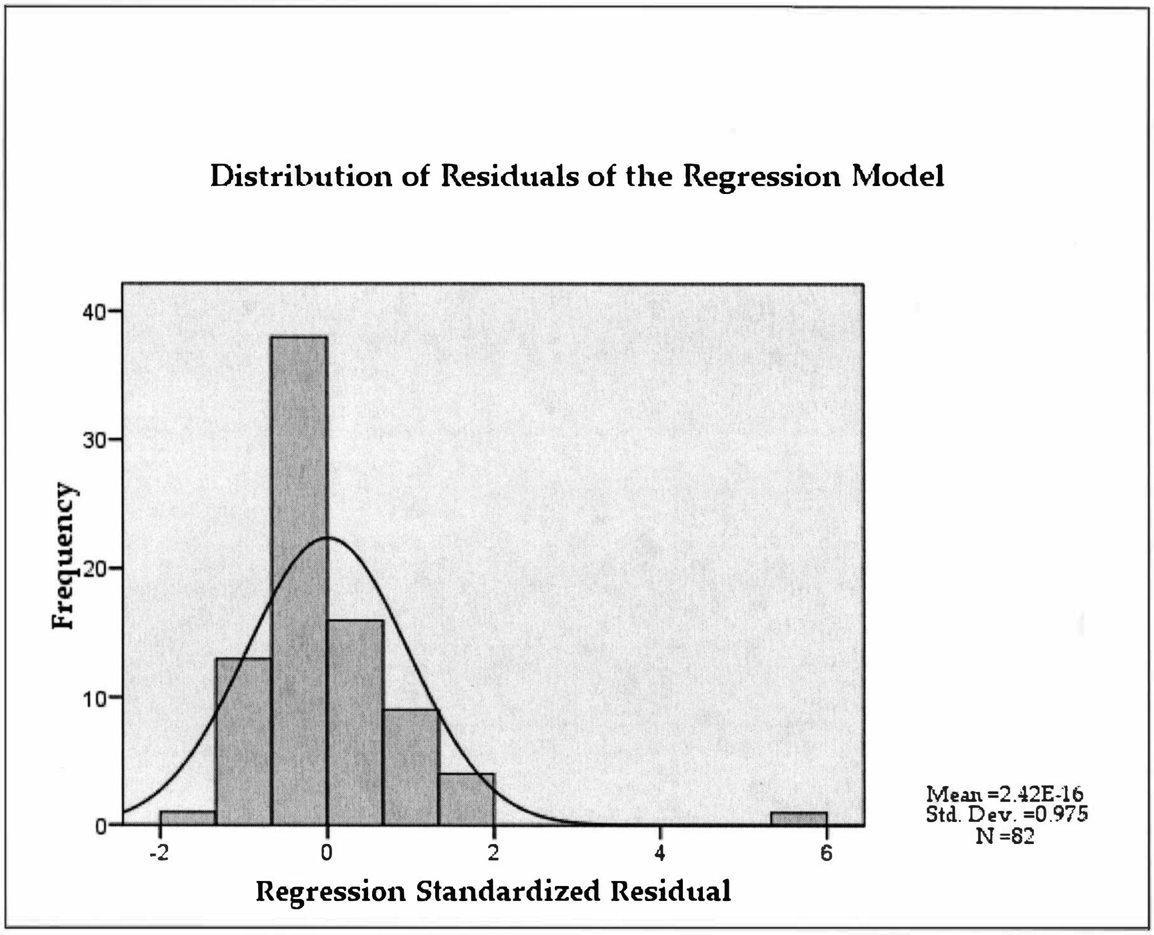

Figure 14. Histogram of residuals of the regression model

The model is not accurate at predicting damage with large numbers of seedlings indicated by the high outlier not found under the curve.

As mentioned in previous chapters, the female/male ratio of each of the 24 aguajales were analyzed against proximity from the nearest village to test if there is a negative relationship ($r = -1$) between Euclidean distance (measured in meters between aguajal boundary and nearest village) and the level of damage as stated in the literature. The results indicated that there is no significant linear relationship between distance and female/male ratio ($r = 0.258$) (Fig 15).

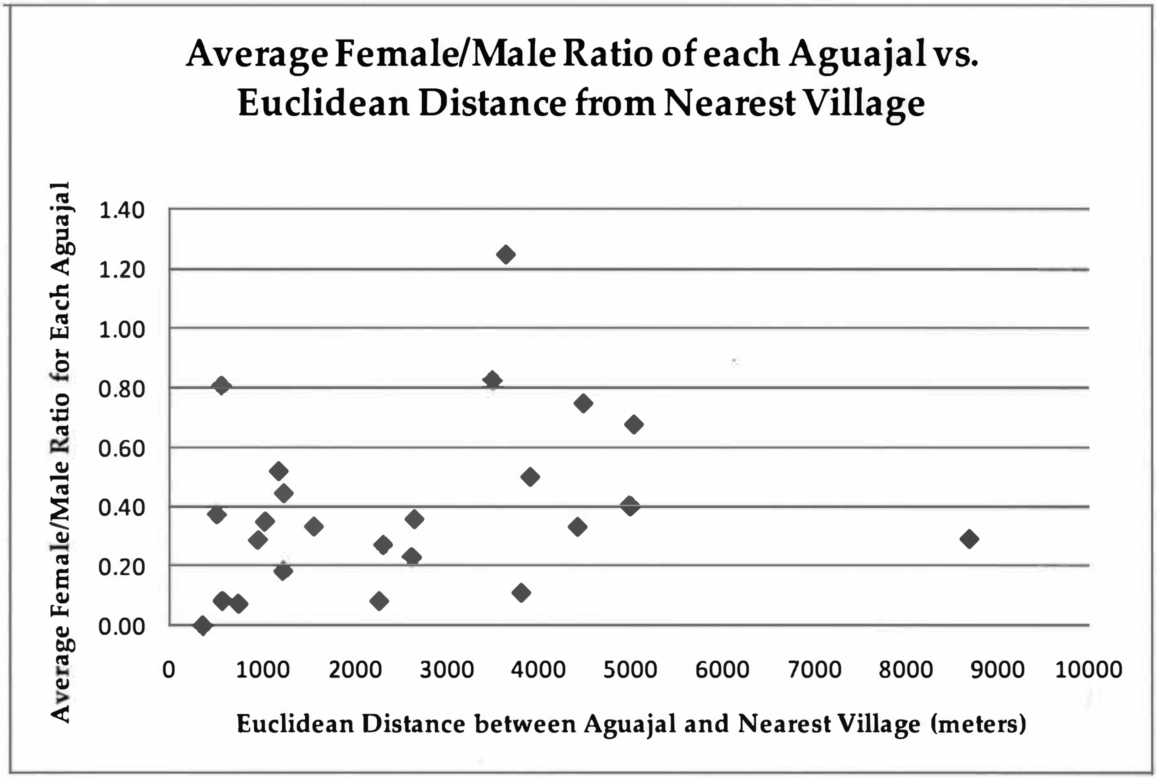

Figure 15. Scatterplot showing average female/male ratio of each aguajal vs. Euclidean distance from nearest village

As the scatterplot illustrates there is no obvious linear relationship between distance and ratio and the few outliers affect the results. Although one aguajal is located over 8000 meters from the nearest village, its ratio was less than 0.40, while one that is located within 500 meters of a village had a ratio about 0.80. These results support the statement that distance does not determine damage.

Female/male ratio was also analyzed against total travel time (measured to nearest ¼ of an hour) to each plot from the extracting village and damage. The results indicated that there is significance between total travel time (canoe and walking time combined) and female/male ratio, although the linear relationship is not very strong ($r = 0.312$, p=0.01) (Fig 16).

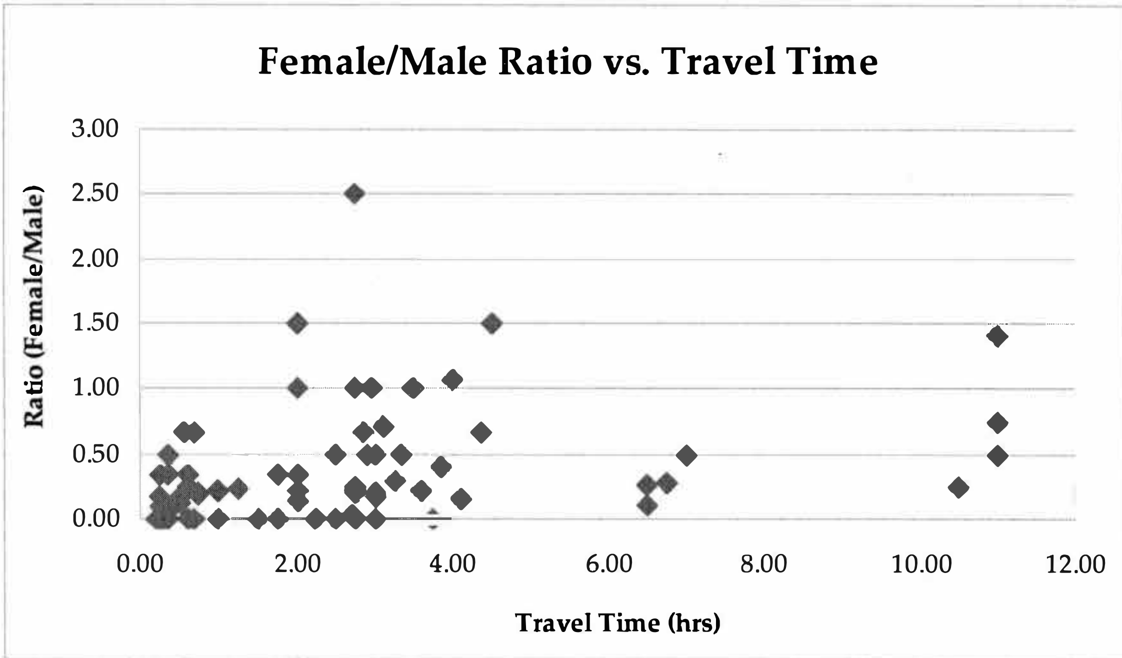

Figure 16. Scatterplot showing relationship between damage and travel time

The scatterplot does illustrate that plots taken in aguajales in close proximity to villages do have low ratios. In fact, none of the plots within two hours from a village had a ratio near 1. Higher ratios were at a distance between two to four hours from the extracting village.

As indicated by the regression model (Table 4) and the scatterplot of damage versus travel time (Fig 15), travel time alone only accounts for only a portion of damage inflicted on the aguajal. Other variables are needed to help explain or predict level of damage and when these other variables are added into the equation (seedlings, recently felled) a linear relationship is much more evident (Fig 17).

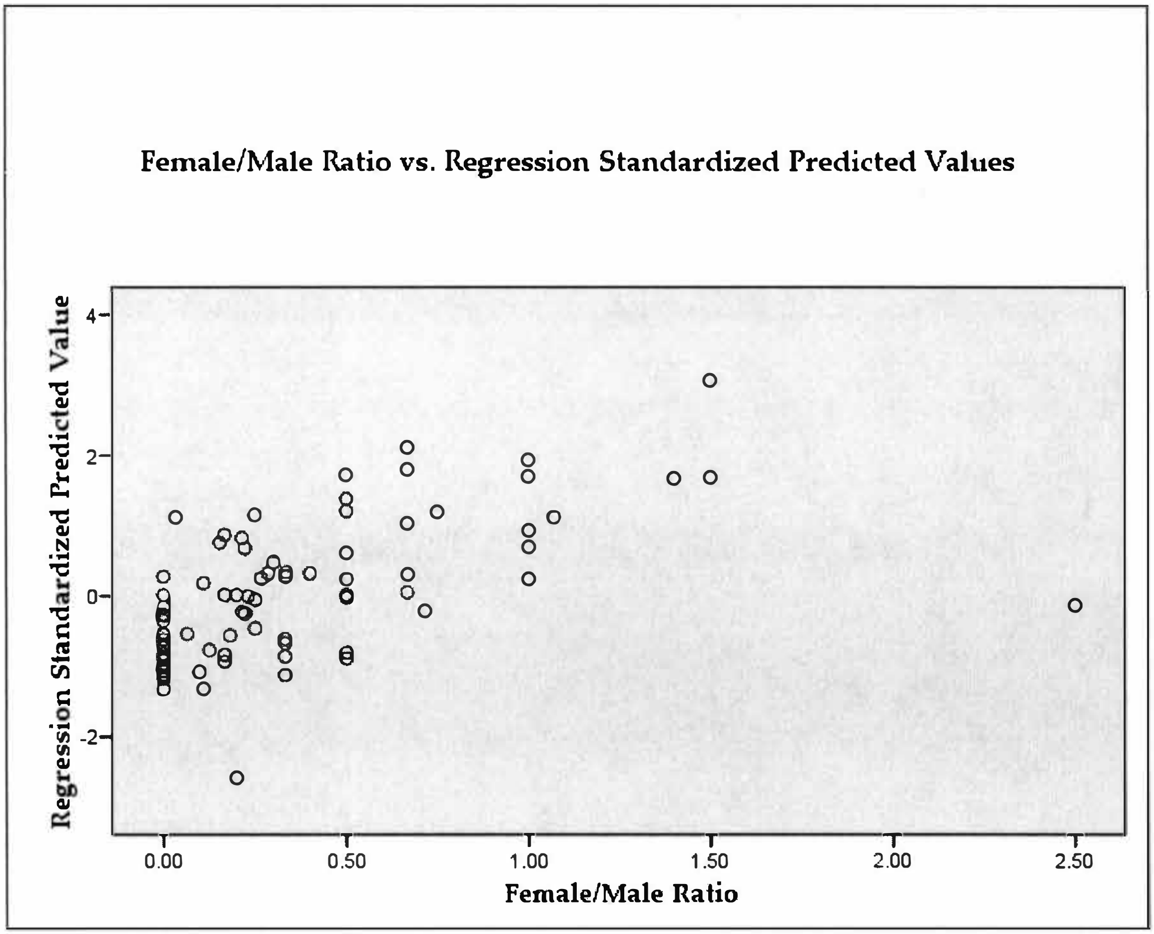

Figure 17. Scatterplot showing ratio vs. the regression predicted values

T-Test Analysis Results

A t-test was also performed on plots that were inventoried at the entrance to the aguajal, the area nearest a useable trail, and plots that were taken at the farthest end of the aguajal, well away from the entrance point, to determine if there are any statistical differences between the female/male ratio. Only the seven floodplain aguajales were used for this comparison because of the size necessary for such an analysis. The result of the t-test showed that there are no statistical differences between ratios of plots taken close to the entrance and ones that were more difficult to access (Table 5). While the means were substantially different, the standard deviation (27.973) of the far plots was quite large accounting for lack of statistical difference between the ratios. The mean of the ratio of the far plots was more than double of the mean of the near plots (Table 5).

Table 5. T-test result of female/male ratio of near and far plots in floodplain aguajales

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	F (ha) near	.2929	7	.23471	.08871
	F (ha) Far	.6257	7	.40033	.15131

		N	Correlation	Sig.
Pair 1	F (ha) near & F (ha) Far	7	.568	.183

Because most inventoried plots contained evidence of extraction, and current literature describes a high level of extraction in the study area, a plot was needed as a control where accessibility was limited and extraction was not a factor in the test for differences. Female/male ratios of each of the 24 aguajales were compared against the female/male ratios of the control plots. The ratio of the control plots were averaged together to derive one value at 0.72, which was compared against the female/male ratios calculated for each of the 24 aguajales (Table 6).

Only two of the 24 aguajales had a female/male ratio higher than the control plots, Tapaje (0.75) and Colmenayo (1.29) (Table 6). Colmenayo actually possessed a higher female density than male (Table 6).

The female density within the floodplain aguajales was very low compared to male density. Most of the ratios are well below the control plot ratio, even well below half. Topal-Lindero had a ratio close to the control plots. Even Tapaje that had a greater ratio than the control plots, overall had low densities of both male and female (84 total mature palms). Charo has high density of males and also contains the highest area.

The ratios for transition aguajales indicated low female density. The ratios are all below the control plot, while female density was even lower than floodplain female density. Not one of the four transition aguajales met or had higher ratios than the control. The individual areas of the aguajales tend to decrease slightly from the floodplain.

Female/male ratios within the upland aguajales did experience more extreme ranges (0.00 - 1.29). Station 1 contained no females while Colmenayo had a higher density of females than males, and was the only upland aguajal to have a higher ratio than the control. It also contained the highest area of the upland landform. Upland aguajales tend to be the smallest in size and are considerably smaller than transition and floodplain.

Table 6. Comparison of female/male ratio in all aguajales versus female/male ratio of control plots

Aguajal	Avg. Females per ha	Avg. Males per ha	Ratio F/M	Area (ha)
	Floodplain			
Charo	65	167	0.40	903.40
Cacaojal	33	101	0.33	15.35
Tapaje	36	48	0.75	131.28
Albergue	24	75	0.32	31.99
Traves	15	44	0.34	75.88
Burropoza	24	102	0.24	7.99
Topal-Lindero	46	69	0.67	76.65
	Transition			
Esperanza	12	62	0.19	36.68
San Pedro	16	38	0.42	3.69
Despensa de Palmichal	12	86	0.14	23.94
Adolfo-Nixon	24	65	0.37	4.38
	Upland			
Don Jorge #1	16	64	0.25	0.24
Don Jorge #2	48	72	0.67	0.62
Palmichal #1	27	85	0.32	3.01
Palmichal #2	16	96	0.17	0.91
Banda de San Pedro	19	79	0.24	0.38
Colmenayo	36	28	1.29	5.65
Rogelio Pinedo #2	5	43	0.12	1.03
Rogelio Pinedo #1	12	35	0.34	1.03
Station 1	0	10	0.00	0.59
Tiny Aguajal	4	31	0.13	1.15
Diamante Azul	4	99	0.04	2.64
Reynaldo #2	23	40	0.58	1.20
Reynaldo #1	16	24	0.67	0.33

ANOVA Results

Ratio of female/male palms were calculated for each plot and then averaged together for each of the three landforms and then compared against the control plot ratio (0.72) with an ANOVA test. Table 7 displays basic information about the female/male ratio of all three landforms and the control plot. Table 8 shows the ANOVA result that there are no statistical differences between the landforms and the control plot ($p = 0.303$). The ANOVA result indicated that there are no statistical differences between the three landform ratios and the control plot ratio. Table 9 shows the significance output between each of the landforms and the control plot and provides further evidence that there is no statistical difference as indicated by the high significance values.

Table 7. ANOVA descriptives for female/male ratio of all landforms against the control plot

	N	Mean	Std. Deviation	Std. Error
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1	39	.4399	.34913	.05591
2	24	.4419	.60214	.12291
3	38	.3021	.37007	.06003
4	2	.7222	.07857	.05556
Total	103	.3950	.42838	.04221

1 = floodplain, 2 = transition, 3 = upland, 4 = control plots

Table 8. ANOVA output for female/male ratio of all landforms against the control plot

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.673	3	.224	1.231	.303
Within Groups	18.045	99	.182		
Total	18.718	102			

Table 9. Post-hoc Tukey results for ratios of all landforms and control plot

Dependent Variable: Ratio
Tukey HSD

(I) Landform	(J) Landform	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-.00195	.11076	1.000	-.2914	.2875
	3	.13776	.09731	.493	-.1165	.3921
	4	-.28232	.30953	.798	-1.0912	.5265
2	1	.00195	.11076	1.000	-.2875	.2914
	3	.13972	.11132	.594	-.1512	.4306
	4	-.28037	.31421	.809	-1.1015	.5407
3	1	-.13776	.09731	.493	-.3921	.1165
	2	-.13972	.11132	.594	-.4306	.1512
	4	-.42009	.30973	.530	-1.2295	.3893
4	1	.28232	.30953	.798	-.5265	1.0912
	2	.28037	.31421	.809	-.5407	1.1015
	3	.42009	.30973	.530	-.3893	1.2295

1 = floodplain, 2 = transition, 3 = upland, 4 = control plots

Male and female densities were calculated for each landform and then statistical compared against each other. Table 10 displays basic information about male and female density of all three landforms. The floodplain aguajales contain nearly twice the density of females than the other two landforms (Table 10). Female density between transition and upland were about the same. Both male and female density per hectare decreases with each landform type.

The results of the ANOVA test between the male/female density in each landform class shows that there is no significant difference between the three landforms and male density ($p = 0.185$) (Table 11). There is significant difference among female density and all three landforms ($p = 0.005$). Table 12 shows the significance output between each of the landforms and male and female density and provides further evidence of the statistical difference. The results show there is variance in the means between floodplain and both transition and upland, but not between transition and upland (Table 12).

Table 10. ANOVA descriptives for male and female density of all landforms

		N	Mean	Std. Deviation	Std. Error
M/Ha	1	39	82.19	67.141	10.751
	2	24	66.94	49.099	10.022
	3	38	58.35	49.831	8.084
	Total	101	69.60	57.426	5.714
F/Ha	1	39	32.27	32.985	5.282
	2	24	15.77	17.374	3.547
	3	38	15.27	16.479	2.673
	Total	101	21.95	25.515	2.539

1 = floodplain, 2 = transition, 3 = upland

Table 11. ANOVA output for male and female density of all landforms

		Sum of Squares	df	Mean Square	F	Sig.
M/Ha	Between Groups	11154.317	2	5577.158	1.715	.185
	Within Groups	318624.2	98	3251.268		
	Total	329778.6	100			
F/Ha	Between Groups	6767.770	2	3383.885	5.685	.005
	Within Groups	58334.289	98	595.248		
	Total	65102.059	100			

Table 12. Post-hoc Tukey results for densities of all landforms and control plot

Dependent Variable	(I) Landform	(J) Landform	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
M/Ha	1.00	2.00	15.245	14.793	.559	-19.96	50.45
		3.00	23.833	12.997	.164	-7.10	54.76
	2.00	1.00	-15.245	14.793	.559	-50.45	19.96
		3.00	8.588	14.867	.832	-26.79	43.97
	3.00	1.00	-23.833	12.997	.164	-54.76	7.10
		2.00	-8.588	14.867	.832	-43.97	26.79
F/Ha	1.00	2.00	16.499*	6.330	.028	1.44	31.56
		3.00	17.004*	5.561	.008	3.77	30.24
	2.00	1.00	-16.499*	6.330	.028	-31.56	-1.44
		3.00	.505	6.361	.997	-14.63	15.64
	3.00	1.00	-17.004*	5.561	.008	-30.24	-3.77
		2.00	-.505	6.361	.997	-15.64	14.63

*. The mean difference is significant at the .05 level.

1 = floodplain, 2 = transition, 3 = upland

The averages of seedlings, large juveniles, small juveniles and trunked juveniles for each of the three landforms are displayed in Figure 18. Of the three landforms, upland aguajales contained the most seedlings at close to 2500 seedlings per hectare while floodplains contained the lowest at over 1500 seedlings per hectare. Large juveniles were about the same for transition and upland aguajales (477 large juveniles per hectare and 461 large juveniles per hectare, respectively) and were about double the amount for floodplain (242 large juveniles per hectare). Transition aguajales contained the most small juveniles and trunked juveniles (312 small juveniles per hectare and 165 trunked juveniles per hectare). Floodplain aguajales contained the least amount of small juveniles at 172 per hectare while upland aguajales contained the least amount of trunked juveniles (106 per hectare).

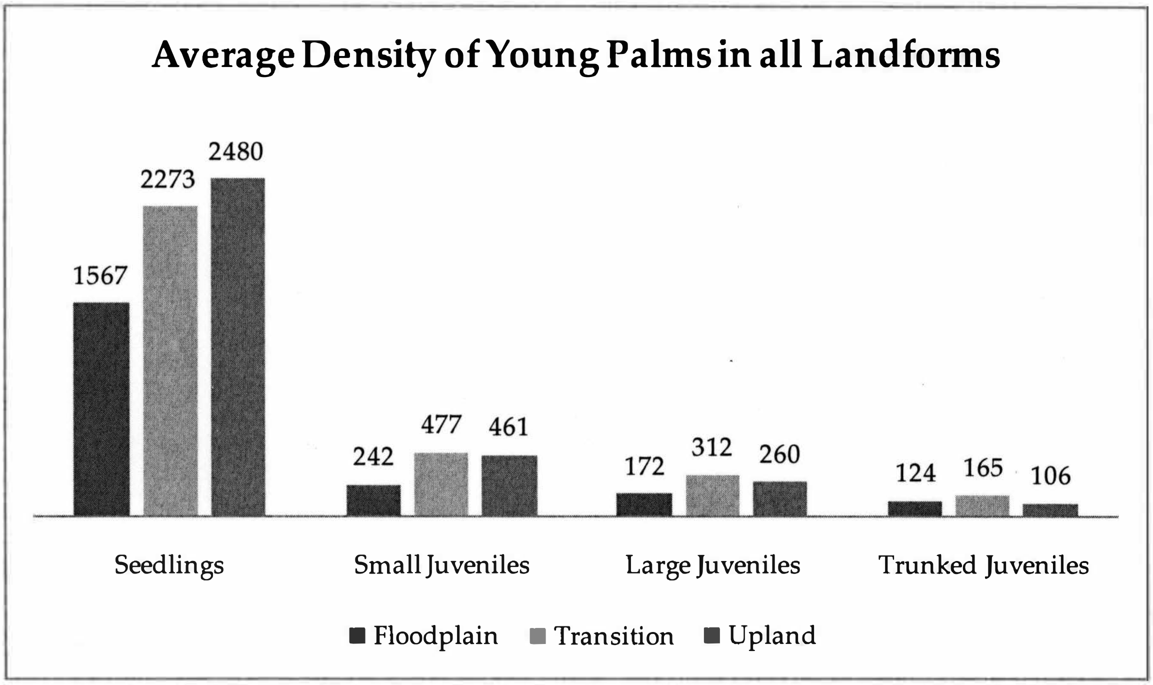

Figure 18. Average density of young palms in all landforms

CHAPTER 5

DISCUSSION AND CONCLUSION

The results of Chapter Four are discussed in this chapter. Limitations of the study are also discussed and suggestions are made for future research directions.

It seems intuitive that the further one is away from a village, the less damage and the higher the female/male ratio. The expected result was a positive linear relationship between distance and ratio. The 10 km radius of the study area was designed because of the article written by Bodmer (1994) stating that within 10 km of Chino, most swamps were heavily damaged and one would have to travel outside a 25 km radius to find intact swamps. He also stated that there was a negative relationship between proximity to the village and degree of damage. The results have shown that most of the swamps within the 10 km radius are indeed heavily damaged. Of the 24 aguajales surveyed within the study period, only two (Tapaje and Colmenayo), had the same or higher female/male ratio than the control plots. This study has proven that distance alone cannot determine the degree of damage. Accessibility is a key factor in determining level of damage. Although, Bodmer (1994) is essentially correct that distance can be a predictor of damage, in this case it is only true once you get out of the 10 km circle.

The data gathered illustrates and reinforces the pattern that these aguajales have indeed experienced high extraction in the past. The old felled female (Fig 13) data shows that more than five years ago, extraction was higher (mean = 20) than within the last five years (mean = 3). This is a positive sign that not as many female trees are being harvested as in the past. This seems to indicate that extraction has slowed down within the last five years. Although, this most likely means that good quality fruit is now reduced in the region so there is less available for extraction.

Correlations and Regression

Surprisingly, female population numbers were not correlated with trunked juveniles, large or small juveniles or seedlings. Because females are responsible for generating seeds that eventually will grow into adults, it would be expected that these values would be associated. Since the results of female density of the 24 aguajales surveyed indicate heavy extraction, this low density could explain the lack of correlation. When extracting fruit from the forest, the palm with the highest amount of ripe fruit would be chosen first to cut and harvest, providing the most monetary value. These palms could possibly have been higher quality aguaje and with each extraction, the most productive females are harvested. This reduces the productivity of the aguajal each year. The female palms that were cut and harvested could have been the parent palm to the existing young palms thus explaining the lack of correlation between female and young palms.

The fact that seedlings, small and large juveniles will eventually become trunked juveniles helps explain that these would be related to each other. It takes some time for seedlings to grow into small juveniles, then large juveniles and finally produce a trunk. Since it takes longer than five years for a fruit to germinate and eventually form a trunk, it also makes sense that trunked juveniles would be related to old felled females since they were harvested more than five years ago, so the trunked juveniles could have been seedlings or germinating fruit when the female was cut.

Because the strongest correlation was between large and small juveniles this shows that there is a good chance that a small juvenile will become a large juvenile. Since small juveniles are related to seedlings, there is a good probability seedlings will mature into small juveniles.

Seeds can stay dormant for a number of years before they start to sprout and become a seedling. This helps explain why seedlings are correlated with recently felled females, because the mature female was cut within the last five years.

For the regression model, it is not surprising to see that canoe time and time spent walking in the aguajal would affect the level of damage. Aguajales close to villages and plots near access points had higher levels of damage than aguajales further away and plots that were not as easily accessible. It also makes sense that lower numbers of seedlings would indicate higher damage because there would be less regeneration occurring within the aguajal. Also if higher numbers of females have been recently cut this affects the level of damage negatively. Obviously, there are other variables involved that also help explain ratio that were not assessed in this research. One of these variables is accessibility.

T-Tests and ANOVA

In this type of environment, accessibility, not distance, is a key variable which determines ratio and ultimately the degree of damage. The t-test conducted to test accessibility surprisingly indicated there were no statistical differences between female/male ratios of plots taken at the entrance to an aguajal and ones there were taken in more inaccessible areas. The high standard deviation of the inaccessible plots accounted for the lack of statistical difference. The low sample size ($n = 7$) could also explain the lack of difference. If a higher sample size could be obtained, the results would most likely be different and hopefully support differences between locations of plots.

Access of aguajales is strongly determined by water levels. During the study period, water levels were low and with each passing day became even lower. This low water level made traveling to aguajales difficult. The floodplain aguajales were difficult to access because there was not as much water in the rivers needed to reach the aguajales. Although transition and especially upland aguajales are more accessible because they are not within the floodplain, the low water levels made traveling along a main river, Quebrada Blanco, difficult. The low water exposed many fallen logs which made navigating and movement challenging.

Landform Features Impacting Accessibility

Floodplain Aguajales

Floodplain aguajales are the most difficult to access because 1) low water conditions make access by canoe difficult; 2) great distances must be traveled by foot and 3) standing water in the agualajes makes walking difficult. The problem that arises in floodplains is that during high water they are easier to access by canoe, but then the aguaje is green and of lower quality. Once the flood waters have receded during peak season of the fruit in June-July, the walking time is increased because canoes cannot get near the aguajal. The effort involved in harvesting the fruit therefore increases. People do not want to walk far to get to an aguajal because that means they have to carry the fairly heavy sacks of fruit a considerable distance.

During the study period, Tapaje was reached part by motorboat and part by canoe. It was tough proceeding in areas because the water level was low, making it difficult to move by boat. In the spring it is much easier to access because of higher water levels, but then the aguaje is green. This could account for Tapaje having a higher density than the other aguajales. Access protects the aguajal from high extraction. Even when the port of Tapaje was reached, it was still another two hour walk to the far end of the aguajal. Plot inventories taken at the far end had higher female density.

Charo (Fig 8, Table 6) had the largest area and the highest total mature palm density of all the aguajales. The people of the village of Charo extract from this aguajal. In recent years, floods have either not been high enough or have receded too early (June) and the aguaje was not ripe yet. People do cut most of the aguaje green here. Extraction of aguaje from Charo has reduced in the last few years, as fishing from the adjacent oxbow lake, Charo Cocha, has become the mainstay of economic means for the villagers. The remoteness of Charo also explains the higher density. The village is not located on the Tahuayo River but is located miles inward on the shores of Charo Cocha. To extract aguaje would mean not only travel to obtain the aguaje, but then travel to transport the aguaje out to the Tahuayo River for sale and transportation to Iquitos. This is too much effort expended for small results. Fishing in this area provides more guaranteed money with less effort and more food for families. Salted fish will earn up to 40 soles per metal tray. As waters recede, people have the choice between the last of the aguaje and fishing. Fishing simply provides more money.

Transition Aguajales

Transition aguajales are located close to villages and to gardens (Fig 8) where the local people cultivate and grow crops of economic value. These are fairly easy to access, once they were reached by boat, because the trails leading to the aguajales, are well traveled. These aguajales had very low overall female density and have experienced heavy extraction. Esperanza paralleled a trail between the villages of Esperanza and Canaan, so this aguajal is being extracted from both ends. With the ease of the trail, there is not much effort needed to extract aguaje and transport to the village for sale. Despensa de Palmichal and Adolfo-Nixon were located near each other and to a garden used by the inhabitants of the neighboring village of San Pedro. The trail to these aguajales was well traveled making access easy. Once in the gardens, the aguaje is easy to extract and carry back out on the way back to the canoe. San Pedro aguajal is located near the village of San Pedro so traveling to this aguajal is not very difficult.

Upland Aguajales

Upland aguajales are the smallest in size and the most damaged. They are also located near each other since they are so small in area and in close proximity to villages (Fig. 9). Water depths are more consistent in these aguajales, making accessibility the same during high and low water. Many of these aguajales had evidence they are used for hunting grounds as there were hunting platforms located within them. Since it has been documented that mammals feed on aguaje (Bodmer 1990, Bodmer et al. 1997) and meat catches a fairly decent price in Iquitos' markets, hunting on these grounds seems logical.

Low water levels during the study period made travel from Chino to the upland aguajales near Diamante Azul on the Quebrada Blanco difficult. The river lost more and more water each day, exposing the fallen trees on the bottom of the river which greatly impeded progression.

Having a high ratio, Colmenayo is another aguajal where access requires effort. It is a two hour walk from the village of San Pedro, covering very hilly terrain. Because it is located out of the floodplain, with no access or ability to shorten the travel time by canoe, this aguajal is protected from extraction. In the past, a research assistant harvested aguaje here because of the high quality of fruit, but no one in the village currently wants to make the effort needed to extract and carry the fruit so far.

The upland aguajales that contained extremely low densities of females (Station 1, Tiny Aguajal, and Diamante Azul and Rogelio Pinedo #2) (Fig 9, Table 6) were very close to the village of Diamante Azul, in fact they were all within a 20 minute walk from the village on very well traveled paths. It would not take much effort to walk down the path, extract aguaje and carry the sacks back to the village. This could account for the low densities within this area.

Some upland aguajales are protected by the people in the village against extraction (Rogelio Pinedo #1) because known mammals come to the aguajales to feed on the fallen fruit, so females are preserved to attract game. There is more money in game meat than aguaje fruit.

Transition and upland aguajales are both smaller in size and have less density of females than floodplain which means any extraction lowers the number of reproducing females even more.

People use to travel long distances and work very hard to extract aguaje for money. People currently living in villages today are elderly because the young people have moved away to the city of Iquitos. The population dynamics of the study area has changed. There are actually less people than in years past. People remaining in the villages are not as willing to work as hard for the payouts of aguaje, but find other resources that will earn more money, including hunting, fishing and growing cash crops.

Although the average ratio of all the plots inventoried within the aguajales was low, there were some plots that contained high densities of females. This means that there is still aguaje left to extract, though greatly reduced in quantity and accessibility.

Aguaje palms prefer the floodplain environment over dryer conditions so this accounts for the higher density of male and females in the floodplain landform. Although literature has documented the high densities and high production of the floodplain environment, the ANOVA test did not indicate any significance between the male densities among the three landforms (Table 12). The plot inventories did indicate higher overall male density within the floodplain than the other two landforms. Female densities, on the other hand, were shown to be significantly different amongst the landforms. Transition and upland were significantly different than the floodplain environment, but not different between them. Whether this difference is because of ecological differences or an indication of the level of extraction transition and upland have sustained is not clear.

Conservation Efforts

There are other alternatives to cutting female aguaje such as the climber. The climber has been effective in parts of the Pacaya-Samiria National Reserve, where many families harvest the fruit without having to cut down the female palms. Although it is considered a sustainable method because the palm is not cut down and can produce fruit for years, it does take away the regeneration power of the species because the fruit is taken out of the forest and cannot produce next years' seedlings. This device is more effective in areas where female density is higher because there is a greater chance for fruit from some females to fall and germinate.

In the ACRCTT, the climber, at this time, would not be beneficial, since the data has shown the extremely low density of females. Any fruit that these females produce probably needs to stay in the forest to assist regeneration. Very low male/female density indicates that extraction has already done damage to these aguajales and will continue to be a problem. With low numbers of productive females, the base for regeneration is being depleted. The remaining females are not producing as high a quality of fruit as their ancestors and these fruits often seemed small in size.

Although the reserve (ACRCTT) was set up in 1991 to protect wildlife and keep out commercial logging and fishing companies, without much government involvement, laws that had been set for the reserve were unclear and so police were reluctant to enforce them. Because of the increasing pressures and unsustainable practices conducted in the forest that exploit and deplete the natural resources, new laws and stronger administration have been established. The Programa de Conservación, Gestión y Uso Sostenible de la Diversidad Biológica de la Región Loreto (PROCREL), is one of these newly created administrative bodies designed by the province of Loreto to support and uphold the laws surrounding reserves, promote sustainable development in communities, and maintain the ecological processes essential to the health of the Amazon ecosystems while improving the livelihoods of the rural residents (NCI 2008). This program was also created to improve management of protected areas for present and future generations.

Hopefully with this renewed effort to conserve biologically diverse areas, conservation efforts will continue and increase in the future. When this study was being conducted, PROCREL was aware of our presence in the area, and we met with them about the research that was being conducted and they were very interested in the results from the research. Results of this research along with a copy of this thesis will be given to PROCREL for use at their discretion. Before this study had been done, there was no quantitative data to work with on the wellbeing of the aguajales and to indicate how damaged and depleted the aguajales in this area are. Hopefully with the results of this research, PROCREL will support management efforts in this area to assist local residents with the sustainable management of aguaje and other non-timber resource products. PROCREL has selected the ACRCTT as a "pilot" program and model for future protected areas in northern Peru because of its success with the communal organization and dedication and commitment from the local people to preserving the fauna and flora and the reserve (RCF 2008).

Restoration could also be another answer in this area, not only for the aguajales but as a symbol to the local people on the importance of sustainable practices. For example, aguajal Adolfo Nixon (Fig 8) is a prime candidate for restoration primarily because it is isolated (out of sight from poachers), and located next to two aguaje gardens owned by friends who can lay claim to it and work on preserving the females and restoring the aguajal. It would be there for them to harvest from and protect quite easily, so the geographic qualities make it appropriate for restoration.

Conclusion

Limitations

Limitations of this study include time and daylight constraints. With the limited time in the study area (one month), it was necessary to reach as many aguajales as possible. Our main concern was to obtain a representative sample of aguajales from the three landforms. Since the study area was near the equator, daylight was 12 hours a day, with daylight only lasting until 6:00pm. Including the time that it took to reach the aguajales by boat and on foot, there was often, not much time to acquire perimeter points. Some larger aguajales required three days of data collection.

Future Research

Although this study was a great beginning effort to analyzing health of aguajales, continuing this study year after year by returning to the same aguajales would be beneficial. Annual data is important to understanding the complicated relationship between extraction and natural response. In addition, more remote aguajales could be surveyed to determine the damage to these aguajales and to discover if in fact there are no intact swamps within the reserve.

Since aguaje is widespread throughout the greater Amazonian basin, this study could also include other reserves including the Pacaya Samiria National Reserve to analyze the differences between the reserves in amounts of aguaje present and to evaluate management plans of the different reserves.

Gathering data on the exact number of sacks of aguaje that enters the markets of Iquitos and other towns would also be an addition to the research to investigate how much aguaje is being extracted from the region's forests. This would help determine the economic value of the species, which could influence policy-making in a positive way.

Future research designs could include ways to test the assumption that accessibility is the number one variable that determines damage. This would mean collecting data over a number of years, revisiting the same aguajales to conduct plot inventories. Water level data would also need to be measured every year to see how the changes in water level affect the ratios. Within the study area, the water levels have been down within the last five years. How would higher water levels affect damage and extraction?

Surveys could also be designed and conducted within the villages to determine exactly who is doing the extraction and how much aguaje they are actually carrying out of the forest and selling in the markets of Iquitos. Data on the plantations of aguaje, exactly who is growing them and measuring their success would also be a great addition. Tracking the success of "Proyecto Aguaje" would benefit both the forest and the local people.

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