FLORIDA INTERNATIONAL UNIVERSITY
Miami, Florida

DEMOGRAPHIC EFFECTS OF THATCH HARVEST AND IMPLICATIONS FOR SUSTAINABLE USE OF IRAPAI PALM (*LEPIDOCARYUM TENUE*, MART.), BY RIVERINE COMMUNITIES IN THE PERUVIAN AMAZON

A dissertation submitted in partial fulfillment of the
requirements for the degree of
DOCTOR OF PHILOSOPHY
in
BIOLOGY
by
L. Alíce Warren
2008

To: Dean Kenneth Furton
College of Arts and Sciences

This dissertation, written by L. Alíce Warren, and entitled Demographic Effects of Thatch Harvest and Implications for Sustainable Use of Irapai Palm (*Lepidocaryum tenue*, Mart.), by Riverine Communities in the Peruvian Amazon, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

Maureen Donnelly

Carol Horvitz

David Lee

William Vickers

Bradley C. Bennett, Major Professor

Date of Defense: September 26, 2008

The dissertation of L. Alíce Warren is approved.

Dean Kenneth Furton
College of Arts and Sciences

Dean George Walker
University Graduate School

Florida International University, 2008

ACKNOWLEDGMENTS

Completing a project as involved, at such a distance, and over a span of multiple years has made me acutely aware of the need for support; that one person cannot accomplish such an endeavor as an island. I would like to thank Drs. Kelsey R. Downum and Kember Mejia who were strategic in bringing about the international interagency agreement between FIU and IIAP that permitted this study to be completed. I would like to thank my Committee members including my major professor, Dr. Bradley Bennett, Dr. Maureen Donnelly, Dr. David Lee, Dr. Carol Horvitz (University of Miami, Department of Biology), and Dr. William Vickers for their assistance with this experience.

A successful graduate student benefits from the experience of and mentoring from great people. I am deeply appreciative of the assistance from and discussions with Drs. Suzanne Koptur, Paulette Johnson, Anthony Koop, Carol Horvitz, and Phil Stoddard who helped guide me through interpretive stages of data analysis, and Drs. Paulette Johnson and Phil Stoddard, again, who provided statistical, interpretive, and Matlab programming assistance. Anthony Koop, Paulette Johnson, and Tamara Ticktin provided valuable feedback on manuscript drafts.

I want to acknowledge the love and support of my family especially my mom, Carol Warren, dad, Earl Warren, and step-mom, Sylvia Warren, who provided abundant patience and understanding that allowed me to see this project to fruition. My friends and colleagues were invaluable: Richard Moyroud, for field assistance in 1997 and as a scientific sounding board, Eduardo Salcedo for field assistance with INRENA in Lima, and the friendship of Lori Whitacre and Kathy Neer. Keith Bradley provided field assistance in 1998 and 2000. Eduardo and Sophie Salcedo critiqued draft presentations.

I am greatly indebted for all of the assistance that I received in Peru, including Charlie Strader of Explorations, Inc., Pam Bucur and Peter Jenson of Explorama Tours, S.A., and the Civil Association for the Conservation of Nature in the Peruvian Amazon, (CONAPAC). CONAPAC and Explorama Tours allowed me to work in their ecotourism reserves, provided support, and assisted with transportation, lodging and food during fieldwork.

I especially would like to thank Sr. Agapito Rios Torrez (Gobiernador Tenete de Sucusari); Sr. Felice Cosentino Altamore, Regional President of COAMUNA (Coordinadora de Agencias, Municipales Dependencia: Rio Nanay) and former village mayor, Sr. Fidencio Zulta (Mishana), Sr. Carlos Acosta Gomez (Corporación Hotelera del Amazonas; Zungarococha Amazon Lodge), and the residents of Mishana; Sr. Juan N. Maldonado Romer for field and data collection assistance and facilitation (especially with vendors of irapai thatch tiles, called crisnejas, at Moronacoche as well as data collection in Nuevo Triumfo and Punga); the residents of Nueva Triumfo and Punga (part of the Reserva Communal Tamshiyacu-Tahuayo); Ing. Walter Solano, Dr. Hector Cisneros, and Sr. Carlos (for assistance with community meetings, plot set up and monthly monitoring) of CARE Peru.

The Peruvian Amazon Research Institute (I.I.A.P.) and the Institute's Director of Research and Palm Biologist, Dr. Kember Mejia, were extremely helpful in providing guidance, direction and all-around assistance. IIAP and Sr. Carlos Quiñones facilitated monitoring work at the IIAP Allpahuayo Biological Field Station, and Irene Castro, of IIAP - CIGAP, assisted with map creation. This project would not have been possible without the continuing logistic and field support of these groups throughout its duration.

The Amazon Herbarium (AMAZ) of the National University of the Peruvian Amazon facilitated access to their collection for consultation.

Field research, equipment, supplies, travel and logistics were supported by Mrs. Paula Sculley (Garden Club of Allegheny County, Sewickly PA), and in 1997 and 1998 by Paula and David Sculley. This work would not have been possible without financial support from the Tropical Research Biology Program of Florida International University. Research trips in 1998 and 2000 were partially funded through the Program’s Tropical Biology Field Expedition grant, and conducted with the understanding of and in cooperation with my employer, Miami-Dade County.

ABSTRACT OF THE DISSERTATION

DEMOGRAPHIC EFFECTS OF THATCH HARVEST AND IMPLICATIONS FOR SUSTAINABLE USE OF IRAPAI PALM (*LEPIDOCARYUM TENUE*, MART.), BY RIVERINE COMMUNITIES IN THE PERUVIAN AMAZON

by

L. Alíce Warren

Florida International University, 2008

Miami, Florida

Professor Bradley C. Bennett, Major Professor

Lepidocaryum tenue Mart. (Arecaceae) is a small, understory palm of terra firme forests of the western and central Amazon basin. Known as irapai, it is used for roof thatch by Amazonian peoples who collect its leaves from the wild and generate income from its fronds and articles fabricated from them. Increasing demand has caused local concern that populations are declining. Cultivation attempts have been unsuccessful. The purpose of this study was to investigate market conditions and quantify population dynamics and demographic responses of harvested and unharvested irapai growing near Iquitos, Peru.

Ethnobotanical research included participant surveys to determine movement of thatch tiles, called crisnejas, through Moronacocha Port. I also conducted a seed germination trial, and for four years studied five populations growing in communities with similar topography and soils but different land tenure and management strategies. Stage, survival, leaf production, and reproductive transitions were used to calculate ramet demographic rates and develop population projection matrices.

Weavers made an average of 20 - 30 crisnejas per day (90 – 130 leaves each), and earned US$0.09 to 0.70 each (US$1.80 to 21.00 per day). Average crisnejas per month sold per vendor was 2,955 with a profit range of US$0.05 to 0.32 per crisneja. Wholesalers worked with capital outlay from US$100 to 400, and an estimated ten to twenty vendors could be found at a given time. Consumers paid between US$0.23 to 1.20 per crisneja. Although differences in demographic rates by location existed, most were not significant enough to attribute to management.

After 60 months, mean seed germination rate was 19.5 % in all media (37.9% in peat). Seedling survival was less than two percent after twelve months. Annual palm mortality was three percent, and occurred disproportionately in small (<50 cm) palms. Small palms grew more in height. Unharvested palms grew less than harvested palms. Large palms (≥50 cm) produced more leaves, were more likely to reproduce, and collectors harvested them more frequently. Reproductive potentials (sexual and asexual) were low. Population growth rates were greater than or not significantly different from 1.0, indicating populations maintained or increased in size. Current levels of irapai harvest appear sustainable. DNA analysis of stems and recruits is recommended to understand population composition and stage-specific asexual fecundity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I.

NON-TIMBER FOREST PRODUCTS AND ISSUES OF SUSTAINABILITY

INTRODUCTION

Irapai (*Lepidocaryum tenue* Mart.) is a small, rhizomatous, understory palm endemic to terra firme tropical forests of the Amazon (Henderson 1995). Residents of riverine communities throughout the region use its fronds as roofing thatch. Irapai reaches a typical height of one to two meters. The palm has long thin petioles, with palmate fronds that are divided into four nearly equal linear segments. The leaf's thick waxy coating and its local abundance make irapai highly desirable for weaving crisnejas (thatch tiles), used as roofing materials for houses and boats (Mejia and Kahn 1996). Increased tourism-related construction has expanded the demand for irapai beyond traditional subsistence applications. Tourism-generated revenue in Peru grew from US $1,358,000 in 1994 to US $2,453,000 in 2001 (PINEI 2005). Irapai is not cultivated. Locals, known as ribereños, harvest irapai fronds from wild populations to supplement income from fishing, farming and harvesting other forest products (Acero Duarte 1979).

Inspired by Peters, et al. (1989), conservationists and resource managers began to consider the harvest of non-wood products such as irapai, as alternatives to more destructive uses of forests. The key to rational use of natural resources is the elusive concept of sustainability. While promising in theory, defining sustainability is difficult in part because it encompasses biological, cultural and economic components (*e.g.*, Myers 1995, Godoy and Bawa 1993, and Repetto 1987).

Defining Sustainability: Callicott and Mumford (1997:38) defined sustainable management as an "overall appropriate management strategy that benefits both ecological and human economic environments," although resource use levels to meet criteria for each may vary widely. While conceptually useful, the lack of defined spatial and temporal scales renders this definition untestable. Resource managers in the U.S. forestry and fisheries fields have focused on maximum sustainable yield of a single or a few resources (O'Hara 1998, Tivy and O'Hare 1982). However, these approaches do not address ecosystem sustainability. Moreover, the persistence of populations of a species in space and time is not the only relevant factor to the sustainability of a biological resource, nor is it a guarantee that the harvest of a species is sustainable. Indeed, demographic sustainability of a species may be dependent upon the maintenance of an entire ecosystem. The harvest of one species may affect another species that also utilizes the harvested product (*e.g.*, agoutis and palm fruit).

In forest communities sustainability is connected to resource productivity, harvest levels, yield maintenance, and population demographics and stability (Conway 1985). To be sustainable, the target population must survive human utilization. Economic sustainability of a resource activity is another aspect of the equation. To be economically sustainable, an individual must be able to recoup more than the cost of efforts expended to harvest, create, and transport a product to market.

In his discussion of international commerce, Paul Hawken (1993:5) describes the ideal promise of business as one that increases "the general well-being of humankind through service, a creative invention, and ethical philosophy". Taking this ideal to a species market level, the inference is that harvest of a biological product should consider long-term implications. Overharvest of a resource could reduce its population size to a point where collection is not economically feasible or demographically sustainable.

Economic sustainability then, includes economic or market productivity, harvesting levels, and resource population demographics. Specific relevant economic factors include distance to markets, transportation costs, product perishability, and value of the product which often fluctuates.

Culturally sustainable economic activities can be defined as those that are consistent with an ethnic group’s way of life. For example, they are connected to resource availability, population stability, and demographics; temporal and spatial relations, including product preparation requirements and distances to markets; and economic valuations (Bennett 2002). The very nature of commerce forces a conflict with a traditional economy. Market forces demand that a new structure develop within a culture to accommodate the additional economic factors of supply and demand.

Callicott and Mumford (1997:38) proposed the concept of ecological sustainability as “the maintenance, in the same place at the same time, of two interactive systems: the culturally selected human economic activities and ecosystem health.” Sustainability is an important characteristic to maintain a resource. Overharvest can cause local extirpation or global extinction. These concepts and the need for conservation often are interwoven in ethnobotanical research. They manifest themselves as goals of research including the investigation of ways “to strengthen the protection of natural areas and contribute to the well-being of local communities” (Martin 1995:3). The harvest of irapai should meet the above criteria for the economic, ecological, and cultural definitions of sustainability to be considered a sustainable product.

Non-Timber Forest Products: Extractive reserves have emerged from the sustainable harvest concept, although strictly speaking the two are separate entities, only crossing into common ground at this juncture. In my study, several communities harvested irapai palms that grew in an extractive reserve. According to Browder (1992), an extractive reserve is a social space where locals are able to collect non-timber forest products (NTFPs) for income (NTFP 2005). The Brazilian government defines extractive reserves as “forest areas inhabited by extractive populations granted long-term usufruct rights to forest resources which they collectively manage,” thus protecting the economic opportunities for select groups (Schwartzman 1989:151). The Brazilian definition fails to consider impacts on biodiversity and, therefore, does not meet all of the criteria herein considered to define sustainability. While extractive reserves may function sufficiently for other social purposes, the complex nature of the term sustainability means extractive reserves often fall short of realizing such goals. In an ideal world along with any other features, extractive reserves also would be places of sustainable harvest of biological materials. This is not necessarily the case, however, and from this, much controversy has developed regarding the topic. Extractive reserves, as such, do not necessarily have to be harvested sustainably because they are defined so many ways.

Ethnobotanical and economic botany studies have helped identify more than 30 Amazonian rainforest products, including rubber, Brazil nuts, chocolate, manioc, quinine and curare (*e.g.*, Bennett 1992, Clay 1989) that have international commercial value. These studies have also been responsible for identifying and encouraging the development of sustainable harvest and processing methods including the concepts of extractive reserves and agroforestry. Some level of resource utilization is sustainable because indigenous people have been doing so for thousands of years. Numerous researchers have advocated extractive reserves as a way to achieve sustainable development in the tropics and a potential alternative to deforestation (Bennett 1991 and 2002, Fearnside 1989, Gradwohl and Greenberg 1988, Myers 1995, Repetto 1987, Salafsky *et al.* 1993, Schwartzman 1989). In 1988 Brazil's government began considering extractive reserves as a legal form of land tenure (O'Hara 1998). Fearnside (1989:215) stated, "extractive reserves produce salable goods on a sustainable basis, using known harvesting techniques" proven over many generations. Gradwohl and Greenberg (1988:150) considered extractive reserves to be an "immediately economically competitive" forest use system that is "sustainable in the long run." Detailed studies that support these statements, however, are lacking and detailed economic analyses have a variety of methodological difficulties (Bennett 2002, Godoy and Bawa 1993, Kremen *et al.* 1994, Browder 1992). Population levels and movements of indigenous groups into new areas may have contributed to a sustainable use of a resource. Controversy today relates to whether sustainable use is possible at current population levels and cultural disintegration.

In their benchmark study, Peters *et al.* (1989) investigated the net revenue obtainable from NTFPs within a one-hectare tract of rainforest in the Peruvian Amazon. The premise behind the study was that until that time, financial appraisals of forest resources usually reported net revenue of forest tracts to be small, thus, encouraging logging and other types of forest conversion. The authors pointed to the lack of detailed accounting in these appraisals. They collected production and market data on the commercial tree species of a one-hectare forest plot located 30 kilometers southwest of Iquitos, Peru, on the Rio Nanay near the village of Mishana. Non-timber forest products included edible fruits and latex (representing 90% of the $6,820 net present value), and the authors considered the periodic selective harvest of marketable timber. Their survey did not, however, include medicinal plants, lianas or commercially important understory plants. Peters *et al.* (1989) demonstrated that tropical forests have a much higher potential economic value than previously assumed, and that timber financial benefits are low in comparison to NTFPs. The authors showed that the net present value of NTFPs could be greater than that of cattle ranching or timber production. While this study spurred much attention and generated high expectations, its findings in many cases were unrealistic.

Peters *et al.* (1989) acknowledged several limitations including the lack of replication and that their data came from a plot selected for its high diversity, not necessarily representative of the overall forest. Further, they noted that actual market benefits could be higher or lower than projected depending on closeness of market, temporal variations in market prices, intensity of collecting, and production levels (Peters *et al.* 1989). While results vary tremendously, this analysis could be accomplished by using a discounting model to determine the net present value (NPV) or the “full value of all future income in today’s dollars” (Grimes *et al.* 1994:408). Net present value is equal to V/r, or the net revenue each year (V) divided by a 5% inflation-free discount rate of the annuities (r) (Peters *et al.* 1989). This study is extremely important to conservationists working to protect tropical rainforests because it provides a benchmark of hard economic support for alternatives to deforestation. Analyses from Ecuador, including medicinal plants, small palms, and lianas showed similar results (Bennett 1991, Grimes *et al.* 1994).

Godoy *et al.* (1993), attempting to compare these results with other valuations, criticized the Peters *et al.* (1989) methods for being incompatible with the valuation techniques of other studies, and also for failing to include economic benefits from faunal extraction. Browder (1992:176) determined the study's findings to be unrealistic because they "only estimate the hypothetical maximum potential value" of a forest near urban markets and because the authors used "an unrealistically long planning horizon (50 years) and low discount rate (5%), which exaggerate probable returns." Other financial analyses have contra-indicated high financial returns from extractive reserves (*e.g.*, Anderson 1989, Lafluer 1989, and Schwartzman and Allegretti 1987).

There are other limitations to NTFPs as well, including those related to non-target resource damage from harvest and numerous difficulties with methodologies such as proper species identification as well as standardizing sample size and realized economic valuation (Bennett 2002). Browder (1992) discouraged advocating extractive reserves as a panacea, however, citing differences between theoretical concept and social reality. Browder suggests that "alternative non-extractive livelihood programs for individuals" are needed for biodiversity conservation to succeed, although he believes extractive reserves could be part of a larger solution (1992:180).

NTFPs function as income supplements that help many people rise above poverty level. These markets exist and persist, and they have become established as part of economic strategies of rural peoples. While there are valid criticisms of the Peters *et al.* (1989) study, its real significance is its attempt to change public policy by focusing the spotlight on the issue of alternatives to deforestation. Deforestation and conventional land use activities including farming, logging and subsequent grazing usually destroy forest (Browder 1992, Fearnside 1987), and local residents or communities earn minimal income. Finding commercially viable NTFPs such as nuts and fruits used in some flavors of Ben & Jerry's Ice Cream, is an appealing potential opportunity that could encourage alternative uses of forests, but here the market is mostly international versus locally consumed market products. Alternatives, such as extracting locally utilized NTFPs, however, provide and distribute more economic benefits locally.

Forest conservation efforts will be more successful when they become profitable, but this is only one leg of the table and extractive reserves are not the only way to protect forest resources. The Peters *et al.* (1989) study offered theoretical quantitative proof that the maximum value obtainable from an intact forest was more financially beneficial in theory than its removal or degradation. The authors had to choose arbitrary harvest amounts as those considered sustainable, however (*e.g.*, 75% take of a resource). As new ways to show resource benefits and more realistic data continues to be collected that documents the ecological services provided by natural systems (watershed protection, climate moderation, *etc.*), these studies too will influence conservation biology further justifying conservation and appropriate use of tropical forests. More realistically however, they may play an integral part within the mosaic of alternative forest uses, and provide at least some stopgap biodiversity protection measures as ethnobotanists and others continue to search for additional methods of sustainable development in Amazonia (Salafsky *et al.* 1993).

Study of Irapai: Although its use is well known, little is known about the biology of irapai or of the extent of its commercial thatch market. The potential for overharvest of this important subsistence product makes irapai an important topic of study. For this study, I considered three aspects of sustainability with respect to irapai: demographic, economic, and cultural. In any successful case, there should be no decrease in population growth or net productivity. There may be negative ecosystem effects, such as an increased number of trails created or amount of light reaching the forest floor, but I have excluded these. Harvest may decrease the resource standing stock, but not its rate of population growth. Until this relatively recent increase in demand, indigenous and mestizo peoples could gather sufficient quantities of fronds without the need to protect the palm when clearing fields or planting the palm in gardens and cultivated fields or chacras. Rural peoples obtain forest resources by planting, protection or collection (Bennett 1992). Cultivation of irapai does not take place currently as thatch is collected only from wild palms. Irapai is not considered endangered. It has few known pests, and in unharvested areas, it can be very abundant. These characteristics could make it a good candidate to be a complimentary extractive product with low maintenance requirements within intact forests, although seed germination rates are low and transplantation has not been successful. With little success growing irapai, the most likely source will continue to be natural forest areas.

I conducted field research between 1997 and 2000. Chapter two, formatted for submission to the journal, *Economic Botany*, describes ethnobotanical research on the movement of irapai thatch tiles to the Iquitos commercial market located at Moronacoche Port. I documented the size and specifics of this portion of the market through surveys. I also discuss the natural history of irapai to help understand population dynamics and demographic responses. Chapter three describes an irapai seed germination trial and subsequent seedling growth and survival. It is formatted for submission to *Palms, Journal of the International Palm Society*.

In chapter four I focus on the demographics of irapai populations in five communities near Iquitos, Peru. In addition to demographics, I document size class transitions as well as survival and reproductive probabilities, both sexual and asexual. My results provide an overall picture of irapai population growth patterns and demographic transitions. These findings can be used to further describe irapai's life history and potential growth and production scenarios for correlation with actual data. This chapter is formatted for submission to the journal, *Ecology*. Chapter five summarizes findings from the others and makes management recommendations.

Evaluating the economic potential for irapai near Iquitos, Peru, could lead to the development of a sustainable harvest, a precursor to a sustainable market, that not only provides an important subsistence resource, but also income and economic potential for ribereño communities who often are ignored by government agencies, politicians, and researchers. Economic systems that integrate Amazonian natural resource products and processes with sustainable harvest and management could lead to the preservation of both Amazonian ecosystems, their cultures (Bennett 1992), and resources that need protection whether via extractive reserves or other methods.

LITERATURE CITED

Acero Duarte, L. E. 1979. Principales Plantas Utiles de la Amazonia Colombiana – Estudio Elaborado por la Unidad Florestal del Proyecto Radargamétrico del Amazonas durante el Periodo Junio 1974 - Diciembre 1979. El Proyecto, Bogotá.

Anderson, A. B. 1989. Estrategias de Uso da Terra para Reserves Extrativistas da Amazonia. Para Desenvolvimento 25:30-37.

Bennett, B. C. 2002. Forest Products and Traditional Peoples: Economic, Biological, and Cultural Considerations. Natural Resources Forum 26(2002):293–301.

Bennett, B. C. 1992. Plants and People of the Amazonian rainforests: the Role of Ethnobotany in Sustainable Development. BioScience 42(8):599-607.

Bennett, B. C. 1991. Biological and Economic Studies to Support the Development of Extractive Reserves in Amazonian Ecuador. Report for the United States Agency for International Development. New York Botanical Garden, Bronx.

Browder, J. O. 1992. The Limits of Extractivism – Tropical Forest Strategies beyond Extractive Reserves. Bioscience 42(3):174-183.

Callicott, J. B. and K. Mumford. 1997. Ecological Sustainability as a Conservation Concept. Conservation Biology 11:32-40.

Clay, J. 1989. Building and Supplying International Markets for Non-Wood Tropical Forest Products. Paper presented at the Symposium Extractive Economies in Tropical Forests: A Course of Action. National Wildlife Federation, Washington, DC, 30 November – 1 December.

Conway, G. R. 1985. Agroecosystems Analysis. Agricultural Administration 20:31-55.

Fearnside, P. M. 1989. Extractive Reserves in Brazilian Amazonia. Bioscience 39:387-393.

Fearnside, P. M. 1987. Deforestation and International Economic Development Projects in Brazilian Amazonia. Conservation Biology 1:214-221.

Godoy, R., and K. Bawa. 1993. The Economic Value and Sustainable Harvest of Plants and Animals from the Tropical Forest: Assumptions, Hypotheses and Methods. Economic Botany 47(3):215-219.

Godoy, R., R. Lubowski, and A. Markandya. 1993. A Method for the Economic Valuation of Non-Timber Tropical Forest Products. Economic Botany 47:220-233.

Gradwohl, J. and R. Greenbert. 1988. Saving the Tropical Forests. Earthscan Pub., London.

Grimes, A., S. Loomis, P. Jahnige, M. Burnham, K. Onthank, R. Alarcon, W. Cuneca, C. Martinnez, D. Neill, M. Balick, B. Bennett, R. Mendelsohn. 1994. Valuing the Rain Forest: the Economic Value of Non-Timber Forest Products in Ecuador. Ambio 23:405-410.

Hawken, P. 1993. The Ecology of Commerce: a Declaration of Sustainability (first ed.). Harper Collins Publishing, New York, NY.

Henderson, A. 1995. The Palms of the Amazon. Oxford University Press, New York, NY 362p.

Kremen, C., A. Merenlender, and D. Murphy. 1994. Ecological Modeling: A Vital Need Integrated Conservation and Development Programs in the Tropics. Conservation Biology 8:388-397.

Lafluer, J. 1989. Alternative Economic Model for Elevating Forest Value in Amazonia. Paper presented at the Symposium on Extractive Economies in Tropical Forests: A Course of Action. National Wildlife Federation, Washington, DC, 30 November – 1 December.

Martin, G. J. 1995. Ethnobotany: A Methods Manual. Chapman and Hall, London. 268p.

Mejia, K. M. and F. Kahn. 1996. Biologia, Ecologia y Utilizacion del Irapai (*Lepidocaryum gracile* Martius). Folia Amazonica 8(1):IIAP19.

Myers, N. 1995. The World’s Forests: Need for a Policy Appraisal. Science 268:823-824.

Non-Timber Forest Products (NTFP) 2005. NTFP home page as accessed at http://www.ntfp.org/definition.html on 24 January 2005.

O’Hara, J. L. 1998. Monitoring Nontimber Forest Product Harvest for Ecological Sustainability: A Case Study of Huano (*Sabal mauritiiformis*) in the Rio Bravo Conservation and Management Area, Belize (Nontimber forest products in conservation strategies). Pages 195 – 208 (Chapter 13:III) in R. Primack, D. Bray, H. Galletti, I. Ponciano, eds., *Timber, Tourists, and Temples: Conservation and Development in the Maya Forest of Belize, Guatemala, and Mexico.* Island Press, Washington, DC.

Peru Instituto Nacional de Estadística e Informática (PINEI). 2005. Ingreso por Turismo (Millones de US dólares)(valor), Evolución: 1994 – 2001 as accessed at http://www.inei.gob.pe/web/aplicaciones/siemweb/aplic/analisis.asp on 12 January 2005.

Peters, C. M., A. Gentry, and R. Mendelsohn. 1989. Valuation of an Amazonian Rainforest. Nature 339:655-656.

Repetto, R. 1987. Creating Incentives for Sustainable Forest Development. Ambio 16:94-99.

Salafsky, N., B. Dugelby, and J. Terborgh. 1993. Can Extractive Reserves Save the Rain Forest? An Ecological and Socioeconomic Comparison of Non-timber Forest Product Extraction Systems in Peten, Guatemala, and West Kalimantan, Indonesia. Conservation Biology 7:39-52.

Schwartzman, S. 1989. Extractive Reserves: the Rubber Tappers' Strategy for Sustainable Use of the Amazon Rain Forest. Pages 150-165 in J.O. Browder, ed., *Fragile Lands of Latin America: Strategies for Sustainable Development.* Westview Press, Boulder, CO.

Schwartzman, S. and M. Allegretti. 1987. Extractive Production in the Amazon and the Rubber Tappers Movement. Environmental Defense Fund, Washington, DC.

Tivy, J. and G. O'Hare. 1982. Human Impact on the Ecosystem. Oliver and Boyd, Edinburgh, Scotland.

CHAPTER II.

IRAPAI (*LEPIDOCARYUM TENUE*) THATCH MARKETS IN IQUITOS, PERU

ABSTRACT

Lepidocaryum tenue Mart. (Arecaceae) is a small, understory palm of terra firme forests of the western and central Amazon basin. Known as irapai, it is used for roof thatch by Amazonian peoples who collect its fronds from the wild. Fronds and articles fabricated from the palm provide some income for local people. Demand from tourism-related construction and population growth in the Peruvian Amazon has led to increased harvest of fronds. Construction of indigenous style tourist facilities creates exceptionally large demand for irapai fronds. Biological, ecological, and economical aspects of sustainability of increased harvesting are unknown, but there is local concern that populations are declining.

Maintaining viable wild population levels begins with understanding the biology of the resource and economic needs of area residents. This study provides ethnobotanical data on irapai and its regional trade by local ribereños in the Iquitos region of Peru. Moronacoche market supports a small but thriving trade, and surveys yielded findings on irapai fronds harvested and sold. Weavers made an average of 20 - 30 thatched tiles or crisnejas per day (90 – 130 leaves each), and earned an average of US$0.09 to 0.70 each (US$1.80 to 21.00 per day). Average crisnejas per month sold per vendor was 2,955 with a profit range of US$0.05 to 0.32 per crisneja. Wholesalers worked with capital outlay from US$100 to 400, and an estimated ten to twenty individuals could be found engaged in opportunistic wholesale or retail market activities at a given time. Consumers paid

between US$0.23 to 1.20 each for quality crisnejas. Average profit made by a vendor was from US$0.05 to 0.50 on each crisneja sold.

INTRODUCTION

Arecaceae supplies multiple products for food, beverage, housing, clothing, medicines and economic revenue (Balick 1984, Cavalcante 1977, Henderson 1995, Kahn 1988, Tomlinson 1990). Palms are conspicuous and generally abundant throughout Amazonia (Kahn and de Granville 1992, Henderson 1995). Amazonian cultures have long utilized palms, and their knowledge has led to the development of commercially valuable products, including oil seeds, vegetable ivory, and palm heart (e.g., Balick 1984, 1986, 1987; Bennett 2002; Bodley and Benson 1979; Boom 1987; Borgtoft *et al.* 1990; Cavalcante 1977; Johnson 1987; Kahn 1988; Padoch 1988; Warren 1992). Palms also produce fruit that is consumed by birds, fish and mammals, all of which supply indigenous groups with protein.

Many researchers advocate the utilization of palm species as renewable natural resources (e.g., Besbes *et al.* 2004, Johnson 1987, Ratsirarson *et al.* 1996; see Appendix 1 on Amazonian ethnobotany). Irapai, *Lepidocaryum tenue* Mart., a dioecious, clonal, understory palm, is endemic to the better drained terra firme or seasonally inundated soils of rainforest communities within the west and central Amazon River basin (Henderson 1995). It is used for roof thatch by Amazonian peoples who collect its fronds from the wild. It also is used to make articles for the tourist trade (Kahn and de Granville 1992). Investigating the sustainability irapai leaf collection requires basic ecological and botanical knowledge of the palm. Human population growth in the Peruvian Amazon has increased the harvest of palm fronds throughout the region (INEI 2005). Detailed demographic studies, however, including the effects of frond harvest on the regenerative capabilities of irapai colonies or individual stems are lacking.

Overharvest threatens the livelihoods of many ribereños, or riverside dwelling individuals, as fronds and articles fabricated from the palm provide subsistence resources and commercialization income (Kahn and de Granville 1992, Pyhälä *et al.* 2006). According to Pyhälä *et al.* (2006), 100% of households studied in the National Reserve of Allpahuayo-Mishana used irapai for subsistence purposes, and for the 31% that collected and sold irapai, they obtained about 5% of their annual income from this palm. This paper describes the thatch market for *Lepidocaryum tenue* in Iquitos, Peru, and how this product moved through one Iquitos market, Moronacocha.

Iquitos – Amazonian Island in the Forest: Site Description and Ethnology

The Iquitos area, with a population of nearly 500,000 people, is situated on the banks of Amazon River in the northeast region of Peru (INEI 2005). It is the commercial and government center of the Peruvian Department of Loreto, which encompasses the majority of the country's Amazonian lowlands. The climate is humid tropical, classified as Af in the Köppen Climate Classification System (Critchfield 1983), with an average annual rainfall of 2900 mm and average temperature of 26°C (Weatherbase 2005).

Most items produced for sale within communities along the Amazon, the Ucayali, the lower Napo, and Marañón Rivers make their way by boat to the markets of Iquitos (Padoch 1988). Due to growing international travel and environmental interest, Iquitos has become a center for ecotourism. Less frequent guerrilla activity and government stability have improved Peru's reputation among travelers. The combination of increased population growth and ecotourism has increased construction of traditional style housing and placed additional demands on palm populations (Jensen 1994, Mejia 1997). In 2005, the most recently available, government statistics recorded 2,906 residential structures (10% of the total) with thatch roofs in the Iquitos district (INEI 2005). Thatch roofs made up a total of 56% of all structures in the department of Loreto. Roof thatch for both commercial tourism-related construction and community needs is collected from wild irapai populations located within a few days travel from Iquitos. Ribereños collect roofing materials for their houses from these same forests.

Moronacocha - Commercial Irapai Thatch Market

Moronacocha market is located along the Nanay River, ten minutes from the Iquitos Amazonian riverfront, and is the largest market place in Iquitos for construction materials including irapai crisnejas (Figure 2 – 1). Crisnejas are thatched roofing tiles approximately two and one half to three meters long, one meter wide, made of irapai fronds woven onto a rib. More than 97% of the irapai thatch sold commercially in Iquitos is sold through Moronacocha (Mejia 1997). This market receives deliveries of materials by both boat and truck, and vendors deliver crisnejas to work sites by boat, truck, motorcycle, and bicycle. Crisnejas are in demand because they do not radiate heat, are less expensive and lighter than metal roofing materials.

A significant amount of leaves extracted for commercial trade comes from forests bordering the Nanay, Napo and Amazon Rivers. Crisnejas arrive by vehicle from the south of Iquitos via the Iquitos – Nauta Highway, where much irapai is cut for commercial use (Mejia 1997), and are transported from the southwest via the black water Nanay River. Some of the most heavily harvested areas are near the village of Mishana on the Nanay River and south of Iquitos approximately 20 to 40 kilometers along the highway between Iquitos and Nauta. Traditionally, communities in this region develop along waterways, but the highway has opened large areas to new exploitation. It is currently the only overland way in and out of Iquitos. Otherwise, the city is accessible to the world only by air or river transport.

Pilings, poles for roof frameworks, planks for floor and wall construction and other timber and harvested wooden construction materials from at least 21 tree species also are sold through this market (Mejia 1997). Besides those of irapai, other types of thatch roof tiles found at the market included those of yarina (*Phytelephas macrocarpa*) and chambira (*Astrocaryum chambira*). A small quantity of irapai crisnejas arrives in Iquitos from the Rio Itaya to the southeast. Often these are sold through the Belen market in Iquitos, but sales here are much lower than those transacted through Moronacocha (Mejia 1997). Irapai crisnejas also are sold at times in the port of Puerto Almendras, located one and one-half hours from Iquitos on the Nanay River and the small port of Santa Clara.

Irapai thatch is collected from areas within several days' travel time from market. Although leaves are more resilient than wild-collected fruits, weaving into crisnejas must be done while leaves are fresh. The maximum distance of irapayales capable of sustaining commercial harvest from markets in Iquitos depends on transport availability and the distance between harvest and weaving locations which is often a full day's travel time. Weaving techniques vary, but each tile can have 90 to 150 overlapping leaves hand woven onto a rib, or paño, usually made from the stem of another palm (e.g., *Socratea* or *Wettinia* spp.). Tiles are dried for one to two weeks on average, although they may be transported and sold immediately or stored up to several months. While these tiles are bulky and area transportation is limited, this economic activity has become important enough for a regional market to develop.

In Iquitos, customers regularly purchase crisnejas for residential use in lots of 50 to 100. Customers purchase an average of 20 to 30 additional crisnejas beyond what is required for the job, and keep them for future repairs. Stored off the ground with proper air circulation, crisnejas can last at least one year. Roof builders typically install crisnejas in overlapping rows spaced 15 - 20 centimeters apart and secured with tamshi (*Heteropsis* spp.) or other lianas (Balick 1986). Properly installed, an irapai roof has an average lifespan of five to six years, longer than most other local palm materials (Kahn and Mejia 1991).

Ethnography

Most local people involved with the regional irapai thatch industry consider themselves ribereños or river dwellers. They are detribalized indigenous peoples generally living along watercourses of the primarily Spanish-speaking lowland Amazonian regions (Kahn and Mejia 1991). In addition to swidden agriculture, ribereños fish and collect numerous forest products that they sell, usually through a market system.

Species Description and Biology

Lepidocaryum species belong to the Lepidocaryeae tribe of the sub-family Calamoideae, which is characterized by fruits covered with overlapping scales (Henderson 1995). Aguaje (*Mauritia flexuosa,* Mart.), another member of the Lepidocaryeae, subfamily Calamoideae, also is economically important in the region (Uhl and Dransfield 1987). *Lepidocaryum* is a monotypic genus with three varieties (*L.*

tenue var. *tenue*, *L. tenue* var. *casiquiarense*, and *L. tenue* var. *gracile*), distinguished by leaf and inflorescence characteristics (Henderson 1995). *L. tenue* var. *tenue* occurs in the Peruvian Department of Loreto, and ranges from Colombia to Brazil (Henderson 1995).

Irapai is a thin, erect palm, on average three to 3.5 meters in height as an adult (Mejia and Kahn 1996). Maximum height, however, can range between 0.8 and six meters (Henderson 1995). Its leaf is reduplicately palmate with open sheaths, ranging from 15 to 80 cm long and has conspicuous petioles, 60 - 130 cm in length (*Ibid.*). A single stem can have eight to twenty palmate and erect or semi-erect leaves, typically with four nearly equal segments (Figure 2 – 2) (Mejia and Kahn 1996). Irapai's uniformly divided, segmented leaves and long, thin petioles are well suited for weaving together to create thatch roofing tiles (Henderson 1995), see Appendices 2 - 2 and 2 - 3. Rarely do irapai fronds exhibit signs of herbivory (Kahn and Mejia 1991). Peaks in fruiting occur in March or April during the rainy season and September or October in the dry season, although fruiting palms can be found over much longer periods (Henderson 1995, Mejia 1997).

Each axis produces creeping rhizomes from its base which are 0.5 to 1.0 cm in diameter extending outward along the soil surface or to five centimeters below it before producing another axis (Henderson 1995, Kahn and Mejia 1991, Mejia and Kahn 1996). Irapai sends out ramets up to two meters, which is unusual and distant compared to other palms such as *Euterpe oleracea* or *Oenocarpus mapora* whose clones form distinct clumps making them much easier to define (De Steven 1989). Clonal shoots have higher survivorship compared to seedlings, and this may be an additional benefit to clonal organisms as a kind of post-natal care of offspring (Callaghan 1984). A rhizomatous habit may mean irapai is suitable for extractivism or other types of ribereño agroforestry programs (Borgtoft Pederson and Balslev 1990, Kahn 1985, Kahn and Mejia 1987a, 1987b).

Abundance and Distribution of Irapayales

Irapai grows in dense stands called irapayales. Although it will grow in some seasonally inundated areas, the palm prefers the better-drained soils of terra firme forests that make up 88% of Peruvian Amazon lowland forests (Salo *et al.* 1986, Räsänen *et al.* 1993). *Lepidocaryum tenue* is more abundant on topographic rises (Kahn 1985, Kahn and Mejia 1987a, 1987b, Mejia and Kahn 1996, Vormisto et al. 2004). It is absent on the most fertile soils (Vormisto 2002).

Stem Densities and Leaf Production within Irapayales

Stem density has a direct impact on thatch supply. Mejia and Kahn (1996) extrapolated irapai stem densities in terra firme and riparian forests from surveys done in two plots of 0.2 hectares each near the village of Jenaro Herrera on the lower Ucayali River, about 200 km southwest of Iquitos. Estimated number of harvestable fronds per hectare ranged from around 4,000 to 40,000 although it is important to remember this palm does not grow in monocultures.

METHODS

Lepidocaryum Specimens and Herbaria

To conduct demographic studies described in chapter four, I established twenty-three 25m^2 plots in irapayales in five irapai harvesting locations outside of Iquitos. Sites were selected based on information from knowledgeable biologists and ecotourism entrepreneurs (Jenson 1994, Mejia 1997) (Table 2 – 1 and Figure 2 – 3). I obtained government permits and authorizations for each site. I collected voucher specimens at each of the five study sites where I established monitoring plots. These were deposited at the UNAP herbarium (Warren and Bradley 001101 through 001107 AMAZ) with duplicates at FTG, NYBG, and Instituto de Investigaciónes de Amazónia Peruana (IIAP; see Appendix 4).

Frond and Stem Abundance within Irapayales

Between 1997 and 2000, irapai stems were assessed and monitored within multiple plots situated in irapayales at each location. Among other variables, harvest of stems was monitored, and at all sites palms were marked discretely so that palms within plots would be considered equally for frond harvest by collectors. During discussions with locals at each site, all were encouraged to utilize irapai palms in and around monitoring plots as they would normally.

Thatch Market Components, Participation and Interviews

Market components include production (frond harvesters and weavers), transportation (middlemen, wholesalers and resellers), and consumption. Ethnobotanical data were collected by interviewing five Moronacoche market vendors connected with the commercial thatch market in Iquitos as well as observing of market activities. Four additional individuals in the ecotourism field who had placed orders for crisnejas for new or to re-roof existing lodges within the previous twelve months, were interviewed. Additional informal interviews were done in the field with collectors, weavers and transporters in each of the five communities where demographic study plots in irapayales were established.

Market participants were selected by observing and approaching individuals with crisnejas who arrived by boat or land at the Moronacocha market. The lead individual transporting crisnejas was asked if he was willing to participate, and only willing individuals were interviewed. Participants helped identify other crisneja vendors. This initial sample of market composition was done to determine current prices and wages for irapai thatch products in the Iquitos area, as well as to document market size (Padoch 1988). Each interview was conducted in Spanish, lasted approximately 30 minutes, and for each one I used a written questionnaire adapted to the product and location specifics of irapai and Iquitos (Appendix 2 – 5). I also tape-recorded each interview and had native Spanish-speakers verify participant understanding of questions and their responses.

Marketed Product: Irapai Crisnejas

From market participant interviews, I collected data on the amounts of leaves harvested from reported areas, and the efforts involved in preparing crisnejas. Often crewmembers of vehicles bringing crisnejas to Moronacocha had been involved in making the crisnejas, and provided first hand ethnobotanical data on this part of the irapai trade. Informants also answered questions about how crisnejas were woven, how many could be woven in a day, the various types of weave, as well as their preferences and reasons for using certain weave types. Two also demonstrated crisneja weaving techniques as did two additional individuals in the field during informal interviews with participants.

RESULTS

Frond and Stem Abundance in Irapayales

Stems per hectare ranged from 7,920 to 12,700, based on averages extrapolated from 25 m^2 demography plots (0.0025 ha) in chapter four, with a mean of four harvestable fronds per plant (31,680 to 50,800 leaves per ha) (Table 2 – 2). All plots except three of those in the Mishana Community Reserve were situated on terra firme soils. Each location had different land tenure and community use restrictions that may affect stem densities, distribution in forests, and frond availability. Findings from this study indicated a required irapayale range between 0.013 ha / m^2 and 0.021 ha / m^2 for a thatched roof. Stem harvest increased from five percent in 1997 to nearly 40% in 2000 (see Figure 2 – 4). These increases occurred despite the fact that two of the five sites were designated as protected areas and that government permits legally must be pulled to harvest. To date enforcement of the latter has been minimal.

Moronacocha Market - Irapai Thatch Trade Structure

Market data revealed monthly crisneja sales of 1,500 to 3,000 per vendor. Consumers and marketers of irapai crisnejas each varied between an estimated 100 and 500 individuals. Usually crisnejas were sold in lots of one hundred. It was possible to purchase smaller numbers of crisnejas for repairs and small roofing jobs, but lots of one hundred were the most typical sale size. They were marketed in the port of their arrival if they had not been pre-ordered by contract. After initial sale, crisnejas commonly were transported to a secondary location where they were resold to other retail or wholesale vendors. They also were resold at the initial location, and lots either remained intact or were sub-divided.

Irapai Crisnejas

Irapai crisnejas are woven onto paños which, according to informants, are derived from species of *Wettinia* (ponilla) or *Socratea* (casha pona). In Mishana, villagers primarily used ribs made from species of *Bactris* (chontilla palm). Table 2 - 3 defines the common types of woven patterns made by local weavers. The fronds form tightly fitting, attractive patterns including the most frequently found cadena (chain), camino de curuinza (ant's trail), pecho de lagarto (alligator breast) and pata de grillo, (cricket or grasshopper legs) (see Figures 2 – 5). The most commonly used attachment loop weave for an irapai petiole to a paño, referred to as 'normal', is three times around. Twice around, known by the name 'yare', is not as common. Other less common weave patterns reported by crisneja vendors are the pata de vaca (cow's foot), costilla de perdiz (deer's rib) and mojarrita (small, flat fish considered locally to be indicative of weave done by indigenous people). Crisnejas are secured on top of one another with tamshi (*Heteropsis* spp.) or other species of liana (Balick 1986). Crisneja width and placement determine overall roof thatch thickness. Typical installation of 15 – 20 cm spacing provides a one-third reveal, and in this case, a roof thatched with irapai crisnejas can be up to five layers thick.

Weavers made an average of 20 - 30 crisnejas per day, depending on weaver skill, availability of materials, and final product quality. At a value of US$0.09 to $0.70 each, this means a weaver can earn an average of US$1.80 to $21.00 for one day's work. There is a noticeable difference in thatch thickness between crisnejas woven for sale at Moronacocha and those obtained by contracted order. There are no specific grades for quality or thickness, but contract orders are of better quality. Weave of the commercial crisnejas is thinner, and typically they do not last as long. Once leaves are woven into place on the crisneja, the excess petioles sometimes are cut off and utilized as popsicle sticks as in Nuevo Triumfo, Tamshiyacu – Tahuayo Communal Reserve. While available in lengths from 2.5 to three meters, consumers generally prefer the longer crisnejas, considering these superior to other local thatch products. It is not uncommon that demand for crisnejas goes unmet on a given market day, although usually this is temporary and results from a lag in transportation. Arrangements for a special order to meet specific needs usually can be made without difficulty, either by transferring crisnejas from a storage location or fresh preparation.

Components of Crisneja Trade and Ecotourism

The web of individuals involved in the crisneja trade included leaf harvesters in irapayales outside of Iquitos, consumers and retailers in Iquitos markets and often a host of intermediaries (Figure 2 – 6). Contracts are an important part of leaf harvest and crisneja marketing. The web of connections linking irapayales to Iquitos crisnejas involved more than two dozen wholesalers located in Iquitos who maintain ties with exterior communities where irapayales are found. Contracts to supply a buyer with a specified number of crisnejas can be made with or without an advance of money to the extractor, depending on the business or reputation of the buyer and seller. Often the seller is a wholesaler or representative of a community or household who arranges the contracts with buyers and then contracts with extractors and weavers who live near irapayales to produce crisnejas. Depending on the size of the contract and the sizes of irapayales available to harvest, there may be more than one intermediary contractor or subcontractors involved and many subcontracted extractors and weavers. Contractors coordinated with the buyer, and at times the buyer's other contractors, to make sure crisnejas were produced on schedule, that their products were not being sold to others, and to arrange transportation for their delivery to the buyer. Delivery and transportation costs normally were included in the negotiated price for crisnejas. Table 2 – 4 shows documented retail and contract crisneja costs. Contractors told a buyer the crisnejas they had for sale came from a particular location, but unless familiar with a particular weaver's style for identification, buyers often had no way to confirm the origin of harvested thatch. Available documented origins of crisnejas contracted or sold retail through the existing market structure included areas northeast, south and southwest of Iquitos (Table 2 – 5).

Crisnejas made without a contracted buyer were available for purchase by wholesalers or retailers at Moronacocha or other docksides. Upon arrival by boat or vehicle, crisnejas were transferred to a seller's stall or storage location. The difficulty of river transfer depended on the level of the river and, based on this, the arrival location of the delivery boat. River levels fluctuate an average of eight to ten meters annually between wet and dry seasons. This means dramatic changes in the set up, arrangement and configuration of and access to ports, accordingly. Offloading can require a secondary, smaller vessel if the delivery boat is not able to dock close enough to the port. Although this did not happen all the time, the cost of delivery increased by a few soles when a secondary vessel or other arrangements were necessary. Some crisnejas brought to market without a contract were displayed in stacks dockside to indicate the seller had them available for sale. Some retailers purchased stacks of crisnejas and relocated them for resale to other retailers or in smaller quantities. Each of these sales represented another part of the trade and marketing web.

Market Vendor Interviews

All five vendors interviewed at Moronacocha market were male and between the ages of 43 and 60, and two had worked in the irapai market for more than five years. Three vendors hailed from the nearby village of Moronacocha, one from Apelán, and one from Saboya village on the Pintuyacu stream off the Nanay River. Three vendors had permanent stalls at Moronacocha market, one had a temporary stall here, and one vendor was ambulatory without any market stall (Table 2 – 6). Crisneja origins, numbers per month and cost data for Moronacocha market transactions, found in Table 2 – 5, depict from 1,000 to 6,000 crisnejas per vendor per month at an average purchase price of US$0.27. Average number of crisnejas per month sold by vendors was 2,955 with a profit range of US$0.05 to $0.32 per crisneja. All five vendors sold crisnejas through additional markets or via contracted orders. Four of the five vendors also sold crisnejas in the village of Moronacocha. One vendor sold crisnejas through a business warehouse space. Two vendors sold crisnejas at Moronacocha market every 15 days, two sold at this location every 20 days and one vendor sold here every 60 days. Four of the five vendors either purchased crisnejas from nearby village producers or had crisnejas made for them. Only one vendor also was involved with crisneja making directly.

One consumer purchased crisnejas for his family's home in Iquitos from Moronacocha in July 1997. One hundred crisnejas cost between S/60-70 (Nuevo Soles, n.s., or US$30 – 35). Each crisneja was US$0.30 – 0.35. In Iquitos, I interviewed three businessmen with ecotourism interests outside of Iquitos. One was in the process of constructing a new ecotourism lodge on Yanamono Island northeast of Iquitos, and paid US$423 (S/1,500 n.s.) for 1,000 crisnejas (US$0.42 each) to roof the new lodge. This price included transportation from Iquitos or other weaving sites. Crisneja deliveries and transport by boat and truck to Moronacocha are common along the Amazon River, and can be observed even during holiday seasons.

Vendors that were interviewed purchased crisnejas from weavers or communities at a price ranging between US$0.09 to $0.50 each for 2.5 m units and US$0.11 to $0.70 for three meter crisnejas (Table 2 – 7). Many times bundles of harvested leaves were more readily available for purchase from communities near irapayales rather than woven crisnejas (Suarez 2002), although all participants interviewed in this study purchased only irapai tiles. Vendors interviewed at the Moronacocha market sold retail crisnejas at prices of US$0.23 to $1.20 each for three meter size tiles, and US$0.14 to $0.80 each for 2.5 m tiles. Vendor cost variables were related to transportation prices or distance from harvest or weaving location. The longer the distance, the higher the transportation costs, and these were passed on to the consumer. Another variable affecting cost was crisneja quality. Better quality crisnejas were those consisting of 100 or more leaves each. These are expected to last six to seven years when properly installed, and provide better coverage for a structure, costing slightly more than crisnejas woven with only 80 to 99 leaves. The average number of crisnejas per trip brought to Moronacocha market by a vendor was between 250 and 500. With an estimated twelve vendors at a given time, the average number of crisnejas passing through this market per month was 3,000 to 6,000.

DISCUSSION

Ecology and Economic Links – Influences of Ecotourism

The market for irapai typically represents about five percent of an individual's or family's annual income. The trade links urban centers of Iquitos with rural forest communities where irapayales are harvested, and the commercial web includes the roles of harvesters, weavers, shippers, cargo handlers, wholesalers and retailers as important parts of the network. Production costs included harvest extraction and processing, which involved labor and time to locate, harvest, gather, carry, weave, load, and transport to market. Irapai frond harvest and sales fall under the purview of the Peruvian Ministry of Agriculture's Department of Forestry and Fauna, and officially harvesters are required to obtain a license and pre-pay fees, as is the case with other economically important forest products such as aguaje fruits (Paddoch 1988). Commercial regulations are not routinely enforced, however, and permits are not required to harvest irapai for personal use. Many people harvest irapai illegally. If demographic study plots in chapter four could be considered representative of areas around Iquitos where irapai is harvested, populations may tolerate up to a 70% increase of current harvest levels. Enforcement of regulations, however, could eliminate the independent participation of small rural extractors of commercial irapai thatch from the market. Bureaucratic complexities often strengthen control of a trade by large, urban-based sellers who obtain exploitation licenses for large areas (e.g., aguaje fruit market).

From irapayale to end consumer can be a short marketing chain of individuals, or crisnejas can pass through many individuals involved in commercialization, including harvesters, weavers, transporters, shippers, boatmen, cargo carriers, contractors, wholesalers, retailers, installers, and workers. With the exception of the consumer, each of these individuals, many of them rural, made part of his or her income from *L. tenue*. While the majority of market participants were male, rural women participated in the trade. As a source of employment for the population of Iquitos, irapai crisnejas provided a small but steady amount. Most wholesalers of irapai crisnejas worked with capital that ranged between US$100 to $400. At a given time, an estimated ten to twenty individuals fitting this description could be found engaged in opportunistic wholesale or retail market activities. Consumers paid between US$0.23 to $1.20 each for quality crisnejas. The average profit made by a vendor was from US$0.05 to $0.50 on each crisneja sold. Selling between 260 and 2600 2.5 m crisnejas, or 65 to 650 three meter units each week dependent upon amount of profit, a vendor could earn around US$130 in a month, more than the Peruvian statutory monthly minimum wage of US$128 (S/450 n.s.) (US State Department 2002). Some estimates place nearly half the Peruvian work force at or below minimum wage, because so many work in the informal sector, which is difficult to regulate (US Department of Labor 2005). While the potential for profit is good, there also was associated risk that went with the outlay of initial funds. A minimum of approximately US$50 capital outlay was needed for a participant to function in the trade. This risk was less than many other markets, however, where products have a much shorter shelf life such as forest fruit, agricultural products, fish or meat.

Commercial Importance

While income from crisnejas was important to rural communities, larger vendors were headquartered in Iquitos, and they received most large contracts and greater profits. The size of a contract dictated how many irapai fronds must be harvested and the timing of such harvests. Iquitos is the center of a consumer market for non-timber forest products (NTFPs). Irapai is a substantial component of the Iquitos urban marketplace because of its regional availability, recognition as a quality roofing material, and market accessibility to urban and rural participants (including women) combined with a relatively low start-up capital requirement to participate. The irapai-thatched roof is a standard element of a rustic Peruvian Amazonian community, and besides serving as quality roofing material, adds an aesthetically pleasing component to a structure or river vehicle. This has increased harvest and associated transportation costs and the price of all subsequent sales of crisnejas. While biological studies are conducted to understand the ecological needs of *L. tenue,* careful monitoring and use of non-predatory harvest techniques need to be implemented by all if the market is to continue its present form or expand as many participants would like. If irapai palms were to be depleted and this valuable thatch material became scarce, the impacts on participants and the crisneja market economy would be dramatic, forcing those involved to find other forest products to market or look for other business opportunities entirely.

The economic benefits of commercial harvesting to ribereño collectors is an attractive supplement for individuals, families and communities. Results of comparisons between house thatching studies (Lopez Parodi 1988, Kahn and Mejia 1987a and b, and Vormisto 2002) and related estimated hectares per square meter of roof indicate that more fronds are available in a smaller area on upland soils, meaning less time is expended by harvesters (Table 2 – 8). Based on findings from demographic plots, levels of thatch harvest were increasing to meet demand for thatch tiles. Methods to propagate irapai should be investigated and developed so that this useful palm and potential revenue generator may be incorporated into community resource management plans. Non-timber forest products may be one possible alternative to help human communities and conserve area biodiversity. Increased harvest of irapai is expected to continue with the region’s growing population and increasing ecotourism. Economic systems that integrate Amazonian natural resource products and processes with sustainable harvest and management, could lead the way to the preservation of both Amazonian ecosystems and their cultures (Bennett 1992).

TABLES

Table 2 - 1. Demographic Study Plots in Irapayales.

Sites:	Location:
1. Reserva de los Mai Huna (Mai Huna Reserve)	Sucusari Creek off Napo River, northeast of Iquitos
2. ExplorNapo Camp Biological Reserve	Sucusari Creek off Napo River, northeast of Iquitos
3. Mishana Community Reserve	Nanay River, southwest of Iquitos
4. Tamshiyacu-Tahuayo Communal Reserve	Tahuayo River southeast of Iquitos
5. Allpahuayo Biological Research Reserve (Instituto de Investigaciónes de Amazónia Peruana – IIAP)	Km 26, Iquitos – Nauta Highway

Table 2 - 2. Irapai Fronds and Stem Densities Available for Harvest in Irapayales.

Irapai Stem Densities and Average Number of Fronds Available for Harvest in Irapayales

Location:	Forest type:	Soils:	No. of stems found / hectare within irapayales:	Average no. of fronds available for harvest / hectare within irapayales (average 4 / stem):
Mai Huna Reserve	terra firme	upland	9,800	39,200
Explorama Preserve	terra firme	upland	7,920	31,680
Mishana Community Reserve	lowland	wetland soils	8,160	32,640
Tamshiyacu-Tahuayo Community Reserve	terra firme	loamy*	11,080	44,320
Allpahuayo Biological Station (Km 26, Iquitos – Nauta Highway)	terra firme	upland	12,700	50,800

*Suarez 2002, who also had study parcels at this location, determined that portions of this site were loamy soils (typic hapludalf, irapai series).

Table 2 - 3. Common Patterns Woven from Irapai Petioles on Crisnejas.

Common Weave Patterns of Irapai Crisnejas	
Spanish name:	English equivalent:
Cadena	Chain
Camino de Curuinza	Ant’s Trail
Costilla de Vaca / Perdiz	Cow’s / Perdiz’s (Quail-like bird) Rib
Pata de Grillo	Crickets’ or Grasshoppers’ legs
Pata de Perdiz / Vaca	Perdiz’s (Quail-like bird) / Cow’s foot
Pecho de Lagarto	Alligator Breast
Mojarrita	Little Mojarra (generic term for a small, flat fish); considered locally to be indicative of weave done by indigenous people; not a true weave, but a method of attachment.

Table 2 - 4. Crisneja Retail and Contract Costs.

Crisneja Retail and Contract Costs.					
Date:	Transaction type:	No. of crisnejas:	Cost (Peruvian Nuevo Soles):	Cost (US$)[1]:	Cost per crisneja (US$):
July 1997	Consumer 1: Personal purchase for family home at Moronacoche	100	60 - 70	30.00 – 35.00	0.30 - 0.35
December 1997	Consumer 3: Riverside delivery for community structure	1000	600 - 700	300.00 – 350.00	0.30 - 0.35
June 1998	Consumer 2: Ecotourism business purchase for lodge construction (Yanamono Island)	1000	1500 (includes transport costs)	423.00	0.42 (includes transport costs)
	Average Purchase Price from Weaver:			$251 – $269	$0.34 – 0.37
December 1997	Vendor 1: Colectivo transport boat from Mishana	1000	700 – 800	350.00 – 400.00	0.35 - 0.40
January 1998	Vendor 2: Fully loaded truck on Iquitos – Nauta Highway	500	300	150.00	0.30
January 1998	Vendors 3 – 12: Crisnejas stacked roadside at Moronacocha	100 - 200 each	70 – 200 each	35.00 – 100.00 each	0.35 - 0.50 each
	Average Sale Price from Vendor:			$178 – 217	$0.33 – 0.40

[1] LatinFocus. 2004. Historic Exchange Rates Peru 1997 – 2004: Banco Central de Reserva del Perú.

Table 2 – 5. Amounts and Origins of Crisnejas.

Sample Amounts and Origins of Crisnejas.

Date:	Consumer or Vendor and Transaction type:	No. of crisnejas:	Total Leaves (80 to 100 leaves per crisneja):	Crisneja Origin (direction from Iquitos):
July 1997	Consumer 1: Personal purchase for family home at Moronacoche	100	8,000 – 10,000	Unknown*
June 1998	Consumer 2: Ecotourism business purchase for lodge construction (Yanamono Island)	1000	80,000 – 100,000	Napo River (Northeast)
December 1997	Consumer 3: Riverside delivery for community structure	1000	80,000 – 100,000	Amazon River (Northeast)
	Average Number of Leaves Used:		29,333 – 70,000	
December 1997	Vendor 1: Colectivo transport boat from Mishana	1000	80,000 – 100,000	Southwest
January 1998	Vendor 2: Fully loaded truck on Iquitos – Nauta Highway	500	40,000 – 50,000	Nauta or Mishana (South)
January 1998	Vendors 3 – 12: Crisnejas stacked roadside at Moronacocha	100-200 each	8,000 – 200,000	Unknown*
	Average Number of Leaves Used:		42,666 – 116,667	

* Crisnejas available or purchased at Moronacocha market; vendor could not identify origin of crisnejas with certainty.

Table 2 - 6. Moronacocha Market Vendors.

Moronacocha Market Vendors Interviewed:					
Vendor:	How often sell at Moronacocha:	Type of stall at Moronacocha:	Other locations also vend:	Type of collector:	Also weave crisnejas:
1	Twice a month	Ambulatory	Moronacoche	Middleman	No
2	Every 20 days	Permanent	Warehouse	Direct market reseller	No
3	Every 60 days	Permanent	Moronacoche	Direct market reseller	No
4	Every 20 days	Permanent	Moronacoche	Direct market reseller	No
5	Every 15 days	Temporary	Moronacoche	Frond collector and weaver	Yes

Table 2 - 7. Crisneja Preparation and Sales Price Data from Vendors at Moronacocha market.

				Price vendor paid per crisneja (US$*):		Price vendor received for each crisneja (US$*):		Vendor Profit:	
Vendor:	Date	Origin of thatch:	No. of crisnejas per Month:	Range for 2.5m	Range for 3m	Range for 2.5m	Range for 3m	Range for 2.5m	Range for 3m
1	6-00	Santa Maria, Nanay River	2,000	0.09 0.30	0.14 0.50	0.14 0.50	0.23 0.80	0.05 – 0.20	0.09 – 0.30
2	6-00	Apetán, Punta Yasin	4,500	0.09 0.30	0.11 0.40	0.20 0.70	0.31 1.10	0.11 – 0.40	0.20 – 0.70
3	6-00	Saboya	1,000	0.11 0.40	0.17 0.60	0.23 0.80	0.34 1.20	0.12 – 0.40	0.40 – 0.60
4	6-00	Anguilla, Nanay River	1,275	0.09 0.30	0.14 0.50	0.20 0.70	0.25 0.90	0.11 – 0.40	0.11 – 0.40
5	6-00	Pinayunga, Pintuyacu River off Nanay River	6,000	0.14 0.50	0.20 0.70	0.21 0.75	0.28 1.00	0.07 – 0.25	0.08 – 0.30
		Totals (Range and Average):	2,955	0.09 – 0.50 0.20	0.11 – 0.70 0.35	0.14 – 0.80 0.44	0.23 – 1.20 0.64	0.05 – 0.40 0.21	0.08 – 0.70 0.32

*2000 exchange rate US$1 = n$3.55 source: Banco Central de Reserva del Perú 2005. (n$1 = US$0.28)

Table 2 - 8. Estimated Harvestable Irapai Stems and Hectares Needed for Roofing.

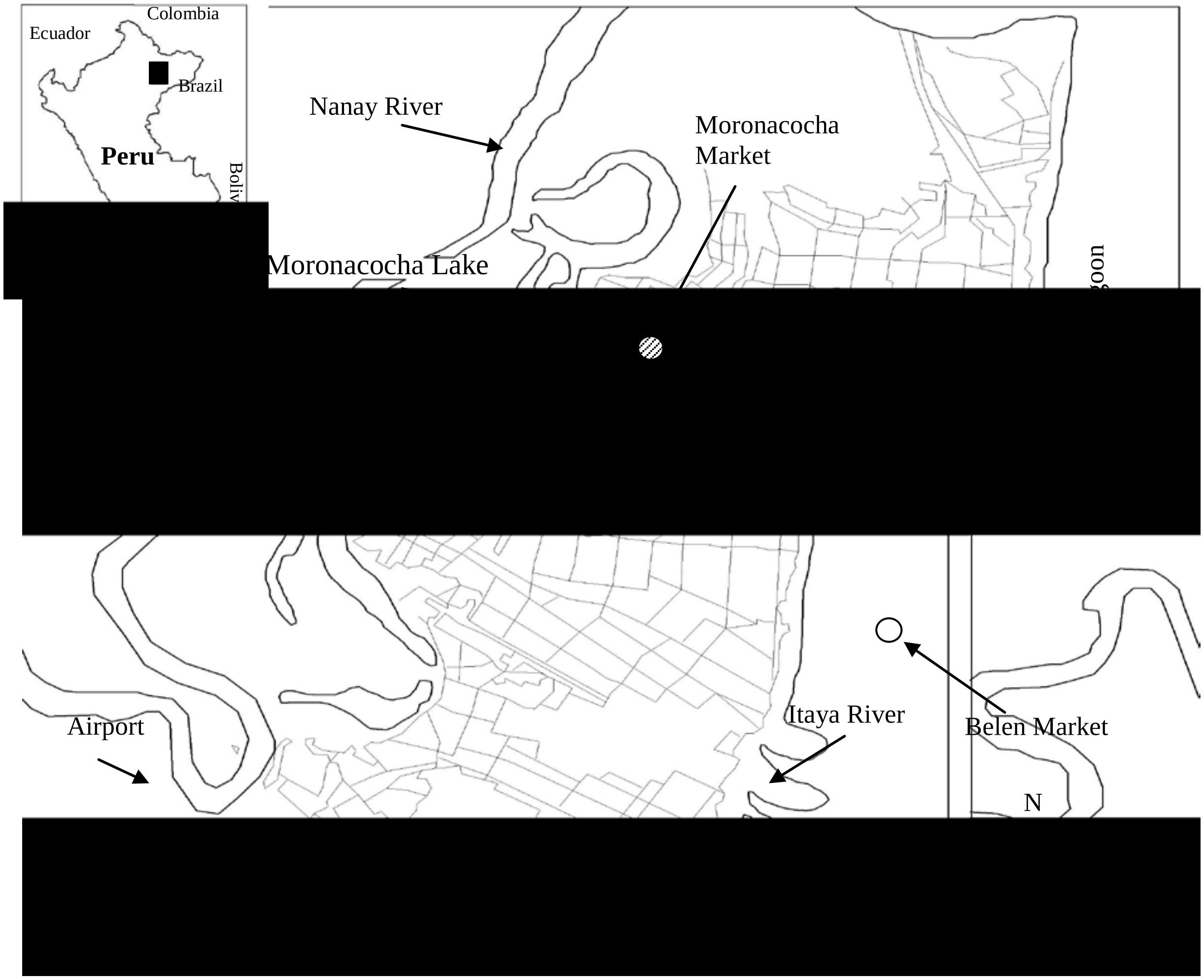
Location/forest type and soils:	Average no. of fronds harvested per stem:	Average no. of stems required to harvest enough leaves for crisnejas needed for one roof:	Estimated no. of hectares required to harvest per roof:	Roof size:	Average estimated hectares per square meter of roof required:
Jenarro Herrera: ferralitic soils[1]	4	9,750	2.5	54 m^2	0.046 ha / m^2
Jenarro Herrera: ferralitic soils[1]	4	5,200	2.0	35 m^2	0.057 ha / m^2
Santa Ana: loamy soils[2]	4	5,200	3.5	35 m^2	0.100 ha / m^2
Puerto Izango: fluvial soils[2]	4	5,200	5.0	35 m^2	0.143 ha / m^2
Mai Huna Reserve	4	9,750	1.0	54 m^2	0.017 ha / m^2
		5,200	0.5	35 m^2	
		81,250	8.3	500 m^2	
Explorama Preserve	4	9,750	1.2	54 m^2	0.021 ha / m^2
		5,200	0.7	35 m^2	
		81,250	10.3	500 m^2	
Mishana Community Reserve	4	9,750	1.2	54 m^2	0.02 ha / m^2
		5,200	0.6	35 m^2	
		81,250	10.0	500 m^2	
Tamshiyacu-Tahuayo Community Reserve	4	9,750	0.9	54 m^2	0.015 ha / m^2
		5,200	0.5	35 m^2	
		81,250	7.3	500 m^2	
Allpahuayo Biological Station	4	9,750	0.8	54 m^2	0.013 ha / m^2
		5,200	0.4	35 m^2	
		81,250	6.4	500 m^2	

[1] Kahn and Mejia 1987a and b.

[2] Vormisto 2002.

FIGURES

Figure 2 – 1. City of Iquitos, Surrounding Waterways, and Location of Moronacocha market. Iquitos is located within the Peruvian Department of Loreto.



[redacted]

[redacted]

Source: IIAP 2002.

Figure 2 – 2. Four-segmented Leaf of Irapai.

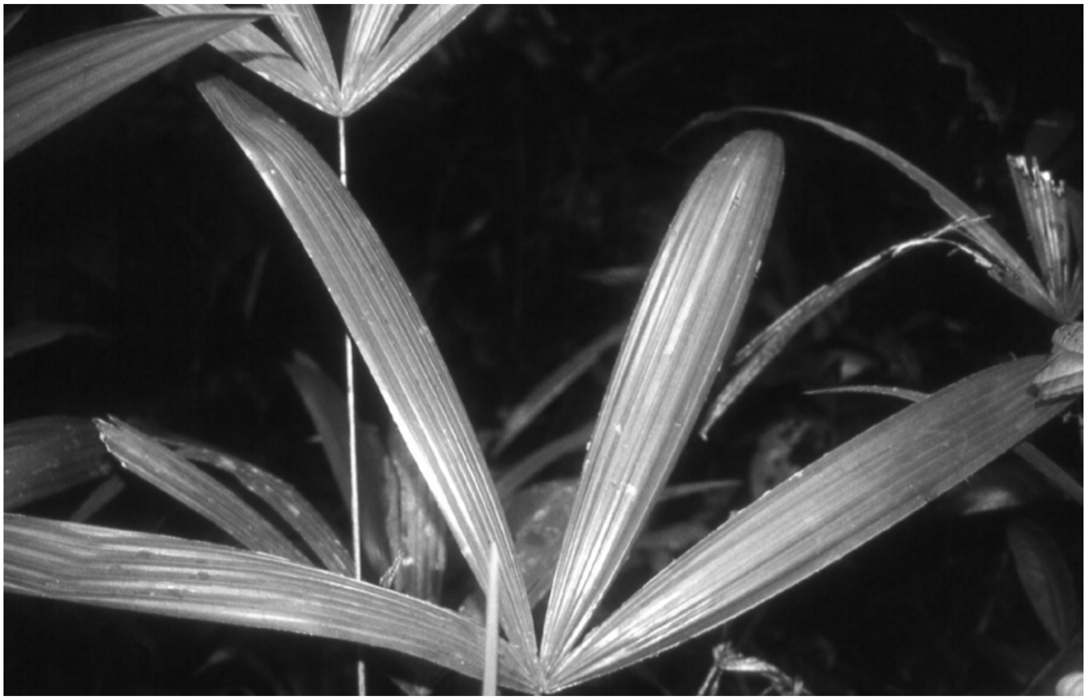
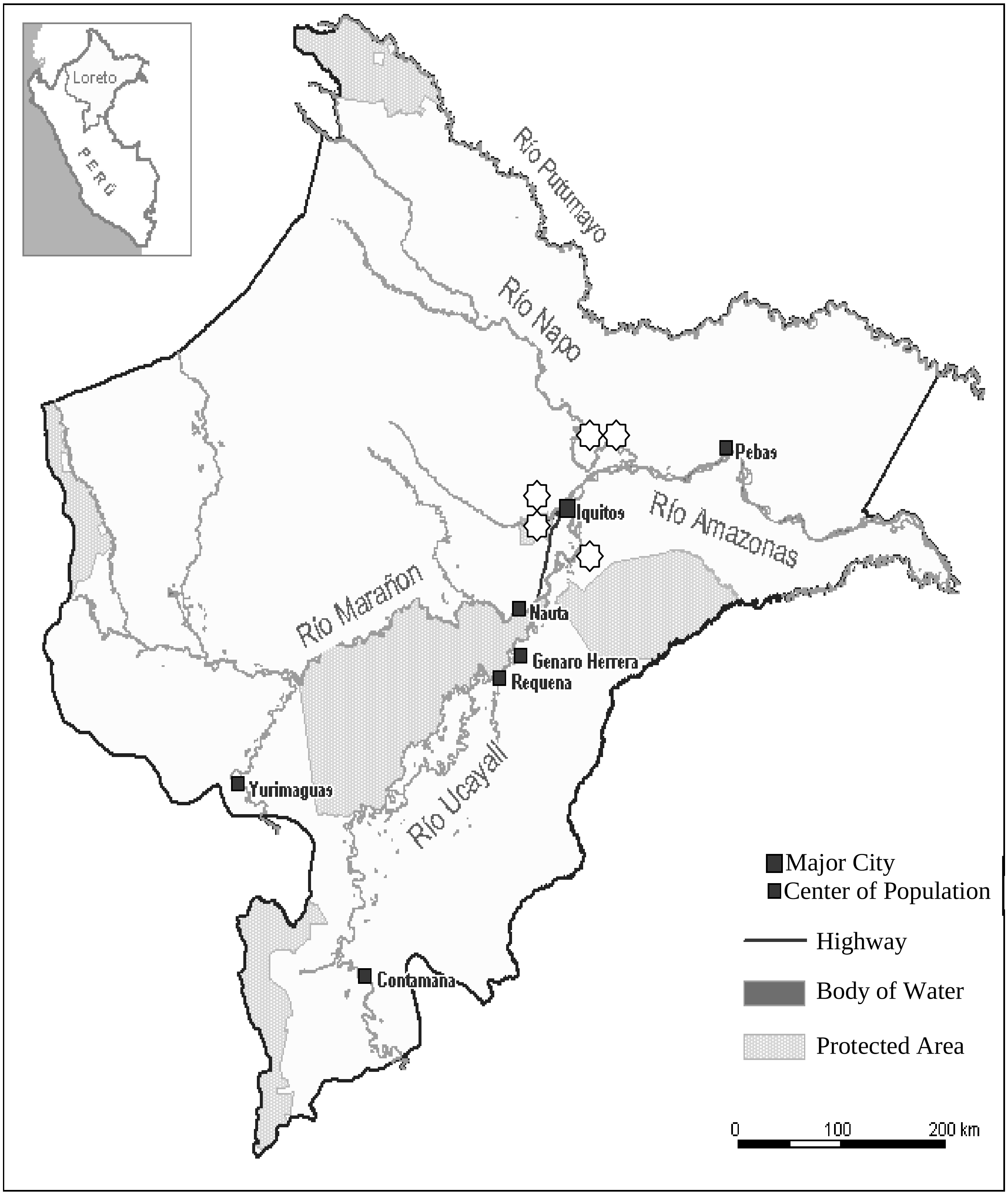


Figure 2 – 3. Irapai Monitoring Plot Locations, Centers of Population, Roads, Waterways and Declared Protected Natural Areas in Department of Loreto.



✡ Irapai Monitoring Plot Locations.

Source: Siamazonia 2005.

Figure 2 – 4. Number of Stems in Monitoring Plots that were Harvested by Year.

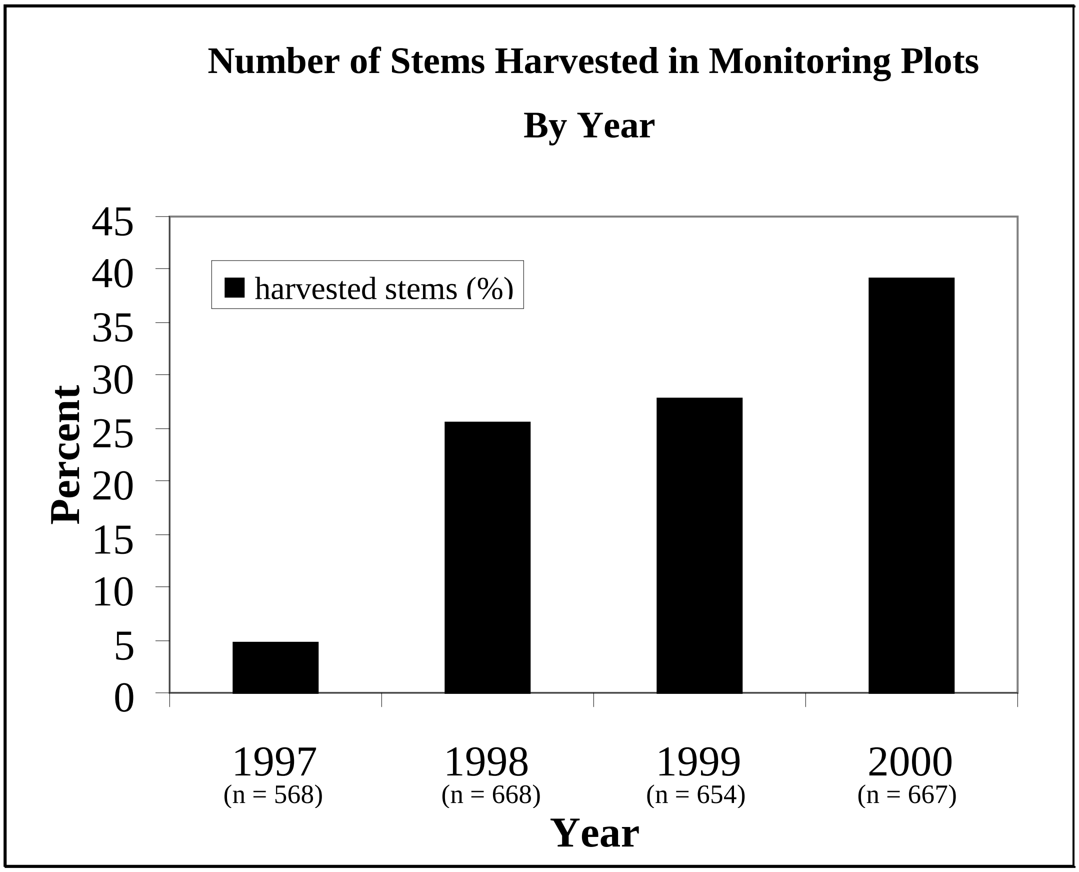


Figure 2 – 5. Crisneja Weave Patterns: (a) Ants' Trail; (b) Chain; (c) Alligator Breast; (d) Grasshoppers' Legs;

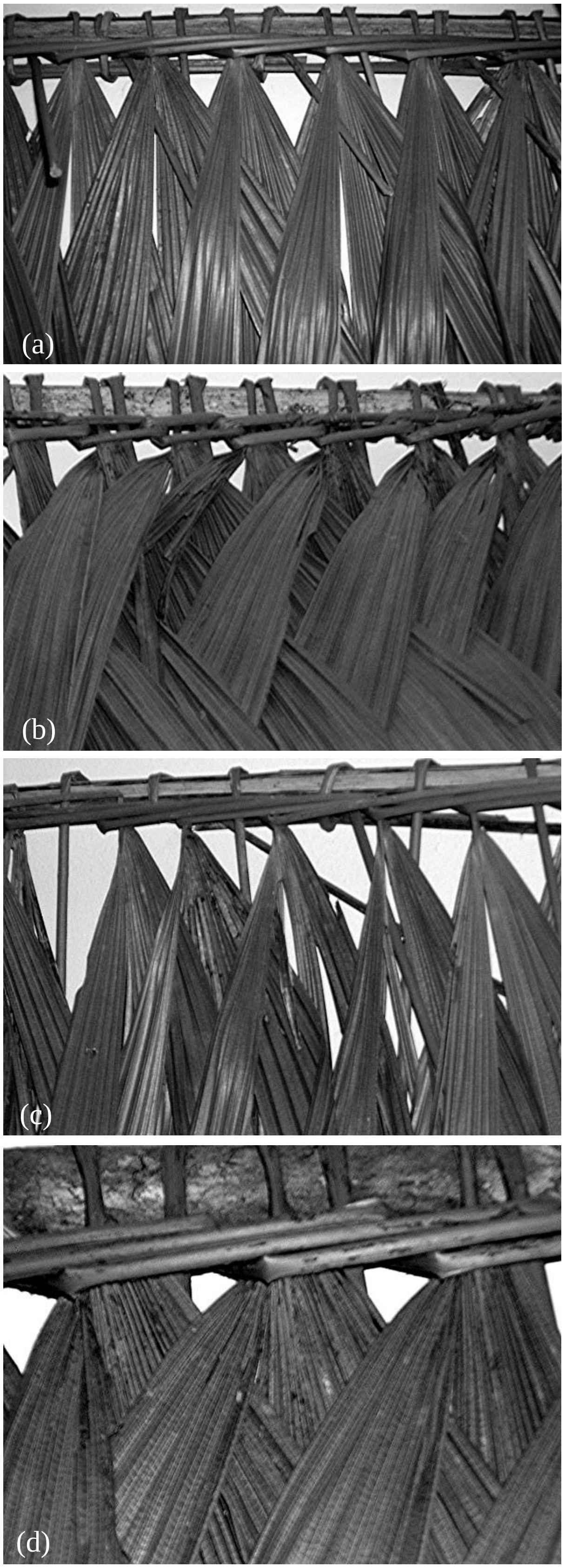
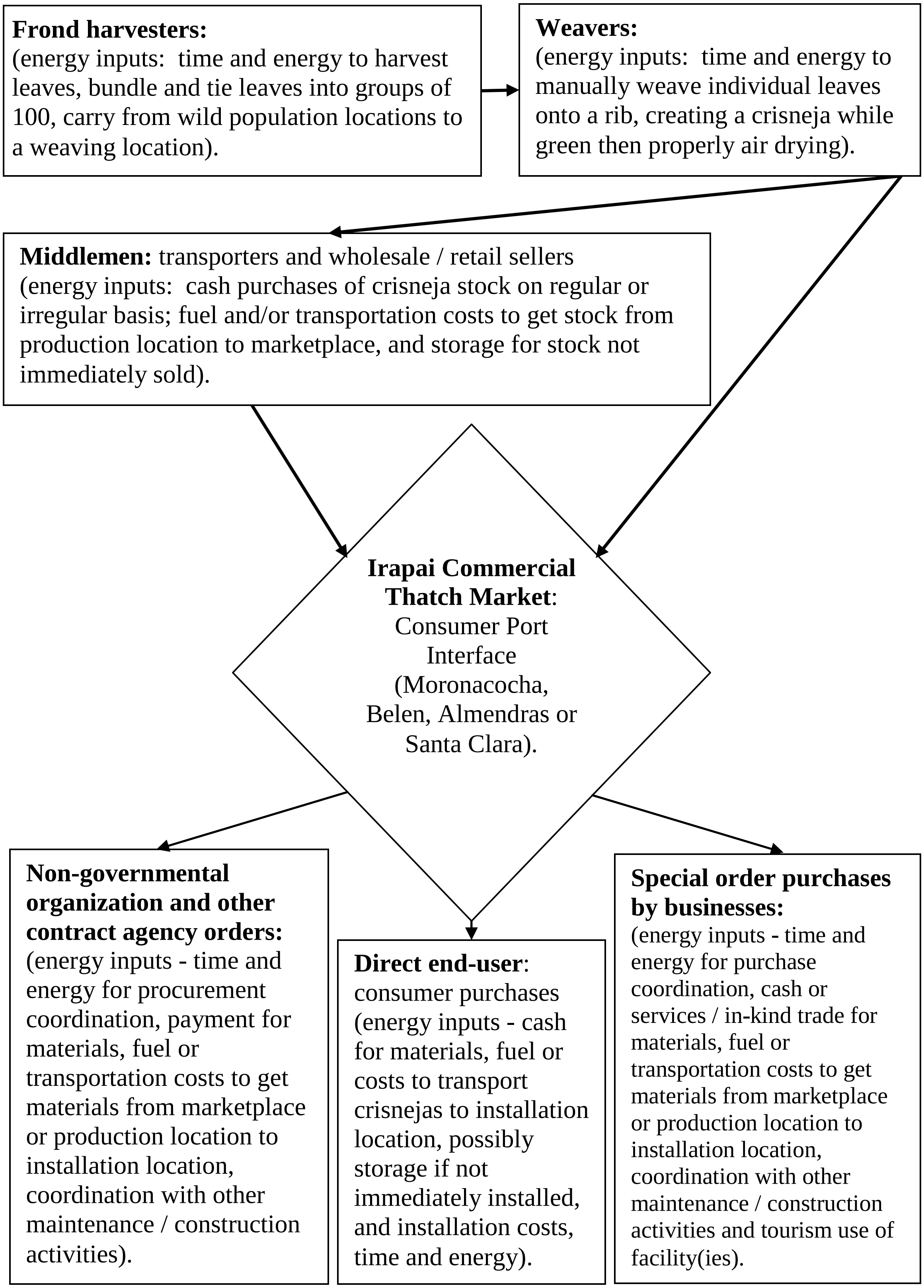


Figure 2 – 6. Irapai Commercial Thatch Market Components.



Frond harvesters:
(energy inputs: time and energy to harvest leaves, bundle and tie leaves into groups of 100, carry from wild population locations to a weaving location).

Weavers:
(energy inputs: time and energy to manually weave individual leaves onto a rib, creating a crisneja while green then properly air drying).

Middlemen: transporters and wholesale / retail sellers
(energy inputs: cash purchases of crisneja stock on regular or irregular basis; fuel and/or transportation costs to get stock from production location to marketplace, and storage for stock not immediately sold).

Irapai Commercial Thatch Market: Consumer Port Interface (Moronacocha, Belen, Almendras or Santa Clara).

Non-governmental organization and other contract agency orders:
(energy inputs - time and energy for procurement coordination, payment for materials, fuel or transportation costs to get materials from marketplace or production location to installation location, coordination with other maintenance / construction activities).

Direct end-user: consumer purchases (energy inputs - cash for materials, fuel or costs to transport crisnejas to installation location, possibly storage if not immediately installed, and installation costs, time and energy).

Special order purchases by businesses:
(energy inputs - time and energy for purchase coordination, cash or services / in-kind trade for materials, fuel or transportation costs to get materials from marketplace or production location to installation location, coordination with other maintenance / construction activities and tourism use of facility(ies).

LITERATURE CITED

Acero Duarte, L. E. 1979. Principales plantas utiles de la Amazonia Colombiana – estudio elaborado por la Unidad Florestal del Proyecto Radargamétrico del Amazonas durante el periodo junio 1974 - diciembre 1979. El Proyecto, Bogotá.

Alexiades, M. N. 1996. Selected Guidelines for Ethnobotanical Research: A Field Manual. Advances in Economic Botany 10:306.

Anderson, A. B. 1988. Use and Management of Native Forest Dominated by Açaí Palm (*Euterpe oleracea* Mart) in the Amazon Estuary. Pages 144-154 in M. Balick, ed., The Palm - Tree of Life: Biology, Utilization and Conservation. Advances in Economic Botany, 6.

Anderson, A.B., P. May and M. Balick. 1991. The Subsidy from Nature: palm forests, peasantry, and development on an Amazon Frontier. New York: Columbia University Press 233p.

Anderson, P. J. 1998. Demography, Stem Harvesting, and Conservation of the Palm, *Iriartea deltoidea*. Dissertation. University of Florida, Gainesville, FL.

Avalos, G. 2004. Production of a Second Set of Stilt Roots in Arborescent Palms: a Solution to the Puzzle. Palms 48(2):83-85.

Balick, M. J. 1988. The Use of Palms by the Apinayé and Guajajara Indians of Northeastern Brazil. Advances in Economic Botany 6:65-90.

Balick, M. J. 1987. Regeneration Population Dynamics and Dissemination of a Palm from French Guyana *Jessenia bataua* ssp. *oligocarpa*. Bulletin du Museum National d’Histoire Naturelle Section B Adansonia Botanique Phytochimie, 9(3):317-336.

Balick, M. J. 1986. The Palm - Tree of Life: Biology, Utilization and Conservation. Advances in Economic Botany, Vol. 6:282.

Balick, M. J. 1984. Ethnobotany of Palms in the Neotropics. Advances in Economic Botany 1:9-23.

Banco Central de Reserva del Perú . 2005. Peruvian Exchange Rate (Nuevo Sol per US$) 1997 – 2004, as accessed at http:// .latin-focus.com/latinfocus/ countries/peru/ perexchg.htm on 3 April 2005.

Bennett, B. C. 2002. Forest Products and Traditional Peoples: Economic, Biological, and Cultural Considerations. Natural Resources Forum 26(2002):293–301.

Bennett, B. C., M. Baker and P. Gomez Andrade. 2002. Ethnobotany of the Shuar of Eastern Ecuador. NYBG Press, Bronx, NY.

Bennett, B. C. 1992. Plants and People of the Amazonian Rainforests: The Role of Ethnobotany in Sustainable Development. BioScience 42(8):599-607.

Besbes, S., C. Blecker, C. Deroanne, G. Lognay, N. Drira, and H. Attia. 2004. Quality Characteristics and Oxidative Stability of Date Seed Oil during Storage. Food Science and Technology International 10(5):333-338.

Bodley, J. H. and F. Benson. 1979. Cultural Ecology of Amazonian Palms. Reports of Investigations, NO. 56, Laboratory of Anthropology. Pullman, WA: Washington State University.

Boom, B. M. 1987. Ethnobotany of the Chácobo Indians, Beni, Bolivia. Advances in Economic Botany 4:1-68.

Borgtoft Pedersen, H. 1996. Production and Harvest of fibers from *Aphandra natalie* (Palmae) in Ecuador. Forest Ecology and Management 80:155-161.

Borgtoft Pederson, H. and H. Balslev. 1990. Ecuadorean Palms for Agroforoesry. AAU Reports 23.

Brako, L., A. Henderson, and F. Kahn. 1993. Palmae. Pages – 1286 in L. Brako and J. Zarucchi, eds., *Catalogue of Flowering Plants and Gymnosperms of Peru* (Monographs in Systematic Botany Vol. 45.). Missouri Botanical Garden, St. Louis, MO.

Brondízio, E. S., C. Safar, and A. Siqueira 2002. The Urban Market of Açaí Fruit (*Euterpe oleracea* Mart.) and Rural Land Use Change: Ethnographic Insights into the Role of Price and Land Tenure constraining Agricultural Choices in the Amazon Estuary. Urban Ecosystems 6(1-2):67-97.

Bucur, A. 1998. Personal communication. ExplorNapo Camp Biological Reserve, near Sucusari, Peru. (1998 field notebook).

Callaghan, T. V. 1984. Growth and Translocation in a Clonal Southern Hemisphere Sedge, *Uncinia meridensis*. Journal of Ecology 72:529-546.

Cavalcante, P. B. 1977. Edible Palm Fruits of the Brazilian Amazon. Principes 21:91-102.

Charles-Dominique, P., J. Chaves, M. Dubois, J. de Granville, B. Riera, and C. Vezzoli. 2003. Colonization Front of the Understorey Palm *Astrocaryum sciophilum* in a Pristine Rain Forest of French Guiana. Global Ecology and Biogeography 12(3):237-248.

Chazdon, R. L. 1986. Physiological and Morphological Basis of Shade Tolerance in Rain Forest Understory Palms. Principes 30:92-99.

Coomes, O. T. 2004. Rain Forest 'Conservation-Through-Use'? Chambira Palm Fibre Extraction and Handicraft Production in a Land-Constrained Community, Peruvian Amazon. Biodiversity and Conservation 13(2): 351-360.

Cotton, C. M. 1996. Ethnobotany: Principles and Applications. J. Wiley and Sons, Sussex, England, 424p.

Critchfield, H. J. 1983. General Climatology, fourth ed., Page 155. Prentice-Hall, NJ, 453p.

Cunningham, A. B. 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan Publications, London, England.

Davis, E. W. and J. Yost. 1983. The Ethnobotany of the Waorani of Eastern Ecuador. Botanical Museum Leaflets 3(29):159-217.

De Steven, D. 1989. Genet and Ramet Demography of *Oenocarpus mapora* ssp. *mapora*, a Clonal Palm of Panamanian Tropical Moist Forest. Journal of Ecology 77:579-596.

Dransfield, J. 1978. Growth Forms of Rain Forest Palms. Pages 247-268 in P. Tomlinson and M. Zimmermann, eds., Tropical Trees as Living Systems. Cambridge University Press, Cambridge.

Duke, J. A., and R. Vasquez. 1994. Amazonian Ethnobotanical Dictionary. CRC Press, Boca Raton, Florida.

Gentry, A. H. 1993. A Field Guide to the Families and Genera of Woody Plants of Northwest South America (Colombia, Ecuador, Peru) with Supplementary Notes on Herbaceous Taxa. Conservation International, Washington D.C.

Godoy, R., R. Lubowski and A. Markandya. 1993. A Method for the Economic Valuation of Non-Timber Tropical Forest Products. Economic Botany 47(3):220-233.

Halle, F. R., A. Oldeman and P. Tomlinson. 1978. Tropical Trees and Forests: an Architectural Analysis. Speringer-Verlag. Berlin, Heidelberg, New York.

Henderson, A. H. 1995. The Palms of the Amazon. Oxford University Press, New York, NY.

Henderson, A. and M. Balick. 1987. Notes on the Palms of Amazonia Legal. Principes 31(3):116-122.

Henderson, A. H. and F. Chavez. 1993. *Desmoncus* as a Useful Palm in the Western Amazon basin. Principes 37(4):184-186.

Instituto Nacional de Estadística y Informática (INEI). 2005. Censos Nacionales X de Poblacion y V de Vivienda. Sistema de Recuperacion de Datos as accessed at ://iinei.inei.gob.pe/iinei/RedatamCpv2005.asp?ori=C on 2 June 2008.

Instituto Investigaciónes Amazonia Peruana. 2002. Ciudad de Iquitos General Map as accessed at http://www.iiap.gov.pe on 28 May 2005.

Jensen, O. and H. Balslev. 1995. Ethnobotany of the fiber palm *Astrocaryum chambira* (Arecaceae) in Amazonian Eduador. Economic Botany 49(3):309-319.

Jensen, P. 1994. Personal communication. Explorama Lodge, Iquitos, Peru.

Johnson, D. V. 1987. Native Palms for Brazilian Development: Three Major Utilization Regions as Examples. Vida Silvestre Neotropical 1(2):43-49.

Joyal, E. 1996. The Palm Has Its Time: An Ethnoecology of *Sabal uresana* in Sonora, Mexico. Economic Botany 50(4):446-462.

Kahn, F. 1988. Ecology of Economically Important Palms in Peruvian Amazon. Advances in Economic Botany 6:42-49.

Kahn, F. 1986. Life Forms of Amazonian Palms in Relation to Forest Structure and Dynamics. Biotropica, 18(3): 214-218.

Kahn, F. 1985. Notas sobre la Biología, Ecología y Utilización de una Pequeña Palmera de la Amazonía Peruana: *Lepidocaryum tessmanni* Burret. Congreso Naciónal Botánica, 14-20 Octubre. Resumen:26; Iquitos.

Kahn, F. K. and J. de Granville. 1992. Palms in Forest Ecosystems of Amazonia. Ecological Studies - Analysis and Synthesis (95). Springer-Verlag, Berlin, Germany.

Kahn, F. K., and K. Mejia. 1991. The Palm Communities of Two “Terra Firme” Forests in Peruvian Amazonia. Principes 35(1):22-26.

Kahn, F. K. and K. Mejia. 1987a. Notes on the Biology, Ecology, and Use of a Small Amazonian Palm: *Lepidocaryum tessmannii*. Principes (31):14-19.

Kahn, F. K. and K. Mejia. 1987b. Notas sobre la Biología, Ecología, y Utilización de una Pequeña Palmera de la Amazonía Peruana: *Lepidocaryum tessmannii* Burret. Informe Técnico (2). IIAP-CIJH, Iquitos, Perú.

Kahn, F. and F. Moussa. 1999. Economic Importance of *Astrocaryum aculeatum* (Palmae) in Central Brazilian Amazonia. Acta Botanica Venezuelica 22(1):237-245.

LatinFocus. 2004. Historic Exchange Rates Peru 1997 – 2004 from Banco Central de Reserva del Perú as accessed at ://www.latin-focus.com/latinfocus/countries/peru/perexchg.htm on 3 April 2005.

Longino, J. T. 2005. Personal communication by e-mail message dated 3-29-05. Specialist in Neotropical Myrmecology (Arthropods of La Selva, Costa Rica – Project ALAS), Evergreen State College, Olympia WA.

López Parodi, J. 1988. The Use of Palms and Other Native Plants in Non-conventional, Low Cost Rural Housing in the Peruvian Amazon. Advances in Economic Botany 6:119-129.

Lugo, A. E. and C. Rivera Batlle. 1987. Leaf Production, Growth Rate, and Age of the Palm *Prestoea montana* in the Luquillo Experimental Forest, Puerto Rico. Journal of Tropical Ecology 3:151-161.

MacBride, J. F. 1960. Flora of Peru. Part I of 2. Botanical Series, Field Museum of Natural History, XIII: 1(of 2), pub. 895. Chicago, IL.

Marmillod, F. 1982. Methodik und Ergebnisse von Untersuchungen über Zusammensetzung und Aufbau eines Terrasssenwaldes im Peruanischen Amazonien. These doktorgrades, Gerog-August Universität, Göttingen.

Martin, G. J. 1995. Ethnobotany: A Methods Manual. Chapman and Hall, London.

Mejia, K. 1997. Personal communication. Moronacoche Market, Iquitos, Peru. (1997 field notebook, p102 – 106).

Mejia, K. M. and F. Kahn. 1996. Biology, Ecology and Utilization of Irapay (*Lepidocaryum gracile* Martius). IIAP Folia Amazonica 8(1):19-28.

Olmstead, I. and O. Alvarez-Buylla. 1995. Sustainable Harvesting of Tropical Trees: Demography and Matrix Models of Two Palm Species in Mexico. Ecological Applications 5(2):484-500.

Padoch, C. 1988. Aguaje (*Mauritia flexuosa* L.f.) in the Economy of Iquitos, Peru. Advances in Economic Botany 6:214-224.

Pinard, M. 1993. Impacts of Stem Harvesting on Populations of *Iriartea deltoidea* (Palmae) in an Extractive Reserve in Acre, Brazil. Biotropica 25(1):2-14.

Potvin, C., R. Cansari, J. Hutton, I. Caisamo, and B. Pacheco. 2003. Preparation for Propagation: understanding germination of Giwa (*Astrocaryum standleyanum*), Wagara (*Sabal mauritiiformis*), and Eba (*Socratea exorrhiza*) for future cultivation. Biodiversity and Conservation 12(11):2161-2171.

Pyhälä, A., K. Brown, and N. Adger. 2006. Implications of livelihood dependence on non-timber products in Peruvian Amazonia. Ecosystems 9:1328-1341.

Räsänen M., Kalliola R. and Puhakka M. 1993. Mapa Geoecologico de la Selva Baja Peruana: explicaciones. Pages 207- 216 in R. Kalliola, M. Puhakka, and W. Danjoy, eds., Amazonia Peruana. Vegetación Húmeda Tropical en el Llano Subandino. Gummerus Printing, Jyväskylä, Finland.

Ratsirarson, J., J. Silander, and A. Richard. 1996. Conservation and Management of a Threatened Madagascar palm species, *Neodypsis decaryi*, Jumelle. Conservation Biology 10(1):40-52.

Rich, P. M. 1986. Mechanical Architecture of Arborescent Rain Forest Palms. Principes, 30:117-131.

Rickson, F. R. and M. Rickson. 1986. Nutrient Acquisition Facilitated by Litter Collection and Ant Colonies on Two Malaysian Palms. Biotropica 18:337-43.

Salo J., R. Kalliola, I. Häkkinen, Y. Mäkinen, P. Niemelä, and M. Puhakka. 1986. River Dynamics and the Diversity of Amazon Lowland Forest. Nature 322:254–258.

Scariot, A. 2001. Weedy and Secondary Palm Species in Central Amazonian Forest Fragments. Acta Botanica Brasileira 15(2) May/Aug. São Paulo, Brazil.

Schatz, G., G. Williamson, C. Cogswell, and A. Stam. 1985. Stilt Roots and Growth of Arboreal Palms. Biotropica 17(3):206-209.

Schroth, G., M. da Mota, R. Lopes, and A. de Freitas. 2004. Extractive Use, Management and In Situ Domestication of a Weedy Palm, *Astrocaryum tucuma*, in the Central Amazon. Forest Ecology and Management 202(1-3):161-179.

Sistema de Información de la Diversidad Biológica y Ambiental de la Amazonia Peruana (SIAMAZONIA). 2005. IIAP Map of Loreto as accessed at ://www.siamazonia.org.pe/ on 28 May 2005.

Solano, W. 2000. Irapai in agroforestry efforts in Nuevo Triumfo (Reserva Comunal Tamhiyaco – Tahuayo). Report to Lima office of C.A.R.E. Peru by Agroforestry Engineer.

Suarez Alvites, H. 2002. Efecto de la Cosecha y de la Luz en la Productividad de Hojas de Irapai (*Lepidocaryum tesmanni*), Comunidad de Nuevo Triunfo, Rio Tahuayo, Loreto. Tesis de Grado para optar el Título de Magister Scientiae en la Especialidad de Manejo Forestal. Escuela de Post Grado, Universidad Nacional Agraria la Molina.

Thomas, M. 2005. Personal communication by e-mail message dated 3-31-05. Taxonomic Entomologist and Entomology Section Administrator Curator of Coleoptera and Orthoptera, Division of Plant Industries – Florida State Collection of Arthropods, Gainesville FL.

Tomlinson, P. B. 1990. The Structural Biology of Palms. Oxford University Press, New York, NY.

Tomlinson, P. B. 1963. Measuring growth rates in palms. Principes 7:40-44.

Tomlinson, P. B. 1961. Anatomy of Monocotyledons. II. Palmae. Oxford University Press, London.

Uhl, N. W. and J. Dransfield. 1987. Genera Palmarum: A Classification of Palms Based on the Work of Harold E. Moore, Jr. Allen Press, p1-69.

United States Department of Labor, Bureau of International Labor Affairs. 2005. Peru – Minimum Wage, as accessed at ://www.dol.gov/ilab/media/reports/oiea/wagestudy/FS-Peru.htm on 4 September 2005.

United States Department of State, Bureau of Democracy, Human Rights, and Labor. 2002. Peru: Country Reports on Human Rights Practices - 2001 (March 4), as accessed at ://www.state.gov/g/drl/rls/hrrpt/2001/wha/8263.htm on 4 September 2005.

Velasquez-Runk, J. 2001. Wounaan and Embera Use and Management of the Fiber Palm, *Astrocaryum standleyanum* (Arecaceae) for Basketry in Eastern Panama. Economic Botany 55(1):72-82.

Velasquez-Runk, J. 1998. Productivity and Sustainability of a Vegetable Ivory Palm (*Phytelephas aequatorialis*, Arecaceae) under Three Management Regimes in Northwestern Ecuador. Economic Botany 52(2):168-182.

Vickers, W. T. and T. Plowman. 1984. Useful Plants of the Siona and Secoya Indians of Eastern Ecuador. Fieldiana, Bot 15:1-63.

Vormisto, J. 2002. Palms as Rainforest Resources: How Evenly are they Distributed in Peruvian Amazonia? Biodiversity and Conservation 11(6):1025-1045.

Vormisto, J., H. Tuomisto, and J. Oksanen. 2004. Palm Distribution Patterns in Amazonian rainforests: What is the Role of Topographic Variation? Journal of Vegetation Science 15:485-494.

Warren, L. A. 1992. *Euterpe* Palms in Northern Brazil: Market Structure and Socioeconomic Implications for Sustainable Management. Master's thesis, Department of Geography, University of Florida.

Waterhouse, F. L. and C. Quinn. 1978. Growth Patterns in the Stem of the Palm *Archontophoenix cunninghamiana*. Botanical Journal of the Linnean Society 77:73-93.

Weatherbase 2005. Source for weather records based on data collected by the National Climatic Data Center, as accessed at ://www.weatherbase.com/weather/weather.php3?s=077348 on March 24, 2005.

Wilson, E. O. 2005. Personal communication by e-mail message dated 3-23-05. Harvard University, Museum of Comparative Zoology, Cambridge MA.

Zona, S. and K. Maidman. 2001. Growth Rates of Palms in Fairchild Tropical Garden. Palms, 45(3):151-154.

CHAPTER III.

IRAPAI (*LEPIDOCARYUM TENUE*) SEED GERMINATION, SEEDLING GROWTH AND SURVIVAL

ABSTRACT

Lepidocaryum tenue Mart. (Arecaceae), irapai, is a small, understory palm found in terra firme rainforests of western and central Amazonia. Ribereños and others collect irapai fronds for use as roofing thatch or for commercial markets in Iquitos, Perú. Tourism and population growth in the Peruvian Amazon have increased demand for fronds, especially for construction of indigenous style tourist facilities. For 60 months, from 2000 to 2005, I conducted a trial to evaluate seed germination, survival, seedling growth, and leaf production on 77 irapai seeds in three different planting media: quartz sand, sphagnum peat and perlite. The two former were representative of soils in irapayales, and the latter functioned as a control. *L. tenue* seeds had a mean germination rate of 19.5 % in all planting media after 60 months, and seedlings had a less than two percent survival rate after twelve months. Seeds planted in sphagnum peat had the highest germination success of 37.9%, while seeds in perlite medium had 16.7% germination success. No seeds planted in quartz sand germinated.

INTRODUCTION

Irapai is a dioecious palm found growing in the understory of better-drained terra firme or seasonally inundated soils of rainforest communities within the west and central Amazon River basin. Population growth (INEI 2004a, 1993, Morey and Sotíl 2000) and tourism (INEI 2004b, 2001) in the Peruvian Amazon have increased the demand for palm fronds throughout the region. Palms throughout the Amazon are used for subsistence and export products, including vegetable ivory, and palm heart (e.g., Balick 1984, 1986, 1987; Bennett 2002; Bodley and Benson 1979; Boom 1987; Borgtoft *et al.* 1990; Kahn 1988; Padoch 1988; Warren 1992). Palms also produce fruit consumed by mammals, birds, and fish which provide protein.

Irapai reproduces vegetatively and by seed, and in some sites, it is the most abundant understory species (Henderson 1995). Like other palms, it gains height through the production of leaves from a terminal meristem. Although a relatively constant rate of leaf production and continuous growth rate have been ascribed to palms, experimental evidence shows that many palms exhibit variable growth rates with rapid spurts of height and diameter growth early in life that commonly are regulated by interplay between genetics and environmental conditions (Zona and Maidman 2001). Clonal proliferation via numerous ramets may allow a genet to harvest patchily distributed resources which may confer a competitive advantage (Janzen 1977). This reproductive strategy also spreads the risk of genet mortality over numerous ramets (Cook 1979). Based upon the higher survivorship of ramets to seedlings, a kind of post-natal care of offspring is a possible benefit to clonal organisms (Callaghan 1984). Abrahamson and Layne (2002) found, however, that ramets of clonal species of *Quercus* in central Florida must accrue energy reserves to reach size thresholds before allocating resources for sexual reproduction, suggesting there may be little sharing of resources among clonal ramets, and integration of stems from the same genotype may be very limited. Irapai reproduces primarily by vegetative propagation and relies on sexual reproduction to a much smaller degree. According to anecdotal information as well as some unpublished findings, *L. tenue* seeds have low germination rates (Solano 2000). A review of irapai seed germination records at Fairchild Tropical Garden in Miami, Florida, in 1997 seemed to confirm this as none of the seeds that did germinate here lived more than six weeks before damping off and dying (Hubbuch 1997, pers. comm.). Attempts to propagate by dividing new shoots from a parent stem, as well as to establish new plants or colonies of *L. tenue* close to Mishana, ExplorNapo Camp Biological Reserve, and the Tamshiyacu-Tahuayo Community Reserve are known to have occurred although all were unsuccessful (Solano 2000, Bucur 1998). Continued harvest of such a species without methods for successful restoration or reintroduction could adversely affect irapayales, and, in turn, cause shortages of a commercial and subsistence thatch resource.

Lepidocaryum is a monotypic genus with three varieties (Henderson 1995). *L. tenue* var. *tenue* occurs in the Peruvian Department of Loreto and ranges from here through sections of Colombia and into Brazil (Henderson 1995). The only variety reported in the literature for the Iquitos area is *L. tenue* var. *tenue.* Its fruit is 1.5 to 3 cm long, ellipsoid or globose, usually 1 to 2 centimeters in diameter, contains a single seed, and has small, overlapping scales, reddish in color when mature, possibly suggesting animal dispersal (Henderson 1995, Tomlinson 1990). According to MacBride (1960), the fruit (mesocarp) can be eaten after being softened in water, much like that of its relative, *Mauritia flexuosa* or aguaje (Uhl and Dransfield 1987). Aguaje fruit is consumed extensively in the region, although I have never seen the fruit of *L. tenue* eaten (Padoch 1988). Little is known about dispersal of irapai seeds by wildlife. Birds or rodents may feed on the seeds, as they are capable of chewing through endocarp (Olmos *et al.* 1999, Tomlinson 1990). Peccaries (*Tayassu* spp.), tapirs (*Tapirus* spp.) or primates are potential dispersers (Fragoso 1997). Uhl and Dransfield (1987) suggest that scatter hoarding by animals may be important for palm seed dispersal. Some of their activities may facilitate seed dispersal and survival while others exemplify seed predation.

Irapai's seed has a homogenous endosperm and a lateral embryo, germination has an adjacent-ligular growth pattern which "may be seen as an adaptation to germination in moist environments," possibly derived from a remote germination type where an elongated cotyledon protects the seed's growing tip from drying and disturbance, providing an ecological advantage in more xeric habitats (Pinheiro 2001:520, Henderson 1995, Uhl and Dransfield 1987). Reproduction by seed, although much less prominent in this species, most likely involves a persistent seed bank. Very little research has been done on irapai's sexual reproduction, seed dispersal, seed behavior, or seedling establishment. When germinating, palms in general, need plenty of moisture and protection from excessive sunlight which may indicate their most vulnerable points, especially if the forest canopy is removed as a result of human activities (Uhl and Dransfield 1987).

This trial studied seed germination and seedling establishment potential, as well as seedling survival, growth and leaf production. My objectives were to reveal seed germination rates in different media and seedling survival rates for this long-lived clonal palm. I tested germination in quartz sand and sphagnum peat planting media, representing components of better drained terra firme and seasonally inundated soils of rainforest communities where irapai is native. Quartzite sand pockets are found within the more acidic, primarily loamy clay soils that are commonplace where irapai grows in the Iquitos region. I documented subsequent seedling survival and growth.

METHODS

Because of the limited number of seeds available, I conducted a simple long-term seed germination experiment with soil type as the only treatment. In this trial, I tested 77 seeds in three media (quartz sand, sphagnum peat, and perlite) to document germination rates and assess the reproductive potential of seeds. The first two medium types were selected as the most representative of soil components observed in irapayales, and perlite as a neutral control (Donselman 1982). Counts, seed and seedling observations as well as moisture, light and temperature conditions were monitored at monthly intervals. Seeds were collected from palms in the Mishana and Sucusari areas (near the IIAP field station at Allpahuayo-Mishana Reserve as well as close to the Explorama Reserve).

Study treatment factor was soil type. Following Meerow's methods (2004), and a thorough fresh water soaking and cleansing by hand to remove the fruit's thin mesocarp, 77 *L. tenue* seeds were set to germinate in one-gallon size air-tight, sealable plastic bags with approximately 450 grams of one of three planting media: quartz sand, sphagnum peat or perlite (Donselman 1982, Pinheiro 2001). Initially seeds were divided into three replicates of each medium; 25 seeds in the control, and 26 seeds in each treatment media. Seeds then were grouped together by collecting location resulting in five replicates of sphagnum and three of perlite and sand. Sphagnum peat moss was representative of more acidic, moisture binding loamy clay, sand of quartzite pockets found in seasonally inundated soils, and perlite was the control providing a neutral germination source (Donselman 1982, Moyroud 2000).

Seeds were buried just below media surface. Into each bag, a maximum of approximately 475 ml of carbon-filtered water (to remove any chlorine) was added, and all bags were sealed. Seed germination, growth, leaf production and survival were monitored monthly for 60 months. For the initial twelve-month period, bags were placed next to one another on a level horizontal rack. Ambient light levels during this period ranged from 100.0 to 500.0 lux, and temperatures ranged from 16° to 36° C, although days below 29° C were fewer than ten. Nearly all palm seeds require high temperatures for "rapid and uniform germination", and between 21° and 38° C is an acceptable range, although 29° to 35°C yields better results (Meerow 2004). Moisture levels remained near constant (85%) due to the closed nature of the microenvironments within the bags, while externally RH ranged from 48% to 96% and averaged 82%.

Approximately every thirty days each bag was opened briefly and each seed visually inspected for germination activity or algal or fungal growth. If needed, up to 475 ml of water was added. At the end of year one, no seeds had germinated. Beginning with the thirteenth month, all bags containing seeds were relocated to a darker secondary location and maintained next to one another horizontally for an additional 48 months. Ambient light levels at this location were much lower, ranging from 0.01 to 20.0 lux, and temperature variations smaller, ranging from 21° to 33° C. Number of days where temperatures below 29° C occurred, were fewer than 12. Moisture levels again remained near constant (85%). After 48 months, no germination had taken place in any sand treatment replicates, and all remaining viable seeds (24) were divided equally and transferred into new replicate treatments of perlite and sphagnum with 475 ml of water. For months 48 to 60 replicates included 5 perlite and 6 sphagnum peat treatments.

Upon germinating, each seed was removed from its bag, measured and photographed, and planted in a one-gallon pot with Premier Pro-Mix ‘BX’ planting media, a lightweight, peat-based mixture with a porous texture to promote root development and a proper water to air ratio (Premier Horticulture 2002). The medium is well drained but has moisture holding capacity, and it has a medium particle size and balanced nutrient charge (Meerow 2004). Soil pH levels were tested prior to planting. Levels ranged between 6.0 and 6.8. Seedling height was measured in centimeters from soil level to point on the stem where the newest leaf separated (Myers 1981). A spear was considered a new leaf as soon as it began expanding. A six-month establishment period was considered the average amount of time needed to account for transplant mortality (Donselmen 1982, Myers 1981, Zona and Maidman 2001). After six months, seedling mortality was considered to have resulted from a cause other than transplant damage. Because a palm seedling’s endosperm provides nearly eight weeks of nutrients, no fertilizer was added to seedling medium until after this time (Meerow 2004).

With the exception of two seeds transplanted immediately following germination, transplantation of seedlings occurred after the formation of one to three leaves to minimize seedling trauma. Palms do not tolerate being planted too deeply. Each seedling was transplanted into fresh medium so that the attached seed remained visible above soil level, and the seedling’s root system was just below soil surface. Newly transplanted seedlings in pots were placed in light shade (between 100.0 to 500.0 lux), and irrigation carefully monitored to avoid water stress. One application of a mild, slow-release fertilizer, Osmocote, was made to potted seedlings in April 2004.

RESULTS

Germination was poor in all planting media. Eleven seeds germinated 791 days after the trial began. Subsequently, an additional three seeds germinated over the following 36 months (Figures 3 – 1 and 3 - 2). Six seeds died without germinating over the course of this trial. Their loss was determined during regular seed checks by easily cracking each endocarp and discovering inside a putrid liquid endosperm. In July 2005, 61 months after planting, one additional seed planted in perlite germinated. Following more than 60 months of monitoring, 15 of the 77 seeds had germinated, and a germination rate of 19.5 percent for untreated seeds determined. Only four seeds planted in perlite germinated (Figure 3 – 3). No germination occurred in quartz sand.

A cross tabulation, the combination of two or more frequency tables, with a chi-square test performed on the percent of seeds germinated by planting medium was significant, χ^2 (2, N = 77) = 13.46, $p < 0.001$. Three post-hoc tests were conducted using Holm's sequential Bonferroni comparisons, overall alpha (α) = 0.05. Mean seedling survival was 7.8 months for those planted in sphagnum peat and 5.3 months for those that started in perlite (Table 3 – 1). The percentage of seeds that germinated in sphagnum peat (n = 11, 38%) was significantly higher than the percentage that germinated in sand (n = 0, 0%). The percentage that germinated in perlite (n = 3, 12.5%) was not different from either sphagnum or sand.

Survival of seedlings germinated in all media was poor. Seedlings survived an average of seven months. The most frequent seedling survival period was five months, although a similar number also survived 12 months (Figure 3 – 4). Palms have several growth phases including pre-germination period, establishment phase, seedling, juvenile and adult (Zona and Maidman 2001). Because their survival averaged just over six months, which was the outer edge of the establishment phase, it was unclear whether they were sensitive to transplanting or succumbed for other reasons. Most seedlings appeared to succumb to a combination of parasitic and fungal infections after an average of 7.3 months. The survival rate after 14 months was near zero. There was no significant difference in the mean number of months lived between sphagnum peat (n = 11, M = 7.82, SD = 2.3) and perlite media (n = 3, M = 5.33, SD = 4.9), t (12) = 0.84, p < 0.42. Length of time alive ranged from 4 to 8 months for perlite and one to 18 months for sphagnum peat. At the end of the study period, only two seedlings remained alive, one 18 months old (sphagnum) and the other one month old (perlite).

Seedling data was recorded from actual month of germination. Height and leaves, however, were analyzed monthly from germination month. There were no significant differences between sphagnum peat and perlite in mean monthly height of plants from the first month sprouted through month eight, ps > 0.433 (Figure 3 – 5). In month nine the one remaining palm that germinated in perlite died. Descriptive statistics for seedling heights are shown in Table 3 – 2. Maximum heights ranged from two to nine centimeters for seeds planted in perlite, and from 0.1 to 12 cm for palms planted in sphagnum peat. The most frequent amount of monthly growth per seedling was one centimeter. There were no significant differences between the two media types in mean maximum height of palms over their lifetimes, t(12) = 0.54, p < 0.60. The greatest monthly growth, or height increase, of 6 cm occurred in October 2002 in a seedling that germinated in sphagnum peat.

There was no significant difference in monthly mean number of leaves on palms by planting media for months one to eight, ps > 0.12. Mean number of leaves made was 2.3 for those germinated in sphagnum peat and 1.8 for seedlings that started in perlite (Table 3 – 3). There was no significant difference in the mean total number of leaves made by planting media, t(12) = 0.45, p < 0.66. On a scale of zero to 1.0, an unopened palm leaf, or spear, was represented as 0.5, and leaf production recorded in 0.10 increments (Figure 3 – 6). Palms with leaves fewer than 0.5 were germinated seeds that died back before making a first spear. The largest number of leaves made by any seedling in a month was 1.9 (Figure 3 – 7). Palms from seeds planted in perlite averaged 1.8 leaves (SD = 1.26) and ranged from 0.5 to 3.0. Palms started in sphagnum peat medium averaged 2.3 leaves (SD = 1.72) and ranged from 0.2 to 5.0 (Figure 3 – 8).

Since there were no significant differences between media on length of time alive, or longevity, maximum height and total number of leaves, the groups were combined and regression analyses were performed on total number of leaves produced by seedlings and maximum height by number of months alive (Figure 3 – 9). There was a significant correlation between the number of months that a seedling lived and the number of total leaves it produced r = 0.87, p < 0.001, and for each additional month that a seedling lived, it produced an average of 0.3 more leaves (SE = 0.05). Maximum height of the palm, however, was not correlated to the number of months a seedling lived, r = 0.39, p < 0.17. As shown in Figure 3 – 10, seedlings appeared to grow quickly during the first six months following germination, and then declined.

DISCUSSION

Germination was extremely limited and slow in all tested media. Different germination rates in planting media types, however, suggest that when this species does sexually reproduce successfully, seedlings have specific germination and survival requirements. Irapai palms are found growing in sandy soils of seasonally inundated areas around Iquitos, but a lack of any germination results in sand suggests these populations may rely strictly on vegetative reproduction. This study had insufficient time to observe complete germination and seedling mortality. In October 2005 Hurricane Wilma's landfall in Florida caused the loss of the two remaining seedlings. Following the termination of this controlled 60-month trial, however, and not included in statistical analyses, an additional five seeds from this group germinated (four planted in perlite and one in peat moss), four at 72 months following planting (one died immediately), and the most recent at 83 months since planting. This lengthy, delayed germination response is extremely unusual for a tropical palm. As of publication date four small seedlings persisted.

Because of physical characteristics, irapai seeds have some protection from predation. The possibility of a long-term seed bank in the wet tropics where seeds remain viable for at least five years, however, is very surprising. Long seed viability usually is associated with dry or cold environments. *L. tenue* successfully reproduces vegetatively, but significantly delayed seed germination is unusual for tropical palms with medium or large seeds, and is unreported from other members of the Lepidocaryoideae. Professional growers typically warn of short seed viability for many palms, from *Mauritia* sp. to *Raphia* sp. (Moyroud 2000, pers. comm.). Low germination rate but long viability persistence would allow some new seedlings to emerge several years after the death of a last clone in an area. This characteristic also could permit irapai to colonize a new area when environmental conditions become more favorable for its survival. In a study of *Raphia* seed germination, a palm that may share some physiology with irapai, Myers (1981) found that these seeds remained viable for extended periods when covered in lowland swamp mud. While there may be some species similarities, there also are differences between dormancy in anaerobic and aerobic environments. Palm seed viability varies, but generally ranges from two to three weeks (Meerow 2004) up to more than a year in some species, given proper storage methods (Broschat and Donselman 1986). There are some exceptions, however, as in the germination of a *Phoenix dactylifera* seed after nearly 2,000 years (Kalman 2005), but these are uncommon.

Manual or chemical scarification of seeds could help with germination times for potential agroforestry use. Scarification is the thinning of the hard endocarp by manual abrasion or a short seed soak (10 to 30 minutes) in sulfuric acid (H_2SO_4). Additional seed pretreatments, including soaking in a 10 to 2000 ppm solution of gibberelic acid (or GA3, $C_{19}H_{22}O_6$) for one day may also improve germination (Doughty *et al.* 1986, Nagao and Sakai 1979, Nagao *et al.* 1980, Odetola 1987). The use of pretreatments should be investigated and potential germination gains weighed against the potential seed loss and additional cost of labor. Another method that might increase palm seed germination is the regular fluctuation of temperatures at twelve-hour intervals (Carpenter 1987, 1989).

Additional vegetative propagation attempts are recommended, but following initial separation from the parent stem via a circular pattern at least 0.3 m in diameter with a sharp blade, the shoot should be allowed to remain in place until substantial new growth is evident. Once this happens, relocation could be attempted by carefully lifting shoots with as much of its root system and soil as possible into the largest size container manageable. Shoots should not be placed in the ground until they become well established, which could be a year, and during this time they should be kept in a shaded area where watering and drainage can be carefully monitored.

This study suggests that *L. tenue* may develop a persistent seed bank, although its germination rate is low and the palm's preferred regenerative strategy remains vegetative propagation. It may be possible to release irapai from seed dormancy following a change (brief or lengthy) in some condition other than relative humidity or temperature, although there may be a connection to changes in light level(s) over time, which could indicate relevance to forest canopy coverage at establishment sites. Effects from seed predation were not determined by this trial, but should be studied. Additional research of the ecology and biology of irapai is warranted. From fieldwork observations, there did not appear to be a large supply of irapai seeds on the forest floor even within irapayales.

Dispersal mechanisms are suspected to be a very important factor in determining irapai's distribution and restricting new irapayale establishment. Until the fruit or seed dispersal transport mechanisms are better known, dispersal difficulties may be the largest factor limiting establishment of new genets in many suitable locations. It is not yet known definitively how long buried seeds remain viable, nor is it known whether seeds can withstand desiccation. Factors such as root herbivores, fungal pathogens, and possibly either the unavailability or absence of a particular soil mycorrhizae or the seedling's inability to form mycorrhizal associations could have been responsible for the decline and ultimate demise of seedlings in this study (Tomlinson 1990, Uhl and

Dransfield 1987). Continued studies of irapai, a non-timber forest product (NTFP), for which a thatch market in the Iquitos, Peru, region already exists, could help local managers better understand species growth and production requirements to expand irapayales. Harvest of irapai is expected to increase along with a growing regional population and increasing ecotourism. NTFPs such as irapai may be one possible alternative among larger strategies, that could help conserve area biodiversity.

TABLES

Table 3 - 1. Seedling Survival (Number of Months) by Planting Media.

Seedling Survival (Number of Months) by Planting Media

Planting medium:	Mean ± Standard Deviation	N	Range	Median
Perlite	5.33 ± 2.31	3	4.00 - 8.00	4.00
Sphagnum Peat	7.82 ± 4.88	11	1.00 - 14.00	6.00
Sand	0.00	0	0.00	0.00
Total	7.29 ± 4.50	14	1.00 - 14.00	5.50

Table 3 – 2. Seedling Growth (Cm) by Planting Media.

Seedling Growth (Cm) by Planting Media

Planting medium:	Mean ± Standard Deviation	N	Range	Median
Perlite	6.00 ± 3.61	3	2.00 - 9.00	7.00
Sphagnum Peat	7.33 ± 3.78	11	0.10 - 12.00	7.00
Sand	0.00	0	0.00	0.00
Total	7.04 ± 3.65	14	0.10 - 12.00	7.00

Table 3 – 3. Number of Leaves Made by Seedlings by Planting Media.

Number of Leaves Made by Seedlings by Planting Media

Planting medium:	Mean ± Std. Deviation	N	Range	Median
Perlite	1.83 ± 1.26	3	.50 - 3.00	2.00
Sphagnum Peat	2.32 ± 1.72	11	.20 - 5.00	2.00
Sand	0.00	0	0.00	0.00
Total	2.21 ± 1.60	14	.20 - 5.00	2.00

FIGURES

Figure 3 – 1. Seedlings of *L. tenue*.

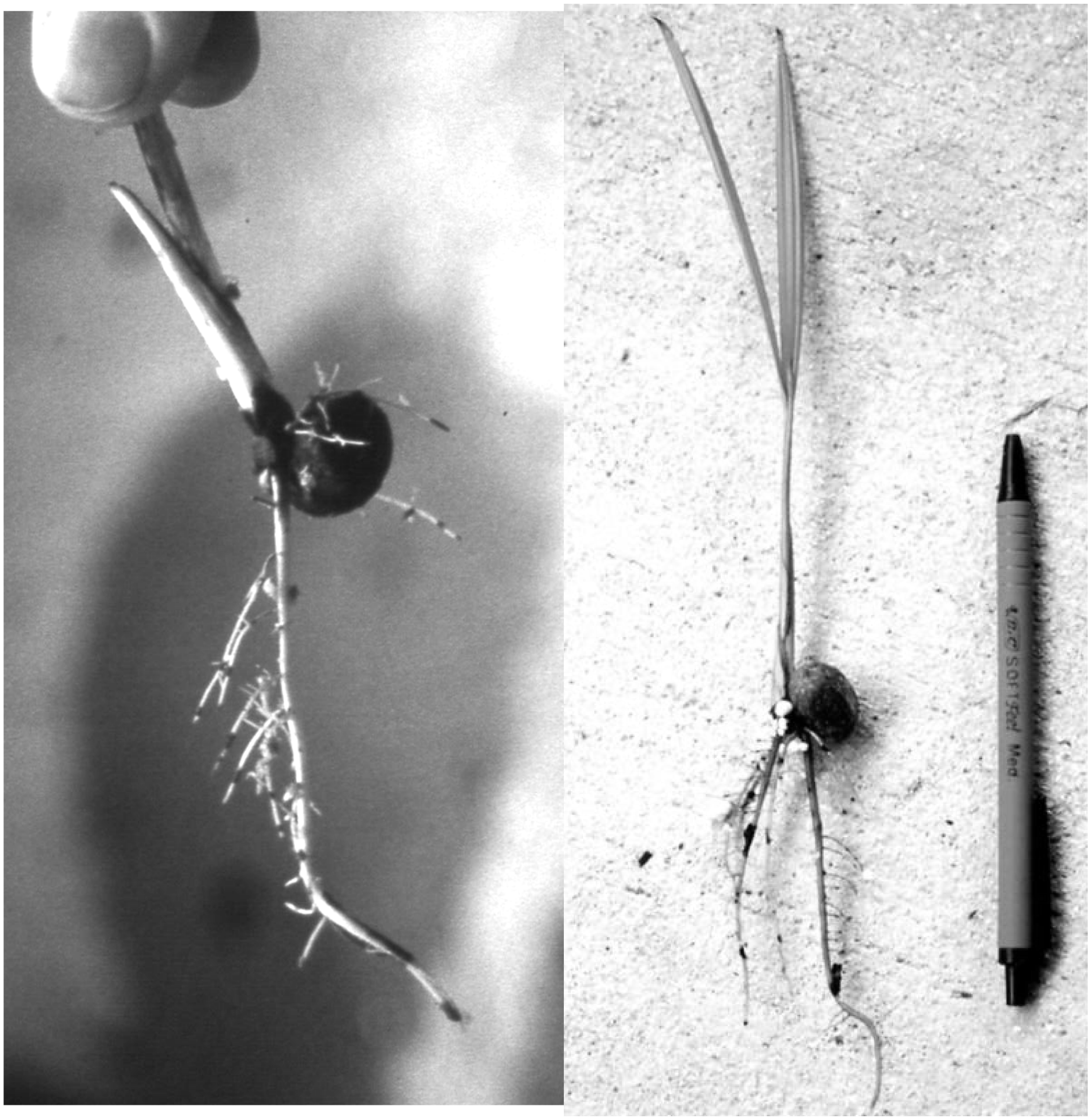


Figure 3 – 2. Seeds and One Seedling in Perlite Medium.

Figure 3 – 3. Seedlings Planted in Pro-Mix BX Medium.

Figure 3 – 4. Irapai Seed Germination Results for Combined Planting Media.

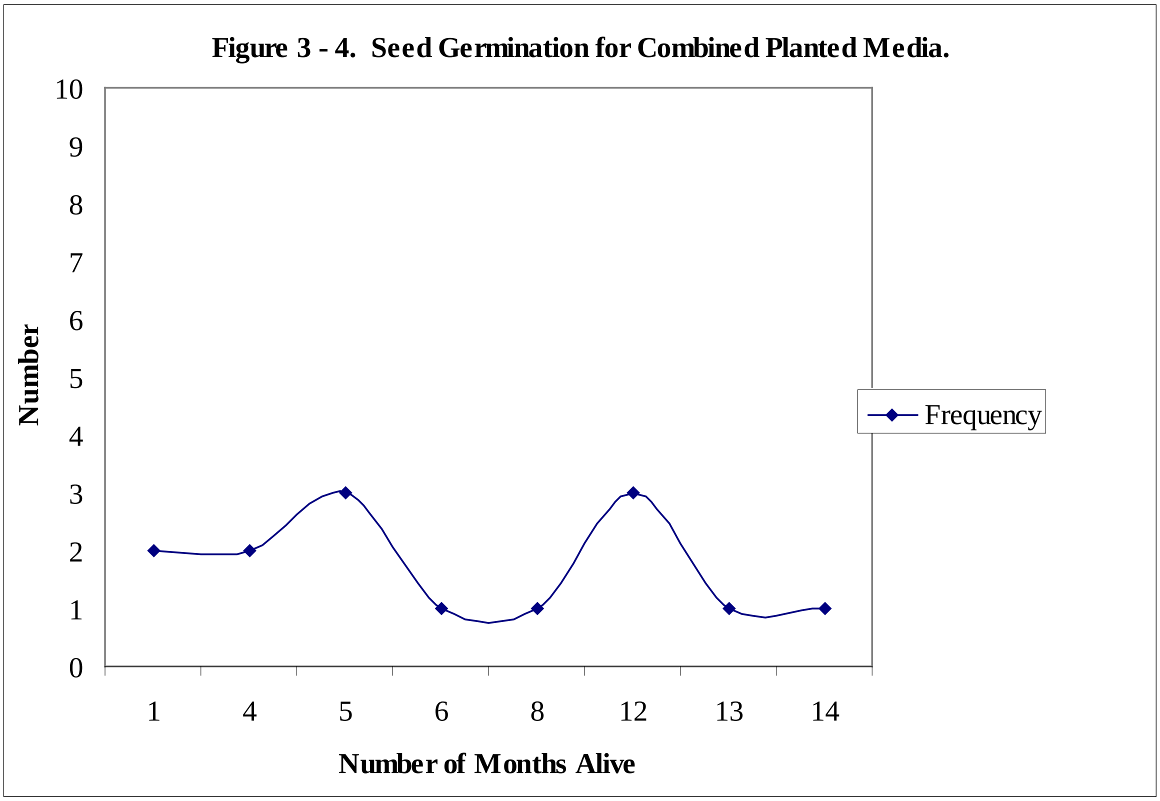
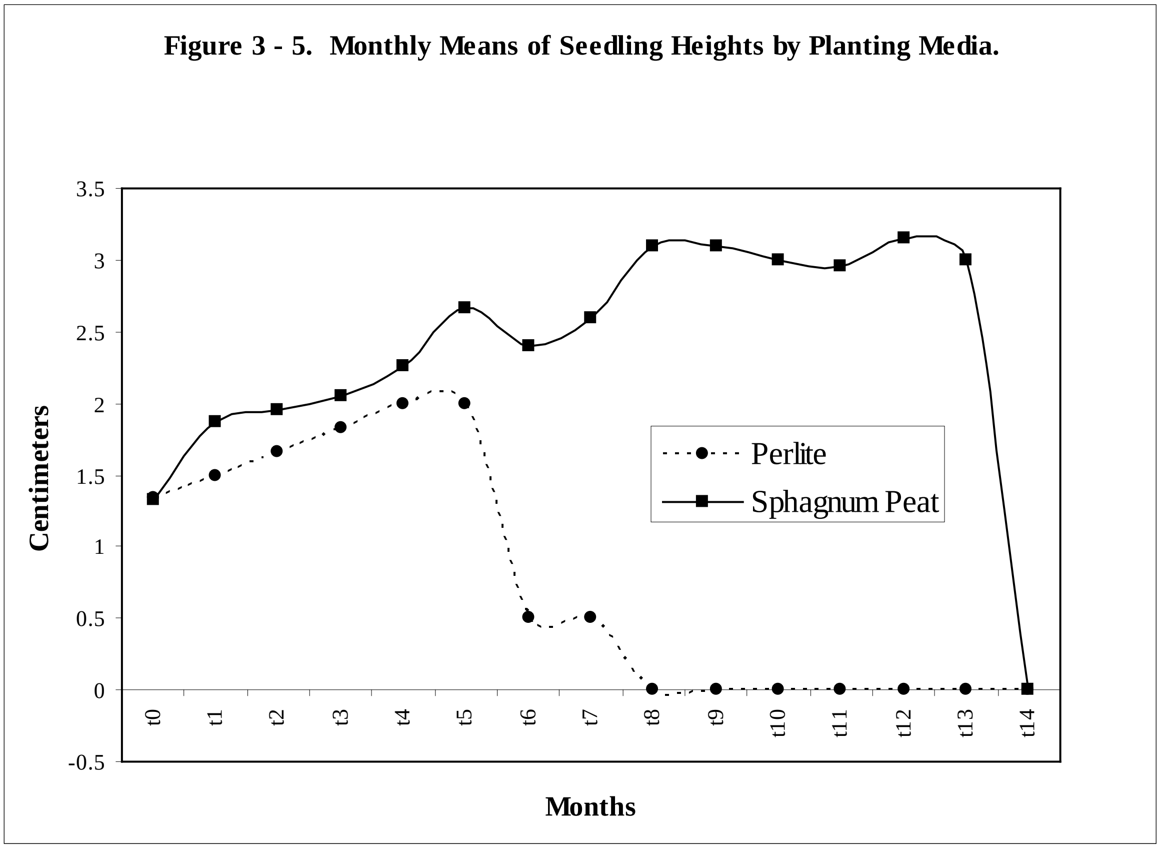
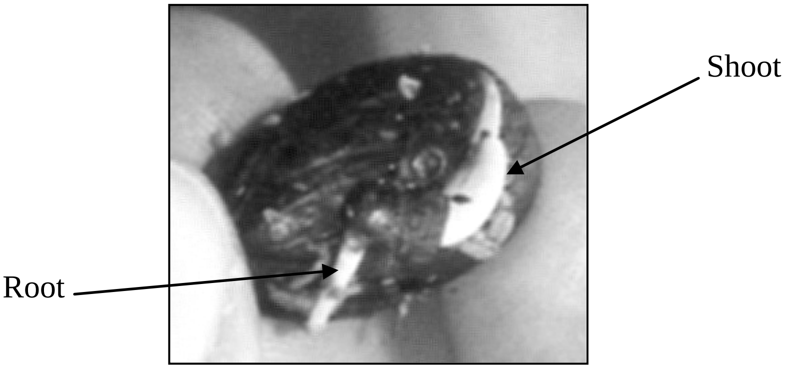


Figure 3 – 5. Monthly Means of Seedling Height by Planting Media.



Note: Stem height measured from soil level to point where newest leaf separates from stem.

Figure 3 – 6. Germinated Seed of *L. tenue*.



Note: Example of seed that germinated to a maximum height of 0.1 cm then died.

Figure 3 – 7. Maximum Monthly Seedling Leaf Production – Combined Planting Media.

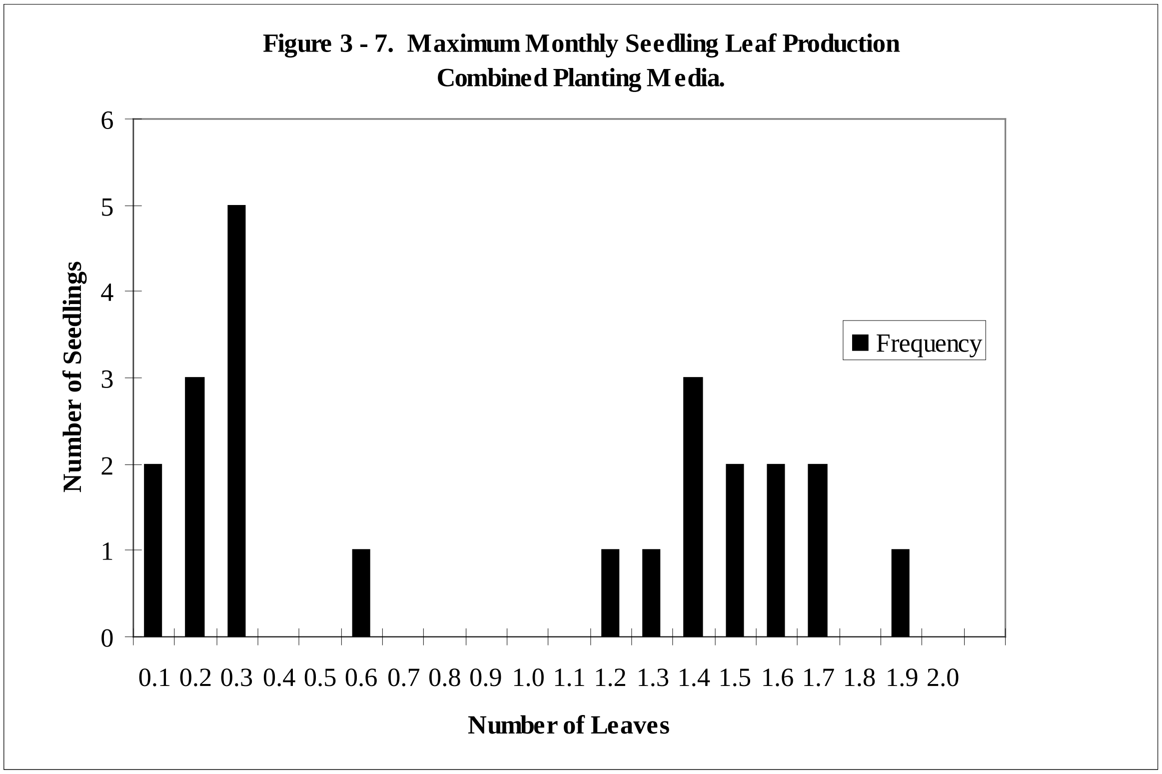


Figure 3 – 8. Average Monthly Seedling Leaf Production – Combined Planting Media.

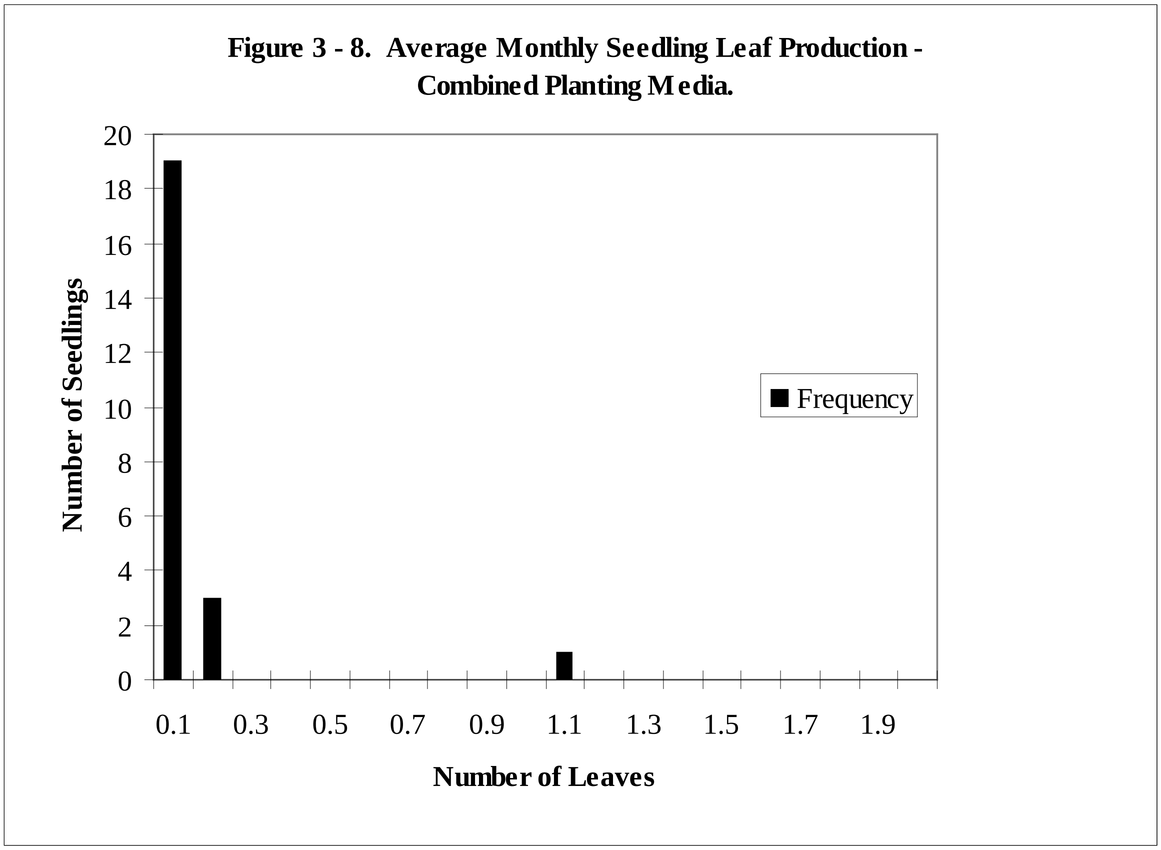


Figure 3 - 9. Correlation of Irapai Seedling Survival and Number of Leaves.

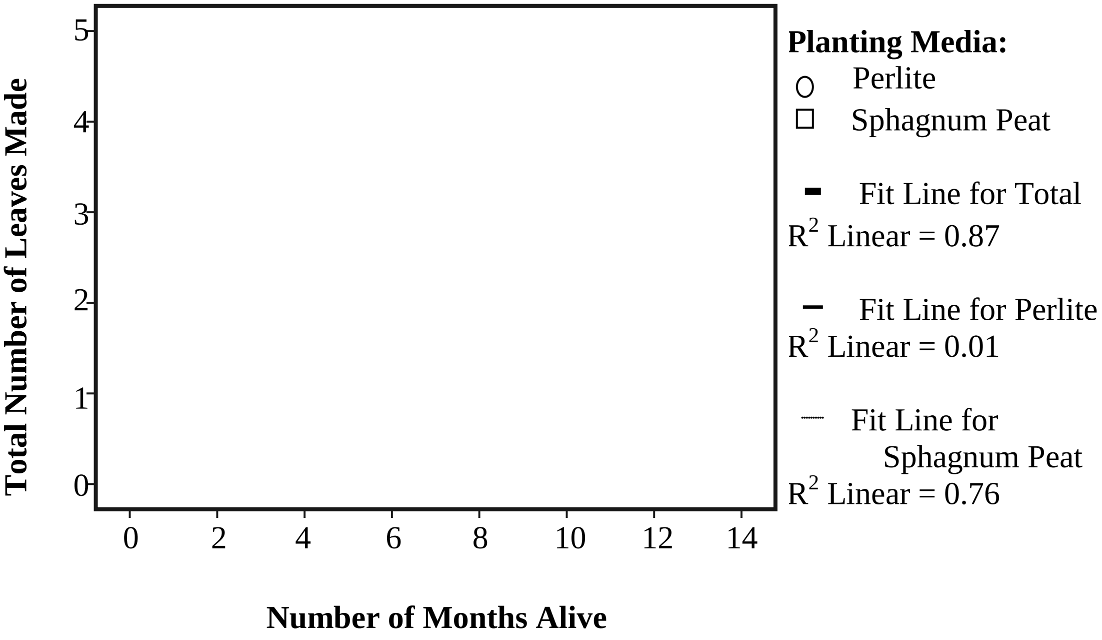
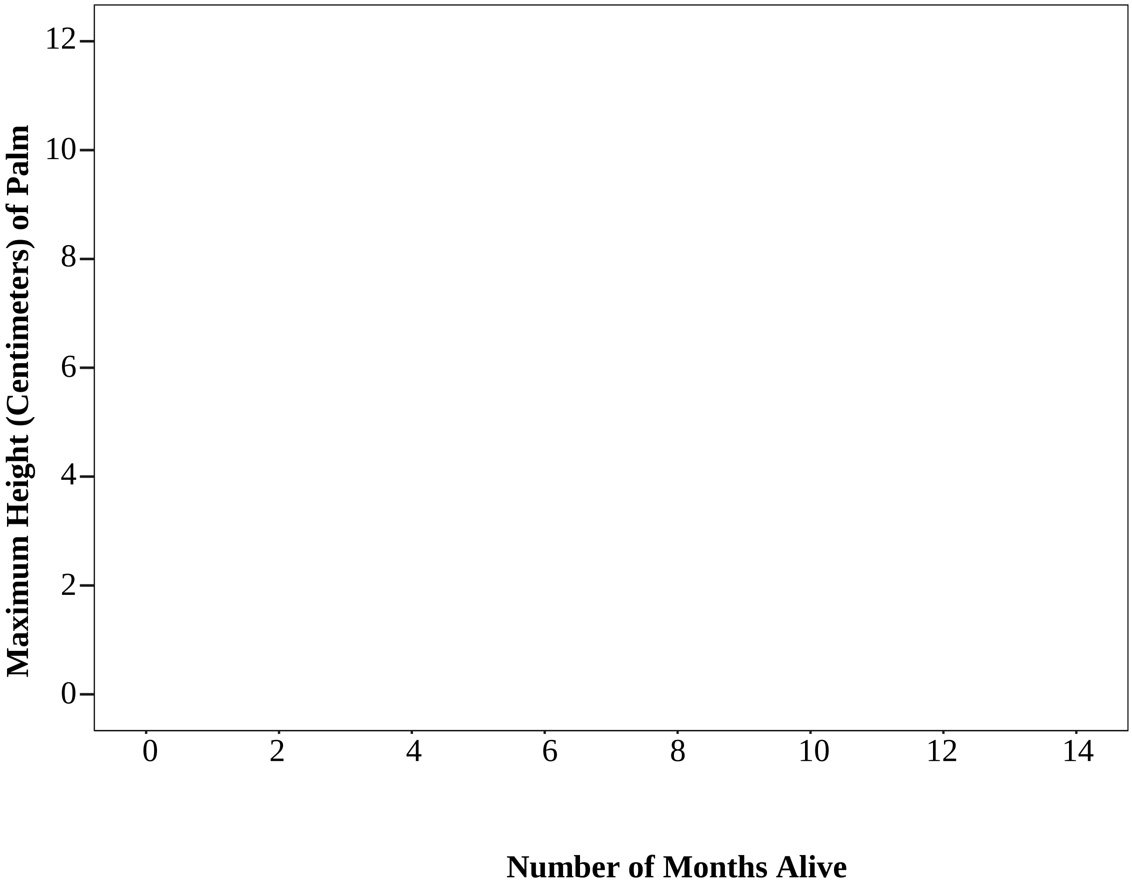


Figure 3 - 10. Maximum Height of Seedlings by Survival – Combined Planting Media.



LITERATURE CITED

Abrahamson, W. G. and J. Layne. 2002. Relation of Ramet Size to Acorn Production in Five Oak Species of Xeric Upland Habitats in South-Central Florida. American Journal of Botany 89(1): 124-131.

Balick, M. J. 1987. Regeneration Population Dynamics and Dissemination of a Palm from French Guyana *Jessenia bataua* ssp. *oligocarpa*. Bulletin du Museum National d'Histoire Naturelle Section B Adansonia Botanique Phytochimie, 9(3):317-336.

Balick, M. J. 1986. The Palm - Tree of Life: Biology, Utilization and Conservation. Advances in Economic Botany, Vol. 6:282.

Balick, M. J. 1984. Ethnobotany of Palms in the Neotropics. Advances in Economic Botany 1:9-23.

Bennett, B. C. 2002. Forest Products and Traditional Peoples: Economic, Biological, and Cultural Considerations. Natural Resources Forum 26(2002):293–301.

Bodley, J. H. and F. Benson. 1979. Cultural Ecology of Amazonian Palms. Reports of Investigations, NO. 56, Laboratory of Anthropology. Pullman, WA: Washington State University.

Boom, B. M. 1987. Ethnobotany of the Chácobo Indians, Beni, Bolivia. Advances in Economic Botany 4:1-68.

Borgtoft Pederson, H. and H. Balslev. 1990. Ecuadorean Palms for Agroforoesry. AAU Reports 23.

Broschat, T. K. and H. Donselman. 1986. Factors Affecting Storage and Germination of *Chrysalidocarpus lutescens* Seeds. Journal of American Society Horticultural Science 111: 872-877.

Callaghan, T. V. 1984. Growth and Translocation in a Clonal Southern Hemisphere Sedge, *Uncinia meridensis*. Ecology 72:529-546.

Carpenter, W. J. 1989. Influence of Temperature on Germination of *Sabal causiarum* seed. Principes 33:191-194.

Carpenter, W. J. 1987. Temperature and Imbibition Effects on Seed Germination of *Sabal palmetto* and *Serenoa repens*. HortScience 22:660.

Cook, R. E. 1979. Asexual Reproduction: A Further Consideration. American Naturalist, 113:769-772.

Donselman, H. 1982. Palm Seed Germination Studies. Proceedings of Florida State Horticultural Society 95:256-257.

Doughty, S. C., E. O'Rourke, E. Barrios and R. Mowers. 1986. Germination Induction of Pygmy Date Palm Seed. Principes 30:85-87.

Fragoso, J. 1997. Tapir-Generated Seed Shadows: Scale-Dependent Patchiness in the Amazon Rain Forest. Ecology 85(4):519-529.

Hubbuch, C. 1997. Greenhouse Seed Germination Records and Personal Communications, Fairchild Tropical Garden, Miami Florida.

Henderson, A. H. 1995. The Palms of the Amazon. Oxford University Press, New York, NY.

Instituto Nacional de Estadística y Informática (INEI). 2004a. Estimación de Población en Regiones de la Amazonía Peruana (1995-2000) as accessed at ://www.siamazonia.org.pe/Bases%20de%20datos/Estadísticas/Población.htm on 23 July 2005.

Instituto Nacional de Estadística y Informática (INEI). 2004b. 2.15.2 Loreto: Principales Indicadores Socioeconómicos, 2003-2004. Oficinas Sectoriales de Estadística as accessed at http:// .inei.gob.pe/ on 28 May 2005.

Instituto Nacional de Estadistica y Informatica (INEI). 2001. Instituto de Investigacion de la Escuela Profesional de Turismo y Hoteleria de la Universidad San Martin de Porres – OMT as accessed at http:// .inei.gob.pe/ on 23 July 2005.

Instituto Nacional de Estadistica y Informatica (INEI). 1993. IX Censo de Poblacion y IV de Vivienda. Directorio de los Centros Poblados, Banco de Informatica Distrital as accessed at http:// .inei.gob.pe/ on 2 April 2005.

Janzen, D. H. 1977. What are Dandelions and Aphids? American Naturalist, 111:586-859.

Kahn, F. 1988. Ecology of Economically Important Palms in Peruvian Amazon. Advances in Economic Botany 6:42-49.

Kahn, F. K. and K. Mejia. 1991. The Palm Communities of Two "Terra Firme" Forests in Peruvian Amazonia. Principes, 35(1):22-26.

Kalman, M. 2005. Seed of an Extinct Date Palm Sprouts after 2,000 Years. San Francisco Chronicle. Sunday, June 12:A-1.

MacBride, J. F. 1960. Flora of Peru. Part I of 2. Botanical Series, Field Museum of Natural History, XIII: 1(of 2), pub. 895. Chicago, IL.

Meerow, A. W. 2004. Palm Seed Germination. Bulletin 274, Florida Cooperative Extension Service, IFAS; University of Florida, Gainesville, Florida. June 10.

Morey Alejo, H. and G. Sotil García. 2000. Panorama Histórico de la Amazonía Peruana: Una visión desde la Amazonía. Imprenta Gráfica Amazonas, Iquitos, Peru. 522p.

Moyroud, R. 2000. Seed Planting Recommendations, Palm Growing and Seed Germination Information through Personal Communications. Professional Nursery Owner and Landscaper. Mesozoic Landscapes, Inc. Lake Worth Florida.

Myers, R. L. 1981. The Ecology of Low-Diversity Palm Swamps near Tortuguero, Costa Rica. University of Florida, Ph.D. dissertation.

Nagao, M.A., K. Kanegawa and W. Sakai. 1980. Accelerating Palm Seed Germination with Gibberellic Acid, Scarification and Bottom Heat. HortScience 15:200-201.

Nagao, M. A. and W. Sakai. 1979. Effect of Growth Regulators on Seed Germination of *Archontophoenix alexandrae*. HortScience 14:182-183.

Odetola, J. A. 1987. Studies on Seed Dormancy, Viability, and Germination in Ornamental Palms. Principes 31:24-30.

Olmos, F., R. Pardini, R. Boulhosa, R. Burgi and C. Morsello. 1999. Do Tapirs Steal Food from Palm Seed Predators or Give Them a Lift? Biotropica 31(2)June:375-379.

Padoch, C. 1988. Aguaje (*Mauritia flexuosa* L.f.) in the Economy of Iquitos, Peru. Advances in Economic Botany 6:214-224.

Pinheiro, C. U. B. 2001. Germination Strategies in Palms: the case of *Schippia concolor* Burret in Belize. Brittonia 53(4):519-527.

Premier Horticulture. 2002. Pro-Mix BX Technical data sheet as accessed at http://.premierhort.com on 15 June 2002.

Solano, W. 2000. Irapai in Agroforestry. Report submitted to Lima office of C.A.R.E. Agroforestry engineer, C.A.R.E. Perú.

Tomlinson, P. B. 1990. The Structural Biology of Palms. Oxford University Press, New York, NY. 477p.

Uhl, N. W. and J. Dransfield. 1987. Genera Palmarum: A Classification of Palms Based on the Work of Harold E. Moore, Jr. Allen Press. p1-69.

United Nations. 2000. Map of Peru. Department of Peacekeeping Operations, Cartographic Section. Map Number 3838, May.

Warren, L. A. 1992. *Euterpe* Palms in Northern Brazil: Market Structure and Socioeconomic Implications for Sustainable Management. Master's thesis, Department of Geography, University of Florida.

Zona, S. and K. Maidman. 2001. Growth Rates of Palms in Fairchild Tropical Garden. Palms, 45(3):151-154.

CHAPTER IV.

STEM DEMOGRAPHY OF IRAPAI (*LEPIDOCARYUM TENUE*): PERUVIAN AMAZON SUBSISTENCE AND COMMERCIAL CONSTRUCTION MATERIAL

ABSTRACT

Lepidocaryum tenue Mart. (Arecaceae), known locally as irapai, is a small, clonal understory palm found in Amazonian terra firme forests. In recent years, riverside dwelling peoples called ribereños, have collected increasing numbers of leaves for subsistence use and commercial roof construction in the Iquitos region of Peru. Cultivation attempts have been unsuccessful. Effects of thatch harvest on irapai populations are unknown.

To assess effects of harvesting, I collected data on survival, growth, leaf production, reproduction, and harvest rates from five irapai populations that included harvested and non-harvested stems. Annual palm mortality was three percent, and occurred disproportionately in small size classes. Small palms (<50 cm) grew more in height. Unharvested palms grew less than harvested palms. Large palms ($\geq$50 cm) produced more leaves and were more likely to reproduce than small palms. On average ribereños harvested stems taller than 50 cm more frequently than small ones. Current levels of irapai harvest appear to be sustainable.

INTRODUCTION

Lepidocaryum tenue Mart. (Arecaceae), known locally as irapai, is a small, clonal understory palm harvested for thatch in Amazonian terra firme forests. Most people working in the irapai thatch industry are ribereños - groups of detribalized indigenous peoples living along watercourses in the Amazon. Other palms that grow sympatically with irapai can be used for thatch, but locals prefer irapai because of its abundance. A roof made of irapai is less expensive than one of metal, and with an average lifespan of five to six years, it outlasts a roof made of most other local palm species (Kahn and Mejia 1991). Leaves are collected from wild stems in most areas proximal to markets, and some locals weed, thin overhead canopy and competitors, and pile detritus around trunk bases to fertilize and / or enhance some large stands, called irapayales.

Approximately 5,200 fronds are required to construct a roof for an average sized house (chapter two), which translates into an equivalent of nearly two hectares of irapayales (Kahn and Mejia 1991). Because irapai has a patchy distribution, however, this could require a forest area at least two to three times this size. Population growth (INEI 2004a, 2005, and Morey and Sotíl 2000) and tourism (INEI 2001 and 2004b) in the Peruvian Amazon have increased demand for palm leaves throughout the region. Irapai has been abundant and easy to collect until recently. Harvesting of irapayales has become more intensive and extensive, and cultivation attempts have not been successful. In some locales, it is disappearing due to predatory harvesting practices (*personal communication*, K. Mejia).

Harvesters have an implicit understanding of harvest techniques that are considered acceptable. They select leaves based on a combination of petiole length and leaf size, and leave varying numbers of leaves per stem. Deviation from accepted practices can increase irapai mortality. Because cutting the stem facilitates collection and transport, harvesters without land access rights fell irapai stems instead of collecting individual leaves.

Data on wild harvested non-timber forest products (NTFP) has generated concern about over-harvesting (Vasquez and Gentry 1989, Clay 1997, Cunningham 2001, Ticktin 2004). For NTFP harvest to be sustainable, rate of extraction must not threaten the harvested species nor cause ecosystem processes and functions to deteriorate (O’Hara 1999, Lesica and Young 2005). For this study, demographic sustainability is defined as extractive activities that do not exceed the capacity of the resource to replace itself. The species must survive the loss of biomass, nutrients, harvest process, and the methods and intensity of collection (e.g., selective frond removal versus cutting the main trunk to harvest fruit).

Matrix models summarize patterns of survival, growth, and reproduction of a population, providing results that can help managers evaluate the long-term impact of current irapai harvesting practices (e.g., Caswell 1989, Horvitz and Schemske 1995, Olmstead and Alvarez 1995, Stewart 2001, Tiktin 2004, Koop and Horvitz 2005). One useful result, the asymptotic growth rate or lambda, can be used to evaluate sustainable harvest (Pinard 1993). Demographic profiles are available for some clonal plant species, although a number are derived from short-term studies (Jackson et al. 1985, Alpert et al. 2003, Wikberg and Svensson 2003, Douhovnikoff et al. 2004, Menges and Root 2004, Roiloa and Retuerto 2005, Palleiro et al. 2006). This study compares demography of unharvested and harvested irapai populations outside of Iquitos, Peru, to determine harvest sustainability. My objectives were to examine the effects of harvesting on population dynamics of this long-lived clonal palm. My primary question was whether demographic parameters of harvested populations differed from unharvested populations. From 1997 – 2000 I studied five irapai populations within 70 km or two days travel of

Iquitos, Peru, which had varying land tenure patterns, use, and management to determine (1) survival and growth, (2) leaf production, and (3) sexual and asexual reproduction rates. Sites included an indigenous reserve, commercial ecotourism preserve, community reserve, communal reserve and a research preserve. (See Appendix 1 for site-specific information.)

Study Species:

Irapai is a dioecious palm found on better-drained terra firme or seasonally inundated ferralitic, fluvial and loamy soils in western and central Amazonia (Kahn and Mejia 1991, Vormisto 2002). Mature ramets range from 0.8 to 6.0 meters in height. Their growth is more vigorous along edges of light gaps. Fruiting palms occurs most of the year, but fruiting peaks during March and September. Many seeds remain dormant beyond a period of one year (>1 yr.) creating a long-lived soil seed bank (see chapter 3). The leaf's palmate, uniformly divided four segments and long, thin petiole are well suited for weaving thatch tiles (crisnejas) used in roof construction. Its waxy cuticle sheds water well and resists decay (see chapter two).

Lepidocaryum tenue can be the most abundant species in the understory, often found in near monospecific densities, although stem concentration varies considerably. Based on estimates from the villages of Sucusari, Mishana, and Tamshiyacu-Tahuayo near Iquitos, irapayale stands (stems growing within two meters of each other) cover an average area greater than a third of a hectare, or 50 meters by 75 meters (3,750 m^2), in old growth forest. Previous research reported irapayale stem densities ranged from 0.13 stems per square meter on fluvial to loamy soils (riverine forests) to 0.25 and 0.35 stems per square meter in terra firme forests on ferralitic to loamy soils (Marmillod 1982, Mejia and Kahn 1996). Distribution of irapayales is patchy. Despite covering large areas, no obvious soil, light, canopy species, or understory differences explain the presence or absence of an irapayale.

Study Areas:

The city of Iquitos (3° 45’ S; 73° 15’ W), elevation of 125 meters, is situated along the banks of the Amazon River and lies within the Peruvian Department of Loreto (INEI 2005). Climate is humid tropical, classified as Af in the Köppen Climate Classification System (Critchfield 1983), with an average annual rainfall of 2900 mm and average temperature of 26°C (Weatherbase 2005). Iquitos has a population greater than 500,000 people, and is the regional commercial and government center (Vasquez 1993, INEI 2005).

METHODS

Sampling:

Study sites were selected to include those where locals were known by biologists and ecotourism entrepreneurs to participate in Iquitos irapai markets (including *personal communications*, P. Jenson and K. Mejia). Community members at all studied sites collected irapai leaves and engaged in ecotourism or tourism related construction work in addition to subsistence activities. After obtaining consent from local communities, I established 27, 5 x 5 m^2 plots, an appropriate size for plants of irapai’s stature, at five sites (Figure 4 – 1). Determined by visual inspection, sites included both harvested and unharvested palms. Each site had at least one irapayale greater than 0.25 ha in size. At each site, I interviewed two or more community members in Spanish regarding harvesting techniques and management practices. I established plots within a two-hour hike of each community to match commercial and subsistence harvest routines described during interviews, and recorded GPS coordinates. Plots per site varied between four and seven (Table 4 – 1). Plots were located such that they typified irapayales of that site (cf., Pinard 1993, Olmstead and Alvarez 1995, Anderson 1998). Plots were a minimum of three meters from an edge of an irapayale. Where locals reported sections of an irapayale had different harvesting levels, at least one plot was placed in each harvesting zone. After establishing a random point for the southeast corner, I aligned plot boundaries with cardinal directions using a hand held compass, meter tape, and collapsible meter pole, and I marked plot corners with metal stakes. I recorded canopy coverage and average leaf widths in 23 plots to see if there was a correlation between palm growth and available light. Density of forest canopy above each plot was measured with a Model-A spherical densitometer by taking the average of four readings per plot, measured from each corner facing the opposite corner. Leaf widths from five representative palms in each plot were measured and averaged.

Because it was not possible to distinguish irapai ramets from genets, I modeled population dynamics of stems that may or may not be genetically related and physically connected under ground. I use the terms ‘individual’ and ‘palm’ to refer to each visible stem. Each palm was marked at ground level with a round, metal, numbered tag on 18-gauge aluminum wire around its stem. Palms were marked discretely so that collectors would consider those within plots equally for frond harvest. During discussions with locals at each site, all were encouraged to use irapai palms in and around monitoring plots as they would normally. I recorded data from tagged stems and subsequent new recruits on (1) survival and growth, (2) leaf production, and (3) reproduction. From each palm, I recorded stem diameter, whether a spear or new emerging leaf was present, and if so at what stage of development. Once a spear began to expand laterally it was considered a leaf. I counted live and dead leaves on each stem. During subsequent censuses, I recorded the number of new leaves each stem produced since last data collection. Each newest leaf was marked with an inconspicuous cable tie or thin-gauge wire, depending on field season, to follow leaf cohorts (Bernal 1998). I also recorded leaf scars and measured distance between them on stems to help determine height changes where possible. Newest expanded leaves were recensused a maximum of 24 months later.

To estimate reproduction, each census I recorded whether a palm was reproductive and if so, its mode (sexual or asexual). I counted inflorescences and fruits per stem to estimate fecundity each year (Table 4 – 1). I measured asexual reproduction, or propagation, by visibly identifying vegetative shoots at the base of each palm and estimating each size class contribution each year. I excluded subterranean shoots not visible without excavation.

Analyses:

I monitored three cohorts of individuals, each consisting of that year’s recruits, for a minimum of one year. To elucidate differences in cohort survival by site and size class I employed cross tabulations, the combinations of two or more frequency tables. Chi-square tests were performed on size class by site for each year to determine differences. To understand the growth of mature stems better, analyses of only unharvested palms were conducted using two-way ANOVAs by size class and site. These included only stems in existence the previous census (seedlings excluded). For significant F-tests ($p < 0.05$), Bonferroni corrected post hoc tests were applied to ranked mean growths. For interpretation, however, the untransformed mean growths (M) were reported. Untransformed mean growth for harvested palms is included for comparison although results do not take into account reduction in height from harvest.

Two-way ANOVAs also were conducted on growth by site and harvest on all stems together. Two-way ANOVAs were conducted on growth of unharvested palms by site and size class. To evaluate leaf production I analyzed differences in numbers of new leaves made by site, harvest, and size class, but cell sizes were too small to use three way ANOVAs. Instead two separate two-way ANOVAs were performed. To understand new frond production of mature stems better, initial analyses were conducted on only unharvested stems followed for at least one year, using two-way ANOVAs on the rank transformed numbers of new leaves by size class from the previous year and by site. A second two-way ANOVA was carried out by site and harvest without considering previous year size class for stems monitored for at least one year. For significant F-tests ($p < 0.05$), Bonferroni post hoc tests were applied to mean ranks of numbers of new leaves produced. For interpretation, however, the untransformed mean numbers of new leaves (M) were reported.

I used two-way ANOVAs on new leaves produced by site and harvest on all palms to investigate whether any observable growth response occurred following leaf or stem harvest, particularly to a recent event occurring within the past one to twelve months (same year harvest). To determine whether a harvested stem produced more leaves than an unharvested one as locally claimed, a ranked ANOVA was performed on the transformed number of new leaves made by harvest and site for each year on stems monitored for at least one year.

To determine whether harvest affected reproduction, reproductive potential was analyzed by harvest status for each site and year separately. Differing from the first analysis, a second cross tabulation was conducted to examine differences between unharvested and harvested stems of each site. I also evaluated reproductive potential by size class alone for each year, since the number of reproductive stems was low in all years. Reproductive potential was analyzed using the previous year's size class to be consistent with analyses conducted on growth and new fronds produced, which was appropriate given the presumed slow growth of irapai. Chi square tabulations allowed me to consider size class excluding both site and harvest. I developed population projection matrices by cross-classifying stages t by $t+1$ across four years. Each plot contained unharvested stems that comprised a non-harvested control group (Hartshorn 1975, McDonald and Caswell 1993). With these, I was able to estimate stem abundance and density per unit area (hectare) leaf production, stage-specific growth, and reproduction and survival rates.

Harvest – As a Factor for Analysis:

Because harvest was the result of resource suitability and harvester selection and was not an applied treatment, it was not included as an independent variable in analyses. I controlled for harvest by including it as either a variable or co-factor in analyses on all available stems to account for its effects on variables of interest such as growth and reproduction. Thus, harvest was evaluated first to see if differences existed by size class and site separately.

Population Projection Matrices:

Projection matrices with elements a_{ij} summarize life transitions from one point in time to the next, and include survival, growth, reproduction and recruitment (Caswell 1989, Koop and Horvitz 2005). Using the variables described above, I created a stage-based projection matrix model of population dynamics (Horvitz and Schemske 1995). I defined stages based on qualitative and quantitative biological data, combining stem height and reproductive state, which maximized within-stage sample size (Bernal 1998). To develop classification criteria for matrix stages, I analyzed size class and reproductive changes from year to year to determine whether reproduction and size were related. Transition years were 1997-1998 (T0), 1998-1999 (T1), and 1999-2000 (T2). Pooled matrix data provided a better demographic summary than averaging separate matrices because in the latter rare transitions are weighted the same as common transitions, affecting matrix values. Parameters for matrix construction included (P_t), the probability that a palm in size i survives and remains in size i; (G_t), the probability that a palm in size i grows into size i+1; (R_t), the probability that a palm survives but regresses to size i-1; (F_1), sexual reproductive output – fecundity; and (F_2), asexual reproductive output. A stage was composed of individuals just reaching the stage and those persisting in the stage since last year or longer. The number in the top left corner of each matrix represented seed dormancy, and other entries in the top row held contributions from stems at time t to the reproductive output of the population (seeds) at time $t + 1$. Vegetative propagation contribution was determined by propagules contributed by size class and year and incorporated into its size class specific stage.

To elucidate population dynamics I used the time-specific linear model, $n_{(t+1)} = \mathbf{A}n_t$, where vector, n_t, represented irapai stems by their respective stages at time, t (Table 4 – 2). Matrix models assumed density independence. Vector $n_{(t+1)}$ was this same population at the next time interval, and **A** was the seven by seven matrix depicting stages that individual stems became or contributed to by the next time period. Repeatedly multiplying the transition matrix column vector and current population numbers eventually yields the dominant eigenvalue, or λ, the asymptotic population growth rate. Stage-classified transition matrices were developed for each of the pooled, harvested, or unharvested populations by year (9 = 3 populations x 3 years), representing an annual cycle from July to July (Koop and Horvitz 2005). See Appendix 2 for procedures to generate full projection intervals. Projection matrices for harvested stems were compared against those for unharvested palms. Transition probabilities, reproductive and asexual contributions were calculated according to Horvitz and Schemske (1995). I calculated asymptotic population growth rate for each matrix by determining its dominant eigenvalue, λ, using MATLAB 6.0 (MATLAB 2000). To identify 95% confidence intervals for λ to determine whether values significantly differed from 1.0, 30,000 bootstrapped projection matrices were created (Caswell 2001). This entailed randomly sampling palms with replacement in stages (Koop and Horvitz 2005). Stages incorporated seedling recruitment as well as vegetative reproduction. I determined transition probabilities, fecundity and recruitment as described earlier.

I evaluated effects of increased harvest and mortality on population growth rate by using MATLAB 6.0 computer simulations to determine tolerance levels on pooled data because theoretically harvest may affect all individuals in a clonal irapayale.

Simulations assumed that if lambda remained $\geq$ 1.0, population growth was stable and irapai harvest was sustainable (Peters 1994, Olmsted and Alvarez 1995). Since survival of all stages was high, I reduced each transition value in 10% increments, simulating changes in growth, survival and fecundity, and observed changes in λ. Furthermore, I determined stable stage distribution and reproductive values using MATLAB 6.0. Stable stage distribution (SSD) is the vector of proportional individual stages associated with lambda that remain constant with each successional matrix transition (Caswell 1989). The left eigenvector associated with the dominant eigenvalue is the stage-specific set of Reproductive Values (RV). Sensitivity and elasticity analyses were conducted to determine population growth (λ) sensitivity to changes in differences in transition matrix elements. Sensitivity analysis (Caswell 2000) investigates how small fixed-size changes in demographic parameters affect lambda. Each matrix element of survival, growth, and fecundity represented the sensitivity of lambda to the associated transition probability for pooled, unharvested and harvested palms. Sensitivity data usefulness is limited, however, because scale affects it, and it is unable to distinguish between observable transition probabilities and those that are only theoretical. Elasticity analysis, however, breaks down lambda to reveal the contributions of each life cycle transition (Pinard 1993, de Kroon et al. 2000, Guedje et al. 2003), quantifying population growth rate changes that respond to proportional changes in matrix coefficients (a_{ij}), $e_{ij} = (s_{ij} * a_{ij}) / \lambda$. Elasticity analysis evaluates the dependence of lambda (population growth) on proportional changes in survival, growth and reproduction at different life cycle stages (Guedje et al. 2003). Lambda is more sensitive to changes in parameters that have higher elasticities. Since elasticities sum to one making demographic comparisons possible, matrix elements also were summed to determine relative importance of growth, survival, stasis and reproduction (Silvertown et al. 1993).

RESULTS

From 1997 to 2000, the pooled number of sampled stems ranged from 568 to 638 with a grand mean across sites and years of 618 (Table 4 – 1). The number of stems sampled per site ranged from 78 to 194. Mean stem density was highest at site five (1.3 palms per m^2), although site four was similar (1.2 palms per m^2). Plot stem density ranged from 0.40 stems per m^2 in site two to 2.04 stems per m^2 in site five (Table 4 – 3), and extrapolated to a range of 7,920 stems ha^{-1} to 12,700 stems ha^{-1} (see chapter 2), keeping in mind that irapai's patchy distribution means a forest area greater than this is needed for collection of sufficient leaves. Although irapayales are not found as monocultures, extrapolations were made to be consistent with previous study results. This compared to a range of 719 (crown harvested) to 1132 (unharvested) stems ha^{-1} for *Geonoma deversa* (Flores and Ashton 2000), another local palm used for thatch. Mean growth rates were similar with small increases over time (Figure 4 – 3). Mean and median palm heights ranged from 65.0 – 100.5 and 34.5 – 80.7 cm respectively. The tallest stem was 469 cm in site five during July 1997. Although overall population size fluctuated, generally the population increased over the study period. Average plot canopy coverage varied widely, ranging from 7.3% to 94.4%, (Table 4 – 4). Over three years, I recorded dramatic changes in overhead canopy coverage resulting from treefalls and small clearings, as well as impressive canopy regrowth. Palm leaf widths of individuals taller than 50 cm ranged from 66 cm to 112 cm with a mean of 85 cm.

Harvesters considered a combination of petiole length and minimum leaf width in frond selection for harvest. If its petiole was at least 65 cm long and its blade a minimum 85 cm wide, most collectors considered a leaf of irapai harvestable.

Because there were no significant differences in stem growth (Table 4 – 5) and leaf production (Table 4 - 6) among plots, individual plot data within sites were combined and analyzed. Subsequently, I found few significant site-specific results. For this reason, I then conducted analyses on all stems representing a single population and analyses on all stems separated into two populations, one consisting of harvested palms and the other of unharvested palms. The smallest mean heights (cm) among sites occurred in 1999 in site five (M = 65.0), and the tallest mean heights occurred in 2000 in site four (M = 100.5). Because medians were in the 35 – 81 cm range while means ranged from 65 – 101 cm, few tall palms were observed indicating skewness, or non-normal distribution of heights. I reviewed frequency distributions for changes or breaks. Thus, small and large size classes were delimited. These groupings of individuals allowed later comparative analyses, and representation of most regularly harvested stems by the large size class. Small size class ranged from 0.1 cm to < 50 cm, included seedlings and juveniles, and numbers of studied individuals ranged from 291 to 312 across years. Large size class included those palms $\geq$ 50 cm, hypothesized more likely to be harvested for thatch, and contained from 256 to 377 studied individuals across surveyed years. Mean heights showed that on average taller individuals were harvested.

Size Classes and Stages:

Chi-square tests performed on size class by site for each year showed for all years there were significant differences in size class distributions by site, 1997 χ^2 (4, N = 568) =

15.67, $p < 0.004$; 1998 χ^2 (4, N = 670) = 9.78, $p < 0.044$; 1999 χ^2 (4, N = 657) = 36.06, p < 0.001; 2000 χ^2 (4, N = 668) = 82.72, $p < 0.001$; respectively. In 1997, 62% of the palms at site two were large compared to only 33% of the palms at site five. In 1998, a similar pattern was observed with site two having 52% large palms while site five had only 32%. In 1999 and 2000, however, the pattern changed with site four having the greatest percentage of large palms compared to all other sites. In 1999, 67% of site four palms were large and in 2000, 83% were, while other sites had from 40% to 57%. These percentages included new recruits and harvested palms.

From classification criteria based on annual size class and reproductive changes, I defined seven matrix stages (Table 4 - 7). Asexual reproduction surpassed sexual reproduction in all years. Because of small sample size, I combined fruit production and asexual recruitment into an overall fecundity rate for statistical analyses. New recruits (seedlings and vegetative stems) were assigned to the nearest reproductive adult. For population projection matrices, both stages ‘size1reproclone’ and ‘size2reproclone’ contained contributions from stems at time *t* to the asexual reproductive output (vegetative propagation) at time $t + 1$ based on annual averaged contributions (see Table 4 – 8).

Survival:

Few palms died during this 36-month study: 21 in 1998, 35 more in 1999, and an additional 25 in 2000. Harvesting was one cause of both small and large size class mortality. Survival of both size classes combined was 89%. The irapai population at site four had the highest annual palm survival (93%), although sites five and three were similar with 92% and 91%, respectively (Figure 4 – 5). Site one had the lowest population survival of 87%. Annual stem mortality rates per site were similar, averaging 3.23%, and occurred disproportionately in small size classes.

Small size class individuals represented 44% to 55% of the irapai population, and large size class palms made up from 45% to 56%. Small size class stems suffered higher mortality rates than large palms. Treefall was a cause of palm mortality, although survival from fallen branches or trees occurred. A decline in the number of leaves produced preceded mortality in very few palms. Of the 25 stems present in 1998 and recorded as dead in 2000, only one showed a decline in the number of leaves in the interim. This indicates death occurred quickly. Seed predation did not appear to be an important mortality factor for irapai (see chapter three).

Cohorts:

For this study there were three cohorts, consisting of those stems in existence for the first time for a given year. Crosstabs of cohort survival were evaluated by size class and by site. The 1997 cohort was the largest (n = 568), and fifty-five percent (55%) were in the small size class (< 50 cm). By 2000, ninety percent (90%) remained alive. New recruits from all sites comprised the 1998 cohort (n = 123). Seventy-six percent were in small size class. By the year 2000, 80% of cohort 1998 individuals survived. Fifty-four percent were in the small size class; 46% were large palms, indicating that small palms grew to become large palms. The 1999 cohort consisted of only 22 palms, and seventy-seven percent were in the small size class. In 2000, 91% of these palms survived, and twenty-three percent were in the small size class. There were 36 new palm recruits in 2000, 75% of which (n = 27) were small.

Because survival rates were high, ranging from 89.7% – 99.1%, chi-square tests performed on survival by site for each cohort by year were not sensitive enough to yield valid results for the 1997 cohort in 1998. For 1999 and 2000 results were not significant, $p < 0.28$; $p < 0.67$; respectively. Results showed a trend by site for low numbers of individual loss over the three-year monitoring period. For the 1998 and 1999 cohorts chi-square tests were not valid due to small cell sizes. Survival of individuals in the 1998 cohort displayed great variability among sites, ranging from 40% at site five to 93.8% at site one after two years. The 1999 cohort had only one year of monitoring at the end of which 91% survived. The 9% that died were all at site four.

Harvesting and Management Activities:

Numbers of palms that were harvested increased from 5% to 40% over the course of this study. A greater percentage of harvested palms were in the large size class, as compared to unharvested palms. Differences in percentages harvested by site were not uniform over the years. In 1997 site two had a greater percentage of palms harvested (23%) than sites one, three, four, and five (ranging from 0 - 7%), reflecting a recent ecotourism structure thatch replacement project. In 1998, fewer palms at site five (5%) were harvested than other sites (29 - 32%). In 1999 site four had a greater percentage of palms harvested (40%) than site five (5%). In 2000 site four had a greater percentage of palms harvested (57%) than sites one, two, and three (37 - 38%) which were all harvested to greater percentages than site five (17%). Site five had fewer than ten palms harvested in all years except for 2000 when 11 out of 20 were felled by treefalls rather than the machetes of harvesters. This was the smallest number harvested of any site and representative of a research preserve that experiences illegal harvesting and has no active-harvest studies. Chi-square tests by year of palms harvested at least once by site revealed differences, χ^2 (16, N = 749) = 163.51, $p < 0.001$, with site four having significantly more palms that were harvested one or more times than all other sites.

Since size class distribution differed by site, harvest was examined by size class as well as site using logistic regression. In 1998 and 2000 the main effect of site was not significant ($p > 0.05$), but in all three years the main effect of size class was ($p < 0.001$). In 1998, 66% of large palms were harvested compared to only 35% of small palms, and regardless of site, large palms were more than three times more likely to be harvested than small palms, Odds Ratio = 4.0, 95% C.I. (2.2 - 7.0). In 1999, 59% of large palms were harvested as were 41% of small ones. Large palms were more than four times more likely to be harvested than small ones, Odds Ratio = 4.1, 95% C.I. (2.4 - 7.2). In addition, the main effect of site was significant in 1999 ($p < 0.001$), with site four harvesting more large and small size class palms than other sites. In 2000, 71% of large palms were harvested while only 29% of small ones were. The odds of a large palm being harvested were more than four times greater than a small palm, Odds Ratio = 3.4, 95% C.I. (2.3 - 4.9).

Size class distribution of only harvested palms by site and year showed an annual increase. Four sites experienced an increase in numbers of harvested individuals over the three years regardless of site management type, and site five remained consistent with an increase in the final year. In 1998, 168 of 670 palms were harvested; in 1999, 181 palms harvested of 659; and in 2000, 261 of 668 were harvested. Management activities in irapayales differed more by level of intensity than type of activity. An important factor for irapayale management that differed by site was level of perceived benefit because of type of land ownership. Table 4 – 9 presents ownership classification, management activities, and frequency data. Site four had the highest level of personally assigned responsibility for forest resource care (by hectare), and also had the highest level of activity intensity and frequency. This may account for high levels of growth and leaf production.

Growth:

Growth (cm) was not normally distributed and exhibited much variability, so rank transforms of palm growth were analyzed by site. Possible control variables included harvest and size class, but too few harvested small palms were available for analysis in all years in several sites so three-way ANOVAs could not be performed. Size class and harvest status were related, however, since taller palms were more likely to be harvested in three of the studied years (1998 - 2000). Thus, same year harvest status (whether harvest activity occurred within the previous one to twelve months) was included as a factor in two-way ANOVAs with site (Table 4 – 5). Two-way ANOVAs conducted on growth by site and harvest on all stems together showed there was a main effect of site in 1998, $F(4,654) = 7.55$, $p < 0.001$. Post hoc comparisons of mean growths for 1998 indicated that there was more growth at site four ($M = 16.0$ cm) than in sites one ($M = 0.8$ cm), two ($M = 2.8$ cm), and three ($M = -5.0$ cm). In addition, there was significantly more growth at sites one and two than site three. In 1999, there was a main effect of site, $F(4, 651) = 37.2$, $p < 0.001$. Pairwise comparisons of sites in 1999 indicated that site four ($M = 21.4$ cm) had significantly more growth than other sites (range of $M = 0.2$ cm at site one, to $M = 6.8$ cm at site two), and site two had significantly more growth than sites one or three. There was also a significant site by harvest interaction, $F(4, 651) = 6.1$, $p <$

0.001. Bonferroni-corrected pairwise comparisons of the interaction indicated palms at site four that were not harvested (M = 15.4) had significantly less growth than palms that were harvested (M = 27.4 cm). In 2000, there was a main effect of site, F(4, 664) = 20.33, $p < 0.001$. Bonferroni pairwise comparisons indicated that site four palms (M = 16.7 cm) had significantly more growth than those at all other sites (M = -3.0 cm, 2.1 cm, 5.1 cm, 2.6 cm, respectively). In addition, sites two and three had significantly more growth than site one.

Two-way ANOVAs conducted on growth of unharvested palms by site and size class showed that in 1998, there was a main effect of site, F(4, 395) = 15.27, $p < 0.001$. Bonferroni post hoc pairwise comparisons of sites indicated significantly more growth in site four palms (M = 19.6 cm) than at any of the other sites, (M = 6.0 cm, 3.6 cm, -1.6 cm, 0.7 cm, respectively). There also was a main effect of size class, F(1, 395) = 7.08, $p < 0.008$. Small size class palms grew more in height (M = 7.9 cm; SE = 1.6) than large size class palms (M = 3.5 cm; SE = 1.9). In 1999 and 2000, the main effects of size class were not significant, but the main effects of site were, $p < 0.05$. Post hoc results for growth of unharvested palms by site were similar to results of earlier analyses of all palms by harvest status and site. In 1999 there was a main effect of site, F(4, 358) = 11.1, $p < 0.001$. Pairwise comparisons of sites indicated that site four stems (M = 18.8 cm) had significantly more growth than others (M = 5.5 cm, 5.3 cm, 2.9 cm, 1.5 cm, respectively). In 2000 also, there was a main effect of site, F(4, 367) = 16.90, $p < 0.001$. Bonferroni pairwise comparisons indicated that site four (M = 18.5 cm) had significantly more growth than other sites (M = 1.4 cm, 2.2 cm, 4.1 cm, 3.9 cm, respectively). In addition, site three had significantly more growth than site one.

Leaf Production:

From 1997 – 2000 means of existing leaves for most palms (maximum frequency) oscillated between six and eight (Table 4 – 6). Median number of leaves was 7.14. New leaf production rate of stems harvested in the previous year was lower than unharvested ones in 1998 (M = 1.54 vs. 1.82, respectively), but was reversed for 1999 and 2000 (M = 1.84 vs. 1.73 and M = 1.83 vs. 1.71, respectively). Large palms produced more new leaves than small palms. The most leaves produced in any year were made by an unharvested stem at site three in 1998 (Max = 12; M = 2.0), and the largest number of existing fronds (23; M = 8.4) was an unharvested stem in site three in 1999. In 1999, the maximum number of fronds per stem produced across all sites was eight (M = 1.5) by an unharvested stem in site three. In 2000, palms with the largest number of fronds had 19 (M = 8.9), and were on unharvested stems in sites three and four. The maximum leaves produced per stem was seven (M = 2.2), also by an unharvested stem in site four.

Two-way ANOVAs conducted on new leaves of unharvested palms by site and size class revealed that in 1998 there was a main effect of site, $F(4, 395) = 3.27$, $p < 0.012$, with palms at site four (M = 1.99) producing significantly more new fronds per stem than site five (M = 1.39). In 1999, site and size class were significant, $F(4, 446) = 7.21$, $p < 0.001$; $F(1, 446) = 19.7$, $p < 0.001$, respectively. Site four palms (M = 2.50) averaged significantly more new leaves than all other sites. In addition large size class palms produced significantly more new leaves per stem (M = 2.01) than small size class palms (M = 1.57). In 2000 there were main effects of site, $F(4, 367) = 5.58$, $p < 0.001$; and size class, $F(1, 367) = 7.70$, $p < 0.007$. Again, site four palms (M = 2.5) produced significantly more new leaves than sites one (M = 1.8), two (M = 1.8), three (M = 1.6), and five ($M = 1.6$). Large size class palms averaged 1.98 new leaves per stem which was significantly more than small size class palms ($M = 1.71$).

The main effect of harvest was significant only in one year, 2000. In 1998, neither main effects of harvest or site were significant. In 1999, there was a main effect of site, $F(4, 627) = 7.64$, $p < 0.001$, with site four palms ($M = 2.3$) producing significantly more new leaves per stem than sites one, two, and three (M ranged from 1.6 - 1.7). In 2000, there was a main effect of harvest, $F(1, 622) = 8.0$, $p < 0.006$, with unharvested palms ($M = 1.8$) producing significantly more new leaves per stem than harvested palms ($M = 1.5$). In addition, there was a main effect of site, $F(4, 622) = 13.5$, $p < 0.001$, with site four palms ($M = 2.3$) producing significantly more new leaves than sites one, three, and five (M ranged from 1.2 - 1.6). Also in 2000, site two palms ($M = 1.9$) produced significantly more new leaves than those at sites three and five. In both analyses excluding 1998 in the latter, site four palms produced more new leaves per stem on average over the three studied years, first for unharvested palms controlling for size class and then for all size palms controlling for harvest status.

Reproduction:

Average fruit production was 17 fruits individual^{-1} year^{-1}, corresponding to a total seed production of 0.02 seeds ha^{-1} year^{-1}. I estimated seed contribution for year and size class from average numbers of observed inflorescences and fruits (Table 4 – 8). Both sexual and asexual propagation were greater in unharvested stems across all years. Overall there was a significant decrease in the number of vegetative offspring in 1999 (58%, $n = 19$) and 2000 (52%, $n = 27$) compared with those identified in 1998 (86%, $n = 100$), although a similar trend was not exhibited for sexual reproductive potential (1998

12%, n = 16; 1999 42%, n = 14; and 2000 48%, n = 25). Based on field observations sexual reproduction usually occurs in large size class individuals (those > 100 cm) but asexual reproduction appears to occur in both small and large size classes (Figure 4 - 5).

Twenty-three percent of all palms reproduced. Sexual and asexual reproduction combined, irapai's reproductive potential, was very low in 1998 (6.5%) and 1999 (7.0%), compared to the initial (1997) and final (2000) censuses, 24.3% and 21.8%, respectively. There were significant differences in reproductive potential by site in 1998 and 1999, χ^2 (4,N = 670) = 15.19, $p < 0.004$ and χ^2 (4,N = 657) = 14.75, $p < 0.005$, respectively, with site four having the most (11%) in 1998 and site two the most (16%) in 1999. Chi-square test cell counts were too low to include for 1999 and 2000. Overall, site two had a greater percentage of reproducing individuals across all three years.

Chi-square tests of sexually reproductive palms by size class revealed significant differences for all years, χ^2 (1,N = 568) = 35.41, $p < 0.001$; χ^2 (1,N = 670) = 17.10, $p < 0.001$; χ^2 (1,N = 657) = 6.84, $p < 0.009$; and χ^2 (1,N = 668) = 13.36, $p < 0.001$, respectively. In all years, more large palms sexually reproduced than small ones. For asexually reproductive palms, chi-square tests were significant for size class in 1997 and 2000, χ^2 (1N = 568) = 28.55, $p < 0.001$; and χ^2 (1,N = 668) = 33.84, $p < 0.001$, respectively. Large palms were significantly more reproductive asexually in these years than small ones.

Chi-square tests of sexually reproductive stems by site were significant for 1997 with site two having the most, χ^2 (4,N = 568) = 25.57, $p < 0.001$, but cell counts were too low in all other years to yield valid results. Chi-square tests for asexually reproductive stems by site were significant for 1997 and 1998, χ^2 (4,N = 568) = 11.97, $p < 0.018$; and

χ^2 (4,N = 670) = 28.94, $p < 0.001$, with sites one, two and four having more than 20% asexually reproductive stems in 1997 and site four having the most (10.6%) in 1998.

After three years, the overall percentage of unharvested palms that reproduced (combined sexual and asexual) was 18% while the percentage of harvested palms was 13% indicating a possible energy trade off between growth / regrowth and reproduction. In 1998 and 1999, there were no significant differences across sites controlling for harvest separately, and no significant difference by harvest within a site. In 2000, reproductive percentages did not differ significantly across harvest status for any of the sites, $p > 0.10$, although there was a significant difference across sites, χ^2 (4,N = 261) = 14.5, $p < 0.006$, when controlling for harvest separately with site two having the most (37.8%). Overall results, however, indicated that site made more of a difference than whether a stem was harvested. Most likely, this is related to soil conditions, light levels or a combination, and possibly management activities. I also evaluated reproductive potential by size class and site, which yielded significant results only in 2000 for all sites. Comparisons of reproduction by size class alone using logistic regression and chi square tabulations revealed in 1998 there was a main effect of size class, χ^2 (1,N = 547) = 12.9, $p < 0.001$, but too few palms reproduced for the effect to be significant. In 1999, the main effect of size class was significant ($p < 0.001$) and large palms were 3.2 times more likely to reproduce, Odds Ratio = 3.413, 95% C.I. (1.54 – 7.57). Also in 2000, they were 4.9 times more likely to reproduce, Odds Ratio = 5.203, 95% C.I. (3.24 – 8.37).

Projection Matrices and Population Structure:

Asymptotic population growth rates, which are measures of environmental fitness, were calculated for pooled, unharvested and harvested palms, and ranged between

1.00 (harvested palms 1998 and 1999) and 2.00 (all palms 2000) (Figure 4 – 6). All lambda values were very close to or greater than 1.0, signifying population stability or expansion for pooled, unharvested and harvested palms. Projection matrices present population dynamics for irapai in Appendix 3. Figure 4 – 7 depicts stage transitions for projection intervals in a life cycle graph. Lambda values for pooled irapai data ranged from 1.6 the first year for all palms to 1.6 in 1998, 1.4 in 1999, and 2.0 in 2000. Unharvested palm matrices yielded population growth rates of 1.3 for 1998, 1.4 in 1999, and 1.3 for 2000. Lambda for harvested palms remained at 1.0 for transition years 1998 and 1999, and then increased to 1.6 in 2000. Population growth rates for all palms decreased between the 1998 and 1999 years, and then greatly increased for the final census in 2000. Unharvested palm population growth rates remained relatively stable, but harvested palm growth rates dramatically increased in the final census. For all palms combined, a 37% reduction in fecundity in all stages was required to reduce lambda to >1.0.

Appendix 4 - 4 displays stable stage distributions (SSD) and reproductive values (RV) predicted from pooled data, unharvested and harvested palms. Stable stage distributions in all populations differed significantly from the observed population structure, especially seed (0) and small non-reproductive (s1) stages. Differences between expected and observed distributions were due mostly to frequency variation for seeds (0), size 1 non-reproductive (s1), as well as size 2 non-reproductive (s2) and size 2 vegetatively reproductive (s2rc) stages. As observed, reproductive value was highest for both size 1 asexually reproductive (s1rc) and size 2 asexually reproductive (s2rc) stages of unharvested palms. Transition probabilities for 1999 showed a decrease in sexual and asexual reproduction. These findings could indicate alternating seasons of lower and higher reproductive output, but the detailed studies needed to investigate this phenomenon were beyond the scope of this project.

Prospective and Retrospective Analyses:

Sensitivity analysis, used to measure how important any transition matrix element was to lambda, resulted in the array presented in Appendix 4 – 5, and predicted changes in lambda for all life-history parameters were mostly in the seed and small vegetative size class, more so for unharvested palms than harvested ones. Discounting the values in the more unlikely transition probabilities, lambda was sensitive to changes in the large size class reproductive stages for both harvested and unharvested palms. Observed transition probabilities indicated that lambda was more sensitive to changes in survival and reproduction than growth and during its entire life cycle.

In Appendix 4 – 6, elasticity matrices, the proportional contribution of the matrix elements to lambda, presented each element as the proportional sensitivity of lambda to the respective transition element. Values higher than 0.1 were considered significant and matrices indicated survival parameters especially for stages s1 (small size class vegetative) and s2r (large size class sexually reproductive) and s2rc (large size class asexually reproductive) contributed more to lambda than other parameters. These results indicate that survival rates of small vegetative and sexually reproductive palms larger than 50cm were the most important for maintaining population stability. Stasis elements for unharvested palms (> 0.01) had low contributions to lambda suggesting harvest of leaves from these stems may have low impact on population dynamics. The largest contributions were made by large size class reproductive and stasis elements for harvested palms (0.01 - 0.03) with a peak at stage s2rc (large size asexually reproductive palms) in year three, indicating individual survival of this stage is important for self-maintenance of the population. These stages are most likely to be harvested and accounted for 0.08 of total elasticity, suggesting populations may be resilient to some leaf harvest of these stages. Survival of all stages for all years accounted for 22.8% of the value of lambda, growth for 30% and fecundity, 47.2%

DISCUSSION

In general, during the course of this study, irapai palms exhibited small increases in growth and slow but steady leaf production. Experiencing very little mortality, most populations increased in size. Despite wide variability in canopy cover among plots and sites, light availability did not significantly affect growth and leaf production. There were site differences, however. For the first two censuses, site two, the private reserve, had the largest percentage of large size class palms, while site five, the research preserve, had the largest percentages of small size class palms. Neither site permits harvesting except to maintain small ecotourism structures or as part of a study, respectively. Illegal harvest, however, was a problem at both sites prior to the start of this project. Staff members at the privately operated site were able to address these issues more responsively, whereas the research agency (site five) with limited personnel and budget struggled. This may help explain why they had the most and least available large size class palms, respectively.

At the third and final censuses, site four had the largest percentage of large size class palms. During the course of this study, site four was managed the most intensely

(Table 4 – 9) which may account for the cultivation over time of the large size class, which is preferred for harvest. Improper harvest and treefalls were reasons for stem mortality, although death from either generally was not preceded by loss of vigor. It is not known whether root interconnections with other stems are able to provide lateral support but if so, a loss of vigor in injured and perhaps connected stems may have been detected. No evidence of stems sharing resources via interconnections was observed aside from direct basal branch budding.

Analyses showed that the most growth of stems in 1998, 1999 and 2000 occurred in site four, and in 1999, the most stem growth occurred in harvested stems here. These findings indicate that combined with management activities, leaving two to four fronds per stem may enhance leaf regrowth. Harvest did take a toll, however, and management appears to be an important additive. In 2000, unharvested palms at site four had the highest leaf production rate of all monitored palms. Harvest appeared to affect sexual and asexual stem reproduction significantly, although because of possible extended cyclical asexual reproductive pulses, it is unclear how much of the effect was cyclic or related to environmental conditions, and how much was due to harvest.

Projection Matrices and Population Structure:

Looking at harvested and unharvested palms from all sites, irapai palms generally maintained population growth rates of 1.0 or greater in all censuses except for harvested palms in 1998 ($\lambda = 0.99$). Lambda ranged from 1.4 - 2.0 for pooled stems, 1.3 - 1.4 for unharvested palms, and 1.0 - 1.6 for harvested irapai. Other harvested tropical palm demographic studies estimated population growth rates (λ) to be 0.99 - 1.02 for *Iriartea deltoidea* (Pinard 1993), 1.09 - 1.15 for *Thrinax radiata,* 1.05 for *Coccothrinax readii*

(Olmstead and Alvarez 1995), and not different from 1.0 for Mexican populations of *Chamaedorea radicalis* (Ash 2007). Mendoza and Oyama (1999) determined population growth rates for unharvested populations of *Astrocaryum mexicanum*, *Chamaedorea alternans* and *Reinhardtia gracilis* var. *gracilior* to be 1.01, 1.36 and 1.02, respectively. Estimates for irapai were nearest the range for the Mexican dioecious understory palm, *C. alternans*, although there are differences between the two species. *C. alternans* is a solitary palm with no asexual reproduction, and its lambda was based on only a two-year study, but showed changes in growth parameters were the most significant.

To consider to what harvest level would be demographically sustainable for irapai populations, I evaluated increased harvest levels and their effects on lambda. From simulations, a leaf harvest increase of +70% above currently recorded levels would be needed for lambda values to fall below 1.0. This would be comparable to Peters (1990) findings for Amazonian understory tree *Grias peruviana*, where 80% seed harvesting was needed to decrease lambda to 1.00 and Bernal (1998) who found 86% seed harvest of vegetable ivory palm (*Phytelephas seemannii*) decreased lambda to 1.0. It is unknown, however, whether these responses in population growth rate are temporary, or would be sustainable over the long-term. Previous studies have shown that following harvest, palms may respond with a short burst of growth that fades or produce new leaves that open quickly but are smaller in size (Lugo and Rivera-Batlle 1987, O’Brien and Kinnaird 1996). Irapai appears to exhibit extended versions of some responses that may not have been observable during this study period.

This study may not have followed long-lived, slow growing irapai populations a sufficient time to discover complete growth and reproductive patterns, but documents only a portion of them. Nearly everything about this palm indicated its response time was slow. Irapai's long life span may buffer the population from temporal reproductive differences as documented in this study and overall low sexual and asexual reproduction levels. Irapai seeds also have a long dormancy (see chapter 3). It may be that long periods of dormancy are a strategy for irapayale re-establishment when environmental conditions improve or perhaps to escape seed predators, which currently may be extinct. To promote maximum seed germination, seeds should not be harvested for other purposes. Considering this to be a short-term study, results indicated that at current densities, harvest levels, and management strategies, continued harvest of irapai palms appears sustainable in the study region. *L. tenue* could represent a good opportunity to document sustainable harvest of a non-timber forest product.

TABLES

Table 4 – 1. Description of $25m^2$ Irapai (*Lepidocaryum tenue*) Plots 1997 - 2000.

Site	Plot	Total Stems	Stems 1997	Stems 1998	Stems 1999	Stems 2000	Flower	Fruit	Harvest Status
1	1-1	21	15	20	20	19	No	No	
	1-2	18	18	17	16	15	No	No	Not harvested
	1-3	19	19	19	18	18	NA	NA	
	2-1	32	26	32	32	29	No	No	Harvested 1996
	2-2	39	32	34	34	36	No	No	Harvested days pre-1998 census
Site Total		**129**	110	122	120	117			
2	1-1	10	6	10	10	10	No	No	Tree fall 11-97
	1-2	44	25	32	31	35	12-97 [1]	No	
	1-3	18	14	16	16	18	6-98	No	
	2-1	15	10	14	14	14	12-97 [2]		
	2-2	28	23	25	23	25		12-97 [4, 5]	Tree fall >2 yrs old
Site Total		**115**	78	97	94	102			
3	1-1	36	33	36	33	33	12-97 [3]	No	Managed community harvest
	1-2	19	18	18	18	18	6-98 [3]	No	Managed community harvest
	2-1	15	15	15	14	14	No	No	Managed commercial harvest
	2-2	17	16	17	17	15	No	No	Managed commercial harvest
	2-3	11	11	11	11	11	No	No	Managed commercial harvest
	3-1	42	37	38	35	36	12-97 [1]	No	Unmanaged commercial harvest
	3-2	16	16	15	15	15	6-98 [3]	No	Unmanaged commercial harvest
Site Total		**156**	146	114	110	109			
4	1	25	17	22	23	20	No	No	
	2	33	13	31	29	27	No	No	
	3	29	9	28	25	25	No	No	
	4	21	4	6	11	21	NA	NA	Unmanaged commercial harvest 2000
	5	36	12	20	34	36	NA	NA	Unmanaged commercial harvest 2000
	6-1	42	37	42	36	36	NA	NA	
	6-2	30	24	30	29	29	NA	NA	
Site Total		**216**	116	179	187	194			
5	1	21	17	21	18	18	No	No	
	2	31	25	27	27	29	6-98 [3]	No	
	3	51	49	48	48	44	No	No	
	4	30	27	29	24	25	No	No	
Site Total		**133**	118	125	117	116			
TOTALS		**749**	568	637	628	638			
MEANS		**149.8**	113.6	127.4	125.6	127.6			

---

[1] Flowers male; [2] Flowers female; [3] Flowers indeterminate; [4] Fruit immature; [5] Fruit mature.

Table 4 - 2. Matrix Model Structure for Population Dynamics of Irapai.
The matrix summarizes how conditions act on a population over time to change numbers of individuals and their relative distribution in different stages (Horvitz and Schemke 1995).

Top row entries (F_1) are contributions from sexually reproductive individuals. These values are added into respective cells in first row of matrix.
Second row entries (F_2) are contributions from asexually reproductive individuals. These values are added to originating size class cell, in either small (fourth) or large (seventh) row. Diagonal entries represent survival while remaining in the same stage (P). Non-zero entries beneath the diagonal indicate growth (G), while those above it represent regression (R).

$$\begin{array}{lccccccc}
N\mathit{t} \rightarrow N\mathit{t} + \mathit{1} & F_{11} & F_{12} & F_{13} & F_{14} & F_{15} & F_{16} & F_{17} \\
 & F_{21} & F_{22} & F_{23} & F_{24} & F_{25} & F_{26} & F_{27} \\
\cline{2-8}
 & & & & & & & \\
 & P_{11} & R_{12} & R_{13} & R_{14} & R_{15} & R_{16} & R_{17} \\
 & G_{21} & P_{22} & R_{23} & R_{24} & R_{25} & R_{26} & R_{27} \\
 & G_{31} & G_{32} & P_{33} & R_{34} & R_{35} & R_{36} & R_{37} \\
 & G_{41} & G_{42} & G_{43} & P_{44} & R_{45} & R_{46} & R_{47} \\
 & G_{51} & G_{52} & G_{53} & G_{54} & P_{55} & R_{56} & R_{57} \\
 & G_{61} & G_{62} & G_{63} & G_{64} & G_{65} & P_{66} & R_{67} \\
 & G_{71} & G_{72} & G_{73} & G_{74} & G_{75} & G_{76} & P_{77}
\end{array}$$

Table 4 – 3. Stem Densities by Site and 5 x 5 m Plot.

Site No.	Name	Stems / Site	Site Density / m^2	Stems / Plot	Plot Density / m^2
1.	Mai Huna Indigenous Reserve	129	1.03	21	0.84
				18	0.72
				19	0.76
				32	1.28
				39	1.56
2.	Explorama Private Reserve	115	0.92	10	0.40
				44	1.76
				18	0.72
				15	0.60
				28	1.12
3.	Mishana Community Reserve	156	0.89	36	1.44
				19	0.76
				15	0.60
				17	0.68
				11	0.44
				42	1.68
				16	0.64
4.	Tamshiyacu-Tahuayo Communal Reserve	216	1.23	25	1.00
				33	1.32
				29	1.16
				21	0.84
				36	1.44
				42	1.68
				30	1.20
5.	Allpahuayo Research Reserve	133	1.33	21	0.84
				31	1.24
				51	2.04
				30	1.20

Table 4 – 4. Average Percent Canopy Cover of Irapai Plots.

Site		Plot	1998 Canopy Cover	1999 Canopy Cover	2000 Canopy Cover
1.		1-1	85.2	81.2	77.2
		1-2	86.2	81.3	76.4
		1-3	na[1]	na	na
		2-1	78.4	58.3	38.2
		2-2	89.1	81.7	74.4
		Mean:	84.7	75.6	66.6
2.	Tree fall 11-97	1-1	91.9	85.2	78.5
		1-2	88.6	81.9	75.1
		1-3	76.3	75.9	75.4
		2-1	90.4	84.8	79.3
	Tree fall >2 yrs old	2-2	86.5	79.6	72.8
		Mean:	86.7	81.5	76.2
3.		1-1	20.8	49.0	77.2
		1-2	16.1	51.7	87.4
		2-1	14.3	45.9	77.5
		2-2	14.3	50.1	85.8
		2-3	14.8	49.9	85.0
		3-1	15.6	45.1	74.6
		3-2	21.1	45.6	70.2
		Mean:	16.7	48.2	79.7
4.		1	86.5	na	na
		2	86.7	na	na
		3	84.4	na	na
		4	na	na	72.3
		5	na	na	63.2
		6-1	na	na	na
		6-2	na	na	na
		Mean:	85.9	na	67.7
5.		1	9.6	41.0	72.3
		2	10.4	43.29	76.2
		3	7.3	49.1	91.0
		4	10.9	52.7	94.4
		Mean:	9.6	46.5	83.5

---

[1] Canopy measurements could not be taken in all plots.

Table 4 – 5. Mean Growth[1] (cm) of Stems by Site by Transition Year:

Unharvested

	1997 - 1998			1998 - 1999			1999 - 2000		
Site	N	Mean	SE	N	Mean	SE	N	Mean	SE
1.	69	7.0	3.6	85	5.5	1.4	71	1.4	2.2
2.	48	3.6	1.9	67	5.3	1.2	55	2.2	2.4
3.	101	-1.5	1.2	104	2.9	0.5	84	4.1[b]	2.2
4.	78	20.0[a]	3.8	90	18.8[a]	2.5	76	18.5[a]	2.1
5.	109	1.7	1.9	111	1.5	1.9	91	3.9	2.0
All Sites	405	5.6	1.2	457	6.8	1.1	377	6.0	1.4

[a] Post hoc pairwise comparisons of mean growth for the year showed significantly more growth in site 4 than all other sites, using Bonferroni ($p < 0.05$) on rank transformed means.

[b] Post hoc pairwise comparisons of mean growth for the year showed significantly more growth in site 3 than site 1, using Bonferroni ($p < 0.05$) on rank transformed means.

Harvested

	1997 - 1998			1998 - 1999			1999 - 2000		
Site	N	Mean	SE	N	Mean	SE	N	Mean	SE
1.	37	-4.0	16.3	35	-6.3	6.8	40	-6.9	6.0
2.	22	2.8	5.5	27	8.5	2.2	37	2.2	5.0
3.	43	-16.0	7.0	39	0.3	1.2	54	5.6	1.4
4.	37	19.9	7.3	75	27.4	2.3	104	17.5	3.1
5.	6	1.9	2.9	6	1.9	2.9	20	1.9	1.4
All Sites	145	-0.2	5.2	182	11.5	2.0	255	7.8	1.8

---

[1] Growth does not take into account initial loss of height due to harvest.

Table 4 - 6. Leaves.

		1997	1998	1999	2000
Existing Leaves Per Stem - All	n	568	676	660	668
	M	6.20	6.71	7.95	7.68
	SD	3.19	3.14	3.59	3.53
	Min	0.3	0.0	0.5	0.5
	Max	17.7	18.7	23.2	19.2
			1997 – 1998	1998 – 1999	1999 – 2000
New Leaves Produced Per Stem - Unharvested[1]	n		368	377	407
	M		1.47	1.61	1.66
	SD		1.17	1.07	1.20
	Min.		0.0	0.0	0.0
	Max.		7.0	7.5	7.0
New Leaves Produced Per Stem - Harvested[1]	n		168	181	255
	M		1.64	1.86	1.68
	SD		1.56	1.16	1.16
	Min.		0.0	0.0	0.0
	Max.		12.0	7.3	6.0

[1] Note: Harvest status from latter transition year used.

Table 4 - 7. Irapai Stem Matrix Stages.

Stage:	1997 Stems:	1998 Stems:	1999 Stems:	2000 Stems:
Seed (0): Not yet germinated; those produced during study only; other seeds in soil bank excluded.	181	58	36	0
Size1 (s1) Vegetative Small size: Stem less than 50cm tall; new sprouts and persistent stems.	277	380	309	265
Size1repro (s1r) Sexually Reproductive Small size: Stem less than 50cm tall with flowers / fruit; germinated same year and persistent stems.	1	1	2	2
Size1reproclone (s1rc) Asexually Reproductive Small size: Stem less than 50cm tall with basal offshoot; seedlings germinated same year and persistent stems.	34	12	10	24
Size2 (s2) Vegetative Large size: Stem at least 50cm in height; usually plants older than one year; some first year seedlings.	161	247	302	265
Size2repro (s2r) Sexually Reproductive Large size: Stem at least 50cm in height with flowers / fruit; usually plants older than one year; some first year seedlings.	30	14	12	23
Size2reproclone (s2rc) Asexually Reproductive Large size: Stem at least 50cm in height with basal offshoot; usually plants older than one year; some first year seedlings.	73	17	22	97
Total Stems	757	729	693	676

Table 4 – 8. Annual Reproductive Contributions for Irapai Matrix Model.

	1997 – 1998 Average Contribution / Stem:	1998 – 1999 Average Contribution / Stem:	1999 - 2000 Average Contribution / Stem:
F1 - Sexual Reproduction[1]			
Small Size Class	1.00 inflorescences 14 fruits / inflorescence	1.50 inflorescences 14 fruits / inflorescence	1.00 inflorescence 14 fruits / inflorescence
Large Size Class	1.36 inflorescences 12 fruits / inflorescence	1.50 inflorescences 12 fruits / inflorescence	1.36 inflorescences 12 fruits / inflorescence
F2 – Asexual Reproduction[2]			
Small Size Class	7 basal buds	3 basal buds	0 basal buds
Large Size Class	7 basal buds	0 basal buds	1 basal buds

[1] Sexually reproductive transitions were multiplied by inflorescences * seeds = Stage 1.

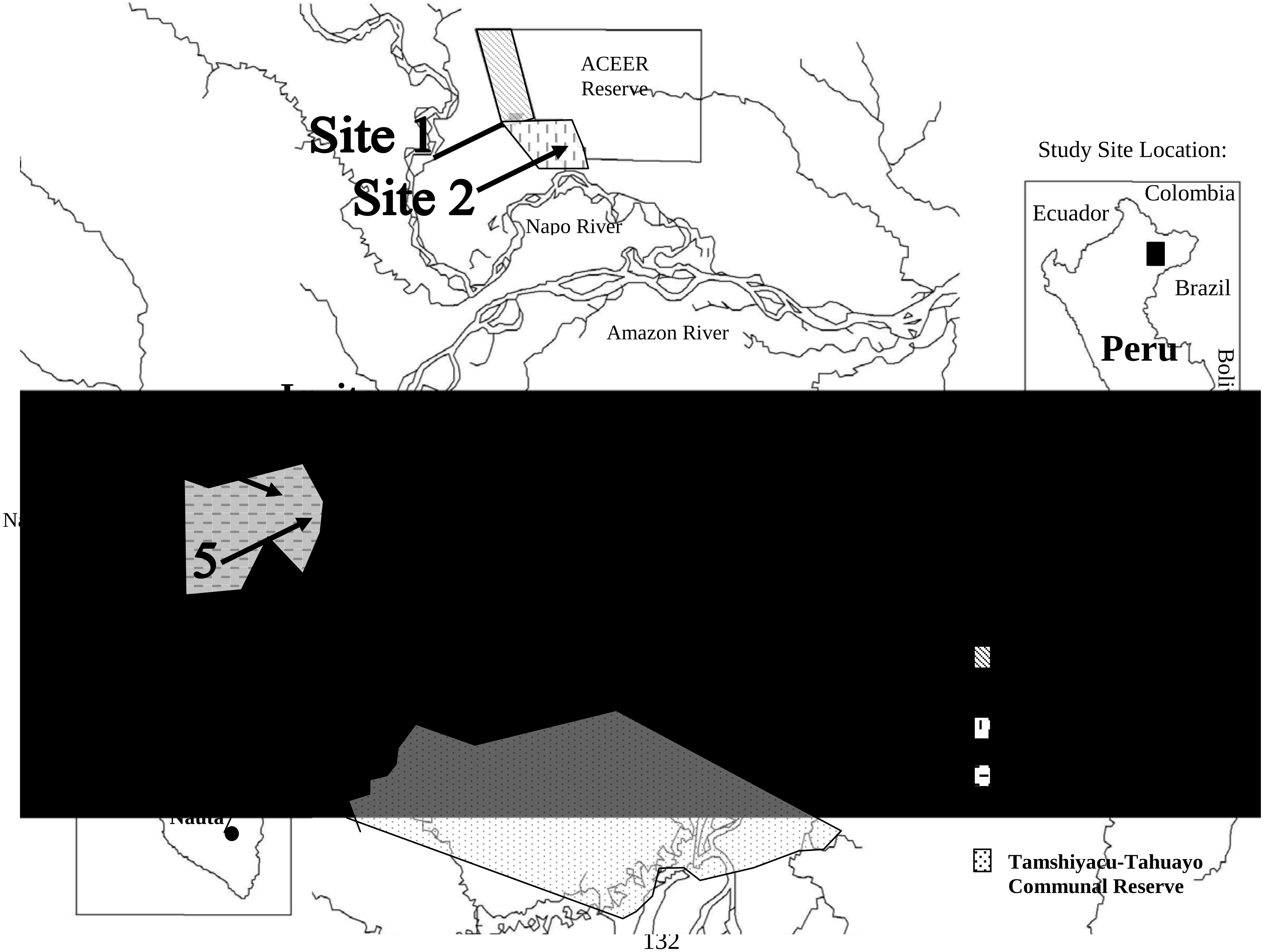
[2] Asexually reproductive transitions were multiplied by number of buds. Result added to same stage.

Table 4 – 9. Irapayale Land Designation and Management Activities by Site.

Site:	Land Designation Type:	Perceived Level of Assigned Resource Ownership:	Irapayale and Related Management Activity(ies):	Activity Frequency:
1	Indigenous Reserve	Community	Harvest rotation; trail maintenance;	Infrequent[2]
2	Private Reserve	Private - Corporate	Trail, border and small clearings maintenance for property; none specifically for irapayales;	Regular[1]
3	Community Reserve	Community	Trail maintenance; debris removal; competitor thinning; harvest rotation;	Infrequent[2]
4	Communal Reserve	Personal	Debris removal; competitor thinning / removal; add fertilizing materials; harvest rotation;	Regular[1]
5	Research Reserve	Institutional	Trail and border maintenance for property; none specifically for irapayales;	Regular[1]

[1] Regular – monthly or quarterly activities.
[2] Infrequent – annual or semi-annual activities.

FIGURES



[redacted]

⛶ **Tamshiyacu-Tahuayo Communal Reserve**

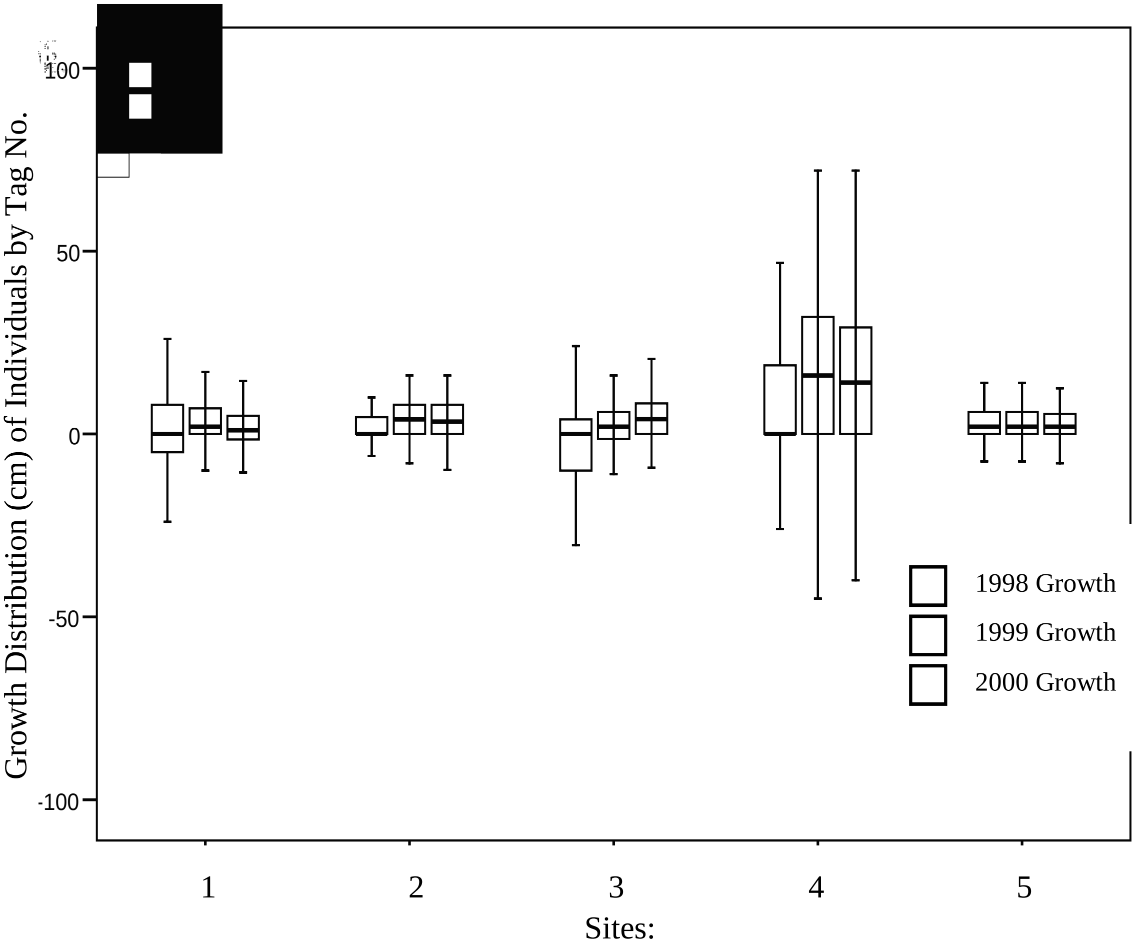
Figure 4 – 1. Iquitos, Peru, and Plot Locations.

Source: IIAP 1999.

Figure 4 - 2. Height Measurements (h) Decreased Before Subsequently Increasing as Irapai Spears Develop into Petioled Leaves.

By K. Janzen

Figure 4 – 3. 1998, 1999 and 2000 Changes in Stem Length (Stem Growth Distributions)[1].



---

[1] Enlarged view excludes outliers.

Figure 4 - 4. 1997 Cohort – Survival by Site.

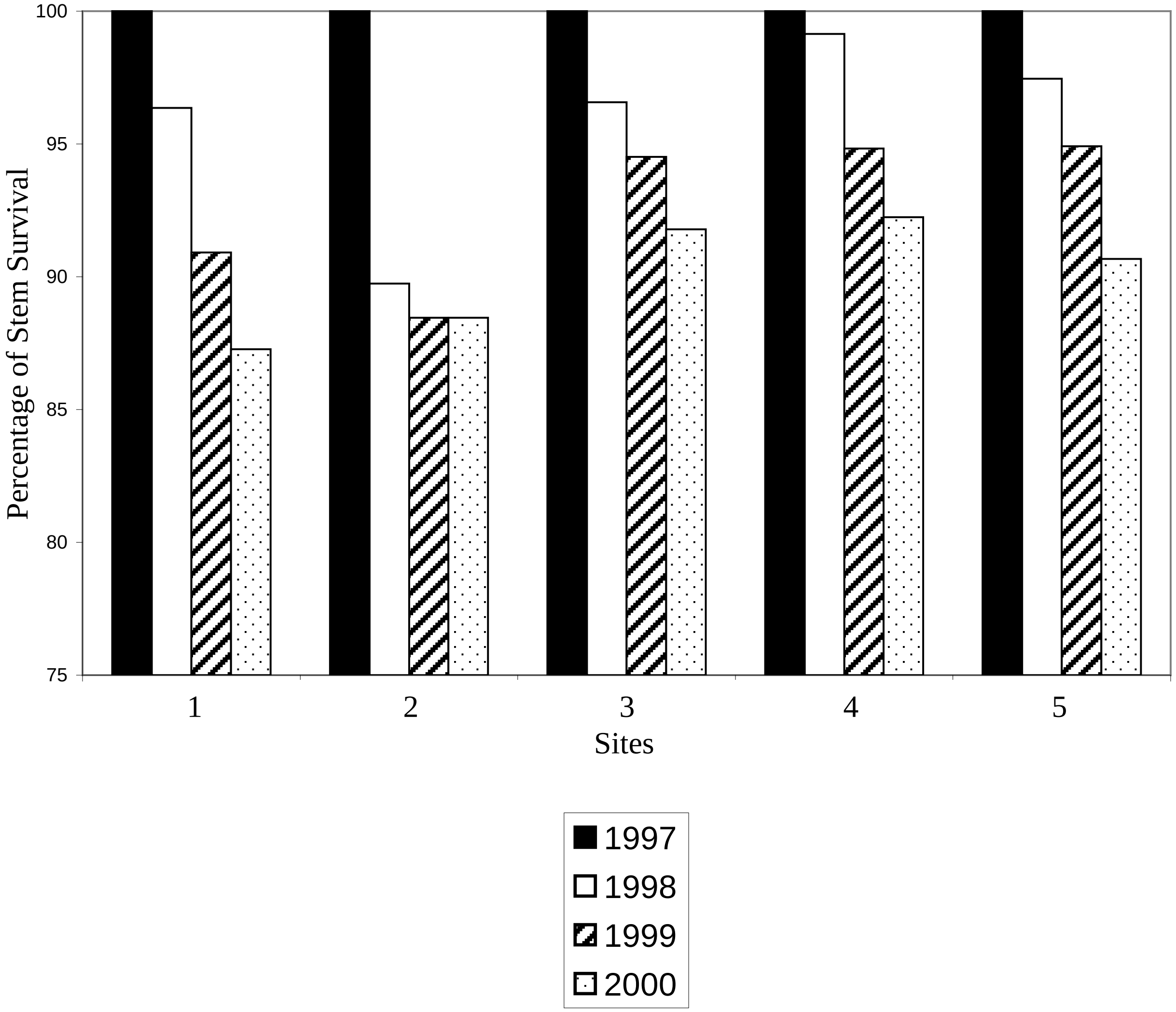


Figure 4 – 5. Sexually and Asexually Reproductive Palms by Size Class and Year.

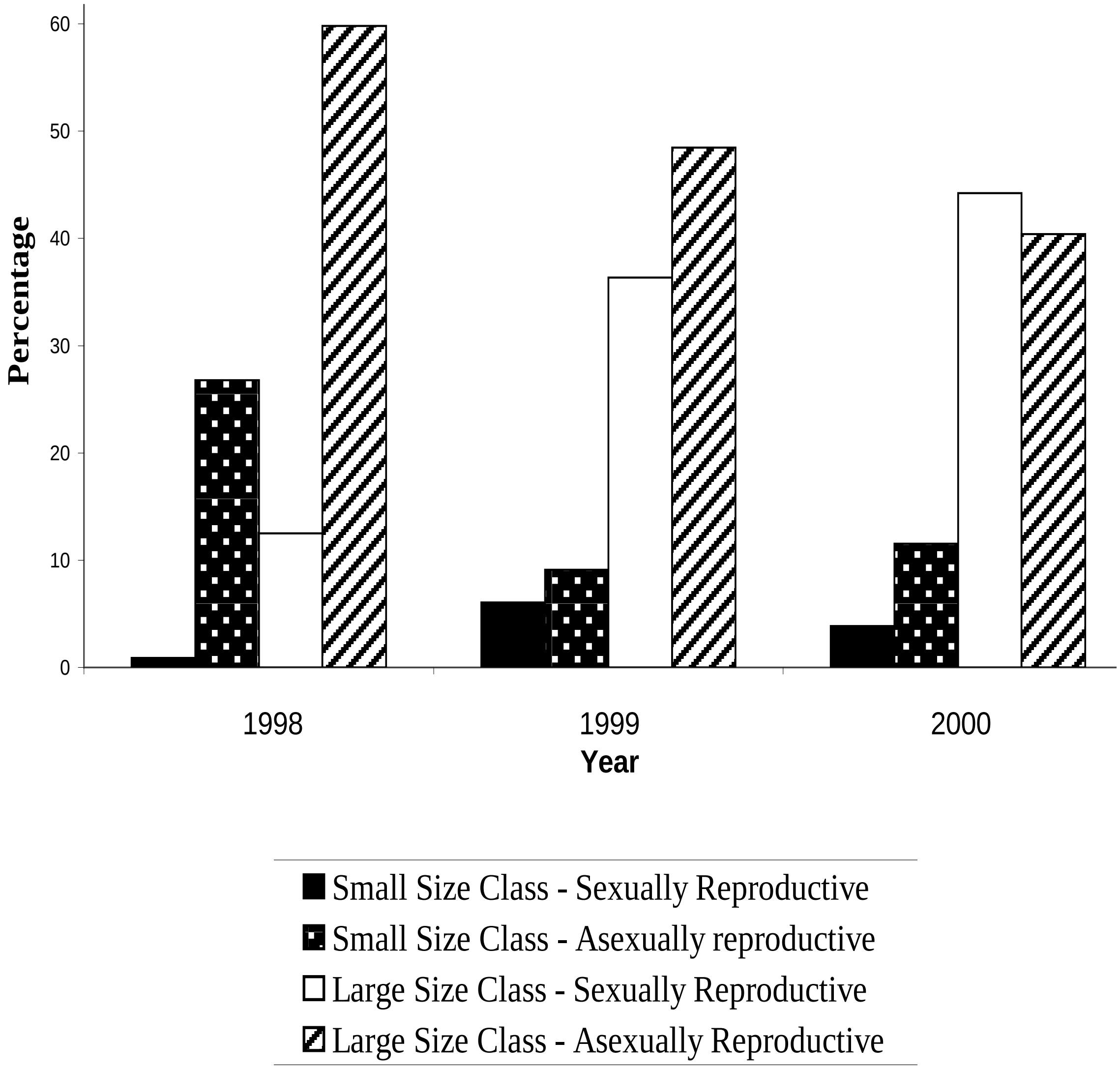
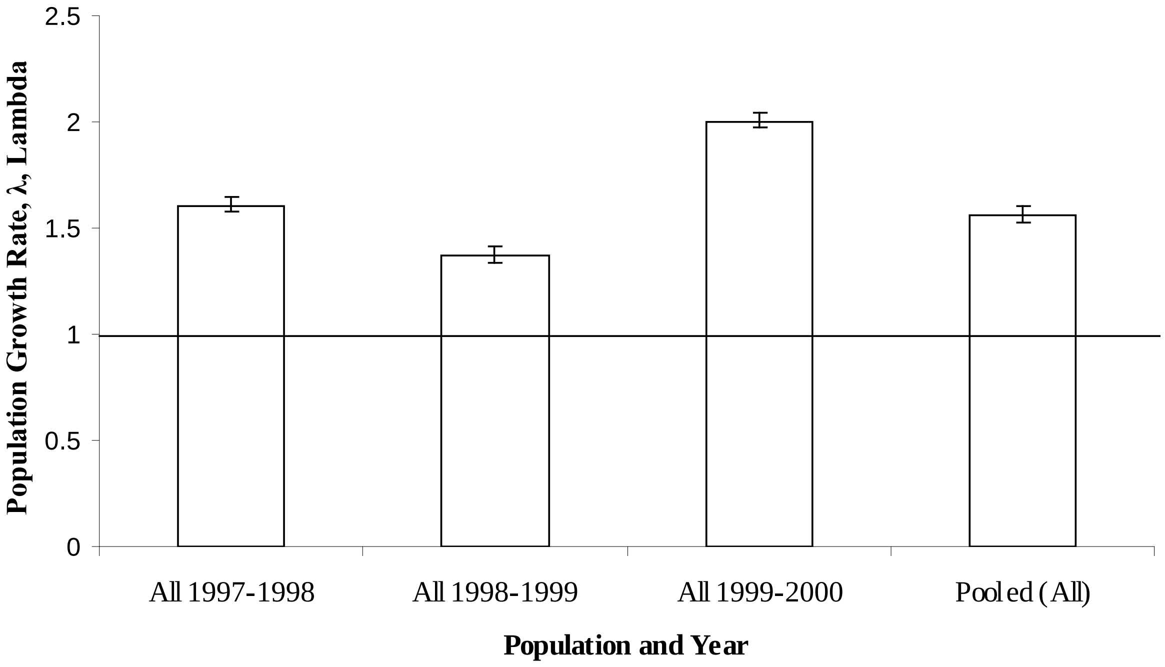


Figure 4 – 6. Population Growth Rates[1] of *L. tenue*.



---

[1] Bars are 95% percentile confidence intervals based on 30,000 bootstrapped populations.

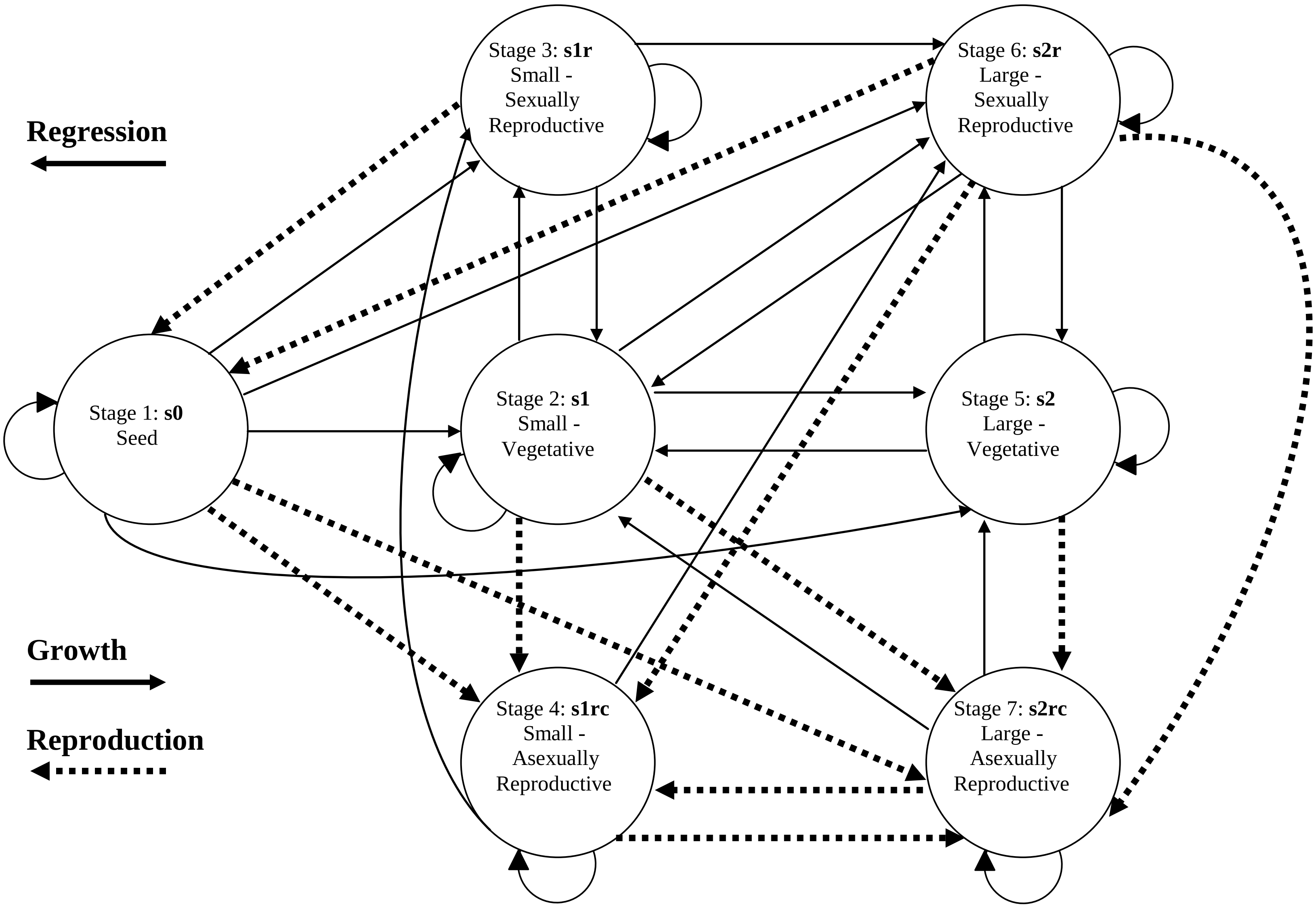


Figure 4 – 7. Life Cycle for Pooled Data for *L. tenue* from 1997 - 2000.

LITERATURE CITED

Alpert, T, O. Raspe, and A.L. Jacquemart. 2003. Clonal structure in *Vaccinium myrtillus* L. revealed by RAPD and AFLP Markers. International Journal of Plant Sciences 164(4):649-655.

Anderson, P.J. 1998. Demography, Stem Harvesting, and Conservation of the Palm, *Iriartea deltoidea*. Dissertation. University of Florida, Gainesville, FL.

Arana, V. 2000. Oportunidades de Inversión Ambiental en Loreto: Informe de la Visita a la Reserva Comunal Tamshiyacu Tahuayo, Sus Comunidades y Zonas de Influencia (5 – 7 de Abril 2000). Report to CARE-PERU.

Ash, J. 2007. Assessment of sustainable leaf harvest from the understory palm, *Chamaedorea radicalis*. Master's Thesis, Miami University (Botany), Ohio. 56p.

Balick, M. 1987. Regeneration Population Dynamics and Dissemination of a Palm from French Guyana *Jessenia bataua* ssp. *oligocarpa*. Bulletin du Museum National d'Histoire Naturelle Section B Adasonia Botanique Phytochimie, 9(3):317-336.

Balick, M.J. 1986. The Palm - Tree of Life: biology, utilization and conservation. Advances in Economic Botany 6. Bronx, NY: NYBG. 282p.

Balick, M. 1984. Ethnobotany of Palms in the Neotropics. Advances in Economic Botany 1:9-23.

Bennett, B.C. 2002. Forest products and traditional peoples: economic, biological, and cultural considerations. Natural Resources Forum 26(2002):293–301.

Bennett, B.C. 1992. Plants and People of the Amazonian Rainforests: The Role of Ethnobotany in Sustainable Development. BioScience 42(8):599-607.

Bernal, R. 1998. Demography of the vegetable ivory palm, *Phytelephas seemannii* in Colombia, and the impact of see harvesting. Journal of Applied Ecology 35:64-74.

Bodley, J.H. and F.C. Benson. 1979. Cultural Ecology of Amazonian Palms. Reports of Investigations, NO. 56, Laboratory of Anthropology. Pullman, WA: Washington State University.

Boom, B.M. 1987. Ethnobotany of the Chácobo Indians, Beni, Bolivia. Adv. Econ. Bot. 4:1-68.

Borgtoft Pederson, H., and Balslev, H. 1990. Ecuadorean Palms for Agroforoesry. AAU Reports 23.

Callaghan, T.V. 1984. Growth and translocation in a clonal southern hemisphere sedge, *Uncinia meridensis*. Journal of Ecology, 72:529-546.

Caswell, H. 2000. Prospective and retrospective perturbation analysis: their roles in conservation biology. Ecology 81:619-627.

Caswell, H. 1989. *Matrix Population Models: Construction, Analysis and Interpretation.* (Chapters 1-3). Sinauer Associates, Sunderland, Massachusetts.

Cavalcante, P.B. 1977. Edible palm fruits of the Brazilian Amazon. Principes 21:91-102.

Chazdon, R. 1991. Effects of leaf and ramet removal on growth and reproduction of *Geonoma congesta*, a clonal understory palm. Journal of Ecology 79:1137-1146.

Clark, D.B., D.A. Clark, and J.M. Read. 1998. Edaphic variation and the mesoscale distribution of tree species in a neotropical rain forest. Journal of Ecology. 86:101-112.

Clay, J.W. 1997. The impact of palm heart harvesting in the Amazon estuary. *In:* Harvesting Wild Species: Implications for Biodiversity Conservation (C.H. Freese, ed.), p283-314. John Hopkins University Press, Baltimore, MD.

Cook, R.E. 1979. Asexual reproduction: a further consideration. American Naturalist, 113:769-772.

Critchfield, H. J. 1983. General Climatology, fourth ed., Page 155. Prentice-Hall, NJ, 453p.

Cunningham, A.B. 2001. *Applied Ethnobotany: People, Wild Plant Use and Conservation.* Earthscan Publications, Ltd., London And Sterling, Va.

de Kroon, H., J. van Groenendael, and J. Ehrlen. 2000. Elasticities: a review of methods and model limitations. Ecology 81(3):607-618.

De Steven, D. 1989. Genet and ramet demography of *Oenocarpus mapora* ssp. *mapora*, a clonal palm of Panamanian tropical moist forest. Journal of Ecology 77:579-596.

Douhovnikoff, V, A.M. Cheng, and R.S. Dodd. 2004. Incidence, size and spatial structure of clones in second-growth stands of coast redwood, *Sequoia sempervirens* (Cupressaceae). American Journal of Botany 91(7):1140-1146.

Endress, B., D. Gorchov, M. Peterson and E. Padrón Serrano. 2004. Harvest of the palm *Chamaedorea radicalis*, its effects on leaf production, and implications for sustainable management. Conservation Biology 18(3):822-830.

Freckleton, R., D. Silva Matos, M. Bovi, A. Watkinson. 2003. Predicting the impacts of harvesting using structured population models: the importance of density-dependence and timing of harvest for a tropical palm tree. Journal of Applied Ecology 40(5):846-858.

Gentry, A. 1988. Tree species richness of upper Amazonian forest. Proceedings of National Academy of Science 85:156-159.

Guedje, N., J. Lejoly, B. Nkongmeneck and W. Jonkers. 2003. Population dynamics of *Garcinia lucida* (Clusiaceae) in Cameroonian Atlantic forests. Forest Ecology and Management 177(1-3):231-241.

Hall, P. and K. Bawa. 1993. Methods to assess the impact of extraction of nontimber tropical forest products on plant populations. Economic Botany 47:234-247.

Hartshorn, G.S. 1975. A matrix model of tree population dynamics. *In* F.B. Golley and E. Medina (eds.), Tropical Ecological Systems, p41-51. Springer-Verlag, New York Inc., New York.

Horvitz, C.C. and D.W. Schemske. 1995. Spatio-temporal variation in demographic transitions of a tropical understory herb: projection matrix analysis. Ecol Monographs 65(2):155-192.

Instituto de Investigaciónes de la Amazónia Peruana, CARE - PERU. 1999. Manejo Sostenido de la Biodiversidad en la Reserva Tamshiyacu Tahuayo, Zonas Aledanas. Marzo.

Instituto Nacional de Estadistica y Informatica (INEI). 2001. Instituto de Investigacion de la Escuela Profesional de Turismo y Hoteleria de la Universidad San Martin de Porres – OMT as accessed at .inei.gob.pe/ on 23 July 2005.

Instituto Nacional de Estadística y Informática (INEI). 2004a. Estimación de Población en Regiones de la Amazonía Peruana (1995-2000) as accessed at ://www.siamazonia.org.pe/Bases%20de%20datos/Estadísticas/Población.htm on 23 July 2005.

Instituto Nacional de Estadística y Informática (INEI). 2004b. 2.15.2 Loreto: Principales Indicadores Socioeconómicos, 2003-2004. Oficinas Sectoriales de Estadística as accessed at .inei.gob.pe/ on 28 May 2005.

Instituto Nacional de Estadística y Informática (INEI). 2005. Censos Nacionales X de Poblacion y V de Vivienda. Sistema de Recuperacion de Datos as accessed at ://iinei.inei.gob.pe/iinei/RedatamCpv2005.asp?ori=C on 2 June 2008.

Jackson, J., L. Buss, and R. Cook. 1985. Population biology and evolution of clonal organisms. Yale University Press, New Haven. 530p.

Janzen, K. 2006. Original graphite line drawing of irapai height measurements and how stem growth and leaf expansion affect them. Boise, Idaho.

Janzen, D.H. 1977. What are dandelions and aphids? American Naturalist, 111:586-859.

Johnson, D.V. 1987. Native Palms for Brazilian Development: Three Major Utilization Regions as Examples. Vida Silvestre Neotropical 1(2):43-49.

Jordan, C. 1970. A study of germination and use in twelve palms of northeastern Peru. Principes 14:26-32.

Joyal, E. 1996. The Palm Has Its Time: An Ethnoecology of *Sabal uresana* in Sonora, Mexico. Economic Botany 50(4):446-462.

Kahn, F. 1988. Ecology of economically important palms in Peruvian Amazon. Advances in Economic Botany 6:42-49.

Kahn, F.K., and K. Mejia. 1991. The Palm Communities of Two “Terra Firme” Forests in Peruvian Amazonia. Principes, 35(1):22-26.

Kahn, F.K. and K. Mejia. 1987. Notes on the Biology, Ecology, and Use of a Small Amazonian Palm: *Lepidocaryum tessmannii*. Principes (31):14-19.

Kenkel, NC. 1996. Markovian spatial-inhibition models for established clonal populations. Pages 29-33 In: Oborny, B. & J. Podani. (eds.) Clonality in plant communities. Proc. 4th Int. Workshop on Clonal Plants. Special Features in Vegetation Science 11. Opulus Press, Uppsala, Sweden.

Kenkel, N.C. 1993. Modeling Markovian dependence in populations of *Aralia nudicaulis*. Ecology 74: 1700-1706.

Koop, A.L. and C.C. Horvitz. 2005. Projection matrix analysis of the demography of an invasive, non-native shrub (*Ardisia elliptica*). Ecology 86(10):2661-2672.

Langer, R., S. Ryle and O. Jewiss. 1964. The changing plant and tiller populations of timothy and meadow fescue swards. I. Plant survival and the pattern of tillering. Journal of Applied Ecology 1:197-208.

Lesica, P. and T. Young. 2005. A demographic model explains life-history variation in *Arabis fecunda*. Functional Ecology 19:471-477.

Marmillod, F. 1982. Methodik und ergebnisse von untersuchungen über Zusammensetzung und Aufbau eines Terrasssenwaldes im peruanischen Amazonien. These doktorgrades, Gerog-August Universität, Göttingen. 198p.

Martin, G.J. 1995. Ethnobotany: A methods manual. Chapman and Hall, London.

Martinez-Ballestré, A., J. Caballero, V. Gama, S. Flores and C. Martorell. 2002. Sustainability of the traditional management of Xa'an Palms by the lownad Maya of Yucután, Mexico. In: Ethnobiology and Biocultural Diversity (J. Stepp, F. Wyndham and R. Zarger, eds.), p381-388. University of Georgia Press, Athens, GA.

McDonald, D.B., and H. Caswell. 1993. Matrix methods for avian demography. Current Ornithology 10:139-185.

Mejia, K.M. and F. Kahn. 1996. Biology, Ecology and Utilization of Irapay (*Lepidocaryum gracile* Martius). Folia Amazonica Vol. 8(1) – 1996 IIAP p19-28.

Mejia, K.M. and F. Kahn 1996. Biologia, Ecologia y Utilizacion del Irapai (*Lepidocaryum gracile* Martius). Folia Amazonica vol 8(1):IIAP19-28.

Mendoza, A. and K. Oyama. 1999. Ecology, management and conservation of potentially ornamental palms. Acta Horticulturae (ISHS) 486:79-86.

Mendoza, A., D. Pinero and J. Sarukhan. 1987. Effects of experimental defoliation on growth, reproduction and survival of *Astrocaryum mexicanum*. Journal of Ecology 75:545-554.

Menges, E.S. and R.B. Root. 2004. The life of a fire-adapted Florida goldenrod, *Solidago odora* var. *chapmanii*. The American Midland Naturalist 151(1):65-78.

Morey Alejo, H., and G. Sotíl García. 2000. Panorama histórico de la Amazonía Peruana: Una visión desde la Amazonía.

Nepsted, D. and S. Schwartzman. 1992. Non-timber products from tropical forests: evaluation of a conservation and development strategy. Advances in Economic Botany 9:1-164.

O'Brien, T. M. Kinnaird. 1996. Effect of harvest on leaf development of the Asian palm *Livistona rotundifolia*. Conservation Biology 10(1):53-58.

O'Hara, J. 1999. An ecosystem approach to monitoring non-timber forest products harvest: the case study of Bayleaf palm (*Sabal mauritiiformis*) in the Rio Bravo Conservation and management Area, Belize. PhD. Thesis. Yale University, New Haven, CT.

Olmstead, I. and E. Alvarez-Buylla. 1995. Sustainable Harvesting of Tropical Trees: Demography and Matrix Models of Two Palm Species in Mexico. Ecological Applications 5(2):484-500.

Oyama, K. and A. Mendoza. 1990. Effects of defoliation on growth, reproduction, and survival of a Neotropical dioecious palm, *Chamaedorea tepejilote*. Biotropica 22:119-123.

Padoch, C. 1988. Aguaje (*Mauritia flexuosa* L.f.) in the Economy of Iquitos, Peru. Advances in Economic Botany 6:214-224.

Palleiro, N., M.C. Mandujano, and J. Golubov. 2006. Aborted fruits of *Opuntia microdasys* (Cactaceae): insurance against reproductive failure. American Journal of Botany 93(4):505-511.

Peters, C. 1994. Sustainable harvest of non-timber plant resources in tropical moist forests: an ecological primer. Biodiversity Support Program. Washington, D.C.

Peters, C. 1990. Population ecology and management of forest fruit trees in Peruvian Amazonia. *In*: Alternatives to Deforestation: Steps toward Sustainable Use of the Amazon Rain Forest (A. Anderson, ed.), p86-98. Columbia University Press, New York.

Peters, C., A. Gentry, and R. Mendelsohn. 1989. Valuation of an Amazonian rainforest. Nature 339:655-656.

Pinard, M. 1993. Impacts of stem harvesting on populations of *Iriartea deltoidea* (Palmae) in an extractive reserve in Acre, Brazil. Biotropica 25(1):2-14.

Roff, D. 1996. The evolution of threshold traits in animals. Quarterly Review of Biology 71:3-36.

Roiloa, S.R. and R. Retuerto. 2005. Presence of developing ramets of *Fragaria vesca* L. increases photochemical efficiency in parent ramets. International Journal of Plant Sciences 166(5):795-803.

Roncal, J. 2004. Habitat differentiation of sympatric *Geonoma macrostachys* (Arecaceae) forms in three Peruvian lowland forests. Edaphic specialization of three *Geonoma* palm species in a Peruvian tropical lowland forest. Annual Meeting of the Association for Tropical Biology and Conservation GEOGRAPHIC AND CONCEPTUAL FRONTIERS OF TROPICAL BIOLOGY Miami, Florida, July 12th – 16.

Roncal, J., J. Francisco-Ortega, C.B. Asmussen, and C.E. Lewis. 2005. Molecular phylogenetics of the tribe Geonomeae (Arecaceae) using nuclear DNA sequences of phosphoribulokinase and RNA polymerase II. Syst. Bot. 30: 275–283.

Silvertown, J. and J. Lovett Doust. 1993. Age and Stage Structure, Pages 96-100 In *Introduction to plant population biology*. Blackwell Scientific, London. 210p.

Steward, J.H. 1948. Western Tucanoan Tribes. Pages 737-748 In *Handbook of South American Indians,* Vol. 3, The Tropical Forest Tribes, J.H. Steward, ed.

Smithsonian Institution, Bureau of American Ethnology Bulletin 143. Washington, D.C.:U.S. Government Printing Office.

Stewart, C. 2001. The commercial harvest of the African cherry (*Prunus africana*) on Mount Oku, Cameroon: effects on traditional uses and population dynamics. Ph.D. Dissertation, Florida International University, Miami, Florida.

Svenning, J. and M. Macia. 2002. Harvesting of *Geonoma macrostachys* Mart. leaves for thatch: an exploration of sustainability. Forest Ecology and Management 167:251-262.

Ticktin, T. 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41(1):11-21.

Tomlinson, P.B. 1990. The Structural Biology of Palms. New York: Oxford University Press. 477p.

Tuomisto H, and K Ruokolainen. 1993. Distribution of Pteridophyta and Melastomataceae Along an Edaphic Gradient in an Amazonian Rain-Forest. Journal of Vegetation Science. 5:25-34.

Vásquez Martínez, R. 1993. Flórula de las Reservas Biológicas de Iquitos, Perú – Allpahuayo - Mishana, Explornapo Camp, Explorama Lodge. Monographs in Systematic Botany from the Missouri Botanical Garden 63; 1046p.

Vásquez, R. and A. Gentry. 1989. Use and misuse of forest-harvested fruits in the Iquitos area. Conservation Biology 3:350-361.

Vormisto, J. 2002. Palms as Rainforest Resources: How Evenly are they Distributed in Peruvian Amazonia? Biodiversity and Conservation 11(6):1025-1045.

Warren, L.A. 1992. *Euterpe* palms in Northern Brazil: Market Structure and Socioeconomic Implications for Sustainable Management. Master's thesis, Department of Geography, University of Florida.

Weatherbase 2005. Source for weather records based on data collected by the National Climatic Data Center, as accessed at ://www.weatherbase.com/weather/weather.php3?s=077348 on March 24, 2005.

Whitham, T., J. Maschinski, K. Larson, and K. Page. 1991. Plant responses to herbivory: the continuum from negative to positive and underlying physiological mechanisms. *In:* Plant-Animal Interactions (D. Price, T. Lewinsohn, G. Fernandes and W. Benson, eds.), p227-256. John Wiley and Sons, New York, NY.

Wikberg, S. and B.M. Svensson. 2003. Ramet demography in a ring-forming clonal sedge. Journal of Ecology 91(5):847-854.

Zuidema, P. 2000. Demography of exploited tree species in the Bolivian Amazon. Ph.D. Dissertation. PROMAB Scientific Series No. 2. Ultrecht University, Ultrecht, the Netherlands.

CHAPTER V.

RECOMMENDATIONS FOR MANAGEMENT: IRAPAI (*LEPIDOCARYUM TENUE*)

INTRODUCTION: NON-TIMBER FOREST PRODUCT

Residents of riverine communities throughout the Peruvian Amazon use irapai (*Lepidocaryum tenue* Mart.) fronds as roofing thatch, collecting it from wild palms. Non-timber forest products (NTFPs) such as irapai function as income supplements that help many people rise above poverty level, and markets for these products have become part of the economic strategies of rural peoples. NTFPs provide and distribute economic benefits locally, as compared with many extractive forest activities (e.g., logging). While increased international tourism will affect commercial irapai thatch production, all of these products are locally produced and consumed unlike those harvested for export. Attempts to cultivate irapai have been unsuccessful. A germination trial (chapter three) revealed irapai seeds can remain viable after 60 months, but had only a 19.5% germination rate even given a five year monitoring period. Population growth, increased demand for irapai leaves for tourism-related construction, and predatory harvest methods have given cause for concern regarding the potential overharvest of this important species.

For this study, the harvest of irapai thatch was evaluated according to sustainability criteria based on economic, cultural, and demographic definitions. Weavers were able to earn up to US$21.00 for a day’s work, and crisneja vendors made an average of US$130 per month (chapter two). These findings as well as being part of the ribereño’s extractive way of life demonstrate irapai harvest meets the criteria for economic and cultural activities. Anecdotal information and the findings from chapter four support the short-term demographic sustainability of irapai leaf harvest, at least under the conditions described. Current levels of lambda were stable. There were no significant decreases in population survival, growth or leaf production until simulated levels of increased harvest reached an additional 70% of current harvest levels. There are other aspects of sustainability; however, this study did not take into account, such as the effects of harvest on organisms that utilize it or on the ecosystem as a whole.

Irapai Harvesting:

In chapter four I focused on the demographics of irapai populations in five different communities. I documented size class transitions as well as survival and reproductive probabilities, both sexual and asexual. Locals from all sites claimed that irapai was resilient and that an irapayale could recover easily from regular harvest, as long as stems were not cut. In this case, locals reported the disappearance of individuals and some populations. Two individuals from site three with whom I spoke about leaf collection frequency reported that if a minimal number of fronds were left on a stem, irapai would flush back after three to four months, healthier than before harvest. At site four, residents of Nuevo Triumfo reported that they harvested between three and six leaves from each trunk. Villagers here believed it was best to leave two to four fronds when harvesting irapai to ensure the stem did not die and that it produced the most harvestable leaves in the future.

Also at site four, residents of the village of Punga, had roofs of palmicho (*Geonoma* sp.) instead of irapai, resource substitution, suggesting that irapai harvest was not sustainable here. Residents said this was because palmicho was much more common and nearer by, but also because they would rather sell irapai than use it themselves, preferring to harvest for quick resale. Villagers here did not seem as interested in reforestation and sustainability as those in site four's village of Nuevo Triumfo (see also Arana 2000). Villagers reported one of their management practices was to leave in place a palm's spear for regeneration and harvest all other irapai leaves regardless of palm size. Evidence in Punga irapayales, however, indicated that many palms were harvested by cutting entire trunks. In September or October of 1999, a parcel custodian in Punga cut every irapai stem in and around monitoring plots. Also at this time data collection ceased so documentation of recovery or stem death was not documented. In June 2000 with the assistance of CARE – PERU staff and local residents, two new monitoring plots were established near Punga, and irapai growth and leaf production data were collected monthly for one year.

Management Opportunities and Recommendations:

Tropical forests are highly heterogeneous with respect to soil characteristics, topography, and light. Studies with trees, ferns, melastomes and palms have indicated that topographic position, slope, drainage, pH, extractable bases, treefall gaps, and light conditions influence the distribution and abundance of plants (Svenning and Macia 2002, Clark et al. 1998, Tuomisto and Ruokolainen 1993, Roncol et al. 2005). Harvest generates additional pressures on wild populations, and demand for irapai thatch is expected to increase. Management practices are recommended to enhance wild populations, including debris removal, placement of detritus around trunks to fertilize, and some thinning of nearby competitors or overhead canopy to open small light gaps. A more closed canopy could account for some levels of lower palm recruitment. There may be limits to population enhancement from increased light levels, however, and management practices could have unintended consequences such as the creation of increased numbers of trails and / or subsequent soil compaction. In addition to leaf harvest, irapai can be affected by the removal of canopy tree species around irapayales. Canopy trees help create the moist understory conditions that irapai prefers. When large canopy trees are removed for timber, there are consequences for the understory, making conditions drier in addition to allowing much more light to penetrate. These conditions would be less favorable for irapai growth.

Freckleton et al. (2003) showed that for *Euterpe edulis* Mart. harvest intensity, form and timing were important elements affecting population growth rate. These authors recommended including density-dependence and harvest timing as part of population models, without which predictions for *E. edulis* erroneously indicated tolerance to high harvest levels. Increased harvest simulations should investigate taking timing and density-dependence into account. Irapai is affected by soil nutrient, water, and light availability, and has been problematic to cultivate (Kahn and Mejia 1987, 1991). If cultivation issues could be overcome, however, irapai’s other characteristics could make it a good candidate for a complimentary crop with low maintenance requirements within intact forests. Until reliable cultivation methods are derived, however, using it as a complimentary crop may not be a viable option.

In the future, if crisneja demand were to significantly increase beyond levels currently suggested as sustainable, it is recommended that collectors harvest only leaves from large size class individuals and leave a minimum of one to three live leaves on each stem. These practices, widespread, could assist to stabilize existing irapayales.

Education of area harvesters and residents (as well perhaps as some level of enforcement) would be crucial for this to happen. Long-term recuperative efforts could be conducted by collecting, scarifying and planting seeds in long-term monitoring flats for reintroduction into habitats appropriate for new irapayale establishment. Further research is required on the correlation of increased light levels and increased growth, seed germination, plant propagation, and to determine an appropriate number of irapayales for establishment or reintroduction projects. In cases where irapai may have disappeared and there is difficulty re-establishing it, *Carludavica* sp. may be a possible substitute. Future studies also should evaluate further economic sustainability and investigate in detail market valuation. It is important to determine the minimum amount of irapai an individual or community must collect regularly to be worthwhile versus the costs involved.

Adaptive resource management strategies are important tools to understand a harvest – species relationship (Ticktin 2004). Some studies have shown harvest practices that enhance managed population persistence (Joyal 1996, Martinez-Ballesté et al. 2002). Locally practiced management activities, however, depend on land tenure and government socio-economic policies, population pressure, education, and cultural factors. Land tenure appears to be an exceptionally significant factor. The more vested the community and individuals, the more likely active resource management will be conducted. Strategies designed to encourage appropriate harvest levels, including community educational components would be beneficial.

The Peters et al. study (1989) offered quantitative arguments that the maximum value obtainable from an intact forest is more financially beneficial in theory than its removal or degradation. While there are valid criticisms of the Peters et al. (1989) study, its real significance is its attempt to change public policy by focusing the spotlight on the issue of alternatives to deforestation. Following Peters (1990), alternative harvesting regimes could be implemented including alternating unharvested areas or harvesting only every third or fourth stem within an irapayale. If necessary tourist facilities could be encouraged to use irapai thatch in a limited fashion, or to create roofs with a steeper pitch that allow roof thatch to last longer. In addition to thatch alternatives, tourist facilities could modify construction with irapai. An initial thatch layer could be installed and then a membrane (e.g., tin, tarp, etc.), permitting the existence of an airspace with an aesthetic layer of thatch on top. Insulated layers of styrofoam panels would allow airflow. The first layer of thatch may not need to be irapai, but could be made from another species as an underlayment that would still be aesthetically acceptable (e.g., *Carludavica* sp.). Initially these alternatives would require a larger expense. Other materials such as tin, mixed materials, and substitute materials or modified designs requiring less material may be additional diversification methods to prevent overuse of irapai thatch.

The recuperation of long-lived large palms may help buffer some irapayales against decline, although their resiliency may not transfer to harvested small palms. Close long-term monitoring of harvested stands would be necessary to confirm predictions of sustainability and use of appropriate management practices. The recommended term for long-term monitoring is at least ten years. Forest conservation efforts will be more successful when they become profitable, and extractive reserves and NTFPs may be important pieces of the puzzle to protect forest resources.

LITERATURE CITED

Arana, V. 2000. Oportunidades de Inversión Ambiental en Loreto: Informe de la Visita a la Reserva Comunal Tamshiyacu Tahuayo, Sus Comunidades y Zonas de Influencia (5 – 7 de Abril 2000). Report to CARE-PERU.

Clark, D.B., D.A. Clark, and J.M. Read. 1998. Edaphic variation and the mesoscale distribution of tree species in a neotropical rain forest. Journal of Ecology. 86:101-112.

Freckleton, R.P. and A.R. Watkinson. 1998. How does temporal variability affect predictions of weed population numbers? (Forum). Journal of Applied Ecology 35, 340-344.

Joyal, E. 1996. The Palm Has Its Time: An Ethnoecology of *Sabal uresana* in Sonora, Mexico. Economic Botany 50(4):446-462.

Kahn, F.K., and K. Mejia. 1991. The Palm Communities of Two “Terra Firme” Forests in Peruvian Amazonia. Principes, 35(1):22-26.

Kahn, F.K. and K. Mejia. 1987. Notes on the Biology, Ecology, and Use of a Small Amazonian Palm: *Lepidocaryum tessmannii*. Principes (31):14-19.

Martinez-Ballestré, A., J. Caballero, V. Gama, S. Flores and C. Martorell. 2002. Sustainability of the traditional management of Xa’an Palms by the lownad Maya of Yucután, Mexico. In: Ethnobiology and Biocultural Diversity (J. Stepp, F. Wyndham and R. Zarger, eds.), p381-388. University of Georgia Press, Athens, GA.

Peters, C. M., A. Gentry, and R. Mendelsohn. 1989. Valuation of an Amazonian Rainforest. Nature 339:655-656.

Peters, C. 1990. Population ecology and management of forest fruit trees in Peruvian Amazonia. *In*: Alternatives to Deforestation: Steps toward Sustainable Use of the Amazon Rain Forest (A. Anderson, ed.), p86-98. Columbia University Press, New York.

Svenning, J. and M. Macia. 2002. Harvesting of *Geonoma macrostachys* Mart. leaves for thatch: an exploration of sustainability. Forest Ecology and Management 167:251-262.

Ticktin, T. 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41(1):11-21.

Tuomisto H, and K Ruokolainen. 1993. Distribution of Pteridophyta and Melastomataceae Along an Edaphic Gradient in an Amazonian Rain-Forest. Journal of Vegetation Science. 5:25-34.

APPENDICES

APPENDIX 2 - 1: AMAZONIAN PALM ETHNOBOTANICAL STUDIES

Ethnobotany is concerned with the interrelationships between people and plants, especially the use, management, domestication and classification of plants by cultures (Alexiades 1996, Balick 1984, Bennett 2002, Cotton 1996, Cunningham 2001). Amazonian ethnobotanists study connections between people and palms to understand how indigenous people and ribereños meet their daily needs and improve their quality of life. Many Amazonian palms are used for subsistence and export products, although the sustainability of such endeavors for many species has not yet been studied. *Aphandra natalia* fibers are used in the manufacture of brooms in Ecuador (Bennett *et al.* 2002, Borgtoft Pedersen 1996). *Astrocaryum* species provide edible seed, fiber, and trunks that can be used as posts (Acero Duarte 1979, Coomes 2004). *Bactris* is widely used, particularly the peach palm (*B. gasipaes*) which has a nutritious fruit and seed oil, and is very important for the Shuar, Quichua, Waorani, and Shipibo cultures (Bennett *et al.* 2002, Bennett 1992, Bodley and Benson 1979, Davis and Yost 1983). The fiber of *Desmoncus,* the New World's substitute for rattan and only climbing palm genus, is widely used in weaving, and a small industry has developed in Iquitos (Henderson and Chavez 1993, Kahn and de Granville 1992). Both apical meristem and fruits of *Euterpe* species are eaten, and trunks are used in house construction.

Management practices and their effects on the regeneration and marketable yields of another palm, açaí (*Euterpe oleracea*), have been studied on managed and unmanaged flooded plots in Belém, Brazil (Anderson 1988, Brondízio *et al.* 2002, Warren 1992). *Geonoma* leaves are a source for thatch, their fragrant fruits sometimes are utilized as perfume, and arrows are made from the stems (Balick 1988, Boom 1987). The trunks of

Iriartea sp. are important for house construction, often as floors and shelves (Anderson 1998, Bennett *et al.* 2002, Balick 1988, Pinard 1993). *Mauritia flexuosa* has edible fruits around which a thriving market has developed in Iquitos (Balick 1986, Padoch 1988).

Palms play such an important role for the Achuar people of Peru and Ecuador, they derived their name from this palm (Bennett *et al.* 2002). The oily fruits of *Oenocarpus bataua* are highly valued for chicha and oil (Balick 1987, Vickers and Plowman 1984). *Orbignya* palms are utilized for their oil-rich kernels (Anderson *et al.* 1991, Balick 1988). *Phytelephas* seeds are a source of vegetable ivory, its leaves as thatch and for fiber (Henderson and Balick 1987, Kahn and de Granville 1992). *Scheelea* is important for wood and thatch to the Shipibo Indians (Bodley and Benson 1979). Floors can be made from *Socratea* wood (Vickers and Plowman 1984).

Extractive uses, demographic studies, fruit yield, and seed germination and dispersal studies of *Astrocaryum* spp. have been conducted (Charles-Dominique *et al.* 2003, Coomes 2004, Jensen and Balslev 1995, Kahn and Moussa 1999, Potvin *et al.* 2003, Schroth *et al.* 2004, Velasquez-Runk 2001). The ethnoecology of *Sabal uresana* in Mexico and demographics of *Thrinax radiata* and *Cocothrinax readii* in Central America and *Phytelephas aequatorialis* in South America have been studied (Joyal 1996, Olmstead and Alvarez-Buylla 1995, Velasquez-Runk 1998). Researchers have studied the harvest and stem demography of *Iriartea* sp. (Anderson 1998, Pinard 1993), as well as the stilt roots, growth, and ethnobotany of *Socratea* sp. (Avalos 2004, Boom 1987, Schatz *et al.* 1985). In addition to thatch, at least one indigenous group uses juice from the softened stems of *Lepidocaryum* sp. to clear eye infections, and in Colombia its stems are employed in basketry (Duke and Vasquez 1994).

APPENDIX 2 - 2: DESCRIPTION OF *LEPIDOCARYUM TENUE*, IRAPAI

Taxonomy

Lepidocaryum belongs to the Lepidocaryeae tribe of the sub-family Calamoideae, which is characterized by fruits covered with overlapping scales (Henderson 1995). *Mauritia flexuosa,* another member of the Lepidocaryeae also is economically important in the region (Uhl and Dransfield 1987). Of the 22 genera that make up Lepidocaryeae, only four (*Lepidocaryum, Mauritia, Mauritiella* and *Raphia*) are found in South America (Mejia and Kahn 1996). *Lepidocaryum* is monotypic with three varieties (*L. tenue* var. *tenue*, *L. tenue* var. *casiquiarense*, and *L. tenue* var. *gracile*), distinguished by leaf and inflorescence characteristics (Henderson 1995). These varieties are distributed throughout the western and central Amazonian river basin regions including parts of Colombia, Venezuela, Guyana, Peru and Brazil. Each variety occupies a relatively discrete range. *L. tenue* var. *tenue* occurs in the Peruvian Department of Loreto, and ranges from here through sections of Colombia and into Brazil (Henderson 1995). *L. tenue* var. *gracile* and *L. tenue* var. *casiquiarense* can be found in Guyana and Brazil (where it is called carana-í do matto), and Colombia (known as igaico), Venezuela and in Amazonas, Brazil, respectively (Gentry 1993, Henderson 1995).

Considerable sub-generic taxonomic disagreement exists in the literature, as the morphology of this genus across its range is complex (Henderson 1995, MacBride 1960, Uhl and Dransfield 1987). *Lepidocaryum gracile* C. Martius has been misapplied to the species in the Iquitos area, as has *L. enneaphyllum* Barboza Rodriguez. Henderson (1995) acknowledges that other authors previously recognized several species based on floral characteristics, including *L. tessmannii* Burret, the name many Peruvian biologists continue to use for irapai palms in the Iquitos region (Brako *et al.* 1993, Macbride 1960). Despite the taxonomic debate, the only variety reported in the literature for the Iquitos area is *L. tenue* var. *tenue.* In my studies, all populations assessed or monitored were of a uniform morphology, and all conformed to Henderson's (1995) description of *L. tenue* var. *tenue*.

Morphology and Ecology

The leaf of *L. tenue* is reduplicately palmate with open sheaths, ranging from 15 to 80 cm long (Henderson 1995). Irapai has no crownshaft and its sheath frequently is covered with dense tomentum (Uhl and Dransfield 1987). Its fronds have conspicuous petioles, 60 - 130 cm in length, that are round or terete in cross-section (Henderson 1995). Its rachis is very short, from 2 - 4 centimeters, and center segments vary from 48 - 75 cm in length and 1 - 13 cm in width, although 5 – 8 cm wide is found more commonly. Margins infrequently have very small spines often close to the apex, and the epidermis has a moderate cuticle (Henderson 1995). In general the strength of a palm leaf relates to its internal anatomy and is "based on the presence of vascular bundles, silica bodies, and fibers" that make the thatch durable (Henderson 1995, Tomlinson 1961).

Irapai has an unarmed stem with distinct internodes. It is erect, and on average is three to 3.5 meters in height as an adult and three to four centimeters in diameter (Mejia and Kahn 1996). Maximum height, however, can range between 0.8 and six meters (Henderson 1995). Unlike dicots that can have several meristems (axillary and apical), aerial palm shoots have only a single terminal bud. This causes them to be more susceptible to mortality from herbivory and treefalls than dicots (Uhl and Dransfield

1987). To offset this disadvantage, palms in general are pachycaulous (Rich 1986). Palm stems actually consist of mature primary tissues that originated from the terminal meristem. Once fully formed many palms are unable to increase in diameter due to a lack of a cambium (Tomlinson 1990, Uhl and Dransfield 1987).

Amazonian palms do not commonly form rhizomes; the only Amazonian palms to exhibit rhizomatous tendencies are *Iriartella setigera* (Mart.) Wendl. and *L. tenue* (Kahn 1986). *Calamus* and other lianescent palms (rattans) develop diverse types of rhizomes described by Dransfield (1978). Kahn and de Granville (1992) report that in tropical rainforests, subterranean stems are an adaptive response correlated to decreasing light filtering onto the forest floor. Irapayales formed by basal branches correspond to the growth pattern defined by the Tomlinson model: "This architecture results from the repeated development of orthotropic modules, equivalent in the form of basal branches that are, initially, restricted to the epicotyledonous regions in the axis of the seedling (the first model) and the basal nodes in the subsequent axes" (Halle *et al.* 1978). Many Amazonian palms follow this model. Compared to a more common clumping form of Tomlinson's model as illustrated by *Euterpe oleracea* and *Phoenix* sp., however, irapai is unusual in that it manifests this growth through creeping rhizomes, the formation of scales, and the radiation of roots from each rhizome along the length of its lower side (Tomlinson 1990).

Each axis produces several rhizomes from the base which are 0.5 to 1.0 cm in diameter and up to two meters in length, that extend outward from an axis to five centimeters below or above the surface of the soil before producing another axis (Mejia and Kahn 1996), although I saw very few stems with rhizomes above or at surface level.

During the horizontal expansion phase, the apex grows vertically to form a new shoot of larger diameter than the rhizome (Tomlinson 1990). Chazdon (1986) stated that the formation of stolons combined with the palm's tendency toward precocious flowering has created an "evolutionary potential for shade adaptation" and a trend of reduced adult height. The rhizomatous habit of irapai could help make irapai suitable for extractivism or other types of ribereño agroforestry programs (Borgtoft Pederson and Balslev 1990, Kahn 1985, Kahn and Mejia 1987a and 1987b).

Vegetative Growth

Palm stems grow and gain height through the continuous production of leaves from a terminal meristem, the abscission scars from which can help determine palm age. Tomlinson (1990) states that, "the foliage leaf in this family represents the most complex determinate vegetative organ built by plants". Leaf production in palms is influenced by environmental and genetic factors similar to those that affect stem formation and development (Tomlinson 1990). Although a relatively constant rate of leaf production and continuous growth rate have been ascribed to palms, experimental evidence shows that many palms exhibit variable growth rates with rapid spurts of height and diameter growth early in life that commonly are regulated by environmental conditions (Lugo and Rivera Batlle 1987, Tomlinson 1963, Zona and Maidman 2001). Lugo and Rivera-Batlle (1987) found light conditions rather than substrate factors regulate height growth of the palm, *Prestoea montana*, negating the commonly held assumption of a constant growth rate for this species. Waterhouse and Quinn (1978) drew similar conclusions regarding the diameter-height relationship of *Archontophoenix cunninghamiana*. External environmental factors that influence frond production include levels of nutrients in the soil, available light for photosynthesis, water availability or periodic drought, and fire (Kahn 1986, Kahn and Mejia 1987a, 1987b, 1991, Rich 1986, Tomlinson 1990). In addition to those found in the soil a palm also may glean nutrients through crown detritus trapping or litter accumulation (Tomlinson 1990, Uhl and Dransfield 1987).

Vormisto *et al.* (2004) investigated whether soil properties or topographic variation influenced the distribution and composition of Peru's upland Amazonian palm species. The authors inventoried $5m^2$ plots along a 0.65-ha transect line, and found that when they took abundance into account, composition closely corresponded with soil cation content. They also discovered that many of the 37 most abundant species were not randomly distributed, but followed topographic variations, although these patterns varied at different sites. *Lepidocaryum tenue* was more abundant than expected on topographic rises and less abundant than expected at lower positions, findings corroborated by Kahn (1985), Kahn and Mejia (1987a, 1987b) and Mejia and Kahn (1996). The authors speculated that the complexity of using topography to measure species distributions might contribute to ambiguous patterns at different sites (Vormisto *et al.* 2004). Vormisto (2002) found irapai missing entirely from the richest soil type locations. The lack of *L. tenue* in at least one plot may have been related to topography as most of at least one transect was relatively flat (Vormisto 2002). Where irapai was present, the clearest population structural trend that she found was a lack of small irapai palms (seedlings and juveniles). The majority were adults one meter in height or taller. In plots where *L. tenue* was found, few other species were documented, and these were not very abundant. Soil properties most likely play a role in density differences, in addition to other elements of forest dynamics, as irapai was not found on soils considered to be nutrient rich (Vormisto 2002). Understanding soil and distribution mechanics as well as data on size class structure and density also can make abundance predictions more accurate.

Kahn and Mejia (1987a, 1987b, 1991) studied irapai ecology and thatch use in Jenaro Herrera on the Ucayali River. They also measured densities of irapai populations found in two different terra firme forests. Mejia and Kahn (1996) estimated the number of stems and irapayale size near the village of Jenaro Herrera, located 200 km southwest of Iquitos. For a given roof size, in an area with similar topography and habitat, *L. tenue* was found to be abundant within irapayales, ranging from 1,330 stems per hectare in wetter soils to 10,000 stems per hectare on some terra firme soils. Based on stem abundance data collected by López Parodi (1988) and Kahn and Mejia (1987a and b), 0.046 hectares per square meter and 0.052 ha per square meter of roof are needed, respectively. Studies done by Vormisto (2002) revealed larger areas of harvestable irapai (0.100 ha per m^2 and 0.143 ha / m^2 of thatched roof) are needed. It is possible these differences in stem abundance were related to soil type. Ferralitic soils yielded the smaller areas needed for harvest, whereas fluvial and loamy soils required larger areas because stem densities were lower. Vormisto *et al.* (2002, 2004) studied dominance patterns in palm communities in the Iquitos-Pebas region of Peru, and found *L. tenue* to be dominant and quantitatively important. Suarez (2002) assessed the effects of light and harvest on frond production at a location within the Tamshiyacu – Tahuayo Communal Reserve.

Wildlife use

Wildlife use of this palm is not well known. On several occasions I encountered an aggressive unidentified species of large, black ant, possibly *Dolichoderus* sp. (Longino 2005) or *Dendromyrmex* sp., Tribe Camponotini (Wilson 2005), that built paper-like enclosures on the undersides of leaves in at least two plots (Figure 2 – 2a). It is unknown whether this is a mutually beneficial association, and field investigation is warranted. Rickson and Rickson (1986) demonstrated that such relationships may be complex and that the palm may receive unexpected benefits such as receipt of additionally absorbed nutrients from water soaked paper nests. While there is evidence of such absorption, experimental verification is needed (Tomlinson 1990). I also experienced three nocturnal incidents where a large invertebrate overhead, most likely a saucer-sized cockroach, *Blaberus* sp. (Thomas 2005) similar to the one in Figure 2 – 2b, ingested or tore off strips of installed crisnejas. Herbivory and fruit predation by wildlife and humans as well as other anthropogenic factors may affect growth, frond or fruit production.

Figure 2 – 2a.

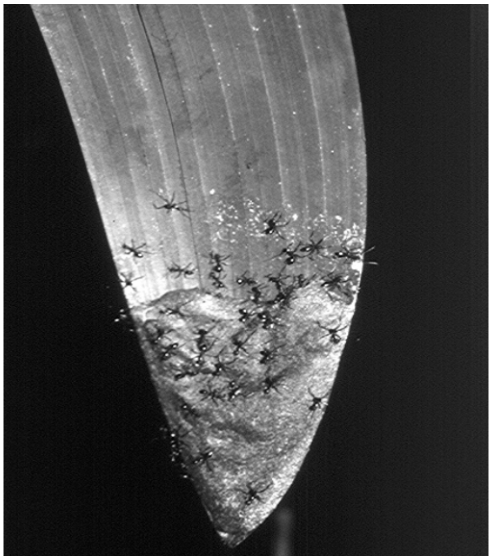


Figure 2 – 2b.

APPENDIX 2 - 3: IRAPAI, *LEPIDOCARYUM TENUE*, FROND USE - THATCH

Irapai leaves are traditionally used as roofing thatch in much of the area where the palm is common (Kahn and Mejia 1987a and b). Irapai thatch also is used for overhead coverings on larger boats, especially those used as water taxis and for mass transportation. Both are true in riverine communities quite distant from Iquitos as well as in some neighborhoods immediately adjacent to the city. Fronds are harvested by cutting the petiole, and leaves are bundled into units of roughly 100 for transport to a weaving location. Leaf shape and a long petiole make irapai fronds easy to weave. While still green, individual fronds are hand-woven together by each leaf's petiole onto a rib, or paño, commonly made from casha pona (*Socratea* sp.) or ponilla (*Wettinia* sp.) or other locally found palms (Kahn and Mejia 1987a and b). The finished product is a thatch tile, or crisneja, approximately 2.5 to three meters long, one meter tall, and only a few centimeters wide. Weaving techniques vary, but each crisneja has between 90 and 150 leaves. Locals believe the number of leaves woven into a crisneja is the most important factor determining the quality of a thatch tile, and secondarily the type of weave pattern holding each frond in place. Irapai became a regional thatch of choice for several reasons. It was much less expensive and lighter than metal roofing materials, and the leaf shape and long petiole make the fronds easy to interweave forming tightly fitting and attractive patterns.

Because of their large size and bulkiness, these tiles can be difficult to transport by road, often done via bicycle in Iquitos, but when installed they provide a considerably thick, layered cover for a structure (Kahn and Mejia 1991). According to Duke and Vasquez (1994), *L. tenue* is the only stemmed palm in the region whose four blades are consistent in shape and size, allowing for uniformity in thatch production. Numerous other palms that can be used as thatch grow in association with irapai, but due to this palm's waxy cuticle, irapai thatch has been considered superior (Mejia 1997). Roofs made of irapai thatch have an average life span of five to six years, and they generally outlast those made from other local materials. This longevity compares with between three and four years for a roof of thatch tiles, or techos, made from chambira (*Astrocaryum chambira*), and four to six years for one tiled with fronds from bonbonaje (*Carludovica palmata,* Cyclanthaceae) (Kahn and Mejia 1991). Thatch tiles also can be made from yarina (*Phytelephas macrocarpa*) and shapaja (*Attalea butyracea*), although typically these are found farther south than Iquitos (Mejia 1997). Another reason for the local preference of irapai has to do with its abundance. There may be better palms or plants from which to make thatch, but the abundance of irapai combined with its other characteristics has made it a favorite choice (Mejia 1997).

Irapai is ubiquitous in the Peruvian Amazon and regionally important for economic and ethnobotanical purposes. Kahn and Mejia (1987a and b) estimated that it takes 160 crisnejas to roof an average size house of 35 m^2 with a 60º double hip (dihedral) roof. If each crisneja is comprised of approximately 130 individual fronds, this means 20,800 leaves are needed to complete one roof (Kahn and Mejia 1991). López Parodi (1988) recommended the use of 300 crisnejas to cover the roof structure of a standard, six meter by nine meter, low cost rural house in the Peruvian Amazon. Requiring the same number of individual fronds would mean 39,000 fronds are needed for this 54-m^2 dwelling. A typical roof size for an ecotourism structure is 500 m^2, requiring approximately 2,500 crisnejas to cover (Table 2 – 3a). Using the same number of leaves per crisneja, this means a total of 325,000 irapai fronds from approximately 81,250 palms are needed.

Mejia and Kahn (1996:24) “reported finding an average of 40,000 irapai fronds in a hectare, south-southwest of Iquitos near Jenaro Herrera.” This is an estimated 5,000 stems per hectare, averaging eight fronds per stem. “If an average of only four fronds were collected from each palm stem, 5,200 stems would be required to construct a roof based on their 35-m^2 structure” (Mejia and Kahn 1996:26). Conservatively this means two hectares of forest per roof “were needed for 160 crisnejas of 130 fronds each, assuming a naturally occurring stem density exceeding 2,500 axes of one meter height or greater” (Kahn 1988; Kahn and Mejia 1987a:18 and b, 1991). López Parodi (1988:124) believed the “125,000 hectares of uplands around Jenaro Herrera could produce enough irapai leaves to thatch 50,000 standard, 54 m^2 houses.” Based on this estimate, the author extrapolated it would require 2.5 hectares of irapai for the fronds to roof one house. Vormisto’s (2002) stem density findings, however, were much lower between 1,040 and 1,462 stems per ha, meaning the same size roof would require frond collection from between 3.5 and 5 hectares. Such variability of stem density has direct impact on thatch supply.

Table 2 – 3a. Estimated Irapai Leaves and Crisnejas Used for Roofs.

Source, Structure Size, and Roof Type:	Square footage:	No. of Crisnejas:	Total Leaves Per Crisneja:	Total Irapai Leaves Needed for Roof:
House - 6m x 9m[1]:	54 m^2	300	130	39,000
House - 5m x 7m: double hip roof[2]	35 m^2	160	130	20,800
Typical Ecotourism structure[3]:	500 m^2	2,500	130	325,000

---

[1] López Parodi (1988)

[2] Kahn and Mejia (1987a&b)

[3] based on an average of five crisnejas needed per square meter coverage.

APPENDIX 2 - 4: *LEPIDOCARYUM TENUE* SPECIMENS AND HERBARIA

To confirm palm identity, in June 2000 I reviewed *Lepidocaryum* herbarium specimens at the Universidad Nacional de la Amazónia Peruana (AMAZ) in Iquitos. Several had been collected near irapai monitoring plots that I established in the ExplorNapo Camp Reserve near Sucusari northeast of Iquitos (see chapter four), near the village of Mishana southwest of Iquitos, and from the Allpahuayo - Mishana Reserve south of Iquitos (Figure 2 – 3). They were identified as either *L. tessmanii* or *L. tenue*. In addition, I reviewed several dozen specimens of *Lepidocaryum* at the U.S. National Herbarium (US) in Washington D.C. in January 2001. I compared specimens identified as *L. tenue* against photographic materials of leaves and palms I observed being used to create crisnejas and those of several wild populations growing outside of Iquitos. The living palms and leaf materials visually matched herbarium specimens reviewed.

Since 1990 conducting international research has become more difficult. Primarily, governmental concern has been related to intellectual property rights and foreign researchers prospecting for profit. This concern extended to the collection of *L. tenue* voucher specimens for herbarium deposit in Peru. In 1997 and 1998 I spoke with representatives at the Peruvian Instituto Nacional de Recursos Naturales (INRENA) office in Iquitos regarding collecting and export permit requirements for voucher herbarium specimens. In addition to requiring permits, Peruvian laws also require that international research be conducted in collaboration with a Peruvian counterpart institution. I worked with the Peruvian Amazon Research Institute or Instituto de Investigaciónes de Amazónia Peruana (IIAP). IIAP Director of Research and palm biologist, Dr. Kember Mejia, included this project under an umbrella agreement between

Florida International University and IIAP, and provided me with a national partner facility. In 2000, two years after submitting the completed application and permit fees to INRENA Lima and Iquitos offices and including collegial interaction on my behalf, official documents were issued for the collection and deposition of voucher herbarium specimens of *Lepidocaryum* for this study.

APPENDIX 2 - 5: IRAPAI VENDOR QUESTIONNAIRE –

MORONACOCHA MARKET

Location of Marketplace: Moronacocha

Collector: Collection No. Date:

Information from Vendor:

Name:

Type of vendor: permanent stall Temporary stall Ambulatory

Village of vendor: Gender: Estimated Age:

How often sell here:

In other markets?

Information on the collection:

Local name: Lifeform:

Village Vegetation type:

Cultivation status: cultivated managed wild

Marketing status: gathered by vendor resold

Number of species in collection: single mixture of ______ plants

Names of other ingredients:

Condition of plants: fresh dried preserved in ____________

Price/unit: Brought to market: daily weekly on occasion

Estimated Quantity: vendor: whole market

Availability: jan feb mar apr may jun jul aug sep oct nov dec

How much sold now compared to in past: more same less

Why? Less available for harvest less demand by buyers other

Use:

Plant part used:

Preparation:

Notes:

Herbarium Information:

Botanical family:

Scientific name:

Preparation: herbarium specimen spirits collection ziploc bag

Distribution: Herbarium Nacional de Peru Other:

Total number of duplicates:

Source: adapted from Cunningham 2001, Alexiades 1996, Cotton 1996, and Martin 1995.

APPENDIX 4 - 1: SITE DESCRIPTIONS

Site one:

The Reserva de los Mai Huna was an Indigenous Reserve in Sucusari, northeast of Iquitos, formerly known as Reserva de los Orejones, established in the 1950s. This reserve was located on the Sucusari River that feeds into the Napo River, approximately 150 km northeast of Iquitos. The Mai Huna were a primarily Spanish-speaking (formerly Western Tucanoan) indigenous group with a population of approximately 300 individuals (Steward 1948). They were affiliated linguistically with the Western Tucanoan tribes, such as the Secoya and Coreguaje (Bellier 1994). Economically important activities for the Mai Huna revolved around fishing, hunting, harvesting forest products and agriculture, sales from which allowed them to acquire some manufactured items. The Mai Huna harvested irapai leaves for local subsistence, community use, and for market trade, some of which was tourism related. Topography in this reserve was nearly flat and had only a few low, white sandy hills (Vasquez 1993). I found numerous irapayales as I hiked through this reserve, and frequently came upon signs of recent leaf cutting. Irapai monitoring plots were closest to the village of Sucusari, which had approximately 90 people living in and around it. At site one no fruit or flowers were observed in any monitoring plots during this study.

Site Two:

A privately held ecotourism company, Explorama Tours Corporation (Exploraciónes Amazonicas, S.A.), in conjunction with the civic association, Amazon Nature Conservation of Peru Association (CONAPAC) owned the 1,725-hectare ExplorNapo Camp Reserve (a.k.a. Amazon Reserve), also in Sucusari, four hours by power boat (157 km) northeast of Iquitos, down the Amazon River and up the Napo (Vasquez 1993). This group owns, oversees and maintains several large protected natural areas. The ExplorNapo Camp reserve has floodplains of loamy clay soils, in addition to well-drained loamy and loamy clay soils in terra firme habitat (Vasquez 1993). No hunting, harvesting, collecting or farming are allowed, and the staff does its best to patrol it. All plants and animals within it are protected. Harvest of irapai leaves is not permitted, but some were cut mostly for small projects or repairs around the reserve. Some illegal harvesting took place. Since 1978, Explorama Tours has encouraged the floristic study of their reserves.

Initially at site two, I found in one plot female flowers and immature fruits and one palm with mature fruit. Between July and November 1997, however, this plot was affected by a large tree fall that took out a quarter of it, and created a large light gap south of it. Most of the palms in this part of the plot were crushed, affecting their growth. Surprisingly at the next census in 1998, several palms in this plot had male flower spikes. This is an unusual change, as proximal *L. tenue* palms tend to be the same sex.

Site Three:

The mestizo village of Mishana is located west-southwest of Iquitos along the southern bank of the black water Nanay River, three hours by boat from the port of Sta. Clara and one and one-half hours upriver from Puerto Almendras. The community of Mishana is home to about 120 people (21 families), and the community school has about forty students. Area topography is nearly flat with a few small hills of white sand. Mishana has low, swampy areas (igapós) containing loamy clay soils, well-drained flat areas with loamy soils, and loamy clay to sandy transitions in flat poorly drained areas.

The Rio Nanay’s Allpahuayo - Mishana Community Collective Reserve contains diverse natural resources, and is a major supplier of crisnejas to the Iquitos market, together with sections of the Iquitos-Nauta Highway (*personal communication,* K. Mejia). Transport of crisnejas into Iquitos occurs by both river and road. Residents harvest irapai for local use or market trade. This Reserve had 1,000 hectares designated for community and ecotourism uses (Vasquez 1993). Within the reserve, residents designated areas with different harvest or use levels. These included sections that remained unharvested, those with managed harvest, and others deemed as unmanaged and commercially harvested. In the managed harvest areas, only mature fronds were collected, no trunks were cut, and at least a few leaves were left on each stem. Locals believe that this management results in healthy stems that are bigger, greener, and stronger after three to four months. The unmanaged parts of the reserve were located farther away from the village, making them more difficult to patrol and control, and subject to illegal use by non-reserve residents. Sampling was stratified across areas with different harvesting levels. I observed several old male inflorescences at site three, but saw no flowers or fruit in three of seven plots during this study. One stem here exhibited significant insect damage, which is very uncommon.

Site Four:

The Tamshiyacu-Tahuayo Communal Reserve is 300,000 hectares located along the Amazon River, near the Tahuayo Quebrada and part of an ecological corridor, about three hours by boat upstream (45 km) of Iquitos, and is another major source of irapai for the Iquitos market (Arana 2000, Bodmer 2003). About thirty communities located throughout the reserve make use of the natural resources found here. The American nonprofit organization, CARE, operated field stations within the Tamshiyacu-Tahuayo Communal Reserve (RCTT), and was interested in various aspects of agroforestry and community development. One of CARE's agroforestry projects, CASPI, initiated, assisted with, and documented enhancement planting and agroforestry activities conducted by individuals and several villages (CARE 1992). The reserve had community harvested, individually controlled parcels of one hectare each for which residents were responsible. Much of the income for the village of Nuevo Triumfo residents was from the sale of charcoal and wood. The village of Punga is located one hour further upriver from Nuevo Triumfo. This village extends along a narrow ridge. Most of the houses in Punga, an evangelist community, had roofs of palmicho (*Geonoma* sp.) instead of irapai because of the latter's scarcity. Reserve areas around both villages had been harvested heavily to supply the crisneja market in Iquitos.

Site Five:

Allpahuayo Biological Research Reserve is a 5,000-hectare agricultural and agroforestry research outpost owned by the Peruvian Amazon Research Institute (IIAP), my in-country counterpart for this study. It is located south-southwest of Iquitos, between Km 34.5 – 37.5 of the Iquitos – Nauta Highway. Topography is relatively level although there are some small hills. Soils in the reserve include well-drained loamy clay Allpahuayo and Shapaja types, well-drained white sandy Varillal soils, poorly drained sandy Cinamillo soils, as well as well-drained and poorly drained San Pedro loamy clay (Vasquez 1993). Nearly ninety percent of the irapai harvested for the commercial market in Iquitos came from the Allpahuayo-Mishana vicinity (*personal communication*, K.

Mejia). Transportation into and out of the city was via the Iquitos-Nauta highway and the Nanay River.

The protected parts of the reserve include 2,750 hectares where no harvesting was permitted. Heavy human colonization surrounded the reserve and illegal irapai harvesting was common and difficult for IIAP personnel to control. Often entire trunks were cut instead of removing individual fronds, which killed the palm. Because IIAP did not have enough staff to control this problem, they attempted to educate those collecting to use non-predatory methods. High demand for thatch in Iquitos markets resulted in heavy travel on the only highway out of the city to harvest the palm. This activity was common, especially around Km 21. Some of the most heavily collected areas were within the first 20 - 40 kilometers of the highway. In June of 2000 at site five, I found two of four plots crushed by a large tree fall that had occurred a few weeks earlier. I was able to relocate most palms from these plots, but I was unable to find 13 palms from one plot that most likely were under the fallen trunk. I was unable to tell whether these palms were alive or dead.

APPENDIX 4 - 2: IRAPAI CENSUSES, DATA COLLECTION, AND PROCEDURE TO GENERATE A FULL PROJECTION INTERVAL FOR POPULATIONS.

In July and December 1997, I censused sites one and two with one assistant. From June 1998 to July 1999, trained Peruvian assistants conducted a monthly census of Nuevo Triumfo plots at site four; they also sampled plots monthly at Punga (site four) from June 2000 to July 2001. An assistant and I provided training for Peruvian counterparts and collected data from all five sites (Amazon, Napo and Nanay Rivers) in June 1998 and June 2000. The data collected included numbers of leaves harvested per stem, numbers of new leaves produced, number of new stems in each plot, whether each palm had a spear, numbers of dead palms per plot, height measured from ground to point of bud emergence, overall height measured from ground to the junction of the longest petiole with its blade (Bernal 1998), number of live and dead leaves, number of petiole remnants and whether they were cut, flowers, fruit, basal branches (if present), and stem diameter at 10 cm above ground level to minimize effects of soil accumulations around stem base.

The following occurrences caused stem heights, measured to the point where the newest expanded leaf separates from the stem, to decrease and a large size class palm to regress, reflected in the data as transition to a small size class (R_t). When harvesters cut stems, palms moved from large size class to small size class. At times, leaf harvesting reduced palm size, resulting in size class regression. Falling canopy debris sometimes damaged but did not kill an individual causing the palm to regress to the small size class. Additionally, seedlings and young shoots initially elongate prior to developing full leaves with petioles (Figure 4 – 2) causing the appearance of shrinking when they first do. In addition, as each new leaf expands, the petiole elongates initially then separates from the stem, its angle changing from near vertical to 45 degrees or less. Thus, as the large size class added palms that increased in height, the small size class also added individuals previously in the large size class by several methods.

To generate a complete projection interval for irapai populations censused in 1998 and 2000 as well as for sites not surveyed in 1997, a method was needed to estimate demographic parameters between these two samplings. I examined growth, survival and reproduction from surveys conducted in June and December 1997, as well as monthly monitoring conducted by trained Peruvian assistants from June 1998 to July 1999 and June 2000 to July 2001. For demographic data for the transition year, 1999, I broke down into monthly increments the census data between 1998 and 2000 and compared against monthly monitoring data to determine stem survival and growth. These data were used to construct a 7 x 7 matrix ($\mathbf{A}$) for all vegetative stages over the 24-month projection interval showing their fates at the 12-month mid-point between the two censuses.

Because a projection matrix may be used to determine population structure and size at time $t + 1$ from a stage abundance vector at time t through the formula, $\mathbf{n}_{(t+1)} = \mathbf{A} \times \mathbf{n}_{(t)}$, it is also possible to find population structure at $t - 1$ by the rearranged formula, $\mathbf{n}_{(t-1)} = \mathbf{A}^{-1} \times \mathbf{n}_{(t)}$, where $\mathbf{A}^{-1}$ is $\mathbf{A}$ inverted. The two vectors determined in this manner were used as the margins of a cross-classified frequency table. Since very few palms died during this study and fates for transition year 2000 were known, remaining individual stage abundance was assigned from matrix ($\mathbf{A}$) based on census mid-points.

APPENDIX 4 - 3: POPULATION PROJECTION MATRICES FOR *LEPIDOCARYUM TENUE* ACROSS THREE YEARS[1]

	Stage at time N*t*						
Stage at time N*t+1*	Seed (0)	Size1 (s1)	Size1 repro (s1r)	Size1 repro clone (s1rc)	Size2 (s2)	Size2 repro (s2r)	Size2 repro clone (s2rc)
				1997-1998 (T1)			
Seed (0)	0.3978	0.0000	0.0000	0.0000	0.0000	7.0720	1.1178
Size1 (s1)	0.4972	0.8700	1.0000	0.6765	0.1366	0.0000	0.0411
Size1repro (s1r)	0.0055	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Size1reproclone (s1rc)	0.1326	0.0866	0.0000	0.9412	0.0000	0.0000	0.2192
Size2 (s2)	0.1492	0.0939	0.0000	0.0588	0.7950	0.5333	0.7123
Size2repro (s2r)	0.0000	0.0000	0.0000	0.0000	0.0000	0.4333	0.0685
Size2reproclone (s2rc)	0.0884	0.0578	0.0000	0.2353	0.1988	0.2667	0.8767
				1998-1999 (T2)			
Seed (0)	0.9310	0.0553	21.000	0.0000	0.2915	9.0000	0.0000
Size1 (s1)	0.2931	0.7447	0.0000	0.2500	0.0243	0.0000	0.0000
Size1repro (s1r)	0.0000	0.0026	1.0000	0.0000	0.0000	0.0000	0.0000
Size1reproclone (s1rc)	0.0000	0.1053	0.0000	0.0000	0.0000	0.0000	0.0000
Size2 (s2)	0.0345	0.1842	0.0000	0.1667	0.8623	0.4286	0.5882
Size2repro (s2r)	0.0172	0.0000	0.0000	0.0000	0.0162	0.5000	0.0000
Size2reproclone (s2rc)	0.0345	0.0000	0.0000	0.1667	0.0526	0.0000	0.2941
				1999-2000 (T3)			
Seed (0)	0.4533	0.0000	14.000	0.0000	0.5944	13.600	0.7418
Size1 (s1)	0.7500	0.7346	0.0000	0.0000	0.0364	0.0000	0.0000
Size1repro (s1r)	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Size1reproclone (s1rc)	0.0000	0.0453	0.0000	0.6000	0.0132	0.0000	0.0000
Size2 (s2)	0.1944	0.1618	0.0000	0.0000	0.6821	0.1667	0.0000
Size2repro (s2r)	0.0278	0.0000	0.0000	0.0000	0.0364	0.8333	0.0455
Size2reproclone (s2rc)	0.0556	0.0194	0.0000	0.6000	0.4503	0.5000	1.7273

---

[1] Rare transition adjustment: growth transitions that were not observed were set to 0.01

APPENDIX 4 - 4: STABLE STAGE DISTRIBUTION AND REPRODUCTIVE VALUES FOR *LEPIDOCARYUM TENUE* ACROSS THREE YEARS

Stage	Predicted Stable Stage Distribution (SSD)	Observed Stage Distribution	Reproductive Value
		1997-1998 (T1)	
Seed (0)	0.1928	8.5876	0.6084
Size1 (s1)	0.2988	3.2214	0.4496
Size1repro (s1r)	0.0007	0.0055	0.2804
Size1reproclone (s1rc)	0.1279	1.3796	1.4036
Size2 (s2)	0.2191	2.3425	0.6874
Size2repro (s2r)	0.0089	0.5018	4.5564
Size2reproclone (s2rc)	0.1518	1.7237	2.4871
		1998-1999 (T2)	
Seed (0)	0.5081	31.2778	0.8891
Size1 (s1)	0.2530	1.3121	0.6008
Size1repro (s1r)	0.0018	1.0026	50.5211
Size1reproclone (s1rc)	0.0194	0.1053	0.2789
Size2 (s2)	0.1765	2.2645	0.8987
Size2repro (s2r)	0.0133	0.5334	9.6452
Size2reproclone (s2rc)	0.0279	0.5479	0.4915
		1999-2000 (T3)	
Seed (0)	0.3718	29.3895	0.3984
Size1 (s1)	0.2226	1.5210	0.1944
Size1repro (s1r)	0.0000	1.0000	5.5707
Size1reproclone (s1rc)	0.0080	0.6585	0.8636
Size2 (s2)	0.0850	1.2050	1.0379
Size2repro (s2r)	0.0228	0.9430	5.6507
Size2reproclone (s2rc)	0.2899	3.3526	2.017

APPENDIX 4 - 5: SENSITIVITIES[1] FOR *LEPIDOCARYUM TENUE* ACROSS THREE YEARS

	Stage at time N*t*						
Stage at time N*t+1*	Seed (0)	Size1 (s1)	Size1 repro (s1r)	Size1 repro clone (s1rc)	Size2 (s2)	Size2 repro (s2r)	Size2 repro clone (s2rc)
	1997-1998 (T1)						
Seed (0)	0.1173	0.1818	0.0004	0.0778	0.1333	0.0054	0.0924
Size1 (s1)	0.0867	0.1344	0.0003	0.0575	0.0985	0.0040	0.0682
Size1repro (s1r)	0.0541	0.0838	0.0002	0.0359	0.0614	0.0025	0.0426
Size1reproclone (s1rc)	0.2706	0.4194	0.0009	0.1795	0.3076	0.0125	0.2131
Size2 (s2)	0.1325	0.2054	0.0005	0.0879	0.1506	0.0061	0.1043
Size2repro (s2r)	0.8786	1.3615	0.0030	0.5827	0.9985	0.0405	0.6916
Size2reproclone (s2rc)	0.4796	0.7432	0.0016	0.3181	0.5450	0.0221	0.3775
	1998-1999 (T2)						
Seed (0)	0.4517	0.2249	0.0016	0.0173	0.1569	0.0119	0.0248
Size1 (s1)	0.3052	0.1520	0.0011	0.0117	0.1060	0.0080	0.0168
Size1repro (s1r)	25.668	12.780	0.0899	0.9826	8.9152	0.6738	1.4117
Size1reproclone (s1rc)	0.1417	0.0705	0.0005	0.0492	0.0492	0.0037	0.0078
Size2 (s2)	0.4566	0.2273	0.0016	0.0175	0.1586	0.0120	0.0251
Size2repro (s2r)	4.9005	2.4398	0.0172	0.1876	1.7020	0.1286	0.2695
Size2reproclone (s2rc)	0.2497	0.1243	0.0009	0.0096	0.0867	0.0066	0.0137
	1999-2000 (T3)						
Seed (0)	0.1481	0.0887	0	0.0032	0.0339	0.0091	0.1155
Size1 (s1)	0.0723	0.0433	0	0.0016	0.0165	0.0044	0.0563
Size1repro (s1r)	2.0710	1.2398	0	0.0445	0.4733	0.1270	1.6150
Size1reproclone (s1rc)	0.3211	0.1922	0	0.0069	0.0734	0.0197	0.2504
Size2 (s2)	0.3859	0.2310	0	0.0083	0.0882	0.0237	0.3009
Size2repro (s2r)	2.1008	1.2576	0	0.0452	0.4801	0.1288	1.6382
Size2reproclone (s2rc)	0.7499	0.4489	0	0.0161	0.1714	0.0460	0.5848

---

[1] Sensitivities obtained from projection matrices in Appendix 4 - 3

APPENDIX 4 - 6: ELASTICITIES[1] FOR *LEPIDOCARYUM TENUE*

ACROSS THREE YEARS

	Stage at time N*t*						
Stage at time N*t+1*	Seed (0)	Size1 (s1)	Size1 repro (s1r)	Size1 repro clone (s1rc)	Size2 (s2)	Size2 repro (s2r)	Size2 repro clone (s2rc)
	1997-1998 (T1)						
Seed (0)	0.0291	0	0	0	0	0.0238	0.0644
Size1 (s1)	0.0269	0.0729	0.0002	0.0243	0.0084	0	0.0017
Size1repro (s1r)	0.0002	0	0	0	0	0	0
Size1reproclone (s1rc)	0.0224	0.0226	0	0.1054	0	0	0.0291
Size2 (s2)	0.0123	0.0120	0	0.0032	0.0747	0.0020	0.0463
Size2repro (s2r)	0	0	0	0	0	0.0109	0.0295
Size2reproclone (s2rc)	0.0264	0.0268	0	0.0467	0.0676	0.0037	0.2064
	1998-1999 (T2)						
Seed (0)	0.3071	0.0091	0.0243	0	0.0334	0.0779	0
Size1 (s1)	0.0653	0.0826	0	0.0021	0.0019	0	0
Size1repro (s1r)	0	0.0243	0.0656	0	0	0	0
Size1reproclone (s1rc)	0	0.0054	0	0	0	0	0
Size2 (s2)	0.0115	0.0306	0	0.0021	0.0998	0.0038	0.0108
Size2repro (s2r)	0.0615	0	0	0	0.0201	0.0470	0
Size2reproclone (s2rc)	0.0063	0	0	0.0012	0.0033	0	0.0029
	1999-2000 (T3)						
Seed (0)	0.0336	0	0	0	0.0101	0.0617	0.0428
Size1 (s1)	0.0271	0.0159	0	0	0.0003	0	0
Size1repro (s1r)	0	0	0	0	0	0	0
Size1reproclone (s1rc)	0	0.0044	0	0.0021	0.0005	0	0
Size2 (s2)	0.0375	0.0187	0	0	0.0301	0.0020	0
Size2repro (s2r)	0.0292	0	0	0	0.0087	0.0536	0.0372
Size2reproclone (s2rc)	0.0208	0.0044	0	0.0048	0.0386	0.0115	0.5047

[1] Elasticities obtained from projection matrices in Appendix 4 - 3

VITA

L. ALÍCE WARREN

Certified Arborist. International Society of Arboriculture.
M.A. Geography (Natural Resources Management) University of Florida.
B.A. Interdisciplinary Environmental Studies. University of Florida.
A.A. Liberal Arts and Sciences, *summa cum laude.* Manatee Community College.

Professional Experience:

6/08 – present Natural Areas Management, Miami-Dade County Parks and Recreation
4/93 – present Deering Estate at Cutler (Park), Miami-Dade County Parks and Recreation
5/96 – 5/00 Natural Resources Manager and Environmental Education Coordinator
Projects include:

- Chicken Key Bird Rookery – Island Restoration
- Coastal Saltmarsh creation
- Cutler Slough / Deering Flow Way rehydration
- Cutler Weir installation
- Reconstruction of Historic Keyhole Boat Turning Basin
- Relocation of Large Native Trees (including 60’ Royal Palms)
- Arboricultural Care for plant resources and Treatment for Historic Tequesta Burial Mound Live Oak (*Quercus virginiana*)
- Management Plan, Master Plan and Resource Treatment and Site Plan
- Interdisciplinary Web-based Middle School Curriculum

9/93 – 12/96 Explorations, Inc., Bonita Beach, Florida. Ecotour Conductor
One to two week duration ecotours for small groups through natural resource zones of tropical regions of Costa Rica and the Peruvian Amazon. Education and co-coordination of logistics.

1/92 – 4/94 Caribbean Conservation Corporation, Gainesville, Florida. Assistant Director of Programs. Projects include:

- Green Turtle Research Activities in Tortuguero, Costa Rica:
- Miskito Coast Protected Area Project in northeastern Nicaragua:
- Paseo Pantera Project: western Caribbean

9/92 Caribbean Conservation Corporation, Gainesville, Florida. Coordinator, International Short Course in Marine Turtle Biology and Conservation on Caribbean and Pacific coast of Costa Rica. Logistics and sponsorship of participants from tropical countries.

7/91 – 12/91 Department of Geography, University of Florida, Gainesville, Florida. Graduate Ethnobotanical Researcher. Socioeconomic aspects of the Açaí palm (*Euterpe oleracea*) fruit economy in Belém, Pará, Brazil.

7/89 – 6/91 Caribbean Conservation Corporation, Gainesville, Florida.
Office Manager.

8/90 – 5/91 Geography Department, University of Florida, Gainesville, Florida.
Research Assistant - demographic and agroecological databases on agricultural sustainability in Africa.

PUBLICATIONS AND PRESENTATIONS:

Snow, R.W., K. Krysko, K. Enge, L. Oberhofer, A. Warren-Bradley, and L. Wilkins. 2007. Introduced Populations of *Boa constrictor* (Boidae) and *Python molurus bivittatus* (Pythonidae) in Southern Florida. Pages 416 - 438 in R.W. Henderson and R. Powell, eds., Biology of the Boas and Pythons, Eagle Mountain Publishing, LC. Eagle Mt., UT.

Warren-Bradley, A. and E. Salcedo. 2003. Role of Miami-Dade County Parks in Educating K-12 Students on Invasive Exotics. Invasive Plants in Natural and Managed Systems (IPINAMS) Conference, Ft. Lauderdale, FL.

Warren-Bradley, A. 2001. Sustainable harvest of Irapai (*Lepidocaryum tenue* Mart.) in the Peruvian Amazon. (second place, and the J. Morton Award in Economic Botany for student presentations Second place – SEB, Julia Morton Award.) Poster presentation for Building Bridges with Traditional Knowledge II., International Meeting of Society for Economic Botany and International Society of Ethnopharmacology. Honolulu, Hawaii.

Warren-Bradley, A. 1999. Potential for the sustainable harvest of Irapai (*Lepidocaryum tenue* Mart.) in the Peruvian Amazon. First Annual Biology Symposium, Miami, FL, 11 February.

Warren, A. 1997. Restoration of Chicken Key Bird Rookery. Poster presentation for the Society for Ecological Restoration Conference, Ft. Lauderdale, FL, 12-15 November.

Warren, A. 1995. Recovery of the Deering Estate's Natural Areas from Hurricane Andrew. Poster presentation for the Miami Dade County Dept. of Environmental Resources Management Natural Areas Workshop, Miami FL, 24 June.

Warren, A. 1994. Overview of the Açaí (*Euterpe oleracea*) fruit economy in northern Brazil. Research Seminar Series, Fairchild Tropical Garden, 1/19, Miami, FL.

Warren, L.A. 1992. *Euterpe* Palms in Northern Brazil: Market Structure and Socioeconomic Implications for Sustainable Management. M.A. Thesis, University of Florida.

Warren, L.A. 1990. *Melaleuca quinquenervia* (Paper Tree): South Florida's Formative Exotic. B.A. Thesis, University of Florida.