An Ecosystem Approach to Monitoring Non-Timber Forest Product Harvest: The Case Study of Bayleaf Palm (Sabal mauritiiformis) in the Rio Bravo Conservation and Management Area, Belize

A Dissertation
Presented to the Faculty
of
Yale University,
School of Forestry and Environmental Studies

in Candidacy for the Degree of
Doctor of Forestry and Environmental Studies

by
Jennifer L. O'Hara

Committee: Kristiina A. Vogt, Chair
Nicholas Vt. Brokaw, Manomet Observatory
Andrew Henderson, New York Botanical Gardens
Bruce Larson, Yale University
Daniel J. Vogt. Yale University
Kathleen Weathers, Institute for Ecosystem Studies
May 1999

Abstract

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

Jennifer L. O'Hara

1999

Tropical deforestation and concurrent losses of biodiversity have fostered the use of non-timber forest product (NTFP) projects as a conservation strategy. Despite the widespread implementation of this strategy, monitoring and assessment efforts have been limited. This research proposes an ecosystem approach for monitoring harvest of non-timber forest product species through examination of the bayleaf palm case study. This study focuses on one NTFP species: Sabal mauritiiformis a palm species whose leaves are harvested for the production of thatched roofs in parts of Central America.

Past NTFP monitoring approaches have generally focused on harvest effects at the population level. The ecosystem approach examines harvesting effects at multiple scales. At the organismal level, leaf productivity rates, leaf size, percent recovery of original leaf number, specific leaf weight, chlorophyll content, and foliar nutrient content were used to provide rapid assessments of plant vigor. Ecosystem level indicators were monitored because evidence exists that some palm species play an important role in cycling K in tropical forest ecosystems. Palms tend to generate large leaf biomasses as a proportion of total aboveground biomass which implies that removal of large quantities of vegetative structures may have significant ecological implications.

A defoliation experiment revealed that palms which had two mature leaves left on the plant at the time of harvest recovered more rapidly than palms that had one leaf left or all leaves removed. The recovery period for the "two leaves" treatment was approximately five years.

Litterfall and decomposition studies at the ecosystem level found that S. mauritiiformis may play an important seasonal role in cycling P K and Zn during the months of July to September when fine litterfall transfer are lowest. Furthermore this study found that the ecological role of this palm species changes across the landscape, as the densities of S. mauritiiformis vary by forest type. In contrast to claims that harvest of non-timber forest products may be best in oligarchic forests, this research found that where plant species form monodominant stands, the dominant species may be performing essential ecological functions.

Chapter Six: Synthesis

During the past two decades, two realizations have greatly influenced the creation of the non-timber forest product conservation strategy. First, during the 1970's, protected areas underwent a significant paradigm shift from "locking up" natural resources to integrating human needs with conservation objectives (Goodland 1987; Shaffer and Saterson, 3987; McNeely, 1992). Secondly, in the late 1980's, in an attempt to improve conservation of standing forests, three studies reported that the primary cause of deforestation was under valuation (deBeer and McDermott, 1989; Peters, et at., 1989; Panayotou and Ashton, 1992.). This combination was a catalyst for the creation of integrated conservation and development projects (ICDPs), whose primary purpose has been to conserve biological diversity while providing economic opportunities for local human populations (Wells and Brandon, 1992). Non-timber forest product projects are one example of ICDPs. The appeal of these projects has taken the conservation and international development community by storm. Despite the plethora of NTFP projects, there have been minimal efforts to monitor their efficacy (Kremen et al., 1994; Perez and Byron 1999). Is there cause for concern? To date reviews that examine the efficacy of the NTFP conservation strategy have found little evidence that these projects are accomplishing their objectives (Kremen et al., 1994). Furthermore systematic approaches for evaluating project success have been lacking (Perez and Bryon, 1999).

Implementation of non-timber forest product projects can generally be attributed to one or more of six assumptions. It has been assumed that NTFP projects can: 1) generate sufficient income to preclude or minimize more degrading land uses, 2) increase rural income, 3) protect future potential products (i.e., agricultural or pharmaceutical products), 4 support indigenous cultures, 5) integrate conservation of biological diversity and rural economic development objectives, and 6) be ecologically sustainable (see Chapter Two). Studies that have tested these assumptions have found varied results. Although this strategy holds promise, it is not a panacea and should be implemented with caution.

Monitoring of NTFP projects, where it occurs, typically examines potential effects of harvest at the population level. Studies at the population level tend to measure population densities, size class distributions, and effects of harvest on growth reproduction, and survival. Many researchers have used matrix models to estimate effects of harvest (e.g., Peters. 1989; Pinard, 1993; Olmsted and Alvarez-Buylla, 1995; Ratsirarson et al., 1996). However, these models have several shortcomings (Pinard and Putz, 1992; Pinard 1993). Matrix models can be labor and time intensive, and inappropriate for some NTFP species (i.e., palms) because not all of the model assumptions are met (Pinard and Putz, 1992).

Monitoring efforts have largely ignored indicators at the plant level. In many instances, organismal level indicators may provide quicker and more accurate assessments of changes in plant vigor compared to population level variables. Depending upon the plant part harvested, different indicators will be required. For example if tree bark is harvested, one indicator might be to assess plant vulnerability to pest or pathogen infestations. If roots are harvested (without killing the plant) root:shoot ratios could be monitored.

Although plant level indicators can not assess changes at the community and ecosystem levels, they can offer a more efficient method of assessing potential effects of harvest at the NTFP species level. Plant level indicators combined with indicators at other levels of hierarchy can provide a more holistic assessment of harvesting impacts. As demonstrated by the case studies of DDT and DDD summarized in Chapter Two, a combination of indicators from multiple levels of hierarchy can be used to detect early warning signals, changes in community relationships, and changes in ecosystem functions or processes. In these case studies, information on physiological and anatomical changes at the organismal level was combined with environmental parameters such as DDT levels in the atmosphere or DDD in water samples, in order to identify the lethal effects of these pesticides (Hickey et al., 1966; Wargo, 1996).

More recently researchers have begun to examine effects of NTFP harvest at the community and ecosystem levels. Some studies have found critical links between plants and other plant and animal species. For example, many NTFP species provide important forage and studies have found that NTFP harvest can have negative repercussions on wildlife (Kinnaird, 1992; Chapman and Onderdonk, 1998). Other NTFP species are keystones that provide forage during times of shortage (Terborgh. 1986; Hess, 1996; Yamakoshi, 1998). NTFP species can also provide critical habitat (Thoenes and Buchman, 1994; Woolbright, 1996; Choe, 1997; Funakoshi and Akbar, 1997; Dejean et a).., 1998). All of these community level studies indicate that it is necessary to identify and understand potential community level connections when harvesting NTFP products.

Research that examines the effects of harvest at the ecosystem kvel is also at the nascent stage. However several studies have found NTFP harvest can result in changes in ecosystem functioning (e.g., Nepstad et al., 1992; Brown et al., 1995 Mo et al., 1995). Where NTFP projects are promoted in protected areas, natural resource managers have a responsibility to identify potential impacts on community and ecosystem functions since there is the possibility that NTFP species may play significant or keystone roles. Over harvest of NTFP species can lead to negative cascading effects on other community or ecosystem level components (Bonnann and Likens, 1979; Nepstad 1992).

Despite the important role that some species play, it is often difficult to identify keystone species. For example, identification of keystone species requires bridging levels of hierarchy (i.e., organism, population, community etc.,) and temporal and spatial scales (Power et al., 1996; Vogt et al., 1997). This ecosystem approach requires the identification of sensitive plant level variables that indicate changes at the plant level while assessing potential community, ecosystem, and landscape effects. As mentioned earlier, depending upon the product and species harvested, different indicators will be required.

This dissertation used an ecosystem approach to measure potential negative effects of harvest on one non-timber forest product species, bayleaf palm (S. mauritiiformis) in the Rio Bravo Conservation and Management Area, Belize. Potential impacts of leaf harvest were assessed by combining information from previous population level studies on S. mauritiiformis (O'Hara, 1996) with information from studies conducted at the plant, ecosystem, and landscape levels. Leaf productivity monitoring revealed that S. mauritiiformis is relatively slow growing (see Chapter Four). Control plants (2 m in height) produced 1-2 leaves per year hi both the transition and upland mesic forests within the Rio Bravo Conservation and Management Area.

A defoliation experiment was conducted to estimate tolerable harvest intensities and frequencies. The practice of leaving two mature leaves on each harvested plant (as recommended by many extractors), facilitated faster recovery after defoliation compared to other treatments (leaving one mature leaf or 100% defoliation) Leaf productivity rates, used in isolation as indicators of plant vigor, were found to be potentially misleading. Initially defoliated plants tend to have higher rates of leaf productivity compared to controls (Crawley, 1983; Mendoza et al., 1987; Ratsirason et al., 1996). However repeated defoliation of S. mauritiiformis in Rio Bravo showed that after the second defoliation leaf productivity rates did not differ significantly from controls. Harvesting impacts on leaf productivity rates therefore vari&1 with the intensity of harvest frequency.

Without a mechanistic understanding of adaptations of species specific compensatory growth, it is difficult to assess harvesting effects. In this case study, monitoring changes in concentrations of macro nutrients (N, P, K, Ca) in foliar tissues and specific leaf weight did not appear to be sensitive indicators of plant responses to defoliation. The combination of monitoring changes in leaf length (as a proxy of area), percent recovery of original leaf number, leaf productivity rates, C concentrations in foliar tissues and C:N ratios gave a more holistic assessment of the resistance and resilience of S. mauritiiformis to defoliation disturbance. For example, as harvesting intensity increased, both C concentrations and C:N ratios in palm foliar tissues decreased. These results may be indicative of changes in carbohydrate storage in the palm bole. Since carbohydrates are critical to plants as stored nutrient reserves and for maintaining growth and plant organs (Larcher, 1995), changes in C levels can have negative impacts on a plant's ability to adapt to a changing environment. Furthermore higher C:N ratios indicate a greater degree of sclerophylly and increased resistance to herbivory. Sclerophyllous leaves, although a larger investment, are a better deterrent to herbivores (Mauseth, 1988). The decreased C:N ratios for 100% defoliated palms may indicate that these individuals had insufficient C resources to produce new leaves that were as well- protected as leaves from non-defoliated palms. Analysis of chlorophyll in defoliated and undefoliated palms also suggested a decrease in photosynthetic potential since chlorophyll measurements significantly differed between treatment palms and controls. All of these factors suggest a decreased ability of harvested palms to allocate and maintain normal plant functions. Although new leaf production was a high plant priority, the new leaves regenerated were smaller and therefore less effective in maintaining normal plant functioning.

The ecological role of S. mauritiiformis was examined at the ecosystem level in two forest types, transition and upland mesic, within the Rio Bravo Conservation and Management Area. This study is one of a few that have been examined the potential ecological roles of palms. The purpose of this ecosystem level study was to test the hypothesis that S. mauritiiformis was cycling significant quantities of limiting nutrients through litterfall and subsequent decomposition of its leaf tissues. And furthermore, that as population densities of this species changed across the landscape, the magnitude of Sabal's contribution to total ecosystem element cycling would also change.

This research did not find evidence that leaf extraction for thatch harvest would result in the removal of significant quantities of limiting nutrients from the harvest site. However, the importance of analysis at varying temporal scales was highlighted as a result of the litterfall studies. When palm litterfall was compared with dicotyledonous litterfall on an annual basis, the mass of leaf litterfall contributed by palm species was only 27% and 23% of total annual mass of dicotyledonous litterfall in transition and upland mesic forest, respectively. However, when examined on a quarterly basis there were indications that palms, especially S. mauritiiformis in the transition forest, played a critical seasonal role in transferring plant essential nutrients N, P, K, Mg, and Zn. During the months of July, August. and September 1996, palm leaf litter transfers were at their peak while the pulse of dicotyledonous litterfall had already occurred during the months of March, April and May 1996. The pulse of dicotyledonous litterfall was followed by the onset of the rainy season suggesting that much of the nutrients being mineralized from decaying leaf litter from dicotyledonous species were vulnerable to leaching loss (Kimmins, 1997). Potassium is especially noted for its susceptibility to leaching. Thus the K contained in dicotyledonous species litterfall would have fluxed through the system, and K may not have been in an available within less than one month. Therefore the contribution of K in decaying palm litterfall becomes especially important since palm liner is continuously being transferred to the forest floor and decomposing.

Are these results representative of litterfall patterns for transition and upland mesic forest in the Rio Bravo Area or do they describe an isolated event? Furthermore are these results representative of humid tropical forest in general? Research conducted at Rio Bravo and other humid tropical forests support the existence of seasonal pulses of dicotyledonous litterfall. These pulses are primarily driven by changes in precipitation (Reading et al., 1995). For example, in Rio Bravo leaf shedding is most abundant during the months of February through May coinciding with decreases in precipitation (< 100 per month). In contrast, palm litterfall contributions remain relatively constant throughout the year, characteristic of evergreen species (Chabot and Hicks, 1982; Gower and Richards, 1990).

Results from the decomposition experiment supported the conclusion that K leached from dicotyledonous species in a quick pulse immediately after senesced leaves began to decay on the ground. For example, in the transition forest only 21% of the original K remained in decaying dicotyledonous foliage ten days after litterbags had been placed in the field. This contrasted with the slower release of K from decaying Sabal foliage in which 2 of the original K was present after 57 days. The slower release of K from decaying Sabal foliage may serve as a conservation mechanism for this easily lost element.

In the transition forest, where Sabal densities were highest, k values indicated that P and Zn mineralized from decaying Sabal leaf tissues at considerably faster rates than dicotyledonous species. For example, analysis using a single negative exponential model indicated that it would take 5.7 years for 99% of the P to be released from dicotyledonous tissues compared to 2.0 years for Sabal tissues in the transition forest. Because the high pH of the Rio Bravo soils may potentially limit P availability, these differences in P mineralization rates from decaying litter become important. This hypothesis is further supported by soil analyses that found only trace amounts of available P in the Rio Bravo soil samples. Therefore the cycling of P through litterfall and its subsequential release through decomposition are critical sources of available P. The combination of results from soil analysis, litterfall monitoring, and decomposition studies implied that Sabal leaf litterfall is an important link in the P cycle in the transition forest. This palm species may be providing a relatively accessible pool of P consistently throughout the year and especially at times of the year when P supplies from dicotyledonous litterfall are waning.

This research demonstrates that despite claims that harvest of non-timber forest products is best in oligarchic forests (because high population densities facilitate collection and are less likely to result in negative effects on population level dynamics), there are other ecological functions to consider. For example, where plant species form monodominant stands, these species may be performing essential ecological functions and may regulate ecosystem resilience to disturbance. In the case of S. mauritiiformis where this species is dominant (in the transition forest) it appears play an important seasonal role in cycling plant essential nutrients such as P, K, and Zn. Furthermore, results from the decomposition study indicated that K mineralizes from decaying Sabal foliage more slowly than decaying dicotyledonous foliage thereby acting as a conservation mechanism for this easily leached nutrient. As hypothesized, the ecological role of this palm species changed across the landscape, as the densities of S. mauritiiformis varied. Where population densities were highest (in the transition forest), S. mauritiiformis appeared to play a more critical seasonal important role in controlling the cycling of plant essential nutrients P K, and Zn. Although S. mauritiiformis was present in upland mesic forest, densities of this species were lower and therefore the effects of S. mauritiiformis on nutrient cycling rates were less important.

Implications for Management in Rio Bravo and Beyond

Based upon the analyses summarized in this dissertation, it appears that S. mauritiiformis in the Rio Bravo Conservation and Management Area can tolerate leaf extraction rates of at least five-year intervals. Two mature leaves should be left on each harvested plant to facilitate recovery from defoliation. Variables measured at the plant level (i.e., leaf length, percent recovery of original leaf number, leaf productivity rate, C concentrations in foliar tissues and C:N ratios) appeared to be the most useful indicators of plant vigor in this study. A trend was found that as harvesting intensity increased, the concentrations of trace metals in foliar tissues also increased. This dissertation research identified several areas that require future study. For example, it would be important to determine whether leaf harvest makes S. mauritiiformis more susceptible to trace element toxicity (i.e., Al, Fe, and Mn). Other studies are needed to more closely examine C allocation patterns (i.e., changes in carbohydrate reserves) in order to insure that palms do not become more susceptible to herbivory or that harvest depletes nutrient reserves. Research that assesses changes in herbivory rates as a result of defoliation is also likely to be a useful indicator of harvesting tolerance.

This research provides no evidence that leaf extraction will remove substantial quantities of nutrients from the harvesting site. It appeared that available nutrients in soils, litter standing crop and fluxes provided by litterfall and decomposition processes, more than balanced the quantity of nutrients removed by a single or even multiple harvests.

At the ecosystem level, information gained from this study identified that S. mauritiiformis plays an important seasonal role in transferring plant essential nutrients in the transition forest. These results have implications for forest management in the Rio Bravo Area. For example, in the transition forest, timber harvest or litter removal during the months of July, August, and September should be reduced to limit potential negative impacts on the available pools of nutrients.

Beyond Rio Bravo, the ecosystem approach developed in this dissertation has applications for certification schemes of non-timber forest products. To date, certification has focused primarily on timber species. Certification of NTFPs has focused on only a few products (i.e., Brazil nuts and chicle) and monitoring has tended to use a population level approach. The approach developed here can be used to broaden the existing population focus.

This dissertation contributes to the existing evidence that palms may play critical roles in cycling K in humid tropical ecosystems. It is necessary that information be gathered on the potential ecological roles of palms because of their utility and potential use in NTFP projects. Only a few studies have compared the different functions that dicotyledons and palms play in tropical ecosystems (e.g., F et al., 1979; Bloomfield et al., 1993; Vogt et al., 1996). This dissertation contributes to the current knowledge of potential functional differences between dicotyledonous species and palm species by highlighting the unique roles that these plant groups play in cycling of elements through litterfall and decomposition. Furthermore the assumption that harvest of NTFP species is best in oligarchic forests was examined. This dissertation found evidence that where a NTFP species dominates, it may play a keystone role or essential ecological function.

If non-timber forest product projects are to be implemented in protected areas, a more accurate understanding is necessary of the potential roles that non-timber forest product species play at the community, ecosystem, and landscape levels. Not only is ecological monitoring necessary, but monitoring at several hierarchical levels is required to ensure that community and ecosystem linkages are maintained. The plethora of NTFP projects as well as the strategy of integrated conservation and development projects has placed increased burdens and complexities on protected areas and their managers. Are these increased expectations of protected areas realistic and attainable? Over the next several decades, the challenge will continue to be to strike the balance between facilitating human needs while meeting the goals of biodiversity conservation. The use of

NTFP projects as a conservation strategy will likely remain important. However, successful forest conservation will require that NTFP projects be used with care and as part of a portfolio of strategies.