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THE IMPORTANCE OF TRADITIONAL ECOLOGICAL KNOWLEDGE FOR PALM-WEEVIL CULTIVATION IN THE VENEZUELAN AMAZON

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ABSTRACT.—Entomophagy is widespread among indigenous people, promoting the gathering of traditional ecological knowledge of insect life histories and plant-insect interactions. In the Amazon, the cultivation of palm weevil larvae (*Rhynchophorus palmarum* and *Rhinostomus barbirostris*) for food provides an important supplement to the diets of many indigenous people. This study conducted with the Jotï people from Venezuelan Amazonia examined their traditional ecological knowledge (TEK) of palm (*Oenocarpus bacaba*) and weevil interactions and how they have applied their TEK to optimize returns on palm weevil cultivation. They manipulate palms to induce changes in the resource-partitioning and competition that occurs naturally between weevil species, thereby increasing harvests of their preferred species of weevil. We found that the Jotï's traditional ecological knowledge was congruent with scientific findings of weevil natural history and palm and weevil interactions. This analysis identifies potential research directions that may provide solutions to agricultural problems such as palm weevil infestations in palm plantations. We conclude that understanding and preserving traditional ecological knowledge and practices is important for organisms such as palm weevils that rarely have been studied in their natural forest settings.

Key words: entomophagy, palm-weevil cultivation, plant-insect interactions, resource management, traditional ecological knowledge.

RESUMEN.—La entomofagia es una práctica muy extendida entre las poblaciones indígenas que contribuye a que se estudie el conocimiento ecológico tradicional de las historias de vida de los insectos y de las interacciones planta-insecto. En el Amazonas muchos grupos indígenas obtienen un suplemento importante en sus dietas del consumo de los gusanos de palmas (*Rhynchophorus palmarum* y *Rhinostomus barbirostris*). Este trabajo presenta un estudio llevado a cabo entre los Jotï del Amazonas venezolano donde se examina los conocimientos tradicionales que poseen acerca de las interacciones entre la palma (*Oenocarpus bacaba*) y las larvas y cómo se aplica tal conocimiento para optimizar la producción en el cultivo de los gusanos de palmas. El conocimiento ecológico tradicional de los Jotï coincide con la información registrada en la literatura científica sobre la historia natural e interacciones entre las larvas y sus palmas hospedantes. Los Jotï manipulan las palmas para inducir cambios en el reparto de recursos que se presenta de manera natural entre las especies de insectos. Ello les ha permitido seleccionar artificialmente la cosecha de las especies preferidas de larvas. Nuestro análisis del conocimiento ecológico tradicional Jotï identifica posibles líneas de investigación que puedan tener aplicaciones agrícolas asociadas a las infecciones de gusanos de palmas en plantaciones de palmas. Se concluye que el conocimiento y conservación de las prácticas y conocimientos ecológicos tradicionales es importante para organismos como los gusanos de palmas que han sido poco estudiados en su medio natural.

RÉSUMÉ.—L'entomophagie est largement répandue parmi de nombreuses Premières Nations, lesquelles voient à la récolte du savoir écologique traditionnel touchant les cycles biologiques des insectes et les interactions plante-insecte. Dans l'Amazonie, la culture des larves de charançons des palmiers et barbirostres (*Rhynchophorus palmarum* et *Rhinostomus barbirostris*) fournit un supplément alimentaire important aux régimes de nombreux groupes autochtones. Cette étude a été faite avec le peuple jotï de l'Amazonie vénézuélienne et nous avons examiné leur savoir écologique traditionnel (SET) en lien avec le palmier (*Oenocarpus bacaba*) et les interactions avec les charançons. Nous avons également vérifié de quelle façon les Jotïs utilisent leur SET pour optimiser le rendement de la culture des charançons des palmiers. Ils manipulent les palmiers afin d'induire des changements dans la division des ressources et la compétition pour celles-ci qui se présentent de façon naturelle entre les différentes espèces de charançons. Cela leur permet d'accroître la récolte de leurs espèces de charançons préférées. Nous avons pu établir que le SET des Jotïs était conforme aux résultats scientifiques quant au cycle biologique du charançon ainsi que pour les interactions palmier-charançon. Notre étude a permis d'identifier diverses avenues de recherche qui pourront offrir des solutions aux problèmes agricoles comme les infestations des plantations de palmier par les charançons des palmiers. Nous soulignons aussi l'importance de comprendre et de conserver le savoir écologique traditionnel ainsi que ses pratiques surtout en ce qui a trait à des organismes peu étudiés tels que le charançon des palmiers.

INTRODUCTION

Entomophagy, the use of insects as food by humans, has long captured the interest of biologists and anthropologists. It is practiced by cultures worldwide, but to varying degrees by indigenous and westernized people (Choo 2007; Defoliart 1999; Ramos-Elorduy 1997). Across the tropics, at least 2000 insect species are eaten as food (Ramos-Elordy 2005). Within the biologically hyper-diverse Amazon basin region, indigenous groups consume at least 209 species of insects (Paoletti and Dufour 2005). Insect foods are considered delicacies in this region, but they also provide protein, fat, and vitamin supplements to the diet (Bukkens 1997; Cerda et al. 2001; Dufour 1987).

While many species of weevils are consumed as food, *Rhynchophorus* (Coleoptera: Curculionidae) weevils are the most widely used in the world (Defoliart 1995). In Amazonia, they are one of the few insect foods that are managed or cultivated by many indigenous groups, including the Tukanoan, Barí, Hiwi, and Yukpa (Beckerman 1977; Cerda et al. 2001; Dufour 1987; Ruddle 1973). The life history and behavior of *Rhynchophorus* weevils facilitate human manipulation and cultivation. Adult weevils are gregarious. They congregate to mate on palm tissues and each female can lay up to hundreds of eggs. The larvae that emerge burrow into palm tissues where they remain until maturity (Howard et al. 2001). Therefore, large numbers of developing larvae can easily be harvested from a single palm source. By cultivating weevil larvae, people have control over the location and timing of this larvae food supply. They can also assess the progress of larvae development and plan their harvest for the time when the larvae are optimally large.

The general process of cultivating palm weevil larvae has been described for a number of indigenous groups (see papers in Defoliart 1995). Palms are cut down to attract the adult weevils and a few months later the larvae are harvested. What remains unexplored is the traditional ecological knowledge (TEK) associated with weevil cultivation. As forest inhabitants, indigenous people have numerous opportunities to learn about the natural history of insects and to accumulate this knowledge over the generations. We therefore expect traditional indigenous groups that frequently practice weevil cultivation to possess a significant body of TEK on palm and weevil interactions (Zent and Zent 2004a).

Studies show the value of integrating TEK in conservation efforts, restoration ecology, resource management, environmental studies, and population monitoring (Bart 2006; Berkes et al. 2000; Drew 2005; Fraser et al. 2006; Gilchrist et al. 2005). Palm weevil cultivation provides an ideal system to document and evaluate TEK in the realm of plant and insect interactions. The current body of scientific research on palm and palm weevil interactions has largely focused on studies in palm plantations because palm weevil infestations have lead to significant economic losses (e.g., Faleiro et al. 2003; Oehlschlager et al. 2002). As a consequence, palm weevil ecology and behavior in natural forest settings are not well-known (although see Eberhard 1983). The traditional knowledge of forest dwellers may provide an important complement to the scientific understanding of interactions between palms and weevils in their natural settings.

This study documents the TEK of palm weevil cultivation for the Jotï, a traditional and semi-nomadic group of the Venezuelan Amazon. We begin by examining the Jotï's TEK of weevil life history and how they have integrated this knowledge into developing a successful system for cultivating weevils. We then compare TEK with scientific knowledge, and address areas of Jotï TEK meriting further investigations. Lastly, we highlight how human activities themselves can influence the natural interactions and resource-partitioning between plants and insects.

METHODS

The first author conducted the fieldwork for this study between June and August of 2005 and 2006, in the Sierra Maigualida region, close to the state borders of Amazonas and Bolivar, Venezuela. Because the region is inaccessible, an in-depth ethnology of the Jotï people was only recently documented (see Zent and Zent 2004a, 2004c). We conducted our research in three of the approximately 20 distinct Jotï communities in Venezuela: San Jose de Kayama, Caño Iguana, and Caño Majagua (Figure 1). We estimate a population of 300 at Kayama, 165 at Caño Iguana, and 25 at Caño Majagua (Zent and Zent 2004b).

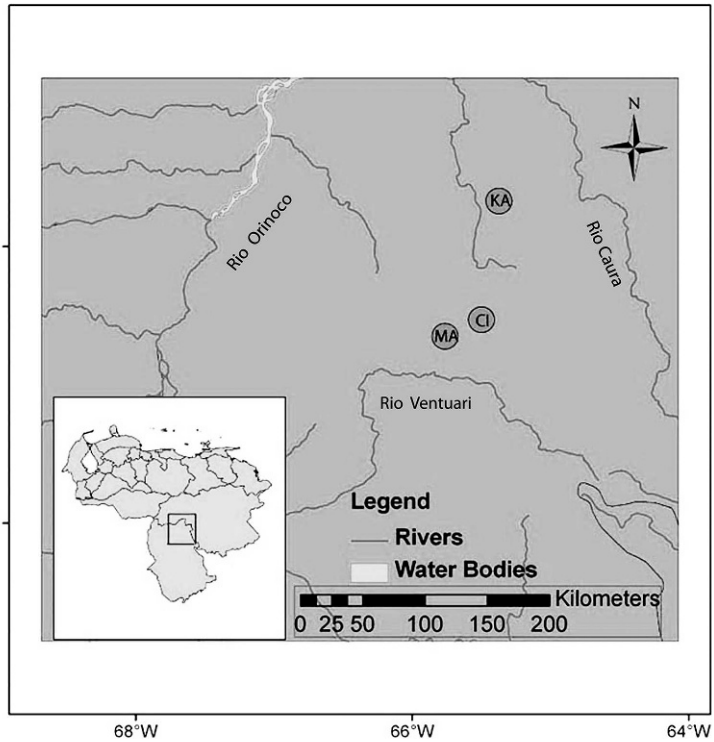

FIGURE 1.—The three Jotï study sites in Venezuela – Caño Iguana (CI), Kayama (KA), and Majagua (MA).

To examine the Jotï's traditional ecological knowledge of weevil ecology and behavior, we compiled information from 18 informants during weevil cultivation expeditions and conducted semi-structured interviews. The estimated ages of consultants ranged from 25 to 55 years, and three were female. Semi-structured interviews were either carried out directly with consultants who spoke Spanish or with the assistance of a Jotï translator when consultants only spoke the native language. To identify weevils that the Jotï cultivated for food, we used the identification keys of Wattanapongsiri (1966).

RESULTS

TEK of Weevil Life History and Behavior.—The Jotï actively cultivate two species of edible palm weevil, *Rhynchophorus palmarum* (L.) and *Rhinostomus barbirostris* (Fab.) (Figure 2). Data from this study and those collected by S. Zent and E. L. Zent (unpublished data) suggest that larvae of *R. barbirostris* are cultivated more frequently than *R. palmarum*. According to the Jotï, the species taste different; *R. barbirostris* larvae have a richer flavor. The Jotï refer to the larvae of *R. palmarum* as ***uli badebodï*** and those of *R. barbirostris* as ***ja̲ni badebodï***. The words "***uli***" and "***ja̲ni***" mean large and small respectively, and describe the relative size of the larvae of these two species, which the Jotï cultivate in the *Oenocarpus bacaba* palm, ***badebodï***. The eggs, pupae, and adult of stages of both weevil species

FIGURE 2.—Harvested larvae of *Rhinostomus barbirostris*.

respectively are called ***ïë***, ***jojo jadï***, and ***wajlilijka***. Every Jotï consultant correctly distinguished between the adults of the two species, and 15 of the 18 also correctly distinguished males from females. To distinguish sexes, the consultants most frequently noted the presence (in males) or absence (in females) of bristles on the rostrums and the smaller bodies of the males.

The Jotï also provided a general description of weevil mating. Consultants indicated that for both weevil species, odors from the cut palm tissues initially attract male and female weevils to congregate and mate. Males initiate mating by mounting the backs (dorsi) of females. Female weevils then drill holes in the palm trunks to oviposit. Consultants emphasized that female weevils appear to be selective about where their eggs are deposited, with *R. palmarum* females preferring to deposit eggs where the inner palm tissues are exposed, while *R. barbirostris* females prefer the surface of trunks, close to internodal scars, and areas with few other eggs. Consultants believe that after mating, *R. palmarum* adults disperse to other cultivation sites in search of fresh palms, whereas many *R. barbirostris* weevils die, because the Jotï frequently find dead *R. barbirostris* adults at cultivation sites.

Our consultants described that after emerging from the eggs, the weevil larvae feed on the inner palm tissues and tunnel deeper into the palm trunk. They observed that *R. palmarum* larvae also burrow out from the trunks into the soil for short periods and then re-enter the trunk. When approaching the pupae stage, *R. barbirostris* larvae tunnel their way towards the surface of the trunk and then carve a thin circular cap near the trunk surface to facilitate subsequent adult emergence. *R. palmarum* larvae, on the other hand, migrate to areas of exposed trunk tissue (e.g., where cuts were previously made) to facilitate their emergence as adults. The Jotï observed that at the pupal stage, *R. palmarum* larvae create cocoons using materials from palm tissues, but *R. barbirostris* larvae do not form cocoons (Figures 3 and 4). The Jotï described the period of metamorphosis when the weevil larvae transform to the pupal and adult stages, literally as the ''changing of skin.''

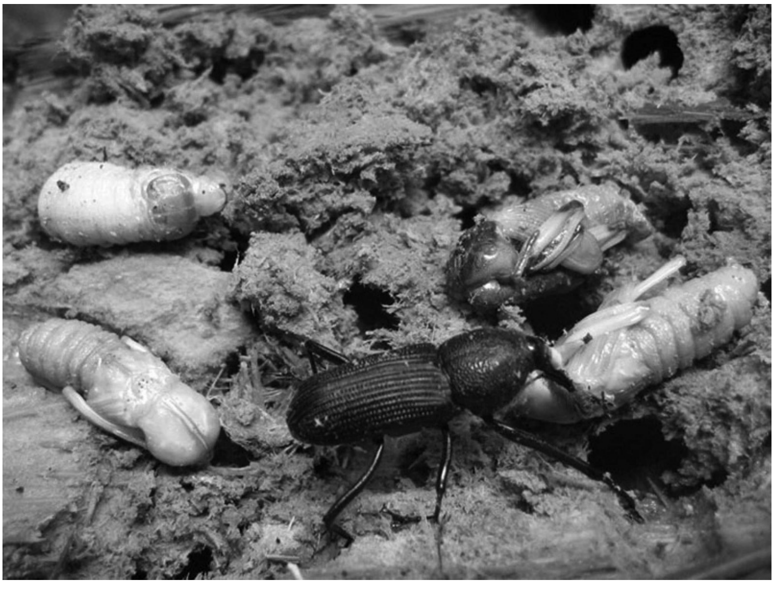

FIGURE 3.—*Rhinostomus barbristoris* larva, pupae, and adult (from top left counter-clockwise).

TEK of the Palm Weevil Cultivation Process.—The Jotï reported that under natural forest settings they find and collect weevil larvae in several palm species including *Attalea maripa* (Aubl.) Mart., *Bactris* spp., *Euterpe oleraceae* (Mart.), *Mauritia flexuosa* (L.f.), and *Oenocarpus bacaba* (Mart.). However, when they

FIGURE 4.—*Rhynchophorus palmarum* larva in cocoon, larvae, and pupa (from left to right).

cultivate the weevil larvae, the Jotï preferentially use *O. bacaba*, as noted in Zent and Zent (2004a). The Jotï consider *O. bacaba* ideal for weevil cultivation presumably because of the large number of larvae they can harvest and the flavor that the palm tissues give to the larvae. Within naturally fallen *O. bacaba* palms, relatively low numbers of *R. palmarum* larvae are found near the base of trunks where palm tissue is exposed, while *R. barbirostris* larvae are more numerous, colonizing the length of the intact trunks. If a cultivator wishes to harvest predominantly *R. barbirostris* larvae, a felled trunk can remain intact. However, further manipulation of the trunk is required if the cultivator chooses to cultivate *R. palmarum* larvae.

Using this knowledge of palm weevil life history, the Jotï adapt their cultivation practices to the specific traits of *R. barbirostris* and *R. palmarum*. They consider four important factors to ensure optimal larvae harvests: 1) when to cultivate – rainy season or dry season, 2) the age, size, and species of available palms, 3) the need to cut into palm trunks to facilitate larvae entry, and 4) when to harvest the larvae. The second and third factors are directed at controlling the species of weevil larvae cultivated.

According to the Jotï, exposed inner palm tissues more strongly attract *R. palmarum* than *R. barbirostris* weevils to mate and lay eggs. *R. palmarum* adults feed on the inner tissues and the females prefer to deposit eggs in exposed inner palm tissues than on the surface of an intact palm trunk. By making wedge-shape cuts into palm trunks after they are cut down, the Jotï facilitate the colonization of *R. palmarum* larvae in these trunks, which would otherwise be dominated by *R. barbirostris* larvae. The Jotï usually make two wedge-shaped cuts along the palm trunks using axes or machetes, cutting deep enough to penetrate to the pith. The first cut is on average 1.58 m (n = 7, SE = 0.23) from the palm crown, and the second is on average 1.54 m (n = 8, SE = 0.12) away from the first. They do not cut near the base of the palm trunk because those tissues are tough and provide poor conditions for larvae development. The Jotï consultants estimated that *R. palmarum* weevils arrive at a palm trunk within 2 to 24 hours after the inner tissues of the palm trunks are exposed (Figure 5). *R. barbirostris* weevils, on the other hand, colonize the intact palm trunks 1 to 2 days after palms are cut down. The Jotï explained that the presence of the early-arriving *R. palmarum* adults and larvae ''spoil'' the palm for the late-arriving *R. barbirostris*. *R. palmarum* larvae presumably degrade and/or deplete the palm such that conditions are unsuitable for *R. barbirostris* larvae. Consequently, palms felled and cut to expose the inner palm tissues yield predominantly *R. palmarum* larvae rather than *R. barbirostris*. So the Jotï decide whether to leave the trunks entire or cut into them depending on which weevil species they want to harvest.

The Jotï also control which weevil species will infest a palm trunk by selecting a particular age and size of palm. Relatively young, short palms, in their pre-reproductive stages are considered ideal for cultivating *R. palmarum* larvae because the odor of the young palm's inner tissues are highly attractive to the adults and the soft inner tissues are ideal for larvae feeding and development. On the other hand, according to the Jotï, *R. barbirostris* weevils are attracted to mature and reproductive palms, which provide the ideal medium for their larvae development. Using the height of a palm as a proxy for its age, we found

FIGURE 5.—*Rhynchophorus palmarum* adults in a cut created in the trunks of *Oenocarpus bacaba* palms and a larva harvested from the trunk (inset).

significant differences in the heights of palms cut down for cultivating the two weevil species (*t*-test with unequal variances: $t_{21} = -5.39$, n = 24, P < .001); those cut down for *R. palmarum* were on average shorter (mean = 5.92 m, n = 9, SE = 0.45) than those for *R. barbirostris* (11.23 m, n = 15, SE = 0.89).

After felling and, if necessary, cutting into the trunk, the Jotï leave the palms on the forest floor until the larvae are ready to be harvested. They may return occasionally before the harvest to check on the larvae's development. Individual cultivators use a variety of methods to discern whether the larvae are ready for harvest, such as counting the days or lunar cycles (i.e., 29.5 days), or examining the color of sawdust expelled from the entry holes larvae create as they tunnel through the palm trunks. Our consultants indicated that in the early stages, the sawdust is whitish, but subsequently, when the weevil larvae are ideal for harvesting, the sawdust turns a darker orange-yellow color. We accompanied the Jotï on several forays and found that their harvests often coincided with a time when relatively few larvae had already pupated or adults had eclosed, that is emerged from the pupa. The time from felling a palm to harvest differed significantly between *R. palmarum* and *R. barbirostris* (t-test with unequal variances: $t_{18} = -7.56$, n = 14, P < .01). *R. palmarum* larvae developed faster with a mean time-to-harvest of 2.25 months (n = 8, SE = 0.37) while *R. barbirostris*, were slower with a mean of 4 months (n = 6, SE = 0.45).

FIGURE 6.—*Oenocarpus bacaba* palm trunks showing portions of trunks that were harvested for larvae.

The Jotï generally harvest *R. palmarum* larvae from the entire palm trunk, but only harvest *R. barbirostris* larvae from the upper half of the trunks (Figure 6; mean proportion of trunk harvested = 43.7%, n = 6, SE = 8.8). Larvae harvest commences from the upper portion of the trunk, just below the palm crown. The Jotï split trunks in half with an axe and extricate the larvae with their bare hands and knives. When we requested that consultants split open the unharvested portion of a trunk in order to assess its contents, we noticed fewer and smaller larvae than in the harvested portions. Since we could not collect data on changes in larva size along the length of the trunk, we indirectly inferred this using the size of larval tunnel holes. Larval tunnel diameters sampled from every meter-section between 4 to 7 m from the base of the trunk were significantly different ($F_{3, 33} = 2.89$, $p < .001$). Tunnels were larger toward the palm crown, suggesting that larvae were larger as well. The Jotï harvested the relatively few pupae of both species when encountered, and although some also collected freshly eclosed *R. barbirostris* adults with soft exoskeletons, in general, the Jotï released newly eclosed adults so they could produce more weevil larvae.

During the harvesting process, we observed children and teenagers consuming raw *R. barbirostris* larvae, but not *R. palmarum* larvae. The Jotï believe that eating raw *R. palmarum* larvae induces stomach upsets. The harvested larvae were taken back to the homesteads and cooked in soups, smoked, or roasted over fires. According to unpublished data from S. Zent and E. L. Zent, each Jotï household harvested on average 2424 grams (n = 17, SE = 550) of *R. barbirostris* larvae, or 2120 grams (n = 5, SE = 341) of *R. palmarum* larvae from each harvesting foray.

The Jotï indicated that the ideal time to cultivate weevil larvae is from September to January, toward the end of the rainy season and the beginning of the dry season. During the peak rainy period, from June to August, heavy and frequent rain deters or prevents adult weevils from seeking out palms, resulting in reduced larvae harvests. The Jotï also believe that weevil eggs are susceptible to damage during downpours. We observed that the rainy season weather may also promote fungal attack that kill larvae. Conditions during the peak of the dry season, approximately February and March, also inhibit larval development. According to the Jotï, felled palms desiccate rapidly at this time, so weevils are not attracted to lay eggs in them. Those Jotï who successfully cultivate weevils in the dry season reported that they cut down palms growing under the canopy of tall trees where shade maintained sufficiently high levels of humidity to prevent the felled palms from drying. Alternatively, cultivators cover the felled trunks with palm leaves to prevent them from desiccating.

Observations of Other Weevil Species.—We found adults of three weevil species that are known to attack palms besides *Rhynchophorus palmarum* and *Rhinostomus barbirostris*: *Metamasius hemipterus* (L.), *Dynamis borassi* (F.), and *Homalinatus* sp. We set out traps baited with fresh sugar cane, Combolure® (ChemTica International SA, San Jose, Costa Rica), and ethyl-acetate on trails at the Kayama study site. We recovered 249 *R. palmarum* adults but only three *D. borassi* and one *Homalinatus* sp. The number of *M. hemipterus* adults was not tabulated; however many individuals were trapped. The larvae of *Dynamis* borassi and *Homalinatus* sp. were not encountered among the samples of *R. palmarum* and *R. barbirostris* larvae harvested by the Jotï and identified by the first author. However, since it was not possible to identify every harvested larva, we cannot rule out the possibility that small numbers of *D. borassi*, *M. hemipterus*, and/or *Homalinatus* sp. larvae were included in the harvest.

Conserving Palms for Weevil Cultivation.—The Jotï's folk beliefs may encourage palm conservation by instilling a fear of retribution for misuse of resources. According to the Jotï, excessive exploitation of forest resources angers spiritual beings, ***jkyo aemodï*** (see Zent 2005), who then inflict ailments such as fevers, stomach pains, and even death in extreme cases on the perpetrators. In the context of palm weevil cultivation, a number of cultivators explicitly rotated every 2–3 years between *Oenocarpus bacaba* groves, ***bate jkwa***, in their efforts to avoid depleting palm populations. Despite their belief system and individual efforts to conserve palms, the Jotï note a significant decline in *O. bacaba* populations. According to a 40-year resident of Caño Iguana, *O. bacaba* palms were abundant within 2 km of settlements when the consultant first moved there and when the Jotï population consisted of small communities of 5 to 35 highly mobile people. However, the increased population of Caño Iguana (currently estimated at 165) and a corresponding increase in felling palm trees to cultivate weevil larvae have depleted *O. bacaba* palms close to Jotï settlements. As a result, the Jotï presently travel between four and twenty hours from their homesteads to encounter suitable palms for cultivating larvae. Assuming an average normal walking speed of 3.6 km/h, this suggests a distance of 14.4 km to 72 km.

Our Jotï consultants at Caño Iguana also believe that this depletion of *O. bacaba* trees has reduced palm weevil populations. They have observed that at present relatively few weevils are attracted to palms that were cut for weevil cultivation and that weevils are taking longer to colonize cut down trunks. In spite of the scarcity of *O. bacaba* palms near settlements, the Jotï do not cultivate them, although they do cultivate another palm, *Bactris gasipaes* Kunth. Unsuitable environmental conditions near settlements, such light gaps or poor soil quality, may limit seedling recruitment. Jotï consultants report that *O. bacaba* seeds that germinate in garbage heaps usually do not survive beyond the seedling stage, presumably due to desiccation.

DISCUSSION

The Jotï's TEK of palm weevil life history and behavior coincide with several scientific findings in Hagley (1965), Eberhard (1983) and Howard et al. (2001). Observations that different weevil species preferentially lay eggs on different parts of the palm trunk may reflect that weevils select sites to increase chances of offspring survival (Renwick 1989). *R. barbirostris* females prefer to lay eggs away from previously oviposited sites, which may be a strategy to avoid intra-specific competition among offspring that is documented for other weevil taxa (Heard 1995; Messina and Renwick 1985). *R. palmarum* females appear to target oviposition in exposed inner palm tissues, which may facilitate larvae access to food.

The dead *R. barbirostris* adults at cultivation sites noted by our Jotï consultants may result from intra-specific competition among male adults, since males are known to engage in intense battles for females (Eberhard 1983). However, these weevils are nocturnally active and the cultivation sites were far from settlements, so we could not confirm that weevil mortality was associated with male competition. This study also allows us to clarify conflicting reports of whether *R. barbirostris* larvae construct cocoons before the pupae stage (Bondar 1940; Howard et al. 2001; Vaurie 1968; Wolcott 1933). The Jotï's TEK and the first author's observations confirm that they do not.

The Jotïs also have a good understanding of palm weevil feeding preferences and nutritional ecology. The Jotïs prefer *Oenocarpus bacaba* palms as host for cultivating weevil larvae, suggesting that weevils find some species of palms more attractive than others. Studies of weevil infestation rates at palm plantations provide additional indirect evidence for species-specific attraction of weevils to palms. For example, Giblin-Davis et al. (1996) found that coconut palms (*Cocos nucifera* L.) are more susceptible to weevil attack than African oil palms (*Elaeis guineensis* Jacq.).

The species of palm also influences larval development, with larval size dependent on the quality and quantity of palm tissue (Howard et al. 2001). Feeding experiments showed that *R. palmarum* larvae reared on *Mauritia flexuosa* weighed 9.6 grams on average, while those reared on *Jessenia bataua* (Martius) Burret, weighed 4.6 grams, over a two-fold difference (Cerda et al. 2001). Even within individual palm trunks, there exist variations in the hardness of the palm tissues or quality of food available to the larvae. In addition, Eberhard (1983) and Bondar (1940) showed that larval density and size are apparently influenced by differences in the nutritional quality of inner palm tissues along trunks. Larvae were smaller and less densely concentrated in the 3 m closest to the base. The Jotï harvest *R. barbirostris* only from the upper trunk segments, which indicates that they recognize this spatial variation in the quality of larvae along individual trunks.

The mechanisms for inter- and intraspecific variation in palm attraction and suitability for weevil larval development are unclear and require further investigation. While palm weevils exhibit a broad niche breadth and use many palm species as hosts (Howard et al. 2001), the Jotï's success using *Oenocarpus bacaba* suggests that palm weevil generalists may favor and perform better in specific palm species. Singer (1982) documented that other phytophagous insects vary in their degree of preference to a range of available hosts. Since palm weevils are notorious pests of palms, a better understanding of how host palm quality and host preference influence weevil population dynamics will likely shed light on the epidemiology of weevil infestation.

Applying their TEK of palm weevil feeding preferences, the Jotïs have discovered how to influence the natural partitioning of resource between palm weevil-species to select the species of weevil larvae they cultivate. Our research shows that the Jotï control which weevil species colonizes a palm by modifying the trunk to attract specific weevils and facilitate oviposition and larval growth; exposing the inner palm tissues favors *Rhynchophorus palmarum* larvae on a resource generally dominated by *Rhinostomus barbirostris* larvae. Studies show that fermented exudates from the inner palm tissues are highly attractive to *R. palmarum* adult weevils and that palm weevils preferentially aggregate, mate, and oviposit in the wounds of palms (Faleiro et al. 2002; Giblin-Davis and Howard 1989; Giblin-Davis et al. 1996; Hagley 1965; Murphy and Briscoe 1999; Wattanapongsiri 1966; Weissling and Giblin-Davis 1994). However, other mechanisms may also cause one species of palm weevil larvae to dominate over another.

We need additional research to understand how peoples' manipulation alters species-specific larvae dominance. Some possible mechanisms are pheromone avoidance or inter-specific larval predation/competition. For example, when multiple species of scolytid beetles are sympatric, the pheromones of one species deter the arrival of competing species, resulting in different beetle species colonizing different regions of the trunk (Ayres et al. 2001). In addition, inter-specific larval competition among beetles can lead to significant mortality in subordinate competitors. Predation by large cerambyscid beetle larvae, for example, causes 76% of the mortality of a subordinate bark beetle's larvae on the same tree (Dodds et al. 2001).

The Jotï's control of the weevil species they cultivate may have nutritional implications. Additional studies will help us determine the criteria the Jotï use to decide which species of weevil to cultivate and in what proportions. Although we documented that more *R. barbirostris* larvae are cultivated than *R. palmarum*, we do not know the nutritional contribution of each species to the Jotï's diet. We documented that taste preference is an important factor, and we hypothesize that the success of cultivating each species and the availability of other insect and non-insect food resources may also influence this decision.

The Jotï's TEK of the optimal timing of weevil cultivation, at the end of the rainy season and into the beginning of the dry season, points to their awareness of seasonal changes in weevil population and activity. We have no scientific data on the population dynamics of *R. barbirostris*, but studies of *R. palmarum* show that weevil abundance is seasonally driven by rainfall patterns. *R. palmarum* weevil populations tend to peak toward the end of the rainy season in Trinidad (Hagley 1965) and during most of the dry season in Brazil, Costa Rica, and Honduras (Chinchilla et al. 1990; Schuiling and Van Dinther 1981). Thus, the Jotï cultivate larvae when adult weevil populations and activity are likely to be relatively high. In addition, the Jotï avoid cultivating larvae during the peaks of the dry and wet seasons, because the rapid deterioration of palm resources during these periods produces low weevil larvae returns. Oehlschlager and Gonzales (2001) have shown that fresh palm material, used to trap weevils in plantations, desiccated rapidly during the dry season and, decomposed rapidly in the wet season, becoming ineffective in attracting adults. Both the Jotï's TEK and scientific data indicate that the attractiveness of palm resource is influenced by seasonal conditions, which in turn determine successful larval colonization of the palms. This information can be applied to the management of commercial palm harvests because harvesting palms during the peak dry season may minimize weevil larvae infestations.

Our study provides qualitative data on how Jotï palm weevil cultivation affects palm populations and forest community structure. Historic palm abundance and distribution data are difficult or impossible to collect when current palm populations are absent or low. This study of palm weevil cultivation allows us to infer that *Oenocarpus bacaba* palms were historically abundant in the Caño Iguana region. Population growth and an increasingly sedentary lifestyle at this settlement combined with the destructive nature of palm weevil cultivation practices may have contributed to the local depletion of *O. bacaba* populations. Weevil cultivation may also influence the regeneration and recruitment of other plant species. Gaps generated from felling palms, for instance, may facilitate the establishment of shade intolerant seedlings. It is also conceivable that, as suggested by the Jotï, depleted palm populations have in turn reduced local population of palm weevils. The cascade effects of palm weevil cultivation on insect and plant populations will require further investigation for us to better understand the consequences of indigenous peoples' food acquisition on forest biodiversity and regeneration in Amazonia.

The current findings confirm the Jotï's extensive TEK related to the ecology of palm and weevil interactions, and supported by scientific literature, raises intriguing questions about palm weevils that merit further investigation. By combining Jotï's TEK with scientific findings, we may be able to better understand the ecology of palm weevils in their natural settings and the implications of anthropogenic activities on historic and present palm populations. Traditional ecological knowledge of plant and insect interactions remains an understudied area, and we hope that this case study serves to highlight the importance of examining the ecological implications of traditional subsistence activities as well as the potential of TEK in complementing scientific research.

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