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Management and Conservation of Natural Populations in Atlantic Rain Forest: The Case Study of Palm Heart (*Euterpe edulis* Martius)[1]

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ABSTRACT

Euterpe edulis (Martius) is a single-stemmed, abundant Neotropical palm of the Brazilian Atlantic Forest (Mata Atlântica). The species produces the heart of palm, locally called palmito, which is an important source of income for forest owners. Because of its high market value, its short-term demands of the forest environment, and its important interactions with animal species, this palm is suitable for sustainable management and conservation purposes. In this paper, we present the results from a 15-year investigation of this species, synthesizing results on its demography, seed dispersion, reproductive biology, genetics, and economics. We have linked these results in a proposal for the species' sustainable management and conservation.

RESUMO

Euterpe edulis Martius (Palmiteiro) é uma palmeira neotropical do sub-bosque que ocorre em alta freqüência e abundância na Floresta Atlântica. A espécie é empregada para obtenção de palmito, sendo uma importante fonte de renda para vários proprietários de terra. Várias características da espécie fazem da mesma uma alternativa para manejo sustentado. Neste trabalho, resultados 15 anos de pesquisa com esta espécie são apresentados e discutidos como fundamento de uma proposta de manejo sustentado das populações naturais da espécie. São apresentados aspectos de demografia, dispersão de sementes, biologia reprodutiva, genética, conservação e manejo das populações naturais.

Key words: Arecaceae; Atlantic Forest; Brazil; conservation; Euterpe edulis; *genetic diversity; natural populations; non-timber forest products; sustainable management.*

The coastal Brazilian Atlantic Forest (Atlantic Rain Forest, Atlantic Forest, or Mata Atlântica) holds a biodiversity comparable to the Amazon Forest; but despite the high potential for sustainable management of several species, this ecosystem has been systematically devastated, a process that began shortly after the arrival of the first Europeans in the 16th century (Dean 1995). Remnants of this ecosystem cover only nine percent of its original 1.1-million ha of forested area (Fundação SOS Mata Atlântica and INPE 1998). Although these remnants are mostly fragmented secondary forests, they still shelter a high number of species, many of which are endemic (Klein 1979–1980). Present exploitation still relies on a few species, mostly for timber production. As in other tropical countries, the value of biodiversity and the environmental services the forest provides are not taken into account by either companies or farmers when managing the ecosystem.

Given that most of the Atlantic Forest remnants are privately owned, we believe that the conservation of this ecosystem biodiversity, defined as the species richness and the genetic variability within each species (Heywood & Baste 1995), should contemplate alternative management systems that combine species conservation and use. Such an approach would be an opportunity to involve local people in conservation efforts, legitimizing their right of making a living from the forest without depleting its resources.

Sustainable management systems are attractive strategies when they combine both economic harvesting levels of forest products and species conservation. Achieving sustainable and profitable harvests of forest products, however, is a complex task in tropical forests, especially when timber is the only commodity desired (Godoy & Bawa 1993, Anderson *et al.* 1994, Gentry 1994). Non-timber forest products (NTFP) may help to overcome the economic difficulties frequently found when managing tropical forests (Peters *et al.* 1989).

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From a broader standpoint, sustainability of managed tropical forests, defined as the use of biological diversity components in order to avoid its erosion and keep its potential to meet needs and aspirations of present and future generations (Convention on Biological Diversity, Rio de Janeiro, Brazil; 1992), is an even more challenging enterprise. Information is a key item in achieving this goal. Establishing a sustainable management system in such a complex environment requires reliable knowledge of population structure and dynamics, population genetics, silvicultural practices, and an understanding of the local people (Bawa 1992, Fantini, Reis, Reis, & Guerra 1992, Godoy & Bawa 1993, Oyama 1993, Reis *et al.* 1994). Knowing the reproductive biology and demography is necessary to understand the evolutionary biology of tropical species, which is a requisite condition for management if a natural regeneration process is to be maintained (Oyama 1993). Information on both demography, including spatial and temporal changes, and allele movements (genetic variation, genetic structure, and the gene flow process) could help establish forest management practices that maintain the genetic diversity (Reis *et al* 1998; Fig. 1).

In this paper, we discuss the application of this type of information to manage tropical forest species, using a case study of the "palmiteiro" (*Euterpe edulis* Martius).

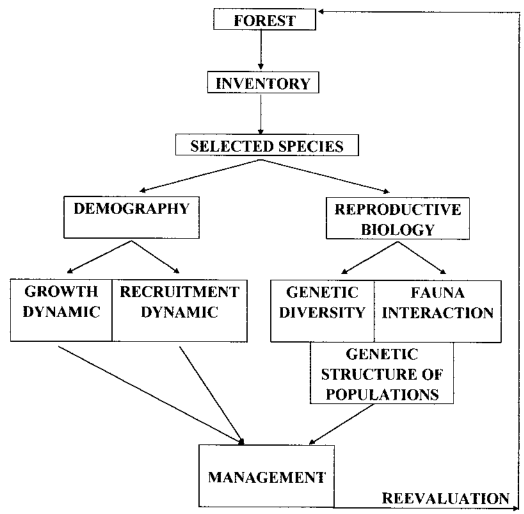

FIGURE 1. A proposed flowchart for sustainable management of tropical forest species.

EUTERPE EDULIS : A KEY SPECIES FOR MANAGEMENT IN THE ATLANTIC FOREST

Euterpe edulis (Palmiteiro) is a native palm tree of the Atlantic Forest, that occurs from southern Bahia (15°S) to northern Rio Grande do Sul (30°S), mainly on the Atlantic coast. The species ranges as far south as eastern Paraguay and northern Argentina (57°W; Klein 1974; Carvalho 1994).

The marketable product obtained from this species is the palm heart, which is called palmito locally and is a delicacy throughout the country. The apical meristem and young undifferentiated leaves of the palm's stem compose the palm heart. Palm heart production is fully absorbed by a strong and expanding internal market. The external market also presents a large demand, but exported Brazilian palm heart comes almost entirely from *E. oleracea*, a native of the Amazon region.

The exploitation of *E. edulis* represents an important supplementary income for forest owners, especially small farmers (Pedrosa *et al.* n.d., Yamazoe 1973, Leão & Cardoso 1974, Reitz *et al.* 1978, Guerra *et al.* 1984, Bovi *et al.* 1987, Nodari *et al.* 1987, A. Reis *et al.* 1992; Pereira 1994, Ribeiro *et al.* 1994, Reis *et al.* 1996). Although sustainable management systems for this palm have been proposed (A. Reis *et al.* 1992; Ribeiro *et al.* 1994; Reis, Conte *et al.* 1999), the option for immediate profits prevails in the region, and *E. edulis* has been a target of intensive and predatory harvesting. Presently, clandestine harvesting and poaching are common practices, both in public and private forests.

Because palmiteiro is a single-stemmed palm, it is necessary to kill the entire plant to get the palmito. In the traditional selective system, all plants > 2 m tall are harvested, and few or no reproductive plants are left behind. In the best harvesting regimes, only individuals > 8 cm DBH (diameter at breast height) are cut; however, most reproductive individuals are harvested as well. These exploitation systems could result in substantial genetic erosion of the populations, and not allow the maintenance of a demographic structure that favors natural regeneration. Decline in population density within exploited forests has been observed in many regions (Reitz *et al.* 1978, Guerra *et al.* 1984). In extreme cases, the species has been locally eliminated, as we observed in some forest patches at Guaraqueçaba-Paraná.

Euterpe edulis has a high potential for sustainable management of its natural populations and can contribute to maintaining forest remnants and

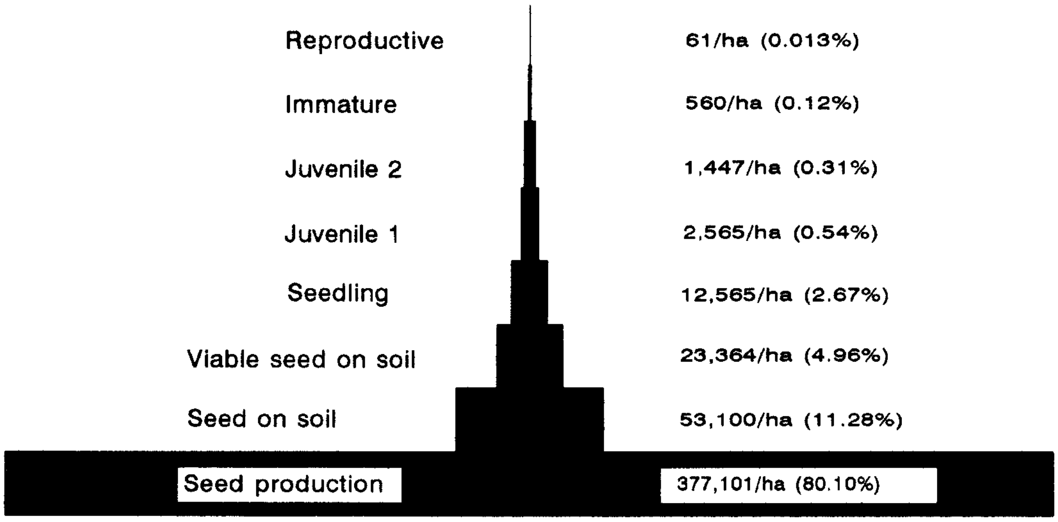

FIGURE 2. Demographic pyramid for a natural population of *Euterpe edulis* at Blumenau, SC (adapted from Reis 1995).

recovering degraded forest patches. The species has several characteristics that make it an excellent candidate for both sustainable management and development: (1) palmito is a valuable commodity in a well established market; (2) harvesting cycles of palmito are short relative to timber species cycles, contributing to the economic success of its management; (3) the high density and the J-shaped curve observed in its natural populations (Reis *et al.* 1996) allow periodic harvests and continuous replacement of the harvested plants in each cycle, if some seed trees are maintained in the forest; and (4) it is a shade tolerant understory species, requiring the presence of a forest environment for successful regeneration and initial growth (Klein 1974). Farmers therefore are required to maintain the forest canopy in order to produce heart of palm. In addition, *E. edulis* is an important resource in the ecosystem, supplying an abundant amount of fruit for up to six months a year (Reis 1995).

DEMOGRAPHIC STUDIES ON *EUTERPE EDULIS*

The demography of natural populations of *E. edulis* has been studied in both old growth (Negreiros 1982; Nodari *et al.* 1987; Reis *et al.* 1991, 1996) and secondary forests (Silva 1991; Alves 1994; Reis, Conte *et al.* 1999). Natural populations show a pyramid-shaped demographic structure, with a large base of juvenile plants and a small number of reproductive individuals (Fig. 2; Table 1).

These data suggest a strong dependence of a large population (at least 17,000 plants/ha) on a proportionally small number of genetically effective individuals (61–113 plants/ha in this survey; Reis *et al.* 1996). These individuals are responsible for the maintenance of genetic diversity, genetic structure, and demographic structure for the entire population. Such a dependency has important consequences for the species' management, especially when natural regeneration is the source of new seedlings. The typical reproductive strategy of the species includes the maintenance of a large seedling bank, averaging 12,000 seedlings/ha (Reis *et al.* 1996).

SEED CROP AND SEED DISPERSION

Natural populations of palmiteiro produce > 300 kg of fruit/ha/yr (Reis 1995, Mantovani 1998). From a study on a 2.5-ha plot, Reis (1995) found that 410 infructescences were produced, and mature fruit were observed for up to six months. Most of the fruit were eaten by a large number of medium and large birds and mammals, including guans, chachalacas, pigeons, parakeets, parrots, bats, monkeys, procyonids, ungulates, and rodents (Reis 1995, Galetti 1996).

Besides helping to shape the spatial distribution

TABLE 1. *Number of* Euterpe edulis *plants per hectare in primary (Blumanau [SC] and Sete Barras [SP]) and secondary forest (São Pedro de Alcântara [SC]).*

	Blumenau (SC)[a]	Sete Barras (SP)[b]		São Pedro de Alcântara[c] (SC)	
Classes	1988	1992	1993	1992	1993
Natural regeneration (palm trees with exposed stipe <1.3 m)					
Total height (cm)					
0–10	6172	13,332	11,251	13,332	11,251
10–50	1083	4506	5230	4506	5230
>50	552	434	230	255	230
Total	7807	18,093	16,711	18,093	16,711
Palm trees with stipe >1.3 m					
Diameter class DBH (cm)					
2–4	85	116	93	81	94
4–6	169	123	130	207	201
6–8	144	67	73	97	97
8–10	86	67	72	64	68
10–12	53	82	86	62	70
12–14	43	48	51	37	39
14–16	41	7	10	6	5
16–18	13	1	1	—	—
18–20	4	—	—	—	—
Reproductives	55	113	113	120	120
Total	560	511	514	554	574

[a] Unpublished data (total area 2200 ha).
[b] Adapted from Ribeiro *et al.* 1993 (total area 164 ha).
[c] Adapted from Reis, Conte *et al.* 1999 (total area 35 ha).

pattern of the species, the zoocoric seed dispersion is also the key element of gene flow (Reis *et al.* 1994, Reis 1995, Galetti 1996, Galetti & Aleixo 1998). As an important food resource, the palmiteiro also could help accelerate succession in secondary forests. By attracting seed dispersers, *E. edulis* indirectly increases the arrival of new seeds coming from neighboring forest patches (Reis 1993, Galetti & Aleixo 1998).

REPRODUCTIVE BIOLOGY OF *EUTERPE EDULIS*

Euterpe edulis has panicle-shaped inflorescences, with rachillae presenting dozens of floral triads that are composed of two male flowers and one female (Reitz 1974). The inflorescence is strongly protandrous; the male flowers remain open for approximately seven days, and after two to four days, the female flower will stay open for seven days (Reis *et al.* 1993, Mantovani 1998). This flowering pattern ensures allogamy for the species, except in cases when two or more inflorescences are produced by the same plant. Such an event occurs in 6.4 percent of the reproductive plants (Reis *et al.* 1993), when male and female blossoms are exhibited concurrently.

A wide variety of insects visit *E. edulis* inflorescences during their long flowering period (Reis *et al.* 1993, Mantovani 1998), attracted by the abundant production of pollen, the flower nectar, and parts of the inflorescence themselves. The most conspicuous species observed on palmiteiro flowers has been the small bee *Trigona spinipes*, which seems to be an important pollinator of this palm (Reis 1996).

Outcrossing rate estimates (t_m; Ritland & Jain 1981) for palmiteiro, based on allozymic markers, showed values nearing 1.00 (range = 0.94–1.04; SE = 0.02–0.04) in seven populations studied by Reis *et al.* (1998). These results further support the preferentially allogamic behavior of palmiteiro, as was suggested previously by Reis *et al.* (1993). The data also suggest the existence of nonrandom matings, possibly associated with the prolonged flowering period (Reis 1996).

The analysis of diversity among reproductive individuals showed an excess of heterozygotes. In addition, the same kind of analysis in progenies indicated a small level of endogamy (Table 2). These results, along with the small proportion of reproductive individuals and the large number of young plants observed in natural populations, suggest that selection favoring heterozygotes is an im-

TABLE 2. *Diversity indices for seven natural populations of* Euterpe edulis *at Santa Catarina (SC) and São Paulo (SP) obtained from analyses of seven allozymic loci in 198 adults and 107 progenies (adapted from Reis 1996).*

	Adults			Progenies		
Population	Mean number of alleles/locus	Expected heterozygosity (HW)[a]	Fixation index (F)	Mean number of alleles/locus	Expected heterozygosity (HW)*	Fixation index (F)
SC450	2.7	0.43	0.082	3.3	0.41	0.005
SC550	2.7	0.41	−0.005	3.1	0.45	0.020
SC650	2.9	0.45	−0.016	3.6	0.45	0.062
SPS100	2.9	0.46	−0.114	3.6	0.40	0.017
SPS250	3.1	0.48	−0.190	3.7	0.41	0.039
SPS350	3.4	0.49	−0.063	3.9	0.43	0.117
SPL700	3.1	0.43	−0.154	3.7	0.43	0.047
Total	3.4	0.45	−0.033	3.9	0.44	0.076

[a] Unbiased estimate by Nei (1978).

portant component of the demographic dynamism. Additional evidence for this hypothesis was found by Reis *et al.* (1998), comparing recruited and unrecruited samples of a cohort with known age (Table 3). In this preliminary study, recruited individuals exhibited levels of heterozygosity higher than those levels found in unrecruited plants; however, heterozygote advantage in recruitment should be confirmed further (a complete study is being conducted), because in our preliminary study, the sample size was too small to be conclusive. The existence of genetic variability for characteristics associated with seedling vigor also was demonstrated by Reis, Venkovski *et al.* (1992) and Nodari *et al.* (1993) in previous provenance and progeny tests.

Estimates of neighborhood size provided by Reis (1996) averaged 67 individuals, with each panmictic deme occupying 8090–18199 m^2, or 37–83 individuals/ha. This estimate is a particularly important parameter for the implementation of strategies to manage palmiteiro. If genetic variability is a concern in addition to sustainable harvests, it is necessary to maintain permanently an average of 60 reproductive individuals/ha.

TABLE 3. *Diversity indices for seedlings of* Euterpe edulis *with and without growth in a natural population in secondary forest (adapted from Reis* et al. *1998).*

Diversity indices	Nongrowing plants	Growing plants
Sample (*N*)	28	18
Alleles/locus	2.8	2.8
Polymorphic locus (%)	66.7	66.7
Heterozygosity observed	0.24	0.38
Heterozygosity expected	0.32	0.40
F (Fixation)	0.25	0.5

CONSERVATION AND BREEDING OF *EUTERPE EDULIS*

We analyzed geographic variation among populations isolated by either distance or elevation using allozyme markers (Reis, Vencovski *et al.* 1999). Genetic divergences were detected regarding the altitudinal gradient when separate populations (sites) were compared in a wider environmental range, possibly resulting from an associated phenological variation. We hypothesized that the isolation-by-distance model, reinforced by the elevation effects (intensifying the drift effects) at the large scale is a basic method of geographically distributing genetic variability in *E. edulis.* The intensification of drift effects related to the elevational gradient must be of great relevance to the microevolutionary process of this species in the Atlantic Forest, because the area covered by this forest involves a continuous altitudinal gradient.

Due to the high density of individuals found in natural populations, the capture of alleles occurring in frequencies of < 0.1 percent can be achieved within an area of about ten hectares. The low values observed for diversity among populations, the large number of alleles, and the high heterozygosity suggest that a few reserves should be sufficient for *in situ* conservation purposes (Reis 1996).

Other ecosystem components, however, have to be taken into account. Pollinators and seed dispersers responsible for the gene flow and the maintenance of diversity levels found in our studies also must be maintained in the reserves. With this additional constraint, we believe that reserves must be large enough to maintain these animal populations.

Regarding *ex situ* conservation, intensive collections at a few sites would be sufficient, given the low divergence and high diversity observed. Adequate numbers of individuals could be attained in relatively small areas. The capture of the rare alleles (frequency close to 0.01) can be accomplished with seed (progeny) collections from *ca* 160 individuals (N_e 500), which could be acquired within three hectares of forest. Collections should prioritize regions with high numbers of alleles (Intervales Farm-São Paulo; Reis 1996), since the levels of heterozygosity were similar for all populations.

Another relevant issue is the possibility of breeding and/or seed production to enrich secondary forests. Such an approach would enhance the dynamics of succession in these forests as a result of the association of palmiteiro and other animal species.

TABLE 4. *Current annual increment rates in DBH and basal area for* Euterpe edulis *in a secondary forest at São Pedro de Alcântara, SC (1992); adapted from Reis Conte* et al. *1999).*

Diameter class (cm)	*N*	IC_{DBH}[a] (cm)	IC_{BA}[b] (cm)
2	5	0.64 (0.75)[c]	3.53 (4.26)[c]
3	76	0.40 (0.48)	2.59 (3.24)
4	128	0.43 (0.53)	3.43 (4.23)
5	79	0.81 (0.61)	7.75 (6.15)
6	42	0.78 (0.53)	8.57 (6.13)
7	55	1.00 (0.60)	12.76 (8.13)
8	35	1.15 (0.69)	16.54 (10.22)
9	29	0.82 (0.57)	13.07 (9.27)
10	28	0.46 (0.59)	8.06 (10.42)
11	34	0.39 (0.59)	7.45 (11.43)
12	23	0.21 (0.35)	4.11 (6.91)
13	14	0.19 (0.46)	4.13 (9.76)
14	6	0.03 (0.06)	0.60 (1.47)

[a] IC_{DBH} = Increment in DBH.
[b] IC_{BA} = Increment in basal area.
[c] Standard deviation.

SUSTAINABLE MANAGEMENT

We have developed a sustainable management system for natural populations of palmiteiro (Floriano *et al.* 1987; Fantini, A. Reis, M. Reis, & Guerra 1992, Reis *et al.* 1992; Reis, Conte *et al.* 1999), which has been tested in private and government-owned forests in São Paulo state (SP) and Santa Catarina state (SC). The data generated so far have been incorporated into the official state regulations and policies for managing natural populations of palmiteiro.

The proposed management of palmiteiro is intended to produce a sustainable yield of heart of palm within natural forest, while providing ecological, economic, and social benefits. The management is based on three basic parameters: (1) population structure (DBH distribution); (2) increment rates; and (3) the number of seed trees per hectare. Population structure and increment rates would be obtained through inventories on permanent plots, with individually tagged plants being evaluated periodically. The minimum number of seed trees to be maintained permanently in the forest would be at least 50 plants/ha, according to the present regulations. This parameter was defined after demographic studies by Reis *et al.* (1988, 1991); however, an average of 60 plants/ha would be better to maintain the same levels of genetic structure and diversity found in natural populations, according to studies on population genetics by Reis (1996).

The data for population structure and increment rates presented in this paper were collected from experimental sites at São Pedro de Alcântara Experimental Station (São Pedro de Alcântara, SC), Faxinal Farm (Blumenau, SC), and Intervales State Park (Sete Barras, SP). Populations at all sites showed similar diameter distributions (Table 1), with the expected reverse J-shaped curve. Small deviations from this shape, observed at São Pedro and Intervales, resulted from past harvests of palm heart (Ribeiro *et al.* 1994; Reis, Conte *et al.* 1999). Data on individual DBH and basal area increment per diameter class are shown in Table 4. We used DBH (or the equivalent basal area) to estimate the heart of palm yield. These parameters were highly correlated, and DBH was the easiest nondestructive parameter measurable on palmiteiro (Fantini, A. Reis, M. Reis, Guerra & Nodari 1992; Fantini *et al.* 1997). Data included in Table 4 suggest that the annual increment rates of basal area peaked at 8–9 cm DBH. These data were used to model the increment in basal area as a function of DBH, by the method of least squares, and to estimate the diameter limit for harvesting.

At São Pedro de Alcântara, increment in basal area peaked at 8.6 cm (8.5 cm for practical purposes) and is assumed to be the diameter limit for cuting. For this population, 151 out of 559 plants/ha would be available for harvesting (>8.5 cm DBH; Table 5); however, the maintenance of at least 50 seed trees/ha would be required. Thus, 106 individuals could be harvested in the first cycle, producing 51.2 kg heart of palm/ha (equivalent to US$100–US$150).

The length of the cutting cycle is another variable to be estimated. The basic idea is that the

TABLE 5. *Palm heart yield from a natural population of* Euterpe edulis *under sustained yield management in a secondary forest at São Pedro de Alcântara, SC (1992; adapted from Reis Conte* et al. *1999.*

DBH (cm)	Number of trees/ha: Total	>8.5 cm	Seed trees	Harvest	Yield: Individual	(kg)[a]
2–3	5					
3–4	76					
4–5	128					
5–6	79					
6–7	42		1			
7–8	55		4			
8–9	35	17	1	16	0.30	4.8
9–10	29	29	3	26	0.38	9.8
10–11	28	28	9	19	0.46	8.8
11–12	34	34	10	24	0.56	13.3
12–13	23	23	8	15	0.66	9.8
13–14	14	14	8	6	0.76	4.6
14–15	6	6	6	—	0.88	—
Total	554	151	50	106	—	51.2

[a] Yield (g) = 5.34. BA = 4.194 DBH^2.

remaining plants will fill out the gaps left by those removed from the forest, and rebuild the desired diameter distribution (steady state) until the next harvesting. The choice for a particular cutting cycle should consider both biological and economic criteria. The diameter distribution of the steady-state population will vary according to the cutting cycle. Under a five-year cycle, the steady-state population would make available for harvesting palm trees that are 8.5–12 cm DBH (Table 5). The periodic yield would be 34.17 kg heart of palm/ha. With a cost of US$48/ha, an average price of US$2.25/kg of palmito (Pereira 1994), and an annual interest rate of 6 percent, the internal rate of return for the project would be 18 percent and the payback period would be three years and seven months (Reis, Vencovski *et al.* 1999b). Internal rate of return is the interest rate value that makes the profit equal zero if a project depends on the payment of such interest. In this case, the internal rate of return is higher than interest rate, which allows a profit higher than zero. We also estimated steady-state populations and harvesting level for cycles of four and six years (Table 6).

For Intervales State Park, the results were slightly different. The cutting limit diameter in this area was 10 cm (Ribeiro *et al.* 1994). The estimated productivity was 55.7 kg/ha in each cycle of six years (data not shown). In this case, assuming an annual interest rate of 6 percent, the internal rate of return of the project would be 31 percent (Pereira 1994).

CONCLUDING REMARKS

The sustainable management of forest species is possible and will contribute to the success of efforts to conserve remnants of the Brazilian Atlantic Forest. Farmers are willing to participate in conservation efforts if they can profit from the forest resources they own. The challenge posed to research-

TABLE 6. *Palm heart yield from a steady-state population of* E. Edulis *at São Pedro de Alcântara, SC (1992; adapted from Reis Conte* et al. *1999).*

DBH (cm)	Number of trees/ha: Total[a]	Seed trees	Harvesting cycle: 5 years: Harvest	Yield (kg/ha)[b]	4 years: Harvest	Yield (kg/ha)[b]	6 years: Harvest	Yield (kg/ha)[b]
4–5	152							
5–6	101							
6–7	67	1						
7–8	46	4						
8–9	35	1	17	5.2	17	5.2	17	5.2
9–10	32	3	29	11.0	29	11.0	29	11.0
10–11	32	9	21	9.7	21	9.7	21	9.7
11–12	31	10	15	8.3	—		21	11.7
12–13	29	8	—		—		—	
13–14	20	8	—		—		—	
14–15	1	6	—		—		—	
Total	546	50	82	34.2	67	25.8	88	37.5

[a] Regulated diameter distribution: $N = 588.40 - 166.62$ DBH $+ 16.56$ DBH$^2 - 0.55$ DBH^3 ($Y^2 = 0.95$).
[b] Yield = 4.194 DBH^2.

ers is to find forest products that can be managed within the forest, which at the same time are sustainable and profitable to the farmers.

Sustainable yield needs to be assessed through investigating the autecology of each species, as well as the relationship between the species and the whole ecosystem. In this paper, we have provided data for a management system of *E. edulis* to produce heart of palm. We believe that the proposed management system can be used as a model to evaluate other non-timber forest products in the Atlantic Forest.

The maintenance and use of many species in this forest, howeve, is the essential condition for the economic success of both managing and conserving the forest as a functional ecosystem.

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