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LETTER

Prospects for conserving biodiversity in Amazonian extractive reserves

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Abstract

Non-timber forest product (NTFP) extraction is a popular alternative to timber extraction that figures prominently in efforts to utilize tropical forests sustainably. But the ability to conserve biodiversity through NTFP management, particularly in extractive reserves in Amazonia, has remained untested. We found that intensive management of *Euterpe oleracea* (Palmae) fruit, one of the most important extractive products in the Amazon, has substantial impacts on biodiversity, whereas moderate management does not. We mimicked traditional levels of fruit harvest in a replicated experiment over one fruiting season. High-intensity harvest (75% of fruits removed) reduced avian frugivore species diversity by 22%. Low-intensity harvest (40% of fruits removed), however, had no effect on diversity. On a larger scale, we found that forests with enriched densities of *E. oleracea* supported more fruit-eating birds but fewer non fruit-eating birds than non-enriched forests. Taken together, these results suggest that intensive NTFP management to meet market demands may trigger substantial ecological impacts, at least at the level of our study. *E. oleracea* harvest should be limited where conservation of biodiversity is a goal.

Keywords

Amazonia, biodiversity, *Euterpe oleracea*, extractive reserves, frugivores, fruit harvest, non-timber forest products.

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INTRODUCTION

Terrestrial biodiversity in tropical regions is increasingly threatened by forest clearing and degradation (Skole & Tucker 1993; Cochrane *et al.* 1999; Nepstad *et al.* 1999; Peres 2001). In the Brazilian Amazon, for example, fire, logging, agriculture, and other land uses are predicted to degrade or deforest up to 42% of the region over the next 20 years (Laurance *et al.* 2001). This grim scenario for non-protected areas implies an increasing need to rely on protected areas as reservoirs of biological diversity (Myers *et al.* 2000; Terborgh 2000; Peres 2001). Although a variety of protected area types exists in the Brazilian Amazon, it is often taken for granted that biodiversity is safeguarded in the millions of hectares of parks, reserves, and other conservation units (Schwartzman *et al.* 2000).

Extractive reserves are public lands in the Brazilian Amazon designated for the sustainable use and marketing of forest products. They are often viewed as an especially promising conservation strategy because they merge the profitable harvest of non-timber forest products (NTFPs), such as latexes, fruits, and Brazil nuts, with the maintenance of forest cover across 40 000 km^2 (Fearnside 1989; Schwartzman *et al.* 2000). Moreover, the economic value of extractive reserves is increased through management, especially enrichment of forests with economically important species (Anderson *et al.* 1995; Kainer *et al.* 1998). The long-term economic benefits of NTFP enrichment and extraction may exceed those realized from logging or converting to pasture (Peters *et al.* 1989; Salafsky *et al.* 1993). To date, however, the long-term ecological costs and benefits of extractive reserves have not been fully evaluated (Vasquez & Gentry 1989; Browder 1992; Godoy & Bawa 1993; Peters 1996). In particular, the conservation of biodiversity in forests dedicated to NTFP enrichment and extraction is largely assumed or based on theoretical models (Peters *et al.* 1989; Anderson & Ioris 1992; Peters 1992; Redford & Sanderson 2000; Schwartzman *et al.* 2000). Thus, the role of these forests in conserving Amazonian biodiversity remains unknown.

We present the first experimentally based evaluation of the ecological impacts of NTFP management. Our study focused on extraction of palm fruits from eastern

Amazonian forests and consists of two components. (1) We experimentally harvested fruit at different intensities and evaluated the impact of these harvests on bird diversity. (2) We compared bird abundances in forests enriched with palm trees to abundances in non-enriched forests. The second component frames the results of the first component on spatial and temporal scales relevant to both bird home ranges and profitable production of NTFPs. Our results reveal significant local, short-term impacts of intensive fruit harvest and forest enrichment. These effects call into question the ability of NTFP management to maintain biodiversity while meeting market demand.

MATERIALS AND METHODS

We studied the dominant NTFP system in the Amazon River estuary: management of *Euterpe oleracea* and extraction of its fruit. Across an estimated 10 000 km^2, people manage forests for production of this palm, locally known as '*açaí*', and harvest up to 13 000 kg fruit ha^{-1} $year^{-1}$ by climbing stems and removing fruit clusters (Calzavara 1972; Anderson *et al.* 1995; Muñiz-Miret *et al.* 1996). The fruits, which are produced during a time of general fruit scarcity in the forest, are processed into a nutritional juice that constitutes a staple in the regional diet and that by 1987 had become 'easily the most important (by value) extractive product in the Brazilian economy' (Richards 1993). The region-wide estimated harvest of 151 886 tons of *E. oleracea* fruit generates approximately 35 million Reais (US$ 20.3 million) annually (IBGE 1996). Such profitability encourages enrichment management, which involves planting and protecting *E. oleracea* and removing competing plants (Anderson *et al.* 1995; Muòiz-Miret *et al.* 1996). Enrichment, which significantly increases *E. olerace*a fruit production (Moegenburg 2000), is concentrated in discrete areas of forest, thereby creating a mosaic of enriched and non-enriched forest within the landscape (Hiraoka 1995).

To test whether *E. oleracea* fruit harvest impacts the species diversity of fruit-eating birds, we simulated harvest by experimentally manipulating ripe fruit availability in palm forests within the Caxiuanã National Forest, Pará State, Brazil (1°42′30″ S, 51°31′45″ W). Experimental plots were 1.8 ha circles, allowing accurate monitoring of all birds within homogeneous, *E. oleracea*-dominated forest and approximating the area of forest from which a family would harvest fruit in one day. Plots were divided into three equal subplots, which were randomly assigned a harvest intensity: ~75% removal of ripe fruit, ~40% removal of ripe fruit, or no removal ($n = 4$ plots and 12 subplots). The 75% harvest intensity mimics extraction for both consumption and marketing of fruit; the 40% intensity mimics that for household consumption only (Anderson & Ioris 1992; Muñiz-Miret *et al.* 1996). The no-removal treatment reflects the situation in some remote *E. oleracea*-dominated forests that are not harvested. During the 1998 fruiting season (July – September), ripe fruit was removed twice per month and avian frugivores were censused on subsequent days. Each census was conducted by two observers walking timed transects and recording the presence of all individuals in subplots during 4.5 h. The long duration of each census, and the characteristically open canopy of *E. oleracea*-dominated forest, allowed the detection of each bird's arrival, movement, and departure from subplots, thereby allowing us to avoid multiple sampling of individuals.

Although harvests decrease the availability of *E. oleracea* fruit on a local scale, enrichment of forests with this palm have increased fruit availability on a regional scale. Although fruit harvest is ongoing in enriched forests, fruit abundance from the frugivores' point of view is nonetheless greater in enriched than in non-enriched forests because: (1) fruit ripening at any given site is continuous, whereas harvest occurs sporadically, and (2) frugivores often eat fruit considered unripe by humans.

We predicted that the greater availability of *E. oleracea* fruit in enriched forests would result in greater abundance of fruit-eating birds than in non-enriched forests. To test this, we censused birds in forests enriched with *E. oleracea* and in adjacent non-enriched forests, during the palm's fruiting season. Five enriched and five non-enriched forest stands near the mouth of the Tocantins River (1°45′52″ S, 48°57′33″ W) were identified through interviews with residents. At each site 12 mist nets (12 m long, 2.6 m high, 36 mm mesh size) were assembled in three groups of four nets. Net groups were placed in parallel lines at least 50 m apart. During September – November, 1998, birds were captured at each site for 2 consecutive days, from 0600 to 1800 h. Estimating bird abundance based on mist net captures can introduce biases associated with interspecific variation in behaviour and habitat-specific differences in the ability of nets to capture birds (Remsen & Good 1996). On the other hand, mist nets are often necessary for censusing species that are otherwise difficult to detect (Karr 1981).

RESULTS

Forty-one species of fruit-eating birds visited the experimental plots (Moegenburg 2000). Species accumulation curves plateaued after the second census (Moegenburg 2000). The number of individuals in plots during each census ranged from 20 to 100 (median = 55). Harvest of 75% of ripe fruit reduced the diversity of fruit-eating bird species by 22% (Fig. 1; $F_{1,6} = 13.08$, $P < 0.02$) over no removal (Shannon–Wiener Index (base 10) = 2.73 vs. 2.11). More dramatically, of the 21 regular visitors, six species (29%) totally ceased visits to the 75% removal subplots. These included a tanager (*Thraupis palmarum*), a trogon (*Trogon collaris*), a parrot (*Deropteus*

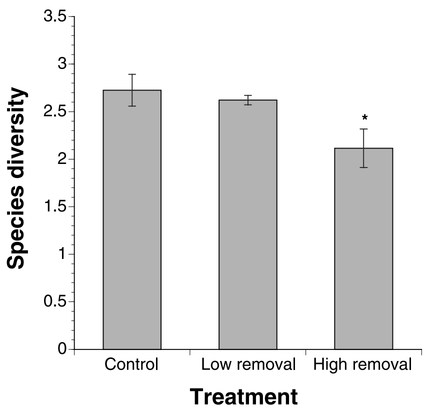

Figure 1 Fruit-eating bird responses to harvest of *Euterpe oleracea* fruit. Species diversity (Shannon–Wiener Index) of fruit-eating birds was 22% lower in the high-removal subplots than in either the control or low-removal subplots (indicated by asterisk; $F_{1,6} = 13.08$, $P < 0.02$). Control and low-removal subplots did not differ significantly.

accipitrinus), two parakeets (*Pionites leucogaster* and *Brotogeris versicolorous*), and a macaw considered vulnerable to extinction (*Ara macao,* Parker *et al.* 1996).

In contrast, harvest of 40% of ripe fruit had no effect on bird species diversity (Fig. 1; Shannon–Wiener Index = 2.62; $F_{1,6} = 0.04$, $P > 0.84$). Moreover, no species ceased visits to low-removal subplots, implying that fruit harvest at low intensity can maintain overall avian diversity, at least on the scale of local harvest during a single fruiting season.

Bird communities in enriched and non-enriched stands differed substantially in species abundance and dietary representation (Fig. 2). We captured 54 species in 43 genera. Two species were captured with equal frequency in both forest types. Thirty-two species were captured more frequently in enriched stands, and 23 of these (72%) werefruit-eaters in the families Tyrannidae, Fringillidae, and Muscicapidae. In contrast, 20 species were captured more frequently in non-enriched stands, and only four of these (20%) were fruit-eaters. In fact, more frugivores were captured more frequently in enriched stands than would be expected by chance alone ($\chi^2 = 6.37$, d.f. = 1, $P < 0.01$). Fifty percent of captures in non-enriched forests were of strictly insectivorous species in the families Thamnophilidae and Furnariidae. Thus, forests enriched with *E. oleracea* hosted a greater abundance of fruit-eating birds and a lower abundance of birds with other diets, implying that the abundance of fruit-eating birds shifts in response to *E. oleracea* management.

DISCUSSION

For more than a decade, NTFP harvest in extractive reserves has been promoted as an alternative to Amazonian deforestation (Fearnside 1989; Peters 1992, 1996; Anderson *et al.* 1995; Kainer *et al.* 1998; Schwartzman *et al.* 2000). The success of extractive reserves hinges on their ability to meet various goals, including generating adequate income for local people and maintaining species diversity (Browder 1992; Godoy & Bawa 1993; Peters 1996). Our results show that both extraction and enrichment of NTFPs can impact species diversity and abundance, at least at the scale of our study. In particular, intensive fruit harvest substantially reduced bird species diversity, and intensive enrichment shifted the bird community towards dominance by fruit-eating species. That birds responded within 1 day of our fruit harvests suggests their high sensitivity to fruit abundance. Moreover, tropical fruit-eating birds are known to track fruit abundance over many scales of space and time (Levey & Stiles 1992). Taken together, this suggests that frugivorous birds may be affected by *E. oleracea* fruit harvest on scales larger than we were able to manipulate. Because most woody plants in Neotropical forests rely on vertebrate frugivores for seed dispersal (Gentry 1982), changes in the number and diversity of frugivores may have far-reaching impacts on recruitment patterns and long-term survival of fruiting plants (Strahl & Grajal 1991; Cardoso da Silva & Tabarelli 2000; Cordeiro & Howe 2001).

Our results also suggest a more optimistic conclusion: that a moderate level of fruit harvest is compatible with the maintenance of bird species diversity. Our extraction of 40% of ripe fruit had no effect on avian species diversity. This suggests a possible threshold level of extraction above which frugivores perceive insufficient fruit supply, but under which extraction may take place without effects on biodiversity.

Because biodiversity conservation is a primary goal of NTFP management in extractive reserves, our results imply that the intensity of NTFP harvest should be limited. In the case of *E. oleracea*, reduced harvest intensity and enrichment will probably result in lowered income. Reduced income from one species could be offset in a number of ways, including diversifying the species of NTFPs that are harvested and sold (Anderson & Ioris 1992; Peters 1996) and certifying NTFPs that are harvested sustainably (Kiker & Putz 1997).

Because our conclusions are narrowly based, further research on NTFP ecology and extraction is clearly needed. Especially useful would be studies on other types of NTFPs (e.g. latexes, fibres, and resins) and research on threshold levels of harvest. We further recommend that NTFP management be incorporated into a suite of strategies for forest conservation that includes strictly protected areas (Redford & Sanderson 2000; Laurance *et al.* 2001; Peres 2001). Throughout Amazonia, the ability of extractive reserves and other protected areas to conserve biodiversity in the face of increasing forest destruction must be better understood.

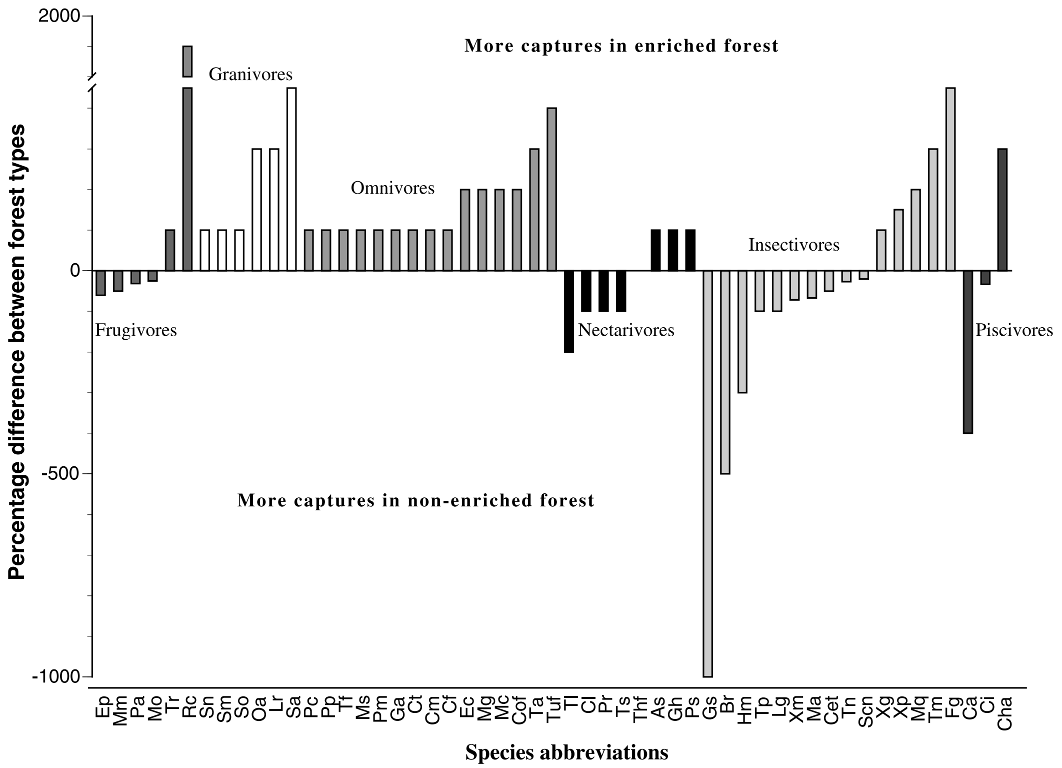

Figure 2 Percentage difference, relative to enriched forest, in the number of individuals of bird species caught in five forests enriched with *E. oleracea* and five non-enriched forests. Bars with positive values indicate more captures in enriched forest, while those with negative values indicate more captures in non-enriched forest. Shaded bars denote frugivorous species, while white bars denote non-frugivores. Significantly more ($\chi^2 = 6.37$, d.f. = 1, $P < 0.01$) frugivores have positive values than would be expected by chance. Species abbreviations as are follows: Ep = *Eucometis penicillata*, Mm = *Manacus manacus*, Pa = *Pipra aureola*, Mo = *Mionectes oleaginea*, Tr = *Tachyphonus rufus*, Rc = *Ramphocelus carbo*, Sn = *Sporophila nigricollis*, Sm = *Saltator maximus*, So = *Saltator orenocensis*, Oa = *Oryzoborous angolensis*, Lr = *Leptotila rufaxilla*, Sa = *Sporophila americana*, Pc = *Pachyramphus castaneus*, Pp = *Pachyramphus polychopterus*, Tf = *Tolmomyias flaviventris*, Ms = *Myiozetes similis*, Pm = *Phaeomyias murina*, Ga = *Geothlypis aequinoctialis*, Ct = *Columbina talpacoti*, Cm = *Crotophaga major*, Cf = *Celeus flavus*, Ec = *Eleania chiriquensis*, Mg = *Myi-Myiopagis gaimardii*, Mc = *Myiozetetes cayanensis*, Cof = *Coereba flaveola*, Ta = *Turdus albicollis*, Tuf = *Turdus fumigatus*, Tl = *Threnetes leucurus*, Cl = *Campylopterus largipennis*, Pr = *Phaethornis ruber*, Ts = *Thalurania* sp., Thf = *Thalurania furcata*, As = *Amazilia* sp., Gh = *Glaucis hirsuta*, Ps = *Phaethornis* sp., Gs = *Glyphorhyncus spirurus*, Br = *Basileuterus rivularis*, Hm = *Hypocnemoides melanopogon*, Tp = *Thamnophilus punctatus*, Lg = *Lophotriccus galeatus*, Xm = *Xenops minutus*, Ma = *Myrmotherula axillaris*, Cet = *Cercomacra tyrannia*, Tn = *Thamnophilus nigrocinereous*, Scn = *Sclateria naevia*, Xg = *Xiphorhynchus guttatus*, Xp = *Xiphorhynchus picus*, Mq = *Microhopias quixensis*, Tm = *Todyrostrum maculatum*, Fg = *Formicivora grisea*, Ca = *Chloroceryle aenea*, Ci = *Chloroceryle inda*, Cha = *Chloroceryle americana.*

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