Elevational changes in a neotropical Fig (*Ficus* sp.p.) community in north western Ecuador

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Differences in primary production levels at high elevations sites have a direct impact on the numbers, and types, of fauna that areas of tropical forest can support. We investigated the effects of increasing elevation on a Neotropical fig (*Ficus* spp.) community in the Andean Choco region of Ecuador. Results show that there is a significant reduction in mean density of fig trees (p = 0.01), likewise mean basal area decreases with increasing elevation (p < 0.05). Causes are suggested and the possible consequences of this on frugivores is discussed.

Keywords: Choco, Cloud Forest, DBH, Frugivore, *Los Cedros* Biological Reserve

Introduction

It is well established that plant community structure and composition in tropical forests is highly influenced by changes in elevation (Smith & Killeen 1998, Tang & Ohsawa 1997). This variation is mainly due to the changes in temperature, soil pH, solar radiation and rainfall levels associated with conditions at high elevations (Bendix et al. 2008, Wilcke et al. 2008) although local topography also plays a role (Nidia & Cuello 2002). One effect of these changes is to create zones or "belts" of forest types which are distinct in the floral assemblages present (Kitayama 1992). These belts are found to occur at different altitudes depending on latitude and local conditions (Nidia & Cuello 2002). As would be expected there are also corresponding changes in faunal assemblages associated with this variation in forest type due to associated changes in primary production levels and the types of food resources produced (Lawes 1992, Marshall et al. 2005, Costa 2006).

The Choco bio-geographic region of northwestern Ecuador contains some of the most diverse forests on earth. The region was listed by Myers et al. (2000) as a "Biodiversity hotspot" and a priority for conservation due to this diversity as well as the high level of endemism and the high threat level faced by this region. The forests of the Ecuadorian Choco originally extended from just above sea-level, up the western slopes of the Andes, to over 3000m. Only an estimated 4% of the original forest cover still remains in Ecuador, most of this within protected areas (Myers et al. 2000), the largest of these being the 45.000 ha Parque Nacional Cotocachi-Cayapas and the contiguous 5.500 ha Los Cedros Biological Reserve (LCBR). The LCBR protects areas of primary and regenerating secondary forest that lie above 1000 meters above sea level. Although these are sizable tracts of intact forest they are of a different structure to those of the formerly forested lowland sites. Thus remaining forest types will have a direct effect on the numbers and types of animals and plants the area can and does support (Hanya et al. 2004).

Within tropical forest communities it has been suggested that there are certain species which play significant roles in the maintenance of the community as a whole. Defined as "keystone resources" (Peres 1994, Patel 1997, Stevenson et al. 1998, Peres 2000, Shanahan et al. 2001), these species must play a very important if not vital role in sustaining an ecosystem (Tutin et al. 1997, Peres 2000). Such "keystone resources" may produce food at times when other resources are scarce, be acceptable and accessible to large numbers of consumers as well as being widely distributed and relatively common (Peres 2000). Throughout the tropics and sub-tropics, including the Ecuadorian Choco, trees of the Genus *Ficus sp.p.* display intra- and inter-specific asynchronous fruiting regimes (Janzen 1979, Milton et al. 1982, Patel 1997, Bronstein et al. 1990, Milton 1991, Tutin et al. 1997) making fruits available to consumers throughout the year (Janzen 1979, Milton et al. 1982, Coates-Estrada & Estrada 1986, Peres 1994, Tutin et al. 1997, Stevenson et al. 1998, Peres 2000), they also feature prominently in the diets of many mammalian and avian species (Shanahan et al. 2001). Furthermore, they are found throughout the Neotropics, including the Choco-Darien bio-geographic zone, from lowland rainforest into the montane forest belt.

This study examines changes in density and distribution within the fig community of the LCBR in relation to increases in elevation. The main questions addressed are: (1) whether fig tree density decreased with increases in elevation; (2) whether DBH of fig trees also decreases with increased elevation; and (3) what effect this will have on fruit production. Both of which will affect the abundance and production of this "keystone resource" and therefore forest carrying capacity. This study forms part of the larger PRIMENET initiative (http://www.primenet.org.uk), which aims to document and protect the remaining areas of Ecuadorian Choco forest, and the critically endangered brown-headed spider monkey (*Ateles fusciceps)* which is endemic to the region (Tirira 2004).

Materials and methods

The Los Cedros Biological Reserve is located in Imbabura province, North Western Ecuador (0° 19' N and 78° 47' W). The reserve encompasses primary and secondary lower montane and montane tropical cloud forest (Holdridge 1971). Situated on the western slopes of the Cordillera de los Andes, The reserve encompasses an altitudinal range from approximately 1000 m. up to 2710 m. at the peak of the Cordillera de la Plata range within an area of 60 km². There are two seasons, one long wet season from September to May and a shorter dry season from June to August, although rainfall still occurs on most days during this period. Average annual rainfall is 3150 mm with an average year round temperature of 20° C (Freiberg & Freiberg 2000). Canopy height ranged from approximately 20-25 meters at lower altitudes to 20 meters at higher altitudes, closed canopy cover was found at all altitudes covered in this study, with crown projection of fig trees ranging from approx 25-100 m².

Between 28 May and 30 July 2006 a total of 19 km of transect walks were completed in nine different locations throughout the reserve; the transects consisted of 16 km of existing trails, at 1200-2000 m, and 3 km of newly cut transects, at 1200-1600 m, all trails were repeated to ensure correct sampling. Strip transect methodology was employed (Kaiser 1983) with 5 m either side of

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the center line as the cut off point, thus giving a 10 m wide sampling strip. This strip width has been used in many previous studies of a similar nature (Hemingway & Overdorff 1999, Chapman & Chapman 2000, DeWalt et al. 2003, Hashimoto et al. 2003) and has been shown to give good coverage of area with limited manpower based on visibility either side of the transect. Smaller strip widths have been employed in other studies (Ganesh & Davidar 1999, Furuichi et al. 2001, Hashimoto et al. 2001, Brugiere et al. 2002) but it was felt that the larger strip width was better suited to this study. The total area sampled was 188.500 m², all fig trees of diameter at breast height (DBH) greater than 10 cm were counted and DBH measured.

DBH measurements were then used to estimate fruit production for the different altitudinal zones using the equation (Peters et al. 1988, Sorensen & Fedigan 2000):

$$Fr = 47 \cdot DBH \cdot 1.9$$

where *Fr* = Fig fruit biomass production in grams, and DBH = diameter at breast height in centimeters.

Breast height was taken to be 150 cm from the ground, although when trees with large buttressed roots were encountered DBH was measured immediately above the buttresses (Chapman et al. 1992). Trees of both the sub-genus *Urostigma,* or strangling figs, and *Pharmacosycea,* or free-standing figs (Milton 1991) were included. Similarly both monoecious and dioecious species were included. Although some differences in fruit production have been noted due to differing pollination strategies, these differences are not large and do not occur regularly (Janzen 1979). Sampled areas were stratified into four altitudinal zones, these were: 1200-1399 m, 1400-1599 m, 1600-1799 m and 1800-1999 m. Fig trees were identified (Gentry 1996) and tagged with high visibility "flagging tape" so as not to be re-counted: tape was removed after the study was completed to minimize impact on the area. Data were also collected on the location of trees on the existing trail system and new transects to test if there was a difference in observed densities, this was done to ensure there was no bias in the results due to sampling methodology (Hemingway & Overdorff 1999).

Data were entered into *Minitab* V13 for analysis. Statistical analyses were carried out to examine trends and test for differences in density and fig tree DBH among the four altitudinal zones. DBH data were log transformed to ensure a normal distribution.

Results

A total of 165 trees were recorded with an overall density of 8.75 ha^{-1}. Slightly higher densities were found on the newly cut transects, but this was not found to be significant ($t = 1.008$, $p > 0.05$). All trails and transects were therefore used in subsequent analysis. Overall mean fig tree DBH was 40.8 cm.

Mean densities of fig trees in the four elevational zones were 9.8 at 1200 - 1399 m, 8.3 at 1400 - 1599 m, 11.7 at 1600 - 1799 m and 1.9 at 1800 - 1999 m. A Kolmogorov-Smirnov test confirmed that density data were normally distributed ($p > 0.05$). Differences in densities were found to be significant ($p = 0.01$). Mean DBH for each of the altitudinal zones was 46.6 cm at 1200 -1399 m, 40.0 cm at 1400 -1599 m, 40.8 at 1600 - 1799 m and 32.7 at 1800 -1999 m.

A Kolmogorov-Smirnov test confirmed that log transformation of DBH data resulted in normally distributed dataset ($p > 0.05$). Regression of log DBH against altitude proved significant for the altitudinal factor ($p < 0.05$). By rearrangement of the regression equation the trend in mean basal area is represented by:

$$Avg.\ Basal\ Area = 103.91^{-0.000641 \cdot ALTITUDE}$$

Estimated fig tree fruit production for 1200 – 1799 m range was calculated together as differences in DBH between these altitudes, without inclusion of higher altitudes, was not significant. Estimated production for this range was $Fr \approx 55$ Kg year^{-1} and 139 Kg ha^{-1} year^{-1}. Estimated fruit production for 1800+m was calculated to be $Fr \approx 35$ Kg year^{-1} and 96 Kg ha^{-1} year^{-1}.

Discussion

The results confirm expected patterns of reduced densities of tropical plants at elevations with more temperate climes. This is also true for the reduction in mean DBH of fig trees. The results also suggest that 1800 m could mark the transition zone between the pre-montane and montane forest belts for this region (Kitayama 1992, Tang & Ohsawa 1997). The reduction in mean DBH of 52% between 1300m and 1800m probably reflects the impact of forest gap generation on the reduced growth rate at increasing altitude which is most probably due to the changes in temperature, solar radiation, humidity and soil pH associated with higher elevations (Marshall et al. 2005).

Tree DBH is used as an estimator of fruit production as previous studies have shown fruit biomass production to be a power function of DBH in many tree species (Sorensen & Fedigan 2000), and specifically tropical and sub-tropical figs (Peters et al. 1988). Similarly, the use of DBH has also proven more reliable then other methods at accurately estimating fruit production (Chapman et al. 1992, Stevenson et al. 1998).

The possible effect on frugivorous consumers who rely on figs when other food sources are scarce stem not only from reduced densities of fig trees, that reduces the number of food resources within a given territory, but also from a reduction in relative production levels of the individual trees between altitudinal zones as a result of smaller size in higher zones. The regression equation suggests a 52% reduction in DBH between 1300 m and 1800 m with a related reduction in relative fruit production (Peters et al. 1988, Sorensen & Fedigan 2000). It follows that these reductions could result in corresponding reductions in the presence and abundance of large bodied frugivores, such as primates. Indeed a reduction in numbers of primates at higher elevations has been reported in several previous studies (Caldecott 1980, Marshall et al. 2005), including spider monkeys (Durham 1975) and is commonly attributed to the increased energetic costs of finding sufficient food as a result of lower densities and reduced quality of resources (Wrangham et al. 1993, Marshall et al. 2005), and in the case of folivores on lower quality, less digestible food as a result of environmental conditions at high elevation sites (Marshall et al. 2005).

In the case of conservation of the Choco bio-geographic region, and its endemic fauna, there are far reaching implications. As mentioned above much of the original forest cover at low elevations has been removed for human settlement. Although there remains some sizable areas of intact forest these are at higher elevations and may not be able to support viable numbers of large bodied frugivores. To properly protect all the species that inhabit the area it may be necessary to extend protection to cover a larger area of forest at lower elevations to help ensure the survival of species such as the brown headed spider monkey (*A. fusciceps).* This may be of prime concern as the very low numbers left in the wild, estimated at less than 250 mature individuals, may be at such levels as the forests they inhabit are unable to support a larger population leaving them, thus prone to extinction from other causes.

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References

Bendix J, Rollenbeck R, Richter M, Fabian P, Emck P (2008). Climate. In: Gradients in a tropical mountain ecosystem of Ecuador (Beck E, Bendix J, Kottke I, Makeschin F, Mosandl R eds). Springer-Verlag, Berlin, pp. 63-74.

Bronstein JL, Gouyon P, Gliddon C, Kjellberg F, Michaloud G (1990). The ecological consequences of flowering asynchrony in monoecious figs: a simulation study. Ecology 71: 2145-2156.

Brugiere D, Gautier J, Moungazi A, Gautier-Hion A. (2002). Primate diet and biomass in relation to vegetation composition and fruiting phenology in a rain forest in Gabon. International Journal of Primatology 23: 999-1024.

Caldecott JO (1980). Habitat quality and populations of two sympatric gibbons (Hylobatidae) On a mountain in Malaya. Folia Primatologica 33: 291-309.

Chapman CA, Chapman LJ (2000). Constraints on group size in Red Colobus and Red-tailed Guenons: examining the generality of the ecological constraints model. International Journal of Primatology 21: 565-585.

Chapman CA, Chapman LJ, Wrangham R, Hunt K, Gebo D, Gardener L (1992). Estimators of fruit abundance of tropical trees. Biotropica 24: 527-531.

Coates-Estrada R, Estrada A (1986). Fruiting and frugivores at a strangler fig in the tropical rain forest of Los Tuxtlas, Mexico. Journal of Tropical Ecology 2: 349-357.

Costa FRC (2006). Mesoscale gradients of herb richness and abundance in Central Amazonia. Biotropica. Early edition published online 15 August 2006.

DeWalt SJ, Maliakal AK, Denslow JS (2003). Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. Forest Ecology and Management 182: 139-151.

Durham NM (1975). Some ecological, distributional and group behavioural features of Atelinae in southern Peru: with comments on Interspecific relations. In: Socioecology and psychology of Primates (Tuttle RT ed). Mouton & Co., The Netherlands, pp.87-102.

Freiberg M, Freiberg E (2000). Epiphyte diversity and biomass in the canopy of lowland and montane forests in Ecuador. Journal of Tropical Ecology 16: 673-688.

Furuichi T, Hashimoto C, Tashiro Y (2001). Fruit availability and habitat use by chimpanzees in the Kalinzu forest, Uganda: examination of fallback foods. International Journal of Primatology 22: 929-945.

Ganesh T, Davidar P (1999). Fruit biomass and relative abundance of frugivores in a rain forest of Southern Western Ghats, India. Journal of Tropical Ecology 15: 399-413.

Gentry AH (1996). A field guide to the families and genera of woody plants of northwest south america: Columbia, Ecuador, Peru. University of Chicago Press. Chicago, USA.

Hanya G, Yoshihiro S, Zamma K, Matsubara M, Ohtake M. Kubo R, Noma N, Agetsuma N, Takahata Y (2004). Environmental determinants of the altitudinal variations in relative group densities of Japanese macaques on Yakushima. Ecological Research 19: 485-493.

Hashimoto C, Furuichi T, Tashiro Y (2001). What factors affect the size of chimpanzee parties in the Kalinzu forest, Uganda: examinations of fruit abundance and number of oestrous females. International Journal of Primatology 22: 947-959.

Hashimoto C, Suzuki S, Takenoshita Y, Yamagiwa J, Basabose AK, Furuichi T (2003). How fruit abundance affects the chimpanzee party size: a comparison between four sites. Primates 44: 77-81.

Hemingway CA, Overdorff DJ (1999). Sampling effects on food availability estimates: Phenological method, sample size and species composition. Biotropica 31: 354-364.

Holdridge LR (1971). Forest Environments in Tropical Life Zones: A Pilot Study. Pergamon. Oxford.

Janzen DH (1979). How to be a fig. Annual Review of Ecology and Systematics 10: 13-51.

Kaiser L (1983). Unbiased Estimation in Line-Intercept Sampling. Biometrics 39: 965-976.

Kitayama K (1992). An altitudinal transect study of the vegetation on Mount Kinabalu, Borneo. Journal Plant Ecology 102: 149-171.

Lawes MJ (1992). Estimates of population density and correlates of the status of the samango monkey Cercopithecus mitis in Natal, South Africa. Biological Conservation 60: 197-210.

Marshall AR, Topp-Jorgensen JE, Brink H, Fanning E (2005). Monkey abundance and social structure in two high-elevation forest reserves in the Udzungwa mountains of Tanzania. International Journal of Primatology 26: 127-145.

Milton K (1991). Leaf change and fruit production in six Neotropical Moraceae species. Journal of Ecology 79: 1-26.

Milton K, Windsor DM, Morrison DW, Estribri MA (1982). Fruiting phenologies of two Neotropical ficus species. Ecology 63: 752-762.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000). Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Nidia L, Cuello NL (2002). Altitudinal changes of forestry diversity and composition in the Ramal de Guaramacal in the Venuzuelan Andes. Ecotropicos 15: 160-176.

Patel A (1997). Phenological Patterns of Ficus in Relation to Other Forest Trees in Southern India. Journal of Tropical Ecology 13: 681-695.

Peres CA (1994). Primate responses to phenological change in an Amazonian terra firme forest. Biotropica 26: 98-112.

Peres CA (2000). Identifying keystone plant resources in tropical forests: the case of gums from parkia pods. Journal of Tropical Ecology 16: 287-317.

Peters RH, Cloutier S, Dube D, Evans A, Hastings P, Kaiser H, Kohn D, Sawer-Foner B (1988). The allometry of the weight of fruit on trees and shrubs in Barbados. Oecologia 74: 612-616.

Shanahan M, So S, Compton SG, Corlett R (2001). Fig-eating by vertebrate frugivores: a global review. Biological Reviews 76: 529-572.

Smith ND, Killeen TJ (1998). A comparison of the structure and composition of montane and lowland tropical forest in the serranía Pilón Lajas, Beni, Bolivia. In: Forest Biodiversity in North, Central and South America, and the Caribbean. (Dallmeier F, Comiskey JA eds). Man and the Biosphere Series 21: 681-700. UNESCO, Paris.

Sorensen TC, Fedigan LM (2000). Distribution of three monkey species along a gradient of regenerating tropical dry forest. Biological Conservation 92: 227-240.

Stevenson PR, Quinones MJ, Ahumada JA (1998). Annual variation in fruiting patterns using two different methods in a lowland tropical forest, Tinigua National Park, Colombia. Biotropica 30: 129-134.

Tang CQ, Ohsawa M (1997). Zonal transition of evergreen, deciduous, and coniferous forests along the altitudinal gradient on a humid subtropical mountain, Mt. Emei, Sichuan, China. Plant Ecol 133:63-78.

Tirira D (2004). Present status of the brown-headed spider monkey (*Ateles fusciceps* Gray, 1866 - Primates: Atelidae) in Ecuador. Lyonia 6: 17-24.

Tutin CEG, Ham RM, White LJT, Harrison MJS (1997). The primate community of the Lope reserve, Gabon: Diets, responses to fruit scarcity, and effects on biomass. American Journal of Primatology 42: 1-24.

Wilcke W, Yasin S, Schmitt A, Valarezo C, Zech W (2008). Soils along the altitudinal transect and in catchments. In: Gradients in a tropical mountain ecosystem of Ecuador (Beck E, Bendix J, Kottke I, Makeschin F, Mosandl R eds). Springer-Verlag, Berlin, pp. 75-86.

Wrangham RW, Gittleman JL, Chapman CA (1993). Constraints on group size in primates and carnivores: population density and day-range as assays of exploitation competition. Behavioural Ecology and Socio-biology 32: 199-209.