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Research Article

Cocoa farming and primate extirpation inside Cote d'Ivoire's protected areas

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Abstract
Côte d'Ivoire is the world's leading cocoa producer, annually generating over 1,500,000 metric tons of *Theobroma cacao* beans. Growth of this agri-business has led to extensive deforestation in Côte d'Ivoire, where the majority of the country's forest (excluding that in Tai National Park) exists as small, fragmented forest islands. Most of these forest blocks are designated as national parks or forest reserves, i.e., protected areas (PAs), but wildlife within Côte d'Ivoire's PAs is increasingly threatened by two illegal activities: hunting and full sun cocoa farming. In this paper, we investigate the impact of cocoa production on primate populations inside protected areas. We surveyed twenty three PAs (5 national parks, 18 forest reserves) in Côte d'Ivoire to determine (1) the number of primate taxa present, (2) the number of human inhabitants living adjacent to or within each PA, (3) the extent of overall habitat degradation, and (4) the extent of habitat degradation due to cocoa farming. Our data reveal a significant positive correlation ($r^2 = .736$, $p < .01$, $\alpha = 0.01$) between cocoa farming and the absence of primate species inside Côte d'Ivoire's national parks and forest reserves. Thirteen of 23 protected areas surveyed have lost all primate populations, and four taxa - *Colobus vellerosus* (white-thighed black and white colobus), *Colobus polykomos* (Western black and white colobus), *Procolobus badius waldroni* (Miss Waldron's red colobus) and *Procolobus badius badius* (Bay colobus) – were not found in any PAs we visited. Aggressive conservation action is needed to curb hunting throughout Côte d'Ivoire, but unless illegal cocoa farming is similarly controlled, even effective enforcement of anti-hunting laws will not prevent the loss of additional primate diversity, since habitats capable of supporting primate populations – including those within protected areas - will no longer exist.

Keywords: West Africa, illegal agriculture**,** deforestation, poaching, monkeys, apes

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Introduction

Côte d'Ivoire comprises part of West Africa's Guinean Forest Region, an ecosystem of great biological richness, species diversity, and endemism. The region is a World Biodiversity Hotspot, hosting over 2,250 endemic plant and 270 vertebrate species [1]. Côte d'Ivoire is home to twenty-two primate taxa, including 18 catarrhine species, and ranks second among West African countries in terms of primate diversity [2]. Forest surveys carried out over the last twenty-five years have documented the continued decline of Côte d'Ivoire's primate fauna, and several taxa are now classified as Endangered [*Pan troglodytes verus* Western chimpanzee, *Cercocebus atys lunulatus* White-naped mangabey, *Cercopithecus diana roloway* Roloway monkey, *Procolobus badius badius* Bay colobus) or Critically Endangered (*Procolobus badius waldroni* Miss Waldron's red colobus) [3-7]. One monkey - *Procolobus badius waldroni* - has not been observed in the wild since 1978 and is likely extinct, while two others – *Cercopithecus diana roloway* and *Cercocebus atys lunulatus* - are among the world's most threatened primates [8, 9].

Factors responsible for the reduction of Côte d'Ivoire's primates include rapid human population growth, a large influx of migrants, widespread and uncontrolled hunting, and the conversion of forest into fields supporting oil-palm, rubber, and cocoa agro-industries [6, 10-13]. While much of the expansion of Côte d'Ivoire's agri-businesses has occurred on plantations owned/leased by companies or on private land of eco-certified cocoa farmers, a growing number of cocoa farms are found inside national parks and forest reserves, or protected areas (PAs) [12-14]. The scale of this phenomenon became apparent during surveys we carried out in twenty-three protected areas while searching for endangered primates [6, 13]. The plantations inside Cote d'Ivoire's protected areas are - by definition – illegal, and as we describe below, the great majority are associated with full sun cocoa production. This method of cocoa production involves removal of all trees and contrasts with shade agroforestry in which selected large canopy trees are retained to provide shade to cocoa trees grown beneath them.

Cocoa farming, introduced to Africa over a century ago, is a major contributor to the economies of several West African countries. Côte d'Ivoire is the world's leading cocoa producer with cocoa sales accounting for approximately 10% of the country's GNP [16, 17]. The expansion of the cocoa agro-industry has been dramatic: between 1961 and 2000, the amount of land devoted to cocoa farming in West Africa increased from three to five million hectares [17], and today in Côte d'Ivoire alone, over 2.4 million hectares of land are devoted to cocoa plantations [18, 19]. Much of the agricultural expansion has come at the expense of old-growth forest. At the outset of the 20th century, an estimated sixteen million hectares of high canopy forest existed in Côte d'Ivoire; today, that number is four million ha and declining due to an annual deforestation rate of approximately 1% [20-23]. Côte d'Ivoire's remaining forest is highly fragmented, consisting largely of nominally protected national parks and forest reserves, i.e. "protected areas" (PAs). Wildlife in these protected areas is threatened by hunting, the encroachment of cocoa plantations on reserve borders, and expansion of illegal cocoa farming within the parks and reserves themselves [6, 24].

In this paper, we combine primate survey data from twenty-three protected areas with information on the scale of human settlements and cocoa plantations within these protected areas to examine the relationship between (illegal) cocoa production and primate diversity in

Côte d'Ivoire. More specifically, our objectives are to determine: (1) the number of primate taxa within each protected area, (2) the number of human inhabitants living adjacent to or within each PA, (3) the extent of overall habitat degradation, and (4) the extent of habitat degradation due to cocoa farming.

Methods

We used historical distribution data and information from primate surveys to identify twenty-three protected areas in central and southern Côte d'Ivoire known to contain at least one haplorrhine primate [2, 6, 13, 25-30]. According to these sources, the number of diurnal primate species expected in any given PA ranges between eight and eleven. These primates are *Cercopithecus petaurista* Lesser spot-nosed monkey, *Cercopithecus campbelli* Campbell's monkey, *Cercopithecus diana roloway* Roloway monkey, *Chlorocebus sabaeus* Green monkey, *Erythrocebus patas* Patas monkey, *Procolobus verus* Olive colobus monkey, *Colobus vellerosus* White-thighed black and white colobus monkey, *Colobus polykomos* Western Black and White colobus monkey, *Procolobus badius waldroni* Miss Waldron's red colobus, *Procolobus badius badius* Bay colobus, *Cercocebus atys lunulatus* White-naped mangabey, *Papio anubis* Olive baboon, and *Pan troglodytes verus* Western chimpanzee. Between 2010 and 2013, we conducted surveys in five national parks (Banco, Ile Ehotilé, Marahoué, Azagny, Mont Péko) and eighteen forest reserves (Dassioko Sud, Port-Gauthier, Bolo-Ouest, Niégré, Rapide Grah, Bossématié, Yaya, N'Gadan-N'Gadan, Séguéla, Haut Sassandra, Bouaflé, Kani-Bandaman Rouge, Koba, Dé, Haute Dé, Moyenne Marahoué, and Monogaga) searching for primates (Fig. 1).

The protected areas surveyed in the course of this study were originally selected based on the likelihood that they contained two primate taxa - *Cercopithecus diana roloway* and *Cercocebus atys lunulatus* - identified as high conservation priorities. We note there are other PAs within the broader sampling area that we did not survey due to time constraints, and we intend to visit these reserves in the near future. Most of the protected areas sampled are situated within the moist evergreen forest zone of central and southern Côte d'Ivoire and were originally covered by dense forest. The four exceptions are Marahoué National Park and Koba, Séguéla and Kani-Bandaman Rouge Forest Reserves in central Côte d'Ivoire, which consist of both dense forest and savanna woodland.

We employed survey methods identical to those described by Gonedelé Bi and colleagues [6] to determine the number of primate taxa present in each PA. Foot surveys commenced at 6:30 AM and lasted until approximately 12:00 AM. Surveys resumed following a two hour break and continued until approximately 17:30 PM, weather permitting. We walked slowly and quietly along existing paths, reserve boundaries, and logging roads, or between rows of cocoa trees, at a pace of 1 – 1.25 km/hour. Transects were not cut in order not to disturb habitats more than necessary; however, we did walk straight line paths determined by compass bearings (see below). During walks we recorded all visual and acoustic cues of haplorrhine primates (chimpanzees and monkeys) and recorded their positions with a GPS. For each cue we noted the date, species, time and location. We made no attempt to determine abundance or group size of any primate taxon. Due to the absence of thick undergrowth, it was relatively easy to move quietly within each protected area; however, as with all surveys, it is possible that primates detected us and fled before we were able to record their presence. During surveys we also recorded all signs of poaching (e.g., number of gunshots heard, snares,

discarded cartridges, etc.) and used these to calculate a poaching index which is defined as the number of poaching signs per kilometer walked in each PA.

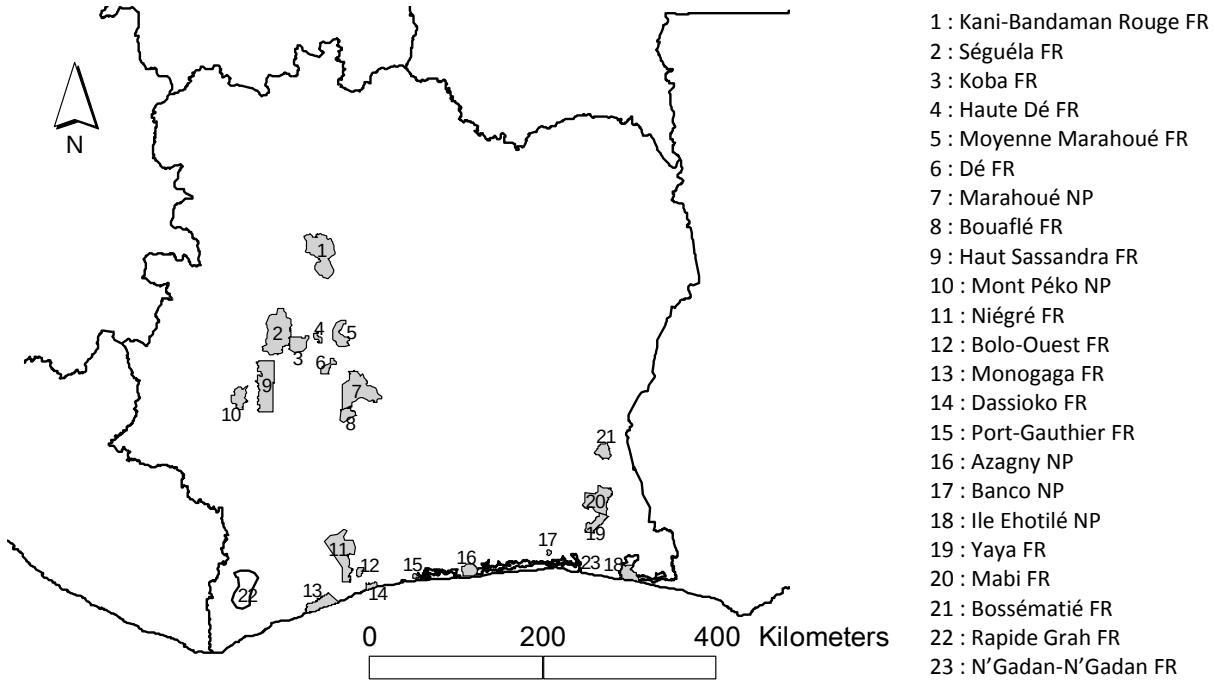

Fig. 1. Location of 23 protected areas surveyed in the course of the study.

We used three mechanisms to estimate: (a) the number of humans living within each protected area, (b) the percentage of PA land that had been degraded, and (c) the percentage of land converted to cocoa plantations. First, we met with village elders from each PA and asked them to estimate the number of households in each village/camp under their authority within a park or reserve. We multiplied these estimates by the mean household size in Côte d'Ivoire (5.3) to approximate the human population residing within each PA [31]. We also asked village elders to estimate the age of the farms and settlements under their jurisdiction. Second, we interviewed staff of the Société de Développement de Forêts (SODEFOR) working in each PA and asked them to estimate: (1) the size of human populations living within each PA, and (2) the proportion of forest in each PA that had been degraded. These estimates were cross-checked with reports written by the SODEFOR staff (SODEFOR 2013). Third, we carried out habitat surveys to assess: (1) the amount of total habitat degradation within each PA, and (2) the amount of each PA occupied by cocoa plantations. Within each park or reserve, we walked straight line compass bearings (transects) in both North-South and East-West directions. The number of survey walks in each PA ranged between six and 11, depending on the size of the PA. The length of each transect varied between four and 10 km, and each transect was separated by two kilometers. During each walk, we noted all instances of anthropogenic forest degradation and used these to calculate: (1) the proportion of overall forest degradation (total surface degradation, regardless of cause), and (2) the proportion of degradation due to cocoa plantation. Forest degradation included secondary forest of any

age, villages, cultivated fields, roads, pathways, etc. We estimated the total annual cocoa yield within each protected area using the national average of 600 kilos per plantation hectare of cocoa plantation [32]. We spent a total of 208 days (1,872 hours) surveying approximately 4,392 km^2 of land, with an average of 190^2 km per PA. Data were analyzed using SPSS software version 16.0. We used Spearman's rank correlation to test the relationship between the proportion of each protected area converted to cocoa plantations and the number of primate taxa absent, with $p < 0.05$ considered statistically significant. Spearman's rank correlation is a non-parametic assessment of correlation appropriate when at least one of the variables, in this case taxa present (the dependent variable), is in interval scale.

Results

Primates encountered

Of the twelve anthropoid primates expected within the survey area, eleven were encountered in at least one protected area (Appendix 1). The two black and white colobus species with distributions in the survey area – *Colobus polykomos* and *Colobus vellerosus* – were not encountered in any park or reserve we surveyed (Appendix 2); however, a population of *Colobus vellerosus* was identified in a sacred grove near the village of Grébou I [33]. *Procolobus badius waldroni* was never observed in the survey area, reinforcing the probability that this taxon is extinct in the wild [2, 4, 8].

Each of the twenty three reserves/parks is characterized by at least one primate extirpation, but most are missing many more primate taxa. Of the 23 PAs surveyed, five have lost half of their primate species and thirteen (57%) have lost their entire primate population. Dassioko Sud and Port- Gauthier Forest Reserves have lost the fewest number of primate species, each having lost two of seven species. Two taxa - *Cercopithecus diana roloway* and *Cercocebus atys lunulatus* - were encountered in only two reserves: Dassioko Sud and Port-Gauthier Forest Reserves. In those PAs containing primates, three taxa were always encountered: *Cercopithecus petaurista*, *Cercopithecus campbelli*, and *Procolobus verus*.

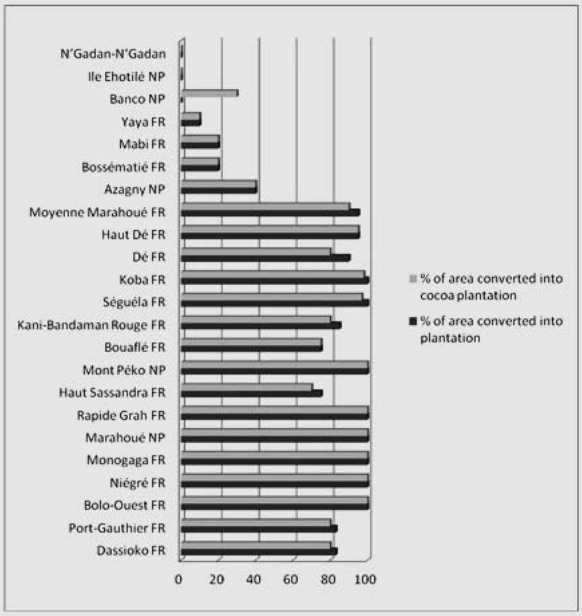

Fig. 2. Forest degradation scores for 23 protected areas in Côte d'Ivoire.

Forest degradation and cocoa farming inside protected areas.

Of the 23 forest reserves visited, sixteen have degradation quotients exceeding 65%. Azagny NP, Bossématié FR, Mabi FR, Yaya FR, Banco NP, Ile Ehotilé NP and N'Gadan-N'Gadan FR all have degradation quotients less than 40%, with Ile Ehotilé National Park and N'Gadan-N'Gadan Forest Reserve having the lowest (Fig. 2). The great majority of forest degradation in the PAs surveyed is the result of cocoa farming. Cocoa is the major crop grown inside the national parks and forest reserves surveyed; we found plantations in 20 of 23 protected areas, and in many of these, the farms are extensive (Fig. 3 - 4). When the 23 PAs are considered collectively, cocoa comprises 93% of illegally grown agricultural products. The other crops encountered (7% of farms in PAs) are subsistence crops such as bananas, yams, maize, rice, and miscellaneous vegetables interspersed and associated with young cocoa trees. Of the approximately 4,392 km^2 (439,250 ha) surveyed, approximately 3,239 km^2 (74% of the total surveyed PAs) have been transformed into cocoa plantation (Appendix 1) leaving approximately 1,132 km^2 (approximately 26% of the total surveyed PAs) uncultivated. Within any PA, the amount of land converted to cocoa plantations ranges from 10% to the entire park or reserve. Seven of the protected areas surveyed (Bolo-Ouest FR, Niégré FR, Monogaga FR, Rapide Grah FR, Haute Bolo FR, Mont Péko NP, and Marahoué National Park) have been completely converted to farms, and within these reserves, cocoa accounts for between 80 and 100% of the protected area's land mass. Based on the mean annual yield of 600 kilos/ha in Côte d'Ivoire, the estimated annual yield of cocoa from farms within these protected area is 195,600 tons. There is a significant and positive correlation ($r^2 = 0.736$, $p < .01$) between the proportion of protected area converted to cocoa plantations and the absence of primate species (Fig. 5).

Fig. 3. Typical plot of young cocoa plants inside Niégré Forest Reserve (Bitty et al., 2013).

Fig. 4. Cocoa beans drying inside Bolo ouest Forest Reserve. The entire forest within this reserve has been replaced by cocoa farms (Photo, Gonédélé Sery).

Human settlements and poaching in protected areas.

The majority [15/23] of PAs surveyed contain human settlements (Appendix 1; Fig. 6). The mean population size of these settlements is 4,417 (sd=8919). Protected areas with particularly large human populations are Marahoué National Park, Mont Péko National Park and Monogaga Forest Reserve, each containing over 10,000 human inhabitants. If we exclude Banco National Park, where a forestry school has been established, the protected areas with the smallest human populations are all situated in the savannah-woodland zone: Kani-Bandaman Rouge FR, Séguéla FR and Koba FR, each with fewer than 600 inhabitants. None of the protected areas that still contain high forest (n=7) have permanent human settlements; however, we did encounter temporary camps inside several reserves where farmers were working plantations. These protected areas are the Bossématié-Mabi-Yaya forest block in east central Côte d'Ivoire, the Ile Ehotilé NP-N'Gadan N'Gadan forest block in south-eastern Côte d'Ivoire, and the Port Gauthier – Dassioko Sud FR in the central coastal region of the country. Information collected during interviews with farmers inside these PAs indicates that most residents have settled there within the last twelve years, a timespan corresponding to a period of significant political unrest in Côte d'Ivoire [10].

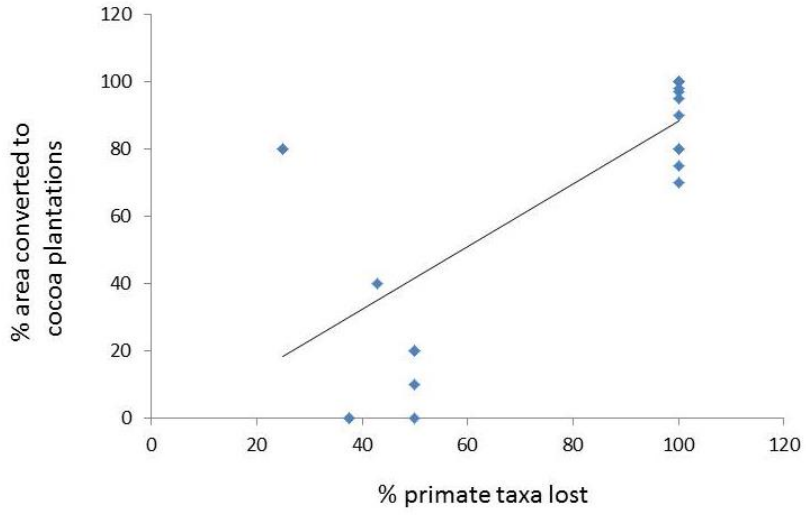

Fig. 5. Correlation between percent of protected area converted to cocoa plantations and primate taxa absent in those areas

Poaching pressure is significant in the PAs that still contain fragments of forest, and with the exception of N'Gadan-N'Gadan FR which is flooded throughout the year, all PAs with high canopy forest (i.e., those not completely converted to cocoa plantation) have poaching index values that exceed 1 (Appendix 1). We encountered clear evidence of poaching in PAs that still contain forest, including numerous discarded shotgun shell casings, monkeys recently shot (Fig. 7), and monkeys being kept as pets.

Fig. 6. Market day inside the Niégré Forest Reserve (Photo: Gonédélé Bi Sery).

Fig. 7. Monkeys: Olive colobus (*Procolobus verus*) **and Lesser spot-nosed guenon** (*Cercopithecus petaurista*) **poached within Port-Gauthier Forest Reserve (Bitty et al., 2013).**

Discussion

Human population pressure lies at the root of the illegal hunting and farming that occur inside Côte d'Ivoire's protected areas. Côte d'Ivoire has the highest deforestation rate in sub-Saharan Africa, with an estimated loss of 265,000 ha per year [21]. Little primary forest exists in south central Côte d'Ivoire, even within protected areas, and that which remains is at risk of being replaced by agricultural plots. Such large scale landscape conversion is attributable in part to the significant rise in human population that has occurred in Côte d'Ivoire in the last fifty years. Part of this increase is intrinsic; however, a significant percentage is due to a large influx of migrants. The economic prosperity that followed Côte d'Ivoire's independence drew scores of persons from poorer, neighboring countries between 1960 and the early 1990s. This period, which coincided with the presidency of Félix Houphouët-Boigny, was a time of relative calm and great economic growth for the country. Since Houphouët-Boigny's death in 1993, Côte d'Ivoire has been characterized by considerable economic, political, and social unrest. During this period, which included a civil war (2002-2004), hundreds of thousands of persons moved into central and southern Côte d'Ivoire from other portions of the country and from neigboring Mali and Burkina Faso. The southward shift of human population was especially acute following the contested presidential election of 2010, with many migrants taking up residence adjacent to or within forest reserves and national parks. Given the government's concerns with national security, safeguarding habitat and wildlife inside parks and forest reserves was likely not a high priority, and thousands of migrants readily occupied protected areas. Most conservation staff charged with monitoring and protecting fled their parks/reserves and south-moving migrants encountered little – if any – resistance. The result was the rapid establishment of permanent human settlements, an increase in cocoa farming, and an escalation of hunting within the country's protected areas [10, 12].

These conditions persist today. Humans can be found living in the majority of the protected areas we surveyed, with settlements ranging in size from 100 (e.g., Bolo-Ouest Forest Reserve, Banco National Park) to 30,000 persons (Marahoue National Park). Increased demand for

bushmeat combined with virtual absence of law enforcement within most PAs accounts for the high degree of poaching pressure in our survey area. In several PAs, we found very low poaching indices, but these scores are almost certainly due to the absence of potential targets rather than adherence to anti-hunting laws. The impact of hunting on Côte d'Ivoire's PAs completely or nearly transformed into cocoa plantations have recently been examined [6]. PAs such as Bolo Ouest, Niégré, Monogaga, Marahoué, where primates were common in the recent past [34-37], have witnessed dramatic reductions of their wildlife.

The combination of forest converted to cocoa farms and high poaching does not fully explain the absence of primates in all cases. For example, both Dassioko FR and Port-Gauthier FR have lost 80% of their forest to cocoa production, yet they still harbor most (six of eight species) of their primates. In contrast, Haut Sassandra FR has lost 70% of its forest and all of its primates. This difference is due not only to differential conservation efforts directed at PAs, but also to the location of PAs within Cote d'Ivoire. The Haut-Sassandra FR is in north central Cote d'Ivoire, and for nearly eight years (2002-2010) the region was occupied by rebel forces. During this period, most governmental institutions stopped operating within the region, including all state-sponsored conservation agencies. In contrast, Dassioko Sud and Port Gauthier FR are among the most southerly PAs in Cote d'Ivoire and therefore have remained under governmental control for longer periods of time. In addition, both Dassioko Sud and Port Gauthier FR have likely benefited from recently initiated surveillance and bio-monitoring patrols involving local communities [38].

While the effects of poaching and general habitat loss on Côte d'Ivoire's primates are well documented [3, 5, 6, 11, 26], the impact of illegal cocoa production has received considerably less attention. Our surveys demonstrate that illegal cocoa farming is the major cause of deforestation within Côte d'Ivoire's protected areas. With only three exceptions (Banco National Park, Ile Ehotilé National Park, N'Gadan-N'Gadan Forest Reserve), all PAs we surveyed exhibit some level of cocoa production, though the extent of forest degradation resulting from cocoa cultivation ranges widely. In some PAs, the area of the park/reserve comprised of cocoa plots is relatively modest and consists of no more than 10% of the PA. In others (e.g., Monogaga Forest Reserve, Mont Peko National Park) the entire protected area has been converted to cocoa plantation. No primates were found in these latter PAs. It is unlikely that any anthropoid primate could survive in plots consisting only of cocoa plants and without access to additional resources - regardless of their size; however, decades of research have demonstrated that several primate species surveyed in this study are so sensitive to habitat disturbance that even moderate perturbation is likely to result in population declines [39]. Thus, when our surveys revealed the scale of cocoa farming, we were disappointed but not entirely surprised to find that primates were absent in fourteen of the twenty-three protected areas we visited.

Nevertheless, it would be unwise to suggest that those primates still present in the other nine PAs surveyed face certain, imminent extirpation. Several recent studies highlighting the costs and benefits of primate – agroforestry dynamics have identified factors that can increase the probability of agrosystems supporting primate populations [40- 41]. One lesson is to view agrosystems as matrices - where the unit of importance is the native habitat and area surrounding native habitat patches - rather than as static, isolated habitats. It has been demonstrated that habitat matrices are compromises which, when properly managed, can

support biodiversity while providing for cash crop production. One example is the shaded-cocoa production in Brazil, a practice known as cabruca. A species of New World monkey – the golden-headed lion tamarin (*Leontopithecus chrysomelas*) - is not only able to live, but even to thrive in such agroforestry matrices. In fact, studies have shown that some groups of *L. chrysomelas* live entirely within these habitats, and that according to several reproductive parameters and life history characteristics, "cabruca tamarins" fare better than populations living in more natural habitats [42]. We are not suggesting this scenario is ideal or that it necessarily applies to primates in different regions of the world. But it does illustrate the adaptive capacities of some primates. With several exceptions, there is comparatively little corresponding information on non-human primate use of agrosystems in West Africa; however, results from available studies [43] are encouraging and indicate that crop production and modified habitats able to support primate populations need not be mutually exclusive. We hope the reviews of primate-agrosystem interactions serve as calls for more analyses of agroecosystem matrices in West Africa and their potential to act as way stations for wildlife whose native habitats are shrinking and increasingly isolated.

Implications for conservation

These results can be used to establish conservation priorities, at least insofar as identifying where efforts for conserving primates should be concentrated. Two PAs, Port Gauthier FR and Dassioko Sud FR, still host a total of six primate species including three taxa - *Cercopithecus diana roloway, Cercocebus atys lunulatus* and *Pan troglodytes verus* - of significant conservation concern. These three taxa have been eliminated from 87% of the PAs surveyed. The two monkey taxa (*Cercopithecus diana roloway* and *Cercocebus atys lunulatus*) have been reported in another area of great conservation significance - the Tanoé forest in south-eastern Côte d'Ivoire [4, 24, 44]. Collectively, these three forest areas (Port Gauthier FR, Dassioko Sud FR, Tanoe community forest) are critical to the survival of Roloway monkeys and white-naped mangabeys, since these primates have been eliminated from most other forests across their range. A third taxon sharing this range - Miss Waldron's red colobus (*Procolobus badius waldroni*) - is likely extinct, as there have been no confirmed sightings of it since 1978 [4, 6, 8]. The population size and distribution of western chimpanzees *Pan troglodytes verus* have declined significantly in recent years, and the range of this ape is now generally limited to areas receiving some form of aggressive protection [5, 45]; however, we confirmed the presence of chimpanzees in the Dassioko Forest Reserve. This forest reserve was not receiving any substantive protection and in 2012 we initiated a community-based bio-monitoring program that involved forest patrols conducted by local villagers. Since the program's inception, the frequency of illegal activity, especially poaching, has dropped dramatically, while encounter rates with primates have risen [38].

Protected areas can provide critical insurance for Africa's biodiversity, but they are increasingly threatened by the encroachment of agriculture [12, 46-50]. It is unlikely that Côte d'Ivoire will have the resources required to halt cocoa production and hunting inside all its protected areas, and given the very low encounter rates during surveys, there is a strong possibility that additional primate populations could be extirpated from forest reserves and parks in the near future. The absence of primates in the protected areas we surveyed is almost certainly due to use of full sun cocoa farming, which involves removal of all trees. Obviously, complete deforestation would constitute a death knell for most primate taxa. In contrast,

shaded cocoa agroforestry, which does not involve the total removal of trees, has been shown to provide comparable revenues for farmers while preserving elements of habitat critical for primate populations. Several recent studies have tabulated those tree species known to thrive in West and Central African cocoa farms where shaded agroforestry is practiced [51], and cocoa farmers recently interviewed in Cote d'Ivoire expressed their desire to retain some tree diversity on their farms, noting that certain trees are compatible with cocoa because they help promote soil moisture retention and improve soil fertility [52]. A complementary study in neighboring Ghana outlined how effective and important such sustainable use policies can be for preserving biodiversity within and between protected areas [53].

Dumont and colleagues [52] raise several additional point of relevance: the cocoa yield in Cote d'Ivoire has declined recently due to aging cocoa fields with lower fertility, and most of the plantations surveyed already practice some form of shade agroforestry. It is also worth noting that it is not clear if any of farmers tending "illegal" plantations inside protected areas participated in the study. Taken together, these points suggest that there is likely to be even greater pressure to improve cocoa yield either by cultivating additional lands or by expanding current plantations through increased deforestation. While we are alarmed at the extent of illegal cocoa farming taking place inside CI's protected areas, it is our strong opinion that there is still time to halt the disappearance of additional forest wildlife. Studies in Côte d'Ivoire and elsewhere in Africa [16] have demonstrated that cocoa production and biodiversity are not mutually exclusive entities. Going forward, it will be essential to promote policies that do not involve complete deforestation, and we are encouraged by the work of Schroth and Harvey [54] who note, "traditional cocoa agroforests with diverse and structurally complex shade canopies are among the agricultural land uses that are most likely to conserve a significant portion of the original forest biodiversity (2007:2238)." Our suggestion of shade-cocoa farming applies to remaining intact forest outside protected areas, and we emphasize that we are not advocating new agriculture – shaded or otherwise - inside protected areas. For degraded PAs, forest regeneration focusing on native tree species should be encouraged.

Finally, we recognize the complexities inherent in trying to balance the needs of humans with the desire to preserve biodiversity. Perhaps nowhere have these issues and problems been more apparent than in West Africa, where promotion of several development projects designed to safeguard wildlife had the unintended consequence of increasing threats to the wildlife they were meant to protect [55]. To be sure, the reduction of primates in any ecosystem has deleterious ecological consequences, such as the loss of important seed dispersal agents. However, any role primates play in maintaining rainforest diversity inside PAs that are devoid (or nearly so) of trees becomes moot if there are no trees left to disperse. In addition to the consequences for rainforest health, the reduction of primate biodiversity highlights a more immediate issue. While we recognize Ivorian farmers could experience diminished revenues if all opportunities for maximizing cocoa crop yields are restricted, we believe that realizing these opportunities should not come at the cost of biodiversity loss, especially in an area such as Cote d'Ivoire where so much wildlife is already endangered. If we are unable to safeguard wildlife from illegal farming and hunting inside areas designated for their protection, what hope do we have of ensuring their survival outside forest reserves and national parks? Given that most or all of Cote d'Ivoire's non-human primates are threatened by fragmented and degraded habitats, intense hunting pressure, and small group size, the immediate priority must be to reinforce surveillance of the remaining blocks of land

set aside for their preservation. Realistic hopes of eventually witnessing primate populations expanding in and into regenerated habitats hinge on our ability to protect the dwindling elements of those habitats now.

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Appendix 1: Results from surveys of 23 protected areas in Côte d'Ivoire.

Survey site	Size (km^2)	% primate taxa lost	Number expected species	Number of species observed	Number of survey days	% area converted to plantation	Forest converted to cocoa farms (Km^2)	Forests left (Km^2)	Estimated annual cocoa production (tons)	Human Population size	Poaching Index
Dassioko FR	79.8	25	8	6	28	80	63.84	15.96	38.304	0	1.1
Port-Gauthier FR	25	25	8	6	22	80	20	5	12	0	1.1
Bolo-Ouest FR	66.1	100	8	0	12	100	66.1	0	39.66	100	.2
Niégré FR	925	100	8	0	14	100	925	0	555	22	.1
Monogaga FR	396.6	100	8	0	6	100	396.6	0	237.96	24	.04
Marahoué NP	1,01	100	9	0	15	100	989.8	0	593.88	30	.7
Rapide Grah FR	109.4	100	8	0	8	100	109.4	0	65.4	1200	.15
Haut Sassandra FR	102.4	100	8	0	8	70	71.68	30.72	43	1600	1.3
Mont Péko NP	34	100	8	0	6	100	34	0	20.4	21,837	.04
Bouaflé FR	20.4	100	10	4	4	75	15.3	5.1	9.18	1600	.9
Kani-Bandaman Rouge FR	105.5	100	11	0	8	80	84.4	21.1	50.64	400	1.2
Séguéla FR	119.2	100	11	0	6	97	115.62	3.57	69.372	600	.8
Koba FR	31.5	100	11	0	4	98	30.87	0.63	18.522	800	.2
Dé FR	13.5	100	11	0	3	80	10.8	2.7	6.48	1,2	.4
Haut Dé FR	7.4	100	11	0	3	95	7.03	0.37	4.218	1	.7
Moyenne Marahoué FR	38.3	100	10	0	5	90	33.70	3.83	20.22	2	.9
Azagny NP	194	42.9	8	4	12	40	77.6	116.4	46.56	0	1.1
Bossématié FR	220	50	8	4	8	20	44	176	26.4	0	1.8

Appendix 1 continued											
Mabi FR	598	50	8	4	14	20	119.6	478.4	71.76	0	1.7
Yaya FR	241	50	8	4	12	10	24.1	216.9	14.46	0	1.4
Banco NP	30	50	8	4	4	0	0	30	0	100	1.2
Ile Ehotilé NP	5.5	37.5	8	5	4	0	0	5.5	0	0	1
N'Gadan-N'Gadan FR	20	37.5	8	5	2	0	0	20	0	0	.09

Appendix 2: Conservation status and expected and observed distributions of primates within sampled protected areas.

PAs / Species	***C. d. rol.* (EN)**		***C. d. dia.* (VU)**		***C. p. pet.* (LC)**		***C. C. low.* (LC)**		***P. ver.* (NT)**		***P. b. wal.* (EN)**		***C. vel.* (VU)**		***C. a. atys* (NT)**	
	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs
Dassioko FR	X	X	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Port-Gauthier FR	X	X	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Bolo-Ouest FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Niégré FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Monogaga FR	-	-	X	-	X	-			X	-	-	-	-	-	X	-
Marahoué FR	X	-			X	-	X	-	X	-	X	-	X	-		
Rapide Grah FR	-	-	X	-	X	-	-	-	X	-	-	-	-	-	X	-
Haut Sassandra FR	-	-	X	-	X	-	-	-	X	-	X	-	X	-		
Mont Péko FR	-	-	X	-	X	-	-	-	X	-	-	-	-	-	X	-
Bouaflé FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Kani-Bandaman Rouge FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Séguéla FR	-	-	X	-	X	-	-	-	X	-	-	-	-	-	X	-
Koba FR	-	-	X	-	X	-	-	-	X	-	X	-	X	-	-	-
Dé FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Haut Dé FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Moyenne Marahoué FR	X	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-
Azagny NP	X	-	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Bossématié FR	X	X	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Mabi FR	X	X	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Yaya FR	X	X	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Banco NP	X	-	-	-	X	X	X	X	X	X	X	-	X	-	-	-
Ile-Ehotilé NP	X	-	-	-	X	X	X	X	X	X	X	-	X	-	-	-
N'Gandan-N'gandan FR	X	-	-	-	X	X	X	X	X	-	X	-	X	-	-	-

PAs / Species	*C. .a. lun.* (EN)		*C. sab.* (LC)		*P. t. ver.* (EN)		*E. pat.* (LC)		*P. anu.* (NT)		*C. c. cam.* (LC)		*C. pol.* (VU)		*P. b. bad.* (EN)	
	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs
Dassioko FR	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Port-Gauthier FR	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Bolo-Ouest FR	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Niégré FR	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Monogaga FR	-	-	-	-	X	-	-	-	-	-	X	-	X	-	X	-
Marahoué FR	X	-			X	-	-	-	X	-	-	-	-	-	-	-
Rapide Grah FR	-	-	-	-	X	-	-	-	-	-	X	-	X	-	X	-
Haut Sassandra FR	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Mont Péko FR	-	-	-	-	X	-	-	-	-	-	X	-	X	-	X	-
Bouaflé FR	X	-			X	-	-	-	-	-	-	-	-		-	-
Kani-Bandaman Rouge FR	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Séguéla FR	-	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Koba FR	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Dé FR	X	-	X	-	X	-	-		-	-	-	-	-	-	-	-
Haut Dé FR	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-
Moyenne Marahoué FR	X	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-
Azagny NP	X	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Bossématié FR	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Mabi FR	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Yaya FR	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Banco NP	X	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-
Ile-Ehotilé NP	X	-	-	-	X	-	-	-	-	-	-	-	-		-	-
N'Gandan-N'gandan FR	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-

Exp: expected; Obs: observed; C. d. rol.: *Cercopithecus diana roloway*; *C. d. dia*: *Cercopithecus diana diana*; *C. p. pet*: *Cercopithecus petaurista petaurista*; *C. C. low* : *Cercopithecus campbelli lowei* ; *P. ver* ; *Procolobus verus* ; *P. b. wal* : *Procolobus badius waldroni* ; *C. vel*: *Colobus vellerosus*; *C. a. atys* : *Cercocebus atys atys* ; *C. .a. lun* : *Cercocebus atys lunulatus* ; *C. sab* : *Chlorocebus sabaeus* ; *P. t. ver* : *Pan troglodytes verus* ; *E. pat*: *Erythrocebus patas*; *P. anu*: *Papio anubis* ; *C. c.cam* : *Cercopithecus campbelli* ; *C. pol* : *Colobus polykomos* ; *P. b. bad* : *Procolobus badius badius;* EN : Endangered ; VU : Vulnerable ; NT : Near Threatened ; LC : Least Concern ; PAs : Protected Areas.