Line-transects : Sampling application to a French Guianan rainforest

Running head : line-transects sampling in French Guiana

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Summary. – Natural resource management has aroused recent interest in French Guiana, with investigations initiated in various parts of the country. Impacts of habitat disturbance, mainly from hunting and timber harvest on large mammal and bird communities, are a dominant topic. Line-transects are the common field method for estimating species abundance, but sampling methods need to be standardized. There are many publications on the topic, but often with emphasis on developing theoretical considerations, and can be far from expected field results. In this paper I present a concise and pragmatic view of line-transect methods, followed by a sampling application to a rainforest area prior to timber harvesting. About 300 km of line-transects were conducted in 1998 to assess large mammal species abundances before the harvest stage. Primates were used as a case study to illustrate how the different calculation procedures from line-transect baseline data may affect the calculated densities. The study area is traditionally hunted ; the hunting impact is evident on a large set of species, mainly large primates and peccaries, preferred game species of local hunters.

Résumé. – La gestion des ressources naturelles est une préoccupation récente en Guyane. Les sites d'étude se multiplient dorénavant sur le territoire. L'évaluation des impacts de la chasse et de l'exploitation forestière sur les populations de grands mammifères et oiseaux constitue un axe de recherche privilégié. Les méthodes d'inventaire par transects linéaires sont classiquement utilisées pour estimer l'abondance des espèces, mais une standardisation des protocoles demeure impérative. La bibliographie abordant les questions de méthodologie est abondante, mais souvent axée vers des considérations théoriques, en général peu pragmatiques. L'objet de cet article est de présenter la méthode des transects linéaires de manière concise, concrète, puis les résultats de son application dans une forêt tropicale humide. Afin d'évaluer les abondances des grands mammifères dans une zone destinée à l'exploitation forestière, près de 300 km de transects linéaires ont été effectués en 1998. Les données relatives aux différentes espèces de primates sont plus particulièrement étudiées pour montrer les variations inhérentes aux différentes méthodes de calcul lors de l'estimation des densités. La zone prospectée étant soumise à une certaine pression de chasse, l'impact de cette activité de prélèvement apparaît enfin, surtout les grands primates et les pécaris, espèces de choix pour les chasseurs locaux.

Key words : sampling, line-transect, game species, hunting impact, French Guiana.

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INTRODUCTION

The knowledge of the number of species and of their respective abundances is a prerequisite for consideration and management of biodiversity. Standardized sampling methods are necessary for valuable comparisons between areas and for longer term follow-up within sites. Among various methods, line-transect census have been used for a variety of animal species : amphibians (Toft *et al.* 1996), reptiles (Rand 1964), birds (Emlen 1971 ; Silva and Strahl 1991), and mammals (for instance in neotropical rainforests : Green 1978 ; Emmons 1984 ; Johns 1986 ; Bodmer *et al.* 1988 ; Janson and Emmons 1990 ; Peres 1996). This method has been used extensively in primatological field work, either to obtain an estimate of population status in both intact and disturbed habitats (Garcia 1993 ; Defler and Pintor 1985 ; Kessler 1998 ; Simmen *et al.* 1998), to make comparisons between areas (Peres 1997a), to follow populations status over time (Sussman and Philipps-Conroy 1995), to investigate the effects of hunting (Freese *et al.* 1982 ; Johns 1986 ; Peres 1997a) and logging (Johns 1986).

The aim of this paper is to present the line transect method in a pragmatic way, with limited theoretical considerations, and its application to a French Guianan rainforest mammal community. Management of natural resources is a recent concern in French Guiana ; field studies have been initiated recently in various areas of the country and would benefit from a standardization of methods. The study site of Counami is a forested area managed by the Office National des Forêts. It is included in a multidisciplinary research program on low impact harvest. Transects were undertaken to estimate mammal population sizes before harvest in order to contribute to the study of the impact of logging and hunting on a French Guiana community of game mammals and primates.

MATERIAL AND METHODS

Study site

The Counami forest (Figure 1) is a 12,400 ha lowland neotropical rainforest in French Guiana approximately 50 km from the coast (53.15°W, 5.20°N). Botanical surveys show a floral composition close to that of other coastal area forests : the dominant tree families are Lecythidaceae (22 % of tress with DBH > 7.5 cm), Caesalpiniaceae (12 %), Chrysobalanaceae (11 %), and Sapotaceae (6 %). Among species, *Eschweilera micrantha, E. sagotiana, Lecythis idatimon, L. persitens* (Lecythidaceae) are dominant, *Eperua alba* (Caesalpiniaceae) and *Licania alba* (Chrysobalaneceae) are also largely represented (L. Teillier, unpub. data). The area is accessible by a track opened 10 years ago, and is hunted by Amerindians and Creoles of the Iracoubo village, and by Hmongs originating from Laos and settled along the track since 1995.

Sampling procedure : the line transect method

Distance sampling methods are still in development, 50 years after the first theoretical considerations (Haynes 1949 ; Emlen 1971 ; Robinette *et al.* 1974 ; Eberhardt 1978 ; Anderson *et al.* 1979 ; Burhnam *et al.* 1980). Within a forested survey area, two transects (each 4 to 5 km long, in a single direction), randomly established, are advised

(Peres 1999). This ideal scheme may be adapted to topography, rivers, survey objectives and habitats to be sampled (e.g., primary forests *vs.* secondary forest, savannas, for instance), The line-transect method consists in movements by foot with a regular and limited speed, 0.8 to 1.5 km/hr, including possible regular, short breaks. While observing the animals, the following data are collected : the species, the number of individuals in the case of gragarious species, the shortest (perpendicular) distance from the animal to the path *(p)*, and/or the distance between the animal and the observer *(d)*. The distances *p* and *d* can be measured with a decametre or a telemeter, but experienced observers may also be able to give reliable estimates. When a sufficient number of observations have been collected (see below), different methods are used to convert field date into quantitative and interpretable parameters. *Species richness* is expressed as the number of species, genera, or any other taxa, observed during the transect, and extrapolated to the area. *Relative abundance* can be expressed by a kilometric index, i.e. the number of observed animals for a given length, or unit of transect, generally 1, or 10 km. There is no estimation of the total number of animals present in the entire study site. *Density* is expressed as the estimated number of animals per surface unit (/km^2, /ha) present in the study area. Four preliminary assumptions have to be respected before all calculation procedures : (i) *d* and *p* are accurately measured ; (ii) each sighting is independent of the others ; (iii) animals are observed before they move away ; (iv) all animals located in immediate proximity of the transect are observed. With L as the total transect length, i.e. the transect lenght x transect repetitions, and n the number of observed individuals, the observed density is $D = n/2L\alpha.\alpha$ is interpreted as half of the « effective strip width » (ESW) : individuals present within ESW but not observed (« missed » by the observer) are in number equal to those observed outside ESW. Various methods are employed to calculate α, using either *(d)* or *(p)*. The « Haynes method » and the King method use the harmonic and the arithmetic mean of d_i, respectively ; the Leopold method uses the arithmetic mean of p_i and the Green method uses the maximal value of p_i. The Kelker method, or « truncated method distance », is based on the « drop distance » : if visibility is satisfactory, the perpendicular sighting distances (p_i), will present a plateau extending from d = 0 to d = w, before decrease. The proportion n_i of individuals observed at distances $d_i[0,w]$ is used. Among methods based on the mathematical « expansion series », the Fourier series were the first used (Burhnam *et al.* 1980). Recently, other models have been developed : hazard rate model, uniform model, half normal model, negative exponential model (for further information, see Thomas *et al.* 1998).

Application at Counami

Transects were censused in homogenous primary forest, in June and July (rainy season), and from September to November (dry season), 1998. Location, number and length of transects were established using maps from the Office National des Forêts, in order to survey equally low ground, hill sides and crests. Three linear transects were used, one of 3.9 km (with 24 repetitions), one of 4.9 km (20 repetitions) and one of 3.7 (25 repetitions) : the total length being 298.7 km. Transects were conducted during the maximal activity period of most of diurnal mammals, between 07:00 and 12:30. Abundance is expressed as the number of animals, or number of groups, per 10 km, mean group size of gregarious species are given. For density calculation of primates, the Leopold, Green, Kelker and expansion series methods were used with the same set of data (Appendix). Results are expressed as the number of individuals/km^2. The Kelker method was used only for howlers (Figure 2) ; in other species no clear plateau in the number of sightings

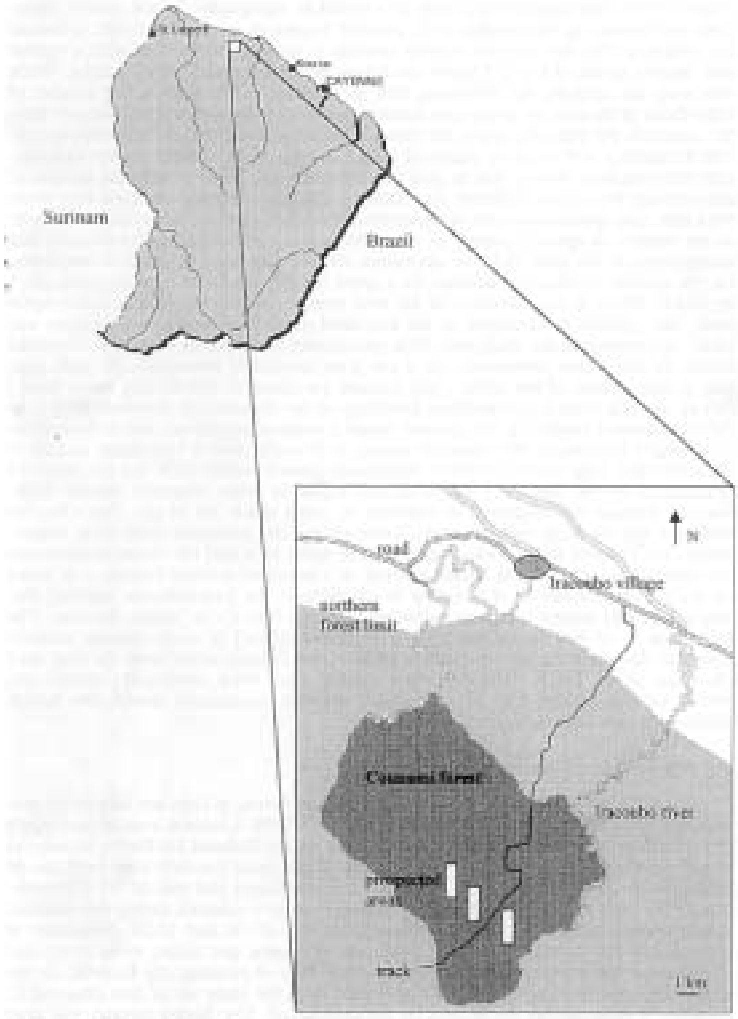

Fig. 1. – Study site location : Counami forest, French Guiana.

between the path and p could be observed, making the method unreliable (Brockelman and Ali 1987). For the expansion series, the hazard rate model with a cosine adjustment has been used, with the Distance© 3.5 program (Thomas *et al.* 1998).

RESULTS

The species richness assessment for mammals (diurnal and diurnal/nocturnal species only) is given in Figure 3. Fifty percent of observed species were recorded during the first 50 km, and more than 75 % during the first 100 km. All primates present on

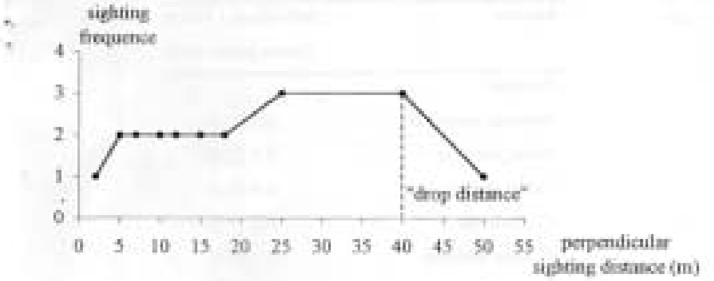

Fig. 2. – Use of Kelker method, or truncated method, to determine the effective strip width. Data (provided in the appendix) from red howler monkeys (*Alouatta seniculus*) perpendicular sighting distance in Counami forest, French Guiana.

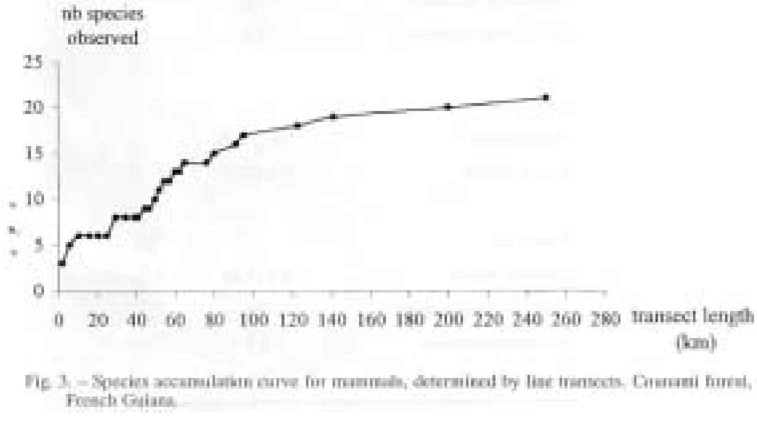

Fig. 3. – Species accumulation curve for mammals, determined by line transects. Counami forest, French Guiana.

the surveyed area were observed within the first 60 km. Relative abundances of mammals are presented in Table 1. Primate densities calculated with different procedures are given in Table 2. Raw data for perpendicular sighting distances for primates are provided in the appendix. Although data are rather limited, it appears that season had no influence on transect results, but this preliminary observation should be confirmed by additional sampling. Inter-transect variations were recorded in 3 primate species : spider monkey, howler monkey, and brown capuchin, were more abundant in one of the 3 areas. Other species observed during the transects include : three-toed sloth *(Bra-*

TABLE 1. – Abundances of mammals in Counami forest, French Guiana (line trnsect survey).

Species	Individuals / 10 km (mean group size)
Primates:	
Alouatta seniculus	5.5 (5.5)
Ateles paniscus	0.5 (2.5)
Cebus apella	6.4 (9.2)
C. olivaceus	0.8 (7.7)
Pithecia pithecia	1.1 (2.4)
Saguinus midas	6.4 (4.9)
Rodents:	
Myoprocta acouchy	1.3
Dasyprocta leporina	3.4
Carnivores:	
Nasua nasua	1.1 (15.8)
Eira barbara	0.2 (2.8)
Ungulates:	
Tayassu tajacu	0.7 (3.8)
Mazama gouazoubira	0.1
Mazama americana	0.3
Tapirus terrestris	0.2

TABLE 2. – Primate densities (individuals/km²) in Counami forest, French Guiana (line transect survey). See the appendix for raw data on perpendicular sighting distances. * see figure 2 ; ** insufficient validity because of limited sightings ; nd : not defined (sighting sample too small).

Species	Green method (d_{max})	Leopold method (d_{mean} ± SD)	Kelker method (drop distance*)	Expansion series
Alouatta seniculus	5.0 (50 m)	12.4 (20.2 ± 13.7 m)	6.2 (40 m)	7.2
Ateles paniscus	0.4 (60 m)	0.8 (31.7 ± 21.5 m)		nd
Cebus apella	5.6 (60 m)	16.5 (20,3 ± 14.9 m)		8.2 **
C. olivaceus	0.8 (50 m)	2.2 (17,7 ± 8.7 m)		nd
Pithecia pithecia	1.3 (35 m)	3.7 (12,6 ± 10.8 m)		2.3 **
Saguinus midas	6.9 (45 m)	19.2 (16,3 ± 11.0 m)		12.3

dypus tridactylus), giant and collared anteaters *(Myrmecophaga tridactyla* and *Tamandua tetradactyla)*, grison *(Galictis vittata)*, margay cat *(Felis wiedii)*, white-lipped peccary *(Tayassu pecari)*, Southern river otter *(Lutra longicaudis)*, and two squirrels *(Sciurus aestuans* and *Sciurillus pusillus)*. Relative abundances were not calculated for these species because of small sample size (< 3 observations), and/or methodology unsuitable for such species. The squirrel monkey *(Saimiri sciureus)* is also present at Counami, but only in its northern riverine forests, not included in the surveyed area.

DISCUSSION

Sampling methods seek to give a reliable estimate of a whole population present in an area, through the sampling of animals present in one part of this area. Line-transect methods allow a reliable index of population states, and have been recommended for short inventory studies with limited technical means (Voss and Emmons 1996). My survey produced a similar species accumulation curve as that of Emmons (1984). Freese *et al.* (1982) suggested that all primate species present in one area should be observed within the first 20 km of transects. However, low to very low densities of some primate species in Counami forest made it necessary to walk many more kilometers to estimate species richness. Abundance has a poor ecological significance, but has the important advantage of not requiring any further calculation. Biases are thus limited, making comparisons with other date more reliable (Emmons 1984). Abundance is also used when only limited data are available, for instance if transect length is too short, or in cases of species rarely observed, such as ungulates (Emmons 1984). For density estimation, methods based on expansion series are widely used in mammalian surveys, and especially for primates. They are the more robust : variation of detectability in successive sightings, due to forest type, species, and observers, has a limited impact (Brockelman and Ali 1987 ; Southwell 1996). But their use may be limited by the necessity of the requirement of large data sets (at least 20 sightings, Peres 1999) and a specific computer program (such as Distance©, Thomas *et al.* 1998). On the contrary, Simmen *et al.* (1998) using the Leopold method, showed that 90 km of transects (representing only one third to one half of the 20 sightings necessary for expansion series) give reliable results for the more abundant primate species (i.e., excepting sakis). Calculation procedures using *p* rather than *d* should be preferred (Brockelman and Ali 1987 ; Southwell 1996) : it has been observed that the distance of detection *d* may vary with the sighting angle (Robinette *et al.* 1974).

In our study site, the Kelker method led to results very close to those obtained with the expansion series for *Alouatta*. This method has been shown to give satisfactory results for *Cebus, Alouatta* and *Callicebus* (Defler and Pintor 1985). My attempt to use it with several species led to inconsistent results. Brockelman and Ali (1987) do not recommend Kelker's method because (i) a clear plateau is rarely observed, leading to subjectivity in calculating *w* ; and (ii) it does not include observations beyond *w*. Chapman *et al.* (1988) found that the Leopold method for *Alouatta* and *Cebus* gave much better results than did Kelker's approach. In French Guiana, the Leopold method gave estimated densities very close to the exact densities of *Cebus apella, Alouatta seniculus*, and *Sanguinus midas* (Kessler 1998). At the Counami site, this method gave densities lower than those calculated with the expansion series. Whatever methods used, densities determined from line-transect counts, conducted over a relatively short period, may ultimately be considered as an index, rather than as a absolute ecological data. Moreover, this index will remain closely dependent on calculation procedures.

At the moment, few forests have been extensively surveyed by line transects in French Guiana. Published data, focused on primate species, are available only from the pristine forest of the Nouragues station (Kessler 1998 ; Simmen *et al.* 1998). Conversely, the Counami forest is accessible by a track and it is hunted ; and like most coastal forests, it is scheduled for timber harvest. My results clearly showed that the hunting impact on a substantial set of species. Among primates, the densities of spider monkeys *(Ateles paniscus)* and wedged-capped capuchins *(Cebus alivaceus)* are much lower than those found in the Nouragues forest, and howler density is also much decreased (Simmen *et al.* 1998). The total density of primates in the Counami area, calculated with the Leopold method, is 55 individuals/km^2, about 20 % lower than that of the Nouragues forest (Simmen *et al.* 1998). Human disturbance alone may not be responsible for all density variations. For instance, independently to hunting pressure, foliage quality is a predominant factor to explain the howler monkey abundance (Peres 1997b) ; *C. olivceus* is known to be distributed in patches (Norconk *et al.* 1996), and is absent or very rare in several undisturbed Frenh Guianan sites (B. de Thoisy, unpub. data). Nonetheless, I assume that hunting pressure is of major importance. The impact of hunting is also evident from peccary numbers. White-lipped peccaries *(Tayassu pecari)* were observed only once during the 5 months of the study, and the abundance of collared peccaries is 5 times lower than that found in intact forests (Peres 1996). In Peru (Bodmer *et al.* 1997) and in Belize (Fragoso 1991), comparisons between hunted and unhunted sites also showed significant decrease of abundance with hunting. On the contrary, my results do not reflect a strong decline due to hunting on *Mazama* spp. and agoutis, as abundances observed at Counami are comparable to those reported from the Trinité Natural Reserve, French Guiana (B. de Thoisy et al., unpub. data), from Peru (Emmons 1984 ; Janson and Emmons 1990 ; Bodmer *et al.* 1997) and northern Brazil (Malcolm 1991). The hunting habits of Creoles and Hmongs are being evaluated at Counami, with preliminary results suggesting a harvest preference for peccaries and primates by Creoles ; and for peccaries by Hmongs (B. de Thoisy, unpub. data). The study is still in progress, but populations of these target species appear to be significantly affected.

As in other neotropical countries, hunting is a major threat to large mammals in French Guiana (de Thoisy and Vié 1998). More extensive studies, both in other areas and over a longer term, are urgently needed to better understand the impact of hunting, the status of game species and the sustainability of current harvesting levels. Sociological studies are also needed to better understand the hunter's expectations, and facilitate the implementation of a policy of natural resources management.

Appendix : Data collection at Counami site, French Guiana : perpendicular sighting distances for primate species (in meters).

species	transect 1	transect 2	transect 3
Ateles paniscus	50	60	14
	20		6
			40
Alouatta seniculus	12	8	5
	35	18	6
	10	40	50
	40	5	35
	25	7	40
	16	7	3
	12	22	25
		10	30
			18
			25
Cebus apella	15	12	12
	20	7	50
	12	35	15
	5	45	38
	30		12
	6		20
Cebus olivaceus	25	20	8
Pithecia pithecia	8	11	17
	15	2	20
	25	5	6
	35	3	4
Saguinus midas	8	4	13
	10	11	22
	20	45	28
	15	18	25
	5	12	2
	12	20	12
	10	30	5
	30	20	23
	35	8	11
	4	6	12
	3	19	
		40	

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