Who ate all the crocodiles?

An investigation of trends and patterns in trade and consumption of bushmeat in Gabon

Kathryn Knights

MSc Conservation Science

September 2008

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science and the Diploma of Imperial College London

Abstract

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Trends through time and space in biomass, price and composition of bushmeat passing through 23 markets in Gabon were investigated, along with volumes and composition of consumption and effects of geographic and socioeconomic variables on consumption from studies covering 10 towns. Volumes and composition estimated from market trade and consumption in Libreville were compared. There is no evidence in markets in this study to support faunal depletion. This is primarily due to limitations of market data and the requirement of further information regarding catchment area and data on alternatives and consumer socioeconomics to infer depletion. No effects of seasonality were observed in market assemblages, indicating that sampling bias according to season does not invalidate comparisons between markets. Markets in Libreville were found to differ significantly in their proportions of reptiles and primates, indicating there may be specialisation of markets for certain produce. Consumption of bushmeat was found to be associated with both socioeconomic and geographic factors, with geographic factors playing a greater role in determining consumption quantity. Relationships between bushmeat consumption and prices and consumption quantities of alternatives were found only to exist for freshwater fish, in contrast to previous studies where the distinction between sea fish and freshwater fish was not made (Wilkie et al., 2005). The possible dietary substitutes for bushmeat are unlikely to include sea fish on the basis of this finding. Markets and consumption in Libreville are not representative of each other, and so interpretations of market studies and consumption studies should be treated with caution. The number one species represented in market assemblages in Libreville, dwarf crocodile, constituting 21% of the total market biomass, was not recorded at all in the consumption study in Libreville.

Table of Contents

Acknowledgements

First and foremost acknowledgement must be given to supporters and funders of the work carried out as a part of Projet Gibier under the Gabonese government, Direction de la Faune et Chasse, the Centre International de Recherches Medicales de Franceville and the Wildlife Conservation Society. Thanks go to all researchers and data collectors who collaborated in the market and consumption studies between 2000 and 2006. The 2002-3 consumption study was financed by the Cultural Anthropology program of the National Science Foundation (grant no BCS-0111905 to Principal Investigators David Wilkie and Ricardo Godoy.)

This thesis owes its existence to all involved in Projet Gibier in Gabon and colleagues at WCS who were eager for research to be carried out on this dataset to further the understanding of the bushmeat issue in Gabon, even if only in baby steps, and let me get a Masters in the process. Endless gratitude for this opportunity and for answers to random questions to Kate Abernethy, David Wilkie, Malcolm Starkey, Olly and Lauren Coad. Heartfelt gratitude also to Lauren for your support throughout, you were absolutely vital and did a blinder of a job. Thanks to Professor E. J. Milner-Gulland for supervision and patience and my international office mates who made it feel like we were all in it together.

List of Figures and Tables

WORD COUNT 15,595 excluding contents pages, references, appendices, tables, figures and captions.

1 Introduction

Bushmeat, or the use of wild animals for food, is a resource of vital importance to the majority of rural and poor people in the tropics. It is also the cause of a looming biodiversity crisis as a result of over-exploitation caused by a combination of growing human populations and shrinking natural habitats. There is a wealth of literature discussing bushmeat, wild food and the impact of exploitation of wildlife on biodiversity (e.g. Robinson and Bennet, 2000; Brown and Davies, 2007) but little of this provides practical recommendations for mitigation measures that can be applied on the ground to alleviate the problems associated with the bushmeat issue. There is the concurrent issue that the biodiversity crisis caused by the over-exploitation of wild animals for food is concentrated in the tropics, where governments of these typically developing nations have few financial and technical resources to draw on to control the problem.

Concern over the impact of the bushmeat issue on biodiversity is concentrated in Central Africa, where the volumes of animals extracted from the forests of the Congo basin are estimated to be in the region of millions of metric tonnes per year (Fa et al., 2002; Wilkie and Carpenter, 1999). This concern led to the founding of Projet Gibier in Gabon, which aimed to study the use and trade of wild animals for food in Gabon with the particular aim of informing policies to control the problems associated with bushmeat. Gabon is of particular significance in the field of bushmeat studies, given that the process of urbanisation has led to the situation where the rural population density approaches the level that sustainable use of wild animals is thought possible. Gabon is thus in a unique position to implement policies to sustain both rural livelihoods and animal populations.

1.1 Projet Gibier

Projet Gibier ran in Gabon between 2000 and 2006 and was chaired by the Direction de la Faune et Chasse, a section of the Gabonese government, and run by the Centre International de Recherches Medicales de Franceville. The Wildlife Conservation

Society was a founding partner and has provided financial support and technical expertise to the project. As a part of this project a comprehensive data set was compiled, consisting of bushmeat market surveys and cross-sectional socioeconomic and consumption surveys covering various sizes and geographical locations of settlement across Gabon. Projet Gibier's collaborators have produced research reports and publications (e.g. Starkey, 2004, PhD thesis; Wilkie et al., 2005) but there remain areas of research that can offer insights into aspects of the bushmeat issue that have not yet been fully explored. This data provides the material on which this thesis is based.

1.2 Problem Statement

It has been posited that the provision of alternative livelihoods and sources of animal protein could help to offset the pressure on wildlife from hunting (Wilkie and Carpenter, 1999). It has also been suggested that market data can be used to infer sustainability of bushmeat extraction and indicate imbalances in supply and demand that may be important to the conservation of wild animal populations (Fa, 2007; Cowlishaw et al., 2005b). Financial support to achieve this control among governments and conservation organisations are limited, but there is support among these institutions to address this issue. Given the limited resources, evidence is needed to determine priority actions that are most likely to succeed in maintaining human livelihoods and food security and perpetuating populations of exploited species.

The data compiled in bushmeat market surveys and socioeconomic consumption surveys under Projet Gibier have been analysed to produce research giving insights into important themes such as alternatives to bushmeat and the distribution of bushmeat consumption among the population of Gabon. Research suggests that there may be a relationship between fish and bushmeat in Gabon that could indicate a) that bushmeat and fish are dietary substitutes, and b) that reducing bushmeat consumption could increase pressure on fisheries, transferring the conservation problem rather than solving it (Wilkie et al., 2005). Further research suggests that the aggregate of urban consumption is higher than rural, and that urbanisation of the population of Gabon is likely to increase this pressure (Starkey, 2004). There are many remaining areas in which the data sets on markets and consumption can provide crucial insights to direct bushmeat mitigation measures. Remaining questions to be addressed are:

- Is fish a viable alternative to bushmeat and are there differences in consumptive behaviour towards sea fish and freshwater fish that could change how the substitutability of fish and bushmeat is viewed?
- What characterises rural and urban consumption, in terms of the geographical location and socioeconomic circumstances of bushmeat consumers, and where is the greatest urgency for control of bushmeat?
- Can seasonality be detected in market assemblages and what are the implications of this in bushmeat enforcement and bushmeat research?
- Are markets heterogeneous in their composition, and how might this impact on how market data is interpreted?
- How does the character of traded bushmeat compare with that of consumption? What is the cause of observed differences and how does this impact on the utility of market data and consumption data as indicators of the bushmeat trade?

Answers to these questions will help to formulate policies for the control of bushmeat and direct the use of financial and technical resources to areas of the bushmeat trade where controls are most needed and most likely to work. This study is aimed at addressing these questions.

1.3 Aims and Objectives

The analysis of the long-term bushmeat dataset is geared strongly towards informing policy that can be implemented in Gabon for the control of exploitation of wild animal populations and protection of access to protein and income for the dependent rural poor. The overall aim was to investigate consumption patterns for bushmeat according to socioeconomic status and geographic region and relate these to potential alternatives, also to investigate market trends through time and space and relate these trends to the exploitation of wildlife. A further aim was to compile an assessment of the utility of market and consumption data as indicators of elements of the bushmeat trade that are of importance to biodiversity conservation. The objectives were the following:

- To investigate the existence of trends in biomass, price and composition of bushmeat passing through markets;
- To find out whether market data can be used to indicate elements of the trade that are of conservation and research interest; seasonality and effectiveness of control measures;
- To find out the contrasts in consumptive behaviour between settlements according to location;
- To assess substitutability among the possible alternatives on the basis of relationships between consumption of bushmeat and alternatives;
- Produce a comparison of market and consumption data, which has not yet been done in bushmeat research.

1.4 Thesis Overview

This thesis addresses the themes, aims and objectives laid out above by first situating the issue in the context of existing literature and past studies of bushmeat and the issues relevant to consumption and market trade in Gabon (section 2, Background). Section 3 addresses the field methods in data collection, methods and rationale of data refinement and statistical procedures. Analysis is carried out in three parts:

- Section 4 investigates the existence of trends in markets in time, space, according to seasonality and enforcement interventions;
- Section 5 investigates the determinants of consumption and relationships between location, socioeconomics, consumption and price of bushmeat and alternatives and the composition of bushmeat in consumption;
- Section 6 compares the volumes and composition of bushmeat in markets and consumption in Libreville and addresses differences between markets within the same location and the origin of bushmeat in consumption.

This thesis concludes with a discussion of trends observed, determinants of consumption, contrasts and similarities between markets and consumption and their relevance to formulating effective policies and control measures, situated in the context of previous research.

2 Background

2.1 The bushmeat crisis in Central Africa

Figure 2.1 Images of bushmeat in Gabon. A woman selling red river hog, duiker and monkey in Makoukou and a whole mandrill on sale. Images adapted from CIFOR and WCS Gabon.

The use of wildlife for subsistence and commercial purposes is worldwide. The hunting of wild animals for food and income – variably referred to as the bushmeat 'trade', the bushmeat 'issue' or the bushmeat 'crisis' – comprises a large part of the livelihood activities of the human populations in the poorest regions of the world (East et al. 2005; Brown and Davies, 2007).

Where bushmeat and the associated biodiversity and poverty impacts has had the most attention, and where arguably the greatest threat to wildlife and human food security exists, is in the tropical forested regions of West and Central Africa (Brown and Davies, 2007; Milner-Gulland et al., 2003). The term 'crisis' is so often attached to discussion of bushmeat in Africa for the simple reason that the situation as it stands is seen to be unsustainable. Extraction of wild animals from the forest is already thought to exceed production rates (Fa et al. 2003) and to have led to local extinctions in some areas (Cowlishaw et al., 2005b; Brashares et al., 2001). Additionally, as a result of reducing selected animal populations, there are knock on ecosystem effects that really can not be predicted, for instance relationships may be altered between browsers and vegetation, in seed dispersal and predator-prey relationships taking the impact of over-exploitation beyond that felt by the exploited species (Bennett and

Robinson, 2000). The added concern of shrinking forest (annual forest loss in Congo Basin forests is estimated at 0.2-0.7%, Fa et al., 2003), increased access to forest as a result of extractive industry and growing human populations (population growth rates estimated for the Congo Basin, 1.5-3.3%, Wilkie and Carpenter 1999) turns this issue into a long-term catastrophe waiting to happen.

To say the bushmeat crisis amounts to a potential biodiversity catastrophe is understating the issue. The majority of rural populations in Central and West Africa depend in a very immediate and definite sense on wild animals for food and income (LWAG, 2002; Davies and Robinson, 2007; Cowlishaw et al., 2007). If animal populations become depleted to the point that they are no longer an exploitable/usable resource there will be a very large portion of the human population in this region with no source of animal protein and few if any alternative livelihood options. Additionally, if constraints or restrictions on bushmeat related activities (harvesting, trade and consumption) are to be imposed in order to control the trade, the economic impact of these restrictions are likely to be felt most severely by the poorest category of people (Brown and Davies, 2007). Bushmeat is, therefore, an issue which encapsulates a biodiversity-poverty linkage.

The scale of the issue in the Central African region, in terms of the sheer volume of animal biomass that must be extracted from the forest to supply consumers, surpasses that of South America and Southeast Asia, where the exploitation of bushmeat has also received attention (Bennett and Robinson, 2000; Milner-Gulland et al., 2003; Fa et al., 2002). Estimated volumes of consumption have been calculated from per capita consumption amounts of urban and rural populations, generalising across the whole of the Central African region. Wilkie and Carpenter (1999) estimate consumption to be almost 1.2 million metric tonnes of bushmeat per year using a rural consumption estimate of 0.13kg/person/day and urban consumption estimate of 0.013kg/person/day. These estimates suffer from being based on per capita consumption, where population estimates for many countries are dubious at best (K Abernethy pers. comm.; Starkey, 2004). Other studies have shown per capita consumption to vary considerably between regions, between urban and rural populations within regions and further between socioeconomic classes of people within these urban and rural settings (Table 2.1). This not only casts doubt on the accuracy of gross estimates, it brings to attention the limited utility of making generalisations with regards to the bushmeat issue. A large scale generalisation homogenising consumption and extraction across Central Africa gives the impression that the problem is blanketed across the region to an equal extent in all places. This is both unrealistic and unhelpful if the short term goals are to formulate effective control measures to achieve the long term objective of sustainability. Whether an extraction: production imbalance exists depends on local circumstances, and the appropriate control measures will be locally dependent also. For example, Cowlishaw et al (2005b) find that the situation surrounding Takoradi market in Ghana is one of 'post-depletion sustainability', and that through historical over-exploitation of vulnerable species, more robust species dominate the bushmeat trade and require little if any regulation (with the caveat that this is dependent on suitable amount of forest remaining and at present human population levels). Investing in control measures regarding extraction and sale of bushmeat would be an uninformed use of scarce resources, and may be better concentrated, for example, in protected area enforcement. Whether a solution to an extraction: production imbalance is to be effective depends on local circumstances, as one solution will not fit all (Wilkie and Carpenter, 1999). Supply and demand structures in the bushmeat trade are the basis for formulating potential methods for control based on the variable local importance of economic and cultural factors.

Table 2.1 Figures collected from the literature for bushmeat consumption in Central and West Africa. Figures are not directly comparable due to unit differences, however give an idea of differences between countries and regions within countries.

Country	*Reference*	Bushmeat consumption estimates
Congo (Brazzaville)	Eves and Ruggiero (2000)	Rural logging village
		Bushmeat consumed on 3.40 days/week
		Rural non-industry village
		Bushmeat consumed on 1.40 days/week
		Rural conservation village
		Bushmeat consumed on 1.05 days/week
Ghana	Cowlishaw et al. (2007)	Rural 0.033 kg per capita per day
		Urban 0.046 kg per capita per day
Gabon	Wilkie et al. (2005)	Overall 0.08 kg/AME/day
		Capital 0.02 kg/AME/day
		Towns 0.05-0.12 kg/AME/day
		Inland village 0.26 kg/AME/day
		Coastal village 0.05 kg/AME/day

2.2 Supply and demand

Options for limiting the impact of bushmeat hunting on wild animal populations, and subsequently on human food and livelihood security, are generally stated as belonging to either supply side control or demand side mitigation measures (Wilkie and Carpenter, 1999). Increasing numbers of animal populations is clearly implausible, so supply side mitigation rests on limiting off-take. Proposals for achieving this relate to the modifying of incentives to hunt, either by increasing opportunity costs by providing more lucrative livelihood activities, or increasing direct costs with enforcement (of quotas, species bans, non-hunting areas, road side searches, market inspections etc.) with fines and penalties (Wilkie and Carpenter, 1999).

The demand side is the more visible of the two, consisting of the consumption of bushmeat and economic circumstances of consumers, which are often easier to research than hunters and their motivations, as the implications of illegality are a lot less incriminating for consumers than for hunters. To affect change in demand and alter the motivation to consume, existing motivations to consume must first be understood.

Drivers of consumption are principally economics, culture and nutrition (Robinson and Bennett, 2000). Within the area of nutrition, meat may be seen as a necessity, as it provides a complement of amino acids which are an essential dietary element that are not available from the plant foods comprising the remainder of the diet of much of rural Congo Basin populations. Conversely, where alternatives to bushmeat are available and affordable, bushmeat is not a nutritional necessity. Culture encapsulates tradition and preference, describing reasons why people may choose to eat bushmeat on the basis that they have always done so, or simply that they like it. It is a potential barrier to success in controlling bushmeat extraction if people have a strong preference for it over alternatives as attempts to reduce access are likely to meet with resistance. Study of preferences has contributed to understanding of the motivations of bushmeat consumers, and has shown that urban bushmeat trades are potential areas for control, as it is far from a necessity or even a highly preferred luxury item. For example, in Gabon a two-choice taste test indicated that a weak preference for bushmeat came mostly from villages (Schenck et al 2006). A study in Equatorial Guinea included an assessment of the most and least preferred foods of a list of meat and fish types, and found that bushmeat as a distinct category did not stand out, but people drew a greater preference distinction between fresh and frozen (East et al., 2005). Both cases indicate that reducing access to bushmeat within these circumstances may not be met with opposition.

Study of preferences has also brought to light the overwhelming indication that rare and endangered species are not high on the preference list, and therefore controlling trade in these species is a possible area in which concentrating resources may be worthwhile (Davies et al., 2007). Preferred and most popular bushmeat species appear to be porcupines (in Libreville, Schenck et al., 2006), duikers and rodents (Davies et al., 2007; Eves and Ruggiero, 2000; Cowlishaw et al., 2005b) which have the added bonus of being fast reproducers with the ability to resist high levels of exploitation.

Economic drivers of demand are, in general terms, the socioeconomic circumstances of consumers in relation to the price of bushmeat and the prices of available alternatives. This is the part of demand that has received much attention (East et al., 2005; Wilkie et al., 2005; Eves and Ruggiero, 2000). Determining what motivates consumers to consume bushmeat demarcates the areas where controls are likely to be effective and have the least detrimental effect on the poor people dependent on bushmeat.

2.3 Consumption surveys and determinants of consumption

In order to properly target geographical areas and points in the chain from forest to consumer where control is necessary and most likely to be effective, the regionally relevant drivers of the trade must first be understood. Consumption studies have provided useful information for determining consumption patterns and indications about the place of bushmeat as a necessary staple, a preferred good, a luxury (Wilkie et al., 2005; Wilkie and Godoy, 2001).

Local elasticity of demand is thought to be an important subject in bushmeat consumption, and is an area of concern for proponents of a bushmeat solution that also addresses development (Wilkie et al., 2005; Brown, 2007; Wilkie and Carpenter, 1999). Indications are that demand is likely an inverted ‘U’ shape, where the very poor and very rich consume little, increasing wealth from the poor end increases consumption, which then decreases as the good becomes an ‘inferior’ good with increasing wealth of consumers (Wilkie and Godoy, 2001). It is, in this case, a concern that development aims (increasing wealth and standard of living in the rural poor) may increase bushmeat consumption and thus negatively impact conservation aims. Bushmeat consumption studies tend to be cross-sectional, whereby they are conducted as a ‘snapshot’ rather than a time-series. With cross-sectional data calculating elasticities is not advisable as these are dependent on time-series data denoting dependence in the income-demand relationship. Elasticities of demand with wealth, income and price may well inform the case for bushmeat control solutions, but as this data is not readily available a case can be made for examining in more simple terms how consumption quantities vary with wealth, income and price.

Wilkie et al. (2005) show that consumption and prices of bushmeat and alternatives are strongly related across geographical regions of Gabon (coastal vs inland and varying sizes of settlement). Prices of fish were found to be cheaper in coastal areas of Gabon and more expensive inland, whereas the reverse was the case for prices of wildlife. It followed that fish was consumed in larger quantities in coastal regions and bushmeat was consumed in larger quantities in inland areas. Consumption of all meat and fish types decreased with increasing price. However, this study also found indicators of socioeconomic circumstances (permanent and transitory income) to be unevenly distributed across the regions. Just as consumption was found to decrease with increasing price, consumption of all animal protein types in this study increased with increasing wealth. It is thus difficult to determine whether consumptive behaviour is a result of location (as a proxy for price and availability of alternatives) or socioeconomic circumstances, or an interaction of these things. It is thus of great use to investigate relationships between price, wealth and consumption of bushmeat at a local scale in Gabon. This will indicate whether suspicions are valid that the urban trade is the area where controls will be most effective and likely to work.

A growing concern is the urban demand and rural supply debate, as studies have indicated that bushmeat is not a necessary staple in urban areas and it is urban demand that is driving the unsustainable element. Kumpel et al. (2007) found that consumption frequency is primarily determined by income in urban areas, with consumption of preferred foods (including bushmeat) increased with increasing income. That consumption also decreased with increasing price and consumers consumed more cheaper alternatives (frozen meat and fish) indicates that bushmeat in urban areas is not a necessary staple. The trade overall is becoming increasingly commercialised. Hunters in a rural village in Equatorial Guinea were found to sell the majority of their catch (89%), indicating that hunting was the major source of income in that village where paid permanent work was not undertaken (Kumpel et al., 2007). Cowlishaw et al. (2007) estimate that 72-87% of all bushmeat in Ghana is traded. Urbanisation is a growing trend in the Congo Basin. As a result, the concern is that increasing urban populations will drive the luxury end of the bushmeat market, where large volumes may be extracted and traded where alternatives are available and affordable. Rural consumption may not be sustainable everywhere, but it remains the case that the curtailment of urban consumption will impact on the health of urban people far less than equivalent constraints in rural areas.

Where consumption studies can provide vital information of the determinants of consumption and drivers of demand, information collected in consumption studies can be informative in a wider ranging sense. Looking at the origin or mode of acquisition of bushmeat consumed in households can help to differentiate where in the trade the concentration of bushmeat activity is situated. Bushmeat consumed in a household may be bought, gifted or hunted by members of the household. Over 40% of bushmeat acquired by households among the poorest socioeconomic categories of villages in Northern Congo (Brazzaville) is received as a gift, a further 40% comes from the husband's activities i.e. hunting (Eves and Ruggiero, 2000). In non-logging and conservation areas in the same study, 40-50% of all household bushmeat sources are gifts, a further 30-40% acquired through the husband's activities. It is thus important to establish, when using data as an indicator of the bushmeat trade, what part of the trade it applies to and how much of the trade it is representative of.

2.4 Market surveys as indicators of trade and sustainability

Bushmeat markets attract attention from researchers as they are concentrations of the issue of interest; they are highly visible and comparatively easy to collect data from. There is often great hope invested in the study of market dynamics with a view to extrapolating to gain an overview of what is happening in the trade regionally (Fa 2007; Cowlishaw et al., 2005b).

It is suggested that markets can be used as indicators of faunal depletion (Fa, 2007; Cowlishaw et al., 2005b). Rarity, endangerment and vulnerability to over-exploitation are related in a general sense. Productivity can be described with an animal's intrinsic rate of increase, which is largely approximated by its body size, and can indicate whether a species is likely to replace harvested individuals rapidly or suffer population depletion. The presence and proportions of large bodied species in markets is suggested to represent the health of the ecosystems from which the harvest is drawn (Crookes et al., 2005). Cowlishaw et al. (2005b) describe the absence of larger species from Takoradi market as indicating depletion of these species from past over-exploitation. Jerozolimski and Peres (2003) show that older, more established and larger settlements in the Neotropics had depleted large mammals in their catchments and a shift to smaller body size in prey is observed.

However, research has shown that market dynamics are complex and largely do not reflect what is going on at other points in the trade (Milner-Gulland and Clayton, 2002). Markets are the most visible centre of the commercial trade, but they do not constitute the whole of bushmeat 'supply'. In fact, this is far from the case and this is a major problem. What reaches a market is a subset of what a trader or wholesaler has obtained from a hunter (85% of sales are made through small restaurants in Takoradi, Ghana, Cowlishaw et al., 2005b). What the hunter sells is a subset of what they bring out of the forest and what they bring out of the forest is a subset of what is actually killed (Davies et al., 2007; Coad, 2007). Filters acting at each point in this chain are uneven, weighting different species differentially – e.g. what is sold or kept for consumption by the hunter depends on the profitability of species they caught (Coad, 2007) – so any of these subsets is not by any means representative of the larger sample it came from.

Davies et al. (2007) compared hunter catches in a forest edge village and market assemblage in the main urban centre of the region of interest in Sierra Leone. The composition of species in hunter catches were significantly different to those in the market. The proportions of ungulates and primates effectively swapped places (hunter bags contained 66% ungulates and 18% primates, market assemblages were composed of 30% ungulates, 50% primates) indicating that hunters preferentially sold primates and kept ungulates either for consumption or distribution to places other than the urban market. Although this is an indication of the discrepancy between what is extracted from the forest and what appears in markets, this study focussed on a single village in a large catchment area, and without more information about hunter catches elsewhere it is difficult to isolate the trade structures leading to the market and determine the source of this discrepancy.

As well as composition differences between markets and other points in the trade, there are notable examples of volume discrepancies, indicating that markets contain only a small portion of the overall trade. Cowlishaw et al. (2007) estimate that 16 metric tonnes of bushmeat are sold in the urban town of Takoradi, but across the catchment including informal sales, rural sales and hunter's household consumption the figure is estimated at 1,130 metric tonnes. As discussed above, much of bushmeat consumed does not actually pass through markets (Eves and Ruggiero, 2000).

The problem of catchment is recurring in bushmeat literature and relates particularly strongly to the utility of market surveys as indicators of sustainability or depletion. In Milner-Gulland and Clayton (2002) wild pig traders were shown to travel significantly further and pay more to obtain animals for sale at the end of the study period compared with the beginning, leading to the inference that resources (in this case wild pigs) had become depleted. Wilkie and Carpenter (1999) describe earlier work by Ngnegueu and Fotso in Cameroon as indicating that hunter catches are 7 times greater if they travel 10 km or more from settlements. Shifting hunting effort to less depleted areas increases hunting success and is a rational response of hunters to depletion (Crookes et al., 2005). And so, without knowledge of the area supplying markets, it is a danger that there could be a wave of depletion passing through the forest before any change in markets is visible (in species composition, species body size or overall volume; Crookes et al 2005).

Long term market datasets have been used to describe market dynamics (e.g. Crookes et al., 2005; Cowlishaw et al., 2005b) but researchers note that information beyond the market sales are necessary to make any useful inferences from trends in species, volumes or prices of bushmeat. Decreasing volumes of trade and increases in price can indicate increasing scarcity, which has supply implications in that resources are likely becoming scarcer (depletion) and demand implications in that demand is likely not being met and people are prepared to pay more. However, as discussed above, markets are probably poor indicators of depletion unless a finite catchment area is known. It is therefore necessary when using market data to make inferences about sustainability, to also collect information about the origin of the bushmeat and hunting techniques and reasons hunters may change their behaviour, as high market demand may drive responses by hunters to use more expensive and efficient hunting gear (i.e. shotguns, Crookes et al., 2005).

2.5 Comparing market and consumption studies

There are currently no existing empirical studies comparing profiles and characteristics of the bushmeat trade gained from looking at both markets and consumption in a given area. This would be of great use in indicating the value of market data as an indicator of the bushmeat trade.

By far the best indicator of depletion or sustainability would be gained from the study of hunter catches, catchment, exploited species and their population biology (Robinson and Redford, 1991). For various reasons this is both implausible to expect on a large scale and difficult to obtain. Detailed data would be needed on all regions where hunting was known (i.e. everywhere in the Congo Basin forests), and data collection may suffer from the fact that much of what is observed may be illegal. Besides this, the effort invested would not lead to rapid indications of where control measures would be best implemented. The data gained may be of great research interest but may not be the best route to take if the formulation of control measures is the overall aim. Markets are favourable as indicators in terms of ease of data collection but suffer from being only a subset of the trade. Consumption studies provide the most comprehensive information regarding the drivers of demand. Comparing what can be ascertained from these with regards to the species composition and volumes of trade would clarify where the most useful data can be gained to direct bushmeat control measures.

2.6 Gabon: the possibility of sustainable use

Gabon is in a unique position among Central African nations. With a large amount of remaining rainforest cover, low population density and relative wealth, there is great potential for meeting the needs of vulnerable rural populations (in terms of food and income) without over-exploiting natural animal populations.

Relative to other Central African countries, Gabon's per capita GDP is high ($14,100 purchasing power parity, CIA 2008), and as a result the government has more incentive to address biodiversity issues than neighbouring countries where maximising sources of state revenue, addressing poverty, development and the interests of the people are more immediate and pressing concerns.

In addition to its relative wealth, Gabon's low population density means that sustainable use of wildlife is a goal that may be within reach in rural areas. Productivity of tropical forest is estimated to be able to supply the protein needs of 1 adult male equivalent (AME) per km^2 (Robinson and Bennett, 2000). Human population density in Gabon is estimated to be $5.2/km^2$. A significant proportion of the population is concentrated in urban areas (Starkey, 2004) and a high rate of rural-urban migration means that populations in rural areas are approaching the 1 AME per km^2 that is estimated to be the limit of sustainability. People in urban areas of Gabon have far less dependence on bushmeat, where it is more a dietary item than a livelihood activity and alternative sources of animal protein are more widely available (Wilkie et al., 2005). It is thus described as more ethically justifiable and likely to be effective to control demand in urban areas than to attempt to curtail consumption and hunting in rural areas (Brown, 2007). Even though per capita GDP is high, this wealth is not evenly distributed and rural poverty is also high. Indications from the literature are that productive species are both preferred and predominant, and that excluding rare and threatened species from the trade and enforcing non-hunting laws in protected areas will have a minimum impact on rural livelihoods (Schenck et al., 2006; Davies et al., 2007).

Global Forest Watch (2000) estimates the remaining forest cover in Gabon to be 80%, which is on the high end of countries in the Congo Basin (estimates vary according to how forest cover is calculated). Extractive industries tend to form a large part of revenues for Central African countries, and Gabon is no exception. Although there is much remaining forest, extensive cover of logging concessions means that access to the forest makes animal populations more in danger of being exploited. Some areas of Gabon are already seen to be depleted of wild animals (Coad, 2007). The situation is far from ideal, but the high percentage of forest with high biodiversity value combined with the low (and falling) rural population density indicates that there are reasons for optimism, if cautious, for the bushmeat issue in Gabon.

3 Methods

3.1 Study Site

Projet Gibier ran market data collection, which was collected by 40 local and international research assistants. Market data was collected between 2000 and 2006 from 23 markets in total which cover 10 towns in Gabon of varying size and geographical location (Table 2.1 and Figure 3.1). Consumption data and socioeconomic data collection was funded by the National Science Foundation and collected by 12 researchers working with Projet Gibier. Data were collected in household surveys in 10 towns in between February and August 2002 (Table 3.2 and Figure 3.1).

Table 3.1 Table showing markets surveyed, location and timing of surveys.

Town	*Market Name*	*Market Code*	*Years Surveyed*	*Months Surveyed*
Libreville	*Premier Campement*	1CP	2000, 2001	1, 12
	Akebe	AKB	2000	3, 4, 5, 6,7
	Mont-Bouet	MBT	2000-2004	1-12
	Nkembo	NKB	2001, 2002	1,2, 5-12
	Oloumi 1	OL1	2000	3-9
	Oloumi 2	OL2	2000	5-8
	PK5	PK5	2001	3-6
Franceville	*Pottos*	FCV	2000-2004, 2006	1-12
Koula-Moutou	*Koula-Moutou*	KLM	2002	2-6
	Koula-Moutou Ravitaillement	KMR	2002	3-6
Lambarene	*Lambarene*	LMB	2002-2004	3-5, 7-9
	Port	LMP	2002, 2004	3, 4, 6-11
Makoukou	*Afane*	AFE	2000-2004	1-12
	Afane Ravitaillement	AFR	2001	2
	Cite Zaotab	CZB	2001, 2002	4, 5, 7-10
	Loua-Loua	LOU	2001, 2002	8-10
Mekambo	*Mekambo*	MEK	2000, 2001	1-5, 12
Moanda	*Moanda*	MOA	2000, 2001	1-12
Ndjole	*Ndjole*	NDJ	2001	12
Okondja	*Gare Routiere*	OKJ	2000-2002, 2004, 2006	1-12
	Mosquee	MSQ	2001	1-3
Oyem	*Carrefour Monaco*	CM	2000-2002, 2004	1-12
Village Obiri (Franceville vicinity)	*Obiri*	VOB	2002	9,10

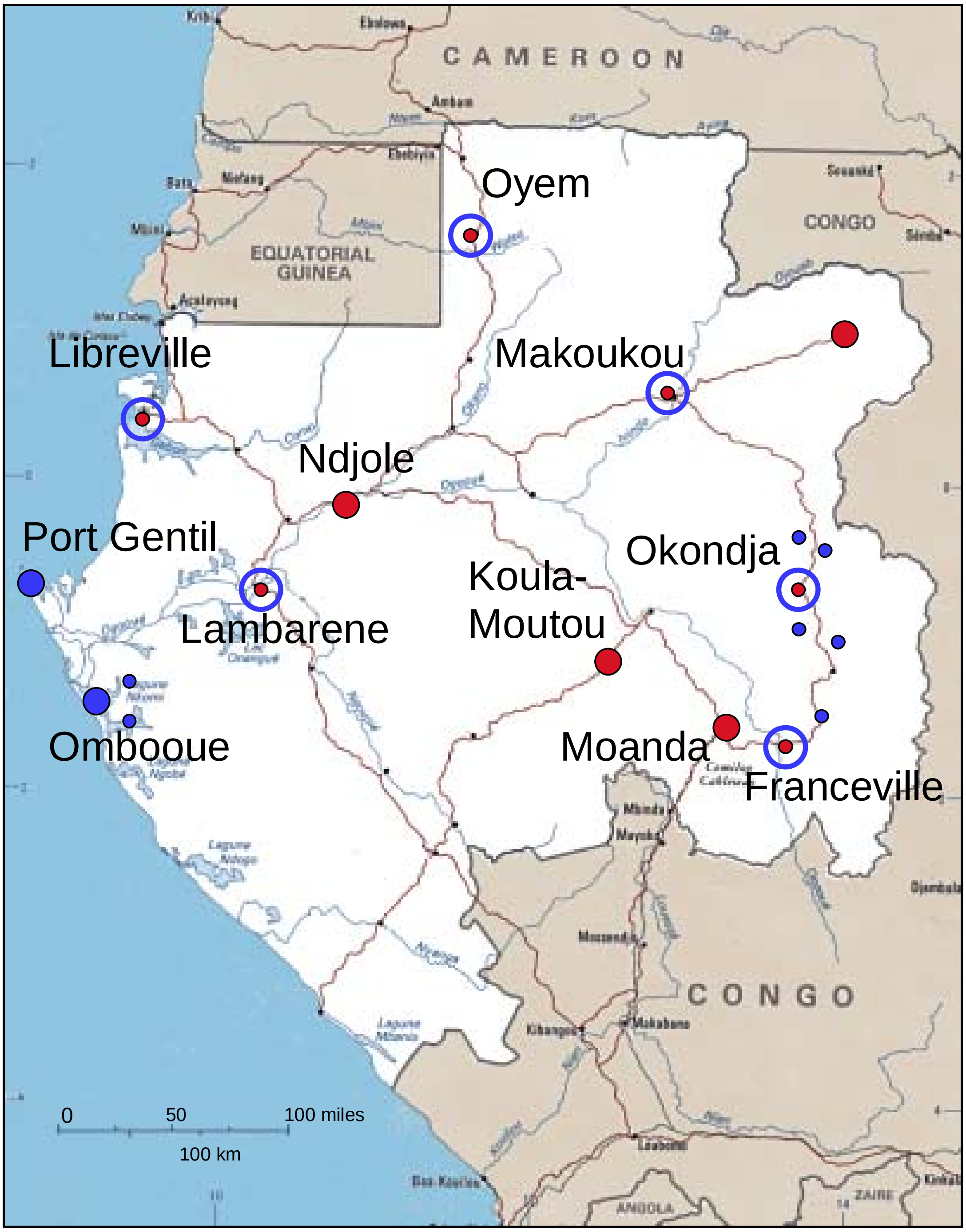


Figure 3.1 A map of Gabon showing the study sites. Red indicates locations of market data collection, blue indicates socioeconomic and consumption data collection. Smaller dots indicate villages.

Table 3.2 Table of towns in household consumption and socioeconomic survey.

Town	Number of households surveyed
Libreville	516
Franceville	215
Lambarene	113
Makoukou	103
Okondja	105
Ombooue	76
Oyem	151
Port Gentil	142
Villages (Inland – Okondja vicinity)	172
Villages (Coastal – Ombooue vicinity)	79
Total	1672

3.2 Data Collection Field Methods and Data

Field methods are detailed in Wilkie et al. (2005) and Starkey (2004), where calculations of biomass in market sales, randomisation of households for sampling, basket of goods method of calculating permanent income and estimation of transient income in the socioeconomic survey are explained fully.

3.2.1 Market surveys

Data collectors were normally required to begin data collection from the first sale of bushmeat of the day and record every sale of bushmeat until the last bushmeat sale of the day. Sales details recorded were species, unit[1], price (per unit and total in sale), state, time of day, number of units sold. A full list of species recorded is provided in Appendix I. Biomass of each sale was calculated using algorithms based on the relationships between species, unit, price and weight from a small sample of weighed units of various species (equations applied by D. Wilkie in preparation of data for analysis in Wilkie et al., 2005). Weights are estimates as it is unknown whether meat in sales was dressed, undressed, bone in or out.

[1] Common meat units included kg (an approximate kilogram), tas (a ‘pile’ of meat), gigot (a part of the animal such as a leg with part of the body), quartier (a leg and body portion roughly one quarter of the headless carcass) and entiere (the whole animal).

3.2.2 Socioeconomic and consumption surveys

Selection of households for surveying was taken from a random starting point, proceeding in a randomly chosen direction and choosing whether or not to survey every sixth house based on a coin toss (for details see Wilkie et al., 2005). Socioeconomic details regarding the members of the household were collected along with details on consumption of meat and fish types by members of the household with a three day recall method. On the day the researcher surveyed a household, members would be asked what household members had consumed over the previous three days. Up to six days total was recorded (households were visited a maximum of twice three days apart).

Socioeconomic information collected about each household includes type of house (rich, middle or popular; A, B, C), nationality, occupation and education level of male and female head of household, combined income from work, rents and remittances and social security of household members and the wealth of the household as defined by the ‘basket of goods’ method. The ‘basket of goods’ is the value (in fcfa) of a selection of items in a list owned by the household in total, used as a proxy measure of wealth or ‘permanent income’. Items included cooking pots, watch, kerosene lamp, cooker, fridge, freezer, air conditioning, television, radio/cassette player, private vehicle.

Consumption data collected from each household included units and prices of bushmeat, domestic meat, poultry, freshwater fish and sea fish consumed by household members. The weight in kg was calculated using the same technique as weights of market bushmeat sales. Origin of meat was also recorded, whether the item was bought, received as a gift or acquired by a family member (as a non-purchased item) and if bought, where the item was bought. Origins were categorised as visiting seller (regular or occasional), fixed boutique, market, other town/village or bought from a person selling from their home.

In order to maintain comparability to previous studies using this data and other studies from the same region, consumption quantities are expressed per AME as calculated by D. Wilkie (for methods see Wilkie et al., 2005). Data on energy requirements for various age and sex categories from Mozambique were used (see Appendix III for energy requirement details). Categories used here are children, adolescents and adult, where the corresponding ages are 0-15 years (0.600 AME), 15-21 years (0.840 AME) and 21+ years (0.879 AME).

Towns were grouped according to settlement size for most analyses. These grouping schemes are based on predictions that whether a household is in the capital, a large town, a small town or a village, or is in a coastal or inland location will be key factors in determining which meat and fish types are more important (based on prior studies e.g. Wilkie et al., 2005; Starkey, 2004). For the categorisations see Table 3.3.

Table 3.3 Categorisations of towns and villages in Gabon according to two geographical schemes.

By Settlement Size		***Coastal/Inland***[2]	
Category	*Town*	*Category*	*Town*
Capital	Libreville	Coastal	Libreville
Large Town	Franceville		Port Gentil
	Lambarene		Ombooue
	Oyem		Villages Ombooue
	Port Gentil		
Small Town	Makoukou	Inland	Franceville
	Okondja		Oyem
	Ombooue		Okondja
			Makoukou
			Villages (Inland)
Village	Villages		
	Village Ombooue		

Employment and education level of male and female head of household were each transformed to factors of 4, 3 levels respectively (Table 3.4). Nationality was found to be uninformative due to the non-Gabonese category living almost entirely in Libreville and Franceville and so is not included in further analyses.

[2] Lambarene is too close to the coast to warrant categorisation as inland but is not coastal so was left out of coastal/inland analyses.

Table 3.4 Education and employment categories.

Category	*Level*
Education level	
0	Low: lower primary or below
1	Middle: Middle primary to secondary
2	High: secondary and above
Employment level	
0	Unemployed
1	Employed
2	Retired
3	No person available

3.3 Statistical Analyses

3.3.1 Data refinement, transformation and modelling

Data handling and refinement was carried out using Microsoft Access 2003 and Microsoft Excel 2003. All statistical analyses were carried out using R 2.6.2. Consumption data was truncated to remove outliers in bushmeat consumption quantities (see Appendix II for details).

Monthly totals for biomass of bushmeat and average price per kg were estimated for each surveyed month of each market as follows:

- total biomass recorded/ (no. surveyed days/no. open days in each month)

(0.2 was chosen as a cut off point for this proportion, below which it is unrealistic to extrapolate to the whole month (0.2 is roughly just less than a week out of a 31 day month). Any month of data from a single market below this was discarded.)

- total sales value/total sales biomass

The mean price per kg taken for each year of each market and estimated annual biomass of bushmeat sold was calculated for each year surveyed at all markets from the estimated monthly biomass as follows:

- Total estimated biomass for months surveyed/(months surveyed/12)

Average body mass of species[3] at markets were calculated using 0.65 as a dressed weight estimate as follows:

- Number of individuals of each species = estimated monthly biomass of species/ (average body mass*0.65)
- Average body mass in a given month at a given market = Total estimated monthly biomass/Total estimated number of individuals

Six of the 23 markets show even sampling of months across the year, the others show sampling bias (Table 3.1). Evidence of systematic bias would mean markets with uneven sampling of months would have to be excluded from further analysis. In contrast, evidence of no systematic bias according to month would mean that the sampling bias would not affect the validity of results gained from using the dataset in its entirety. Any evidence of systematic bias in overall biomass of bushmeat sold, price per kg of bushmeat and species composition according to month was investigated by means of modelling the variation in these variables as a function of month, year and market.

To investigate any changes in the composition, biomass data was broken down into the contribution of eleven orders – Artiodactyla, Aves, Carnivora, Primates, Hyracoidea, Insectivora, Mollusca, Pholidota, Reptilia, Rodentia, Tubulidentata. There are more levels than necessary in the order variable, with four of them only appearing 4 or fewer times in the data set (an appearance amounts to one market month). These orders, Hyracoidea, Insectivora, Mollusca, Tubulidentata were removed before analyses.

Where non-normality was evident in continuous variables these were logged or where logging was not possible due to zero values variables were transformed using the boxcox transformation (Crawley, 2007). For all pairwise comparisons and correlations chi-square tests, t tests, one-way analysis of variance and the non-parametric Spearman's rank correlation were used as appropriate.

[3] Body mass of species are taken from Kingdon (1997)

Modelling variation in biomass, price, species average body mass and species composition involved multivariate models. As non-normality was apparent for all response variables in this data set even after transformation, linear models were not appropriate. Generalised linear models can be used on non-normal data so this family of multivariate models was employed wherever models were built. Due to the nested structure of the data, it was necessary to account for any pseudoreplication or 'random effects' (variance accounted for by the structure within the dataset rather than explained by any given variable) using mixed effects models (Crawley, 2007). Mixed effects models were simplified following the procedure below to attain the minimum adequate mixed effects model which was then compared with a generalised linear model (glm) comprised of the same main effects without random effects (this enables the systematic elimination of the need for random effects).

3.4 Model simplification

Linear mixed effects models (lme) were simplified using the anova function in R to compare a model and another model minus one parameter on the basis of AIC (Akaike's Information Criterion). The maximum likelihood method was specified in each model to enable this comparison. The model with AIC ≥2 more negative was chosen as the best model, in the event of <2 difference in AIC the simpler model was taken as the better model as the same level of explanatory power is indicated for fewer parameters (Crawley, 2007). Lmes were compared with glms using the likelihood ratio test for comparing the log likelihoods of the models (maximising the likelihood of the data given the model parameters). The greater value of log likelihood was taken as the better model if the test returned a significant difference between models. In the event of no difference the simpler model was taken.

On reaching the minimum adequate model the process of step-wise deletion was followed to further simplify the model, inform interpretation and improve model fit. Non-significant levels of factors and levels with similar estimates (similar degree of difference to the intercept) were combined. Models were compared with simplified versions using the anova function (specifying F test for comparison of glms). All minimum adequate model coefficients tables are listed in Appendix IV.

3.5 Model checking

All models resulting from the above processes were inspected for patterning in the residuals using the plot function in R. Heteroscedasticity (systematic changes in size of residuals with size of fitted values) and curvature (under or over-estimates at higher and lower ends of the fitted residuals scale) in the residuals would indicate variation in the data that is not accounted for by the model. All models showed no signs of heteroscedasticity or curvature unless otherwise stated and addressed in the text. Mixed effects model fitted vs residual value plots are shown in Appendix IV with the coefficients tables.

4 Market Data Analysis

Summary

This section of analysis investigates the existence of geographical and temporal trends in bushmeat sales from 23 markets in Gabon. Refinement of the dataset and seasonality are investigated, followed by analyses of changes in biomass, price, species composition and average body mass according to location and year. See Appendix IV for coefficients tables of all models.

4.1 Investigating evidence of systematic seasonal or temporal bias

Markets were investigated for any systematic bias according to month to determine whether the data could be used in its entirety or would require refinement to account for uneven sampling of months. In the course of this investigation seasonality in market assemblages can be concurrently analysed. Minimum adequate models are shown in Appendix IV, a table of estimated annual biomass and average price per kg is provided in Appendix V.

4.1.1 Biomass and price

Linear mixed effects models were built using estimated monthly biomass as the response variable (logged data) with year, month and market as both fixed and random factors. The process was repeated using monthly average price per kg of bushmeat as the response.

Month in this case did not contribute any explanatory power to the model, indicating no systematic bias in the total monthly biomass of bushmeat at any market according to month. The minimum adequate model was a glm with monthly biomass modelled as a function of year and market. Levels of year simplified to three groups of years; 2000-1, 2002/4 and 2003 – where the differences within groups was not significant and the model fit was not altered, but groups are different to each other (Figure 4.2). Levels of market simplified to those shown in Figure 4.1. Overall the highly significant model explained a large proportion of the variation in estimated monthly biomass (adjusted $r^2 = 0.73$, $F_{15,231} = 45.43$, $p << 0.001$).

Results for price per kg of bushmeat were the same; there is no systematic bias evident according to month. The minimum adequate model was a glm modelling price per kg as a function of year and market. This returned a highly significant model (adjusted $r^2 = 0.72$, $F_{5,241} = 128$, $p << 0.001$). So a great deal of the variation in price per kg is accounted for by the market and year. Levels of year simplified to 2001 and all other years grouped together (Figure 4.3). Levels of market aggregated to five groups (Figure 4.4).

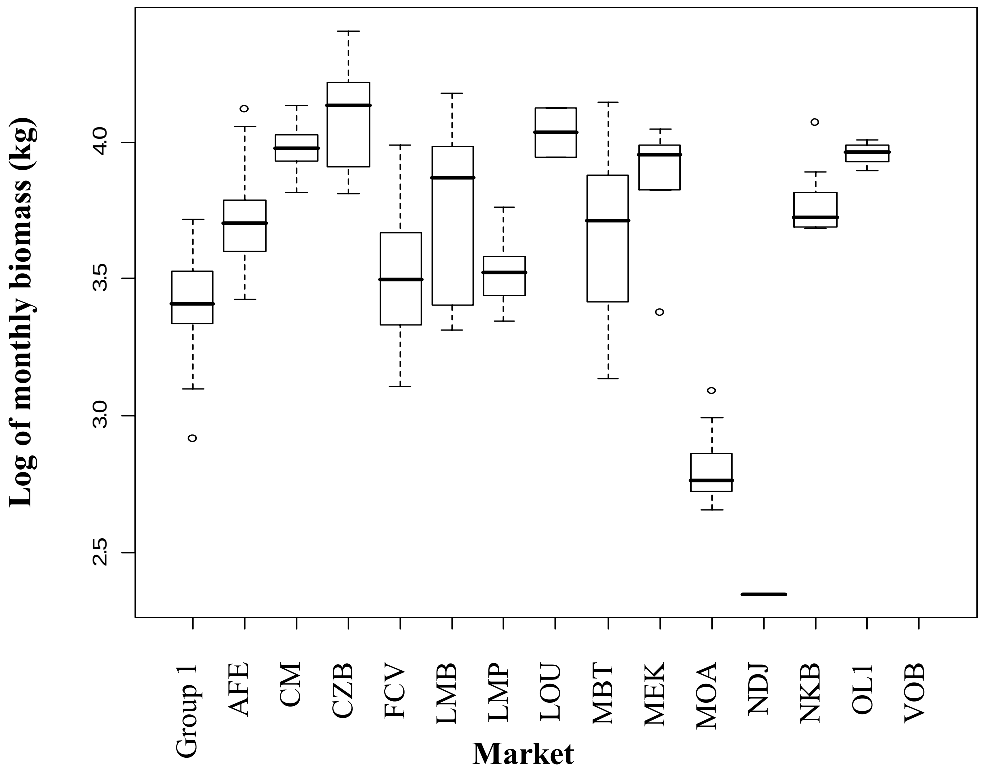


Figure 4.1 Biomass per month by market grouped as terms in the model. Group 1 contains AFR, AKB, KLM, KMR, MSQ, OKJ, OL2 and PK5 in addition to 1CP. For codes see Table 3.1.

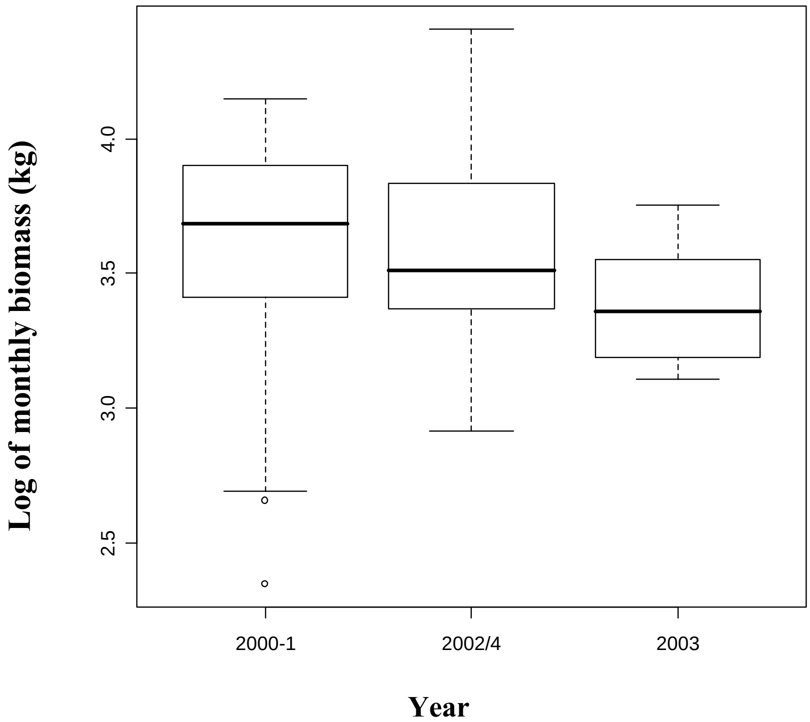


Figure 4.2 Biomass per month by year, with year grouped as the terms in the model using data from all markets.

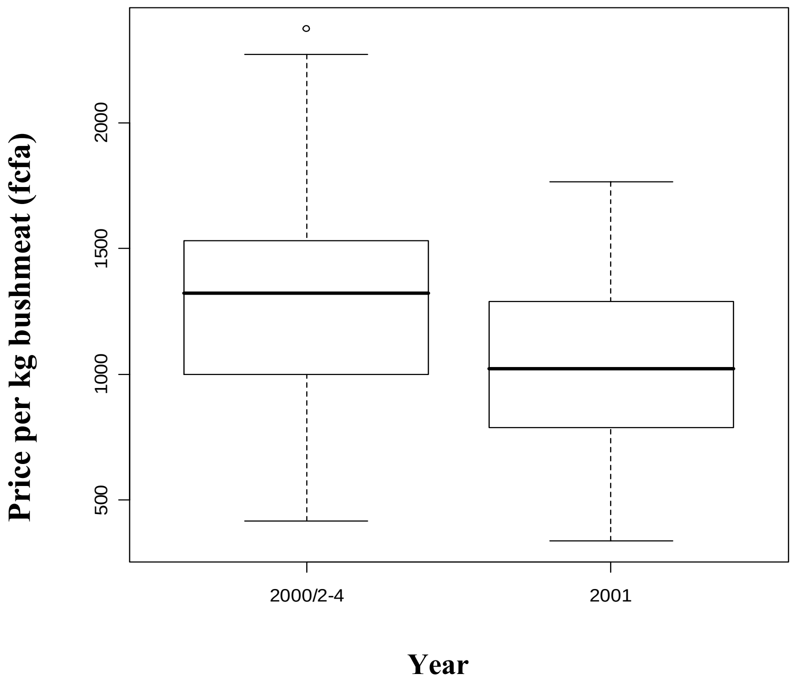


Figure 4.3 Price per kg of bushmeat with year grouped as the terms in the model using data from all markets.

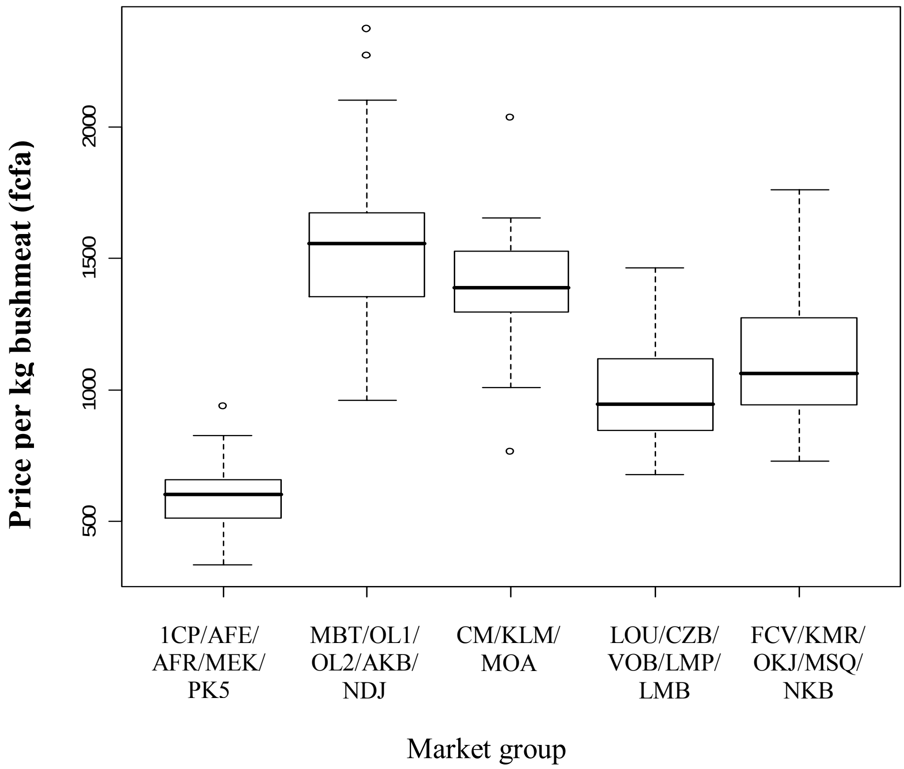


Figure 4.4 Price per kg with markets groups as terms in the model. For codes see

4.1.2 Species composition

The same analysis as above starting with mixed effects models was carried out on the data broken down to Order with order in the model as both a fixed and random effect. The minimum adequate model for the composition of monthly biomass according to Order showed that there was no effect of month. The variance component of the random effect of year was large (75.8% of the variance was accounted for by year). The levels of order could not be aggregated without compromising the model (Figure 4.5), but the levels of market were aggregated as shown in Figure 4.5.

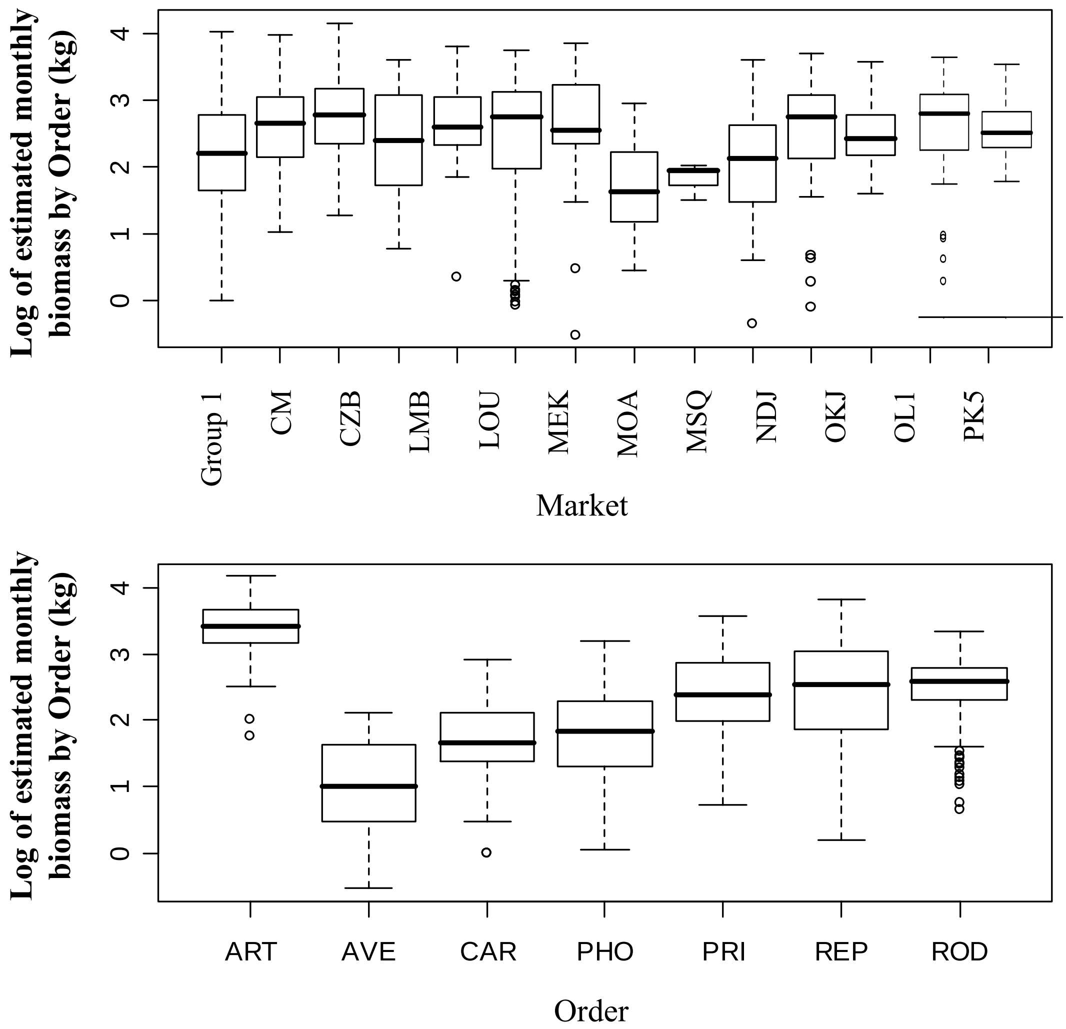


Figure 4.5 Plots showing variation in monthly biomass by Order (below) and variation in monthly biomass by order with markets grouped as significant terms in the model (above). For codes see Table 3.1.

To investigate if there is any difference according to species in the overall biomass by month, lme models were using data restricted to markets sampled in concurrent years[4], using data from one species at a time for a selection of the most important species of varying body size; cane rats (*Thryonomys swinderianus*), porcupines *(Atherurus africanus)*, blue duikers *(Cephalophus monticola)* and red river hog (*Potamocherus porcus*). For each species there is no effect of month and no evidence

[4] Models using the whole data set suffered from missing values for month and year and were uninterpretable.

of a systematic bias in biomass according to month. All four models had no random effects.

Table 4.1 Species biomass variation model results. Plots of fitted values vs residuals for red river hog indicated the model was underestimating small and large values of biomass and slightly overestimating the middle. This would indicate that this model is not explaining the most possible variation in biomass. Given that this model answers the research question at hand, this will not be taken further, for example, fitting quadratic terms or non-linear models.

Species	*Model Statistics*	*Significance*
Brush tailed porcupine	$F_{(4,138)} = 87.32$ Adjusted $r^2 = 0.71$	p <<0.001
Red river hog[5]	$F_{(5,137)} = 35.99$ Adjusted $r^2 = 0.55$	p <<0.001
Cane rat	$F_{(1,77)} = 100.3$ Adjusted $r^2 = 0.56$	p <<0.001
Blue duiker	$F_{(3,135)} = 49.79$ Adjusted $r^2 = 0.51$	p <<0.001

Results from the models for biomass, price, Order and species composition in this section indicate no systematic bias according to month in any of the market data. The uneven sampling of months at any market should not affect the validity of results as month has no effect detectable here on biomass, price or species composition in the markets. There is also no evidence here for any seasonal changes in any of these characters. There is, however evidence that uneven sampling of markets from year to year may impact on validity of results. The following analyses (section 4.3 onwards) are conducted on markets with data from concurrent years.

4.2 Detecting changes in seller behaviour according to interventions

Figure 4.6 indicates the dates of interventions by the Ministry Eaux et Forets in Mont-Bouet market in Libreville (arrows) in 2001 and 2003. In 2001 there was a single inspection in March, then a series of inspections beginning in late July and continuing through August and September with seven inspections during that period. In March

[5] Plots of fitted values vs residuals indicated that the model was underestimating small and large values of biomass and slightly overestimating the middle. This would indicate that there is some sort of non-linear trend in the red river hog data and that this model is not explaining the most possible variation in biomass. Given that this model answers the research question at hand, this will not be taken further, for example, fitting quadratic terms or non-linear models.

2001 in Oyem at the market Carrefour Monaco there was a seizure of bushmeat by the police (Gendarmerie) (Figure 4.7). Together these charts indicate responses (or lack of responses) to inspections and seizures by market sellers of bushmeat. There is a large amount of variation in monthly biomass, but any association with interventions is not strongly evident.

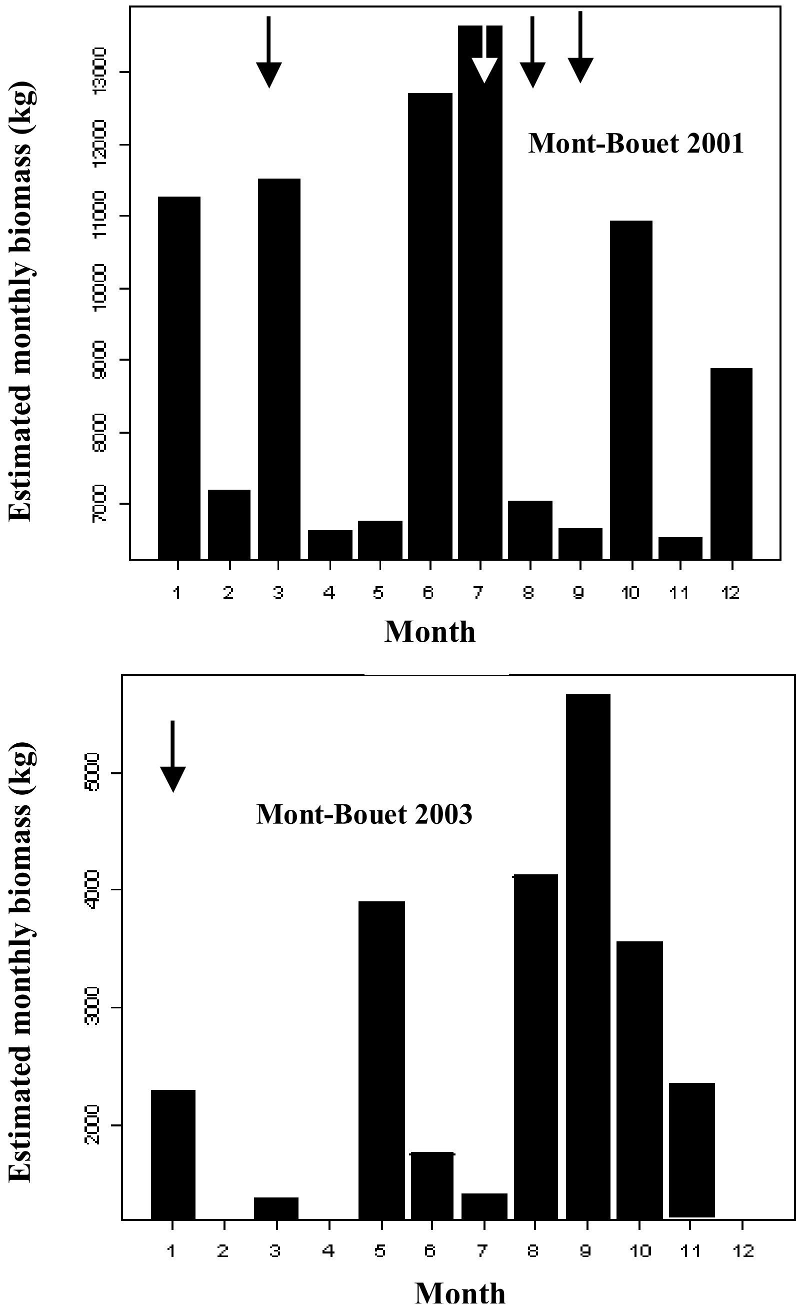


Figure 4.6 Trade volumes of bushmeat through 2001 and 2003 at Mont-Bouet market in Libreville. Instances of market inspections are indicated by arrows.

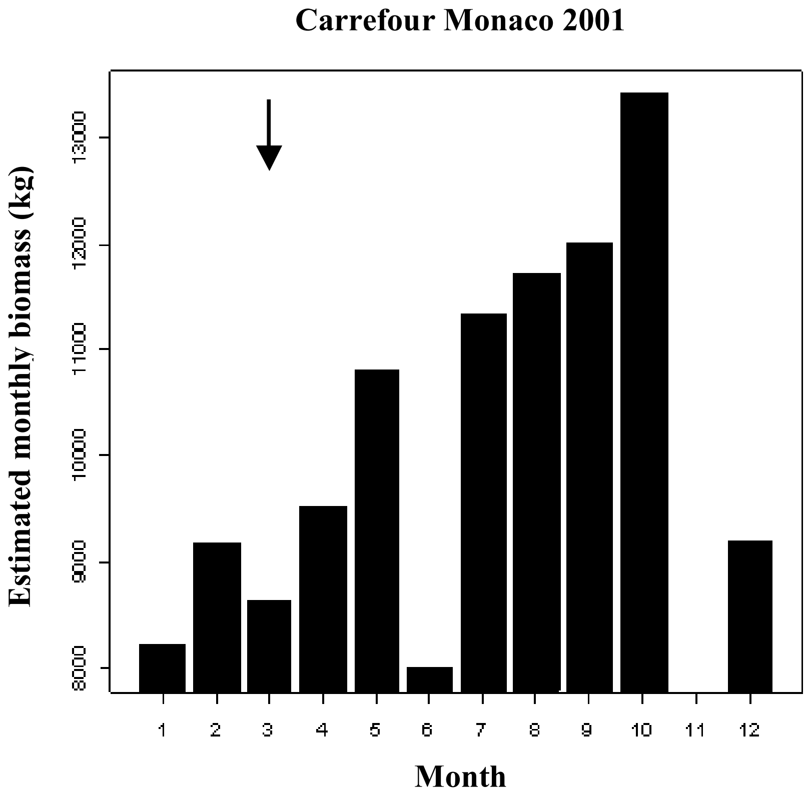


Figure 4.7 Trade volumes of bushmeat at Carrefour Monaco market in Oyem in 2001.

4.3 Trends in bushmeat markets through time and space

4.3.1 Biomass and price

The following analyses used data from markets with four or more concurrent years[6] to account for sampling of markets unevenly across the years. The markets to be compared are Afane (Makoukou), Carrefour Monaco (Oyem), Pottos (Franceville), Mont-Bouet (Libreville) and Gare Routiere (Okondja). To test for differences over time in the biomass sold (Figure 4.8), the estimated annual biomass of each year at each of the five markets was used as the response variable in a linear mixed effects model with year and market as fixed and random effects[7].

[6] 2006 and 2003 were only surveyed for 2 of the five markets, so these were left out of analyses.
[7] Sample size was not large enough to fit interaction terms

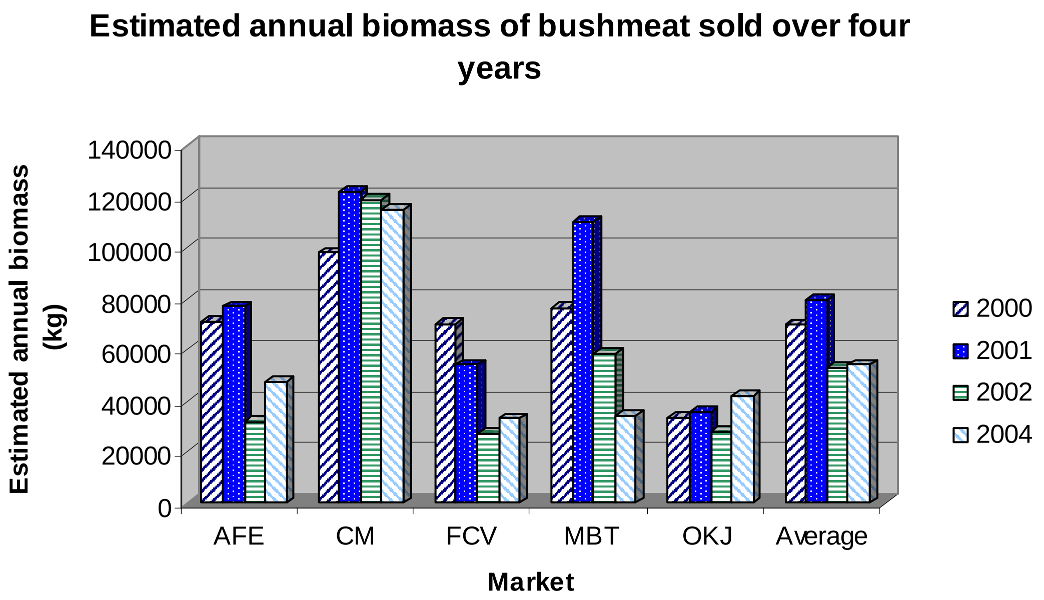


Figure 4.8 Estimated annual trade volumes 2000-2004 at Afane (Makoukou), Carrefour Monaco (Oyem), Pottos (Franceville), Mont-Bouet (Libreville) and Gare Routiere (Okondja).

Through simplification the random effects were eliminated. Year did lend explanatory power to the model, indicating that there is a difference through the years in the annual biomass being sold. Combining levels of year yielded 2 groups that were different to each other, 2000-1 and 2002/4. As shown in Figure 4.8 and Figure 4.9, the volume appears to have decreased over that time. It is worth noting, however, that at Carrefour Monaco it is increasing (Figure 4.8). Market groups only aggregated without compromising the model by one level. Afane and Mont-Bouet combined to a group that was significantly different to Carrefour Monaco and Gare Routiere. Pottos was not significantly different but did not combine with any other market. Figure 4.8 shows that Carrefour Monaco has the largest annual trade and Gare Routiere the smallest. Overall the highly significant model explained a large amount of the variation in annual biomass (adjusted r^2= 0.72, $F_{(4,15)}$= 13.19, $p<<0.001$).

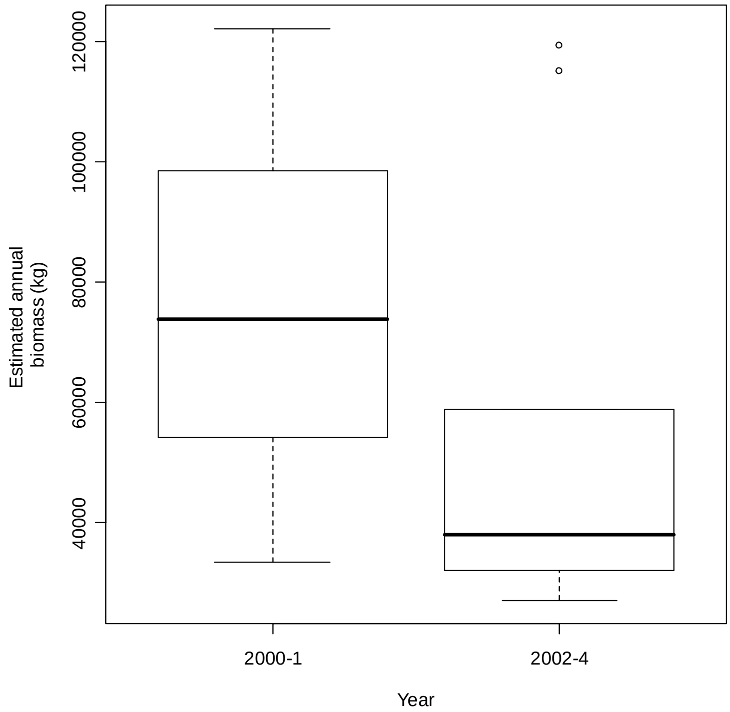


Figure 4.9 Difference in annual trade volume between 2000-1 and 2002/4.

Variations in price per kg over time were analysed using the same 5 markets (Figure 4.10) in a linear mixed-effects model with average price per kg as the response variable with year and market as fixed and random factors. Year did not lend any explanatory power to the model indicating that there is no real variation in price according to year. The model of price per kg as a function of market explained a fair but not overwhelming amount of variation in price (adjusted r^2=0.53, $F_{(1,18)}$= 22.65, $p<0.001$). It is clear that although there are significant differences between these two groups of markets (Figure 4.11) in price per kg, there is also a good deal of variation that is due to factors not taken into account in this model.

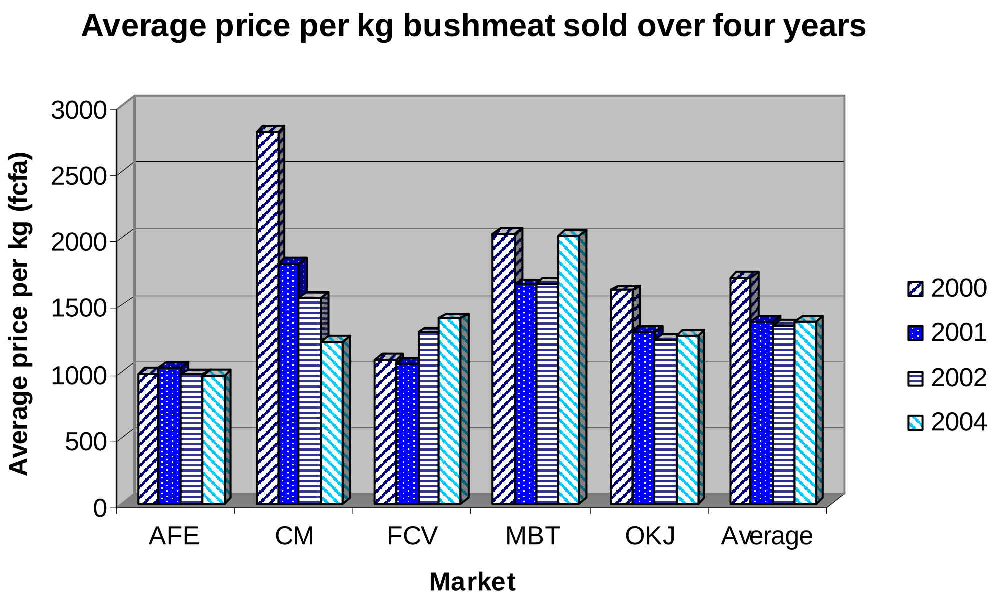


Figure 4.10 Average prices 2000-2004 at Afane, Carrefour Monaco, Pottos, Mont-Bouet and Gare Routiere.

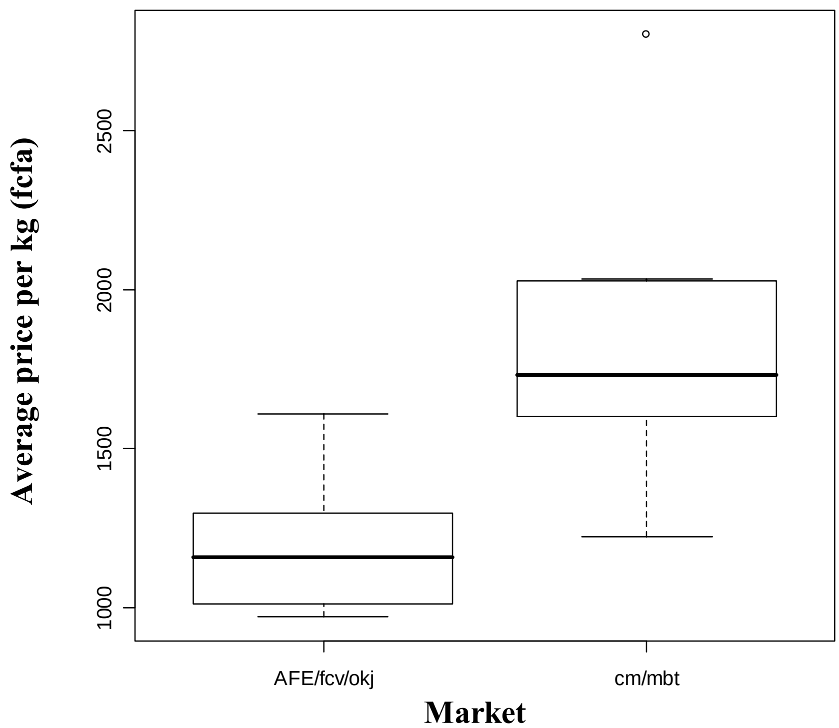


Figure 4.11 Difference in average price per kg of bushmeat 2000-2004, Afane groups with Pottos and Gare Routiere while Carrefour Monaco groups with Mont-Bouet.

4.3.2 Species and Order composition

Table 4.2 shows an approximation of the species diversity passing through each of the five markets sampled between 2000 and 2004. Table 4.3 shows the ten most sold species by biomass at these markets and their IUCN and Gabonese protection status. It is also worth noting from Table 4.3 that of the common species occurring, sitatunga and bay duiker are near threatened under IUCN status, red river hog, dwarf crocodile, sitatunga and water chevrotain are protected under Gabonese law.

Table 4.2 Number of species passing through each market annually and overall through the survey period. Number of Red Listed species are also shown. The Obiri villages are included for comparison as a village unit although this particular sample does not cover 4 years. Mont-Bouet and Gare Routiere were sampled in 2006 but the species count was low, probably due to a smaller sampling period so this year was left out when calculating mean species count per year.

	Market					
	Mont-Bouet (Libreville)	*Carrefour Monaco (Oyem)*	*Pottos (Franceville)*	*Gare Routiere (Okondja)*	*Afane (Makoukou)*	*Villages Obiri*
Settlement Type	Capital	Large town	Large town	Small Town	Small Town	Village
Average Species count per year	49.2	51.5	29.5	34.25	24.5	23
Species count overall	84	74	54	52	44	23
Redlisted species count	**23**	**17**	**15**	**12**	**13**	**7**
	12	9	9	9	6	6
NT	8	6	5	2	7	1
VU	1	1	1			
EN	2	1		1		
CR						

Table 4.3 Top 10 species by percentage biomass of the overall biomass at the 6 markets listed in Table 4.2

Top 10 species	*% of biomass*	*IUCN status*	*Gabon protected status*
Bay duiker	9.1	Lower rist/near threatened	Not protected
Red river hog	8.1	Lower risk/least concern	Partially protected
Blue duiker	7.6	Lower risk/least concern	Not protected
Peter's duiker	7.2	Lower risk/least concern	Not protected
Brush-tailed porcupine	6.5	Least concern	Not protected
Dwarf crocodile	5.5	Vulnerable	Partially protected
Sitatunga	5.3	Lower risk/near threatened	Partially protected
Tree pangolin	2.7	Lower risk/least concern	Not protected
Moustached guenon	1.7	Lower risk/least concern	Not protected
Water chevrotain	1.5	Data deficient	Totally protected

4.3.3 Average body mass

Changes in the average body mass of individuals in market assemblages over time are taken in the literature to indicate, in the event of a decrease in average body size, a depletion in the larger bodied, slower reproducing species (Cowlishaw et al., 2005b; Jerozolimski and Peres, 2003). Changes in average body mass were investigated using data aggregated by month from the reduced data set comparing 5 markets over 4 consistent years. The minimum adequate model did not contain year, indicating that there is no change in body mass over time. The model of average body size as a function of market explained a good deal of variation in average body mass (adjusted $r^2 = 0.70$, $F_{(3,145)}=113.6$, $p<<0.001$). Mont-Bouet grouped with Gare Routiere and Carrefour Monaco but all others remained different. Figure 2.1 shows that average body mass is high at Afane and low in the aggregated group.

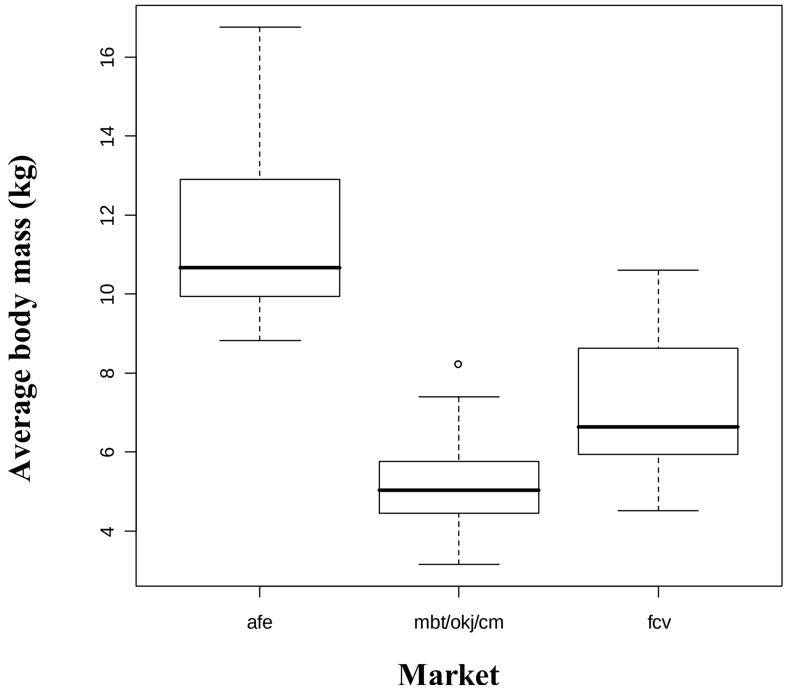


Figure 4.12 differences in average body mass of species at Afane, Mont-Bouet, Gare Routiere, Carrefour Monaco and Franceville.

5 Socioeconomic and consumption data analysis

Summary

This section of analysis addresses the contrasting of consumptive behaviour of households between regions and associations with socioeconomic circumstances, consumption of alternatives and price of alternatives to bushmeat. Means and volumes of consumption are presented. Socioeconomic and geographical factors potentially predicting consumption and consumption quantities across Gabon are investigated along with relationships between price, income and variation in consumption quantities. This section concludes with addressing the composition and origin of bushmeat in household consumption. See Appendix IV for coefficients tables of models.

5.1 Describing consumption of bushmeat and alternatives

After truncation of the data removing outliers the mean consumption amounts of the alternative meat fish types were calculated for the overall sample of 1649 households across Gabon (Table 5.1). It is notable that there is a definite change in the bushmeat mean, stated as 0.08kg per AME per day in Wilkie et al (2005), to 0.052 kg per AME per day using the same dataset. This is due to differences in truncation of the data. See Appendix II for details.

Table 5.1 Consumption quantities of bushmeat and alternative sources of animal protein in the whole sample.

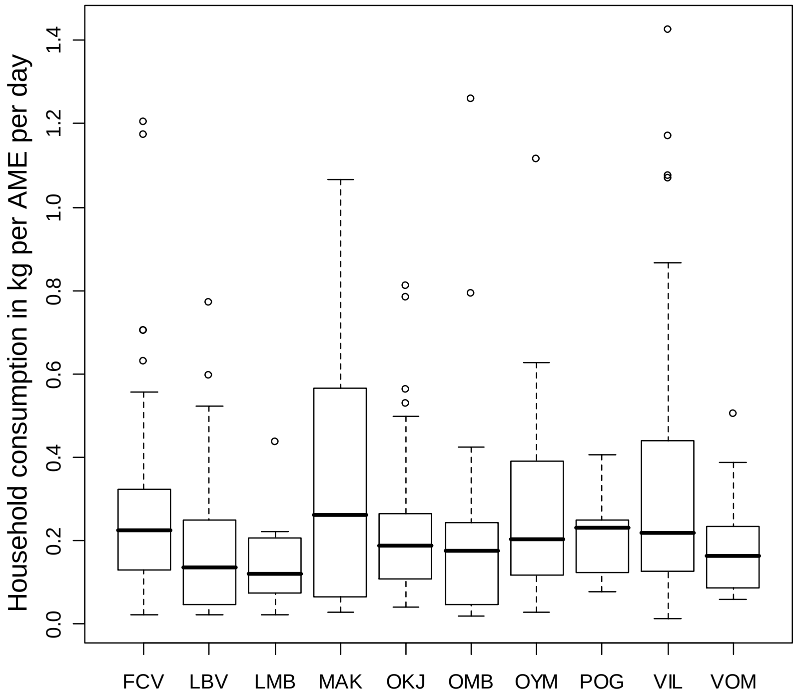
Meat Type	Total Kg	Avg. Kg per AME per day
Domestic meat	1068.2	0.047
Bushmeat	1421.8	0.052
Freshwater fish	671.0	0.029
Sea fish	3281.6	0.143
Poultry	2451.1	0.107
All meat/fish	8893.7	0.378

Table 5.2 shows the means of meat and fish consumption amounts per AME per day at each town. Figure 5.1 shows the range of values and mean values for the bushmeat consumption amounts at the different locations. These figures show that overall sea fish is the most important food type followed by poultry, and comparatively much smaller amounts of bushmeat, domestic meat and freshwater fish are consumed. It is clear that these overall trends vary considerably by location, for example comparatively little sea fish is consumed in Lambarene, Makoukou and inland villages, the latter two show higher consumption of bushmeat than the overall mean while freshwater fish dominates the former.

Table 5.2 Mean consumption in kg per AME per day of bushmeat and alternatives for each of the surveyed towns with 95% range shown

Town	*N*	*Average consumption[8] amount in kg per AME per day*				
		Livestock	Bushmeat	Freshwater fish	Sea fish	Poultry
Franceville	214	0.047 (0.015-0.587)	0.061 (0.030-1.173)	0.027 (0.010-0.378)	0.129 (0.028-1.076)	0.097 (0.039-1.510)
Libreville	515	0.101 (0.071-2.756)	0.013 (0.019-0.751)	0.009 (0.018-0.704)	0.253 (0.122-4.374)	0.189 (0.097-3.779)
Lambarene	111	0.016 (0.007-0.287)	0.020 (0.011-0.425)	0.076 (0.017-0.674)	0.011 (0.004-0.171)	0.064 (0.029-1.134)
Makoukou	101	0.002 (0.002-0.092)	0.108 (0.027-1.041)	0.007 (0.004-0.156)	0.013 (0.003-0.130)	0.024 (0.007-0.283)
Okondja	103	0.008 (0.010-0.378)	0.092 (0.020-0.792)	0.006 (0.003-0.120)	0.077 (0.010-0.384)	0.024 (0.010-0.407)
Ombooue	76	0.020 (0.008-0.299)	0.056 (0.031-1.23)	0.129 (0.018-0.719)	0.129 (0.020-0.787)	0.107 (0.116-4.534)
Oyem	151	0.017 (0.006-0.217)	0.066 (0.028-1.087)	0.012 (0.015-0.567)	0.105 (0.020-0.780)	0.116 (0.058-2.267)
Port Gentil	142	0.053 (0.020-0.762)	0.008 (0.010-0.397)	0.020 (0.013-0.493)	0.134 (0.048-1.889)	0.117 (0.028-1.093)
Villages Inland	158	0.000 (0.001-0.059)	0.164 (0.035-1.390)	0.017 (0.010-0.378)	0.030 (0.013-0.497)	0.008 (0.009-0.375)
Villages Coastal	78	0.017 (0.029-1.134)	0.027 (0.013-0.491)	0.140 (0.024-0.937)	0.233 (0.032-1.260)	0.039 (0.039-1.511)
Overall	1649	0.047	0.052	0.029	0.143	0.107

8 These are overall means where zero values of consumption have been included.



Town

Figure 5.1 Household consumption amounts per AME per day according to location. Means to not reflect overall means, this graph shows the distribution of positive consumption values as including zeros brought boxes down to the zero level and masked the variation.

5.1.1 Volumes of bushmeat consumption

Using census statistics and the above consumption figures it is possible to estimate the national volume of bushmeat consumption. There is considerable doubt surrounding the validity of official census statistics for Gabon. Fortunately this was an issue tackled in an earlier study of the region (Starkey, 2004), where UNHABITAT (1999) projections of population growth were used to estimate 2002 population statistics under four differing scenarios from an earlier more reliable official census conducted in 1993. The four scenarios were based on high and low urban and rural growth where the growth figures were augmented to account for possible error (underestimate and overestimate) in population growth rates. Income categories as a proxy for socioeconomic category in Starkey (2004) are;

1. Income less than1US$ppp (purchasing power parity) per day
2. Income 1-3 US$ ppp per day
3. Income 3-10 US$ ppp per day
4. Income >10US$ ppp per day

In order to apply the population statistics in Starkey (2004), the household consumption amounts were also calculated with these categories. The comparable settlement groupings of Libreville, large town, small town and village approximate the categories Metropolis, Large town, Market town and Rural in Starkey (2004). Results are shown in Table 5.3 where the highest and lowest population growth estimates are used to give an upper and lower estimate of population and consumption.

The lowest income category in villages consumed by far the most bushmeat of any location/income group. Although per AME consumption is not highest in this group, the population is large, and it is also notable that the observed shift in consumption income to category 2 is due to smaller population and not per AME consumption. It is clear from the figures in Table 5.3 that the distribution of amounts of consumption are not only different between regions, as shown above, but relationships within regions between income and consumption differ in direction. In each settlement type income category 2 has higher mean per AME consumption than category 1. However, in small towns, large towns and Libreville, there is a general trend of higher consumption at higher income categories, whereas in the villages consumption increases to the middle income range and then decreases at the higher end. Modelling the variation in bushmeat consumption (per AME per day) as a function of settlement type and income category produced a highly significant model ($F_{(15,1633)}= 11.26$, $p<< 0.001$) but explained little variation (adjusted $r^2= 0.09$). Settlement types small town and village differ in mean consumption amount from the capital. Income categories showed no difference, however there was a significant interaction between small town and income category 4, which is the highest of all per AME consumption quantities. This indicates that the differences seen between categories do not reach statistical significance, however the patterns within location are still evident and are investigated later.

Table 5.3 Consumption volumes of bushmeat calculated using population figures from Starkey (2004) and mean consumption amounts for levels of socioeconomic category calculated in this study.

Town and income category	Population estimate (AMEs)		Bushmeat kg per AME per day	Annual Total Biomass Consumption (kg)		% of total consumption		% of Libreville consumption	
	High	Low		High	Low	High	Low	High	Low
Libreville	**449,871**	**343,351**	**0.013**	**2,814,435**	**2,148,034**	**14.3**	**14.3**		
1	*62,982*	*48,069*	*0.003*	*68,965*	*52,636*	*0.4*	*0.3*	*2.5*	*2.5*
2	*98,972*	*75,537*	*0.006*	*216,749*	*165,426*	*1.1*	*1.1*	*7.7*	*7.7*
3	*179,948*	*137,340*	*0.031*	*2,036,112*	*1,554,002*	*10.3*	*10.3*	*72.3*	*72.3*
4	*112,468*	*85,838*	*0.012*	*492,610*	*375,970*	*2.5*	*2.5*	*17.5*	*17.5*
Large towns	**306,665**	**234,053**	**0.043**	**4,823,152**	**3,681,155**	**24.5**	**24.3**		
1	*70,532*	*53,832*	*0.024*	*617,860*	*471,568*	*3.1*	*3.1*		
2	*73,599*	*56,173*	*0.079*	*2,122,227*	*1,619,748*	*10.8*	*10.7*		
3	*91,999*	*70,216*	*0.026*	*873,071*	*666,350*	*4.4*	*4.4*		
4	*70,533*	*53,832*	*0.047*	*1,209,994*	*923,488*	*6.1*	*6.1*		
Small towns	**156,735**	**119,623**	**0.100**	**5,007,418**	**3,821,754**	**25.4**	**25.2**		
1	*68,963*	*52,634*	*0.052*	*1,308,918*	*998,993*	*6.6*	*6.6*		
2	*34,482*	*26,317*	*0.091*	*1,145,320*	*874,119*	*5.8*	*5.8*		
3	*40,751*	*31,102*	*0.019*	*282,608*	*215,692*	*1.4*	*1.4*		
4	*42,318*	*32,298*	*0.147*	*2,270,572*	*1,732,949*	*11.5*	*11.4*		
Villages	**177,667**	**138,602**	**0.103**	**7,058,083**	**5,506,144**	**35.8**	**36.3**		
1	*122,590*	*95,635*	*0.103*	*4,608,771*	*3,595,398*	*23.4*	*23.7*		
2	*26,650*	*20,790*	*0.0142*	*1,381,270*	*1,077,546*	*7.0*	*7.1*		
3	*13,325*	*10,395*	*0.117*	*569,044*	*443,918*	*2.9*	*2.9*		
4	*16,878*	*13,167*	*0.081*	*498,998*	*389,282*	*2.5*	*2.6*		
Gabon	**1,090,938**	**835,630**	**0.052**	**19,703,088**	**15,517,087**				

5.2 Exploratory analyses of factors determining consumption and non-consumption of bushmeat

Multivariate models are the appropriate tool to investigate the relationships between location, alternatives, socioeconomic variables and bushmeat consumption. The number of survey days were controlled for in multivariate analyses by using number of survey days per household as an additional variable. Multivariate models of bushmeat consumption (logistic regression with consuming/not consuming bushmeat as the response), were attempted with variables selected on the basis of *a priori* expectations of the more important variables (geographical category), further models attempted grouping variables in several different models. All suffered from over-parameterisation due to too many factor levels, resulting in models with no explanatory power. It is also possible that the small count of households consuming bushmeat spread over the number of categories implicit in models was not sufficient for variables to show predictive power.

Univariate tests are here used to describe relationships between variables. Due to the prevalence of zero values, bushmeat consumption was first analysed as a binary consumed/did not consume variable. Alternative meat and fish types were added into analyses as binary consumed/did not consume variables initially, then used as continuous in later correlations and regressions.

5.2.1 Relationships between geographical factors and socioeconomic variables

Given that socioeconomic variables are likely to vary in relation to geographical factors, it is prudent to investigate these associations. If it is clear there is a bias in socioeconomic variables according to location, then relationships between socioeconomic circumstances and bushmeat consumption will be confounded with relationships between location and bushmeat consumption.

Table 5.4 Results of tests of association of socioeconomic category and location.

Comparison	χ^2	*p*	Direction of association
Settlement type			
Male occupation	63.52, df = 9	<<0.001	More unemployed in villages, less in capital and large towns
Male education level	242.17, df = 6	<<0.001	A lot more low education in villages, more high education in capital, more middle in large towns
Female occupation	20.16, df = 9	<0.05	Less employed in capital
Female education level	173.40, df = 6	<<0.001	Less low education in capital and large towns, a lot more in villages, more middle education in large towns, a lot less in villages
Coastal/inland			
Male occupation	60.14, df = 3	<<0.001	More employed coastal, more unemployed inland
Male education level	42.09, df = 2	<<0.001	More low education inland
Female occupation	3.05, df = 3	n.s	
Female education level	42.38, df = 2	<<0.001	More low education inland, more middle and high coastal

Occupation and education levels were investigated for association with geographical factors. χ^2 tests confirmed associations and standardised residuals indicate differences as stated in Table 5.4. House type is strongly associated with geographical factors (settlement type; χ^2= 113.9, df = 6, p<<0.001: coastal/inland; χ^2= 63.8, df = 4, p<<0.001) with more than expected of the rich house type in coastal and large towns, more than expected of the middle house type in coastal towns, large towns and the capital and more than expected of the popular house type in inland towns, small towns and villages. One-way anovas and two tailed t tests confirmed that the mean income and wealth in these categories are significantly different (Table 5.5; settlement type and wealth; $F_{(3,1644)}$=183.9, p<<0.001: settlement type and income; $F_{(3,1645)}$=123.3, p<<0.001: coastal/inland and wealth; $t_{(1535)}$ = 11.03, p<<0.001: coastal/inland and income; $t_{(1348)}$= 9.88, p<<0.001).

Table 5.5 Mean wealth and income of geographical categories with 95% range shown.

Geographical category	***Mean wealth (fcfa)***	***Mean income (fcfa)***
Settlement type		
Capital	4,781,287 (33,591-1,310,039)	556,012 (93,941-2,408,750)
Large Town	2,321,856 (15,565-607,045)	355,647 (50,408-1,292,500)
Small Town	1,126,652 (6,801-265,254)	155,238 (25,691-658,750)
Village	681,680 (5,166-501,484)	188,901 (29,738-762,500)
Coastal	3,581,142 (33,606-1,310,644)	477,207 (93,941-2,408,750)
Inland	1,821,576 (15,566-607,054)	235,638 (50,408-1,292,500)

These analyses indicate that there is clear association of socioeconomic category with location, with higher socioeconomic circumstances more prevalent in coastal towns, large towns and the capital and the converse in inland towns, small towns and villages. The association of these categories and bushmeat consumption may reflect either the effect of location on consumption or the effect of socioeconomic category on consumption.

5.2.2 Associations between geographical variables and bushmeat consumption

1330 households did not consume bushmeat during the survey with 319 consuming bushmeat during the survey. Towns were aggregated according to two geographical categorisations (settlement type and proximity to coast – described in methods). As expected the capital, large towns and coastal locations show a very small proportion consuming bushmeat, while the inland locations, small towns and villages consumed bushmeat more often (Figure 5.2 and Figure 5.3). χ^2 tests confirm the statistical significance of the associations (Table 5.6).

Table 5.6 Results of $\chi 2$ tests on counts of consumers and non consumers of bushmeat in the geographical categories.

Town categorisation	χ^2	*p*	Direction of association
Settlement type	$\chi^2 = 133.249$, df = 3	<<0.001	More consumers in villages and small towns, more non consumers in capital and large towns
Proximity to coast	$\chi^2 = 141.9602$, df = 2	<<0.001	More consumers inland, more non consumers coastal

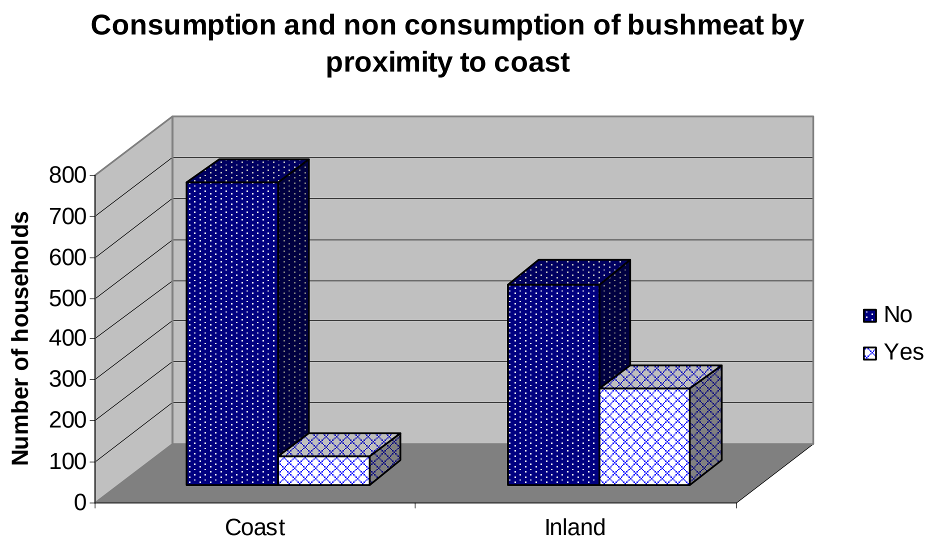


Figure 5.2 Proportions of households in coastal and inland locations consuming and not consuming bushmeat during the survey.

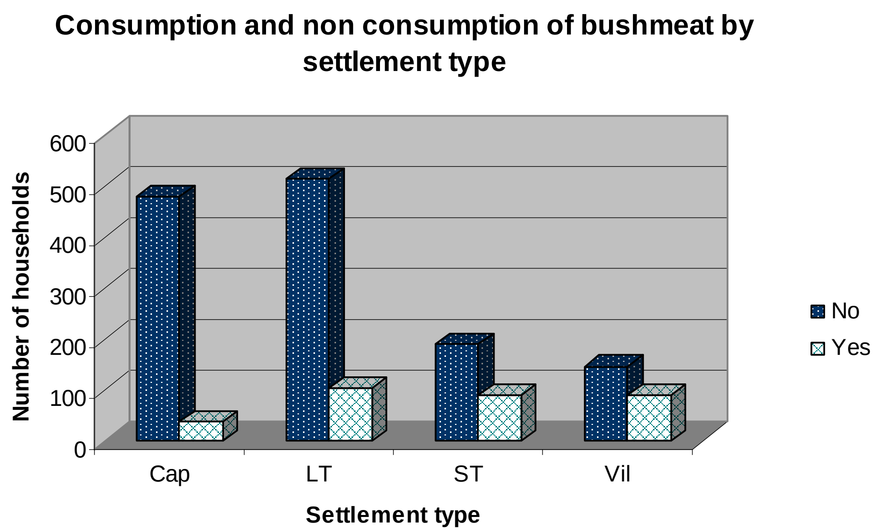


Figure 5.3 Proportions of households in the four settlement types consuming and not consuming bushmeat during the survey.

5.2.3 Associations between socioeconomic variables and bushmeat consumption

Bushmeat consumption (yes or no) was compared with socioeconomic variables in univariate tests, indicating that there is association except in the case of female occupation and mean wealth (Table 5.7).

Table 5.7 Results of tests comparing counts of bushmeat consumers and non-consumers between socioeconomic categories and comparison of mean wealth of consumers and non-consumers. Where χ^2 are significant much of the significance is caused by sensitivity to the large difference between consumers and non-consumers of bushmeat. Standardised residuals indicated the high χ^2 values were as a result there being more non-consumers.

Comparison	*Statistics*	*p*	Direction of association
Employment and education levels			
Male employment	$\chi^2 = 10.68$, df = 3	<0.05	See table caption
Male education	$\chi^2 = 10.74$, df = 2	<0.01	Less consumers in high education category but see table caption
Female employment	$\chi^2 = 5.94$, df = 3	n.s	
Female education	$\chi^2 = 10.84$, df = 2	<0.01	More consumers in lowest category but see table caption
Income category	$\chi^2 = 10.57$, df = 3	<0.05	See table caption
Wealth	$t_{459} = 1.77$	ns	
House type	$\chi^2 = 7.19$, df = 2	<0.05	See table caption

5.2.4 Associations between bushmeat consumption and consumption of alternatives

Important factors in addition to location and socioeconomic category that may be determinants of bushmeat consumption are consumption of alternatives. It is already clear that there are relationships between location, socioeconomic category and consumption of bushmeat, and there are likely to be relationships within these with consumption of alternatives. Figure 5.4-Figure 5.11 show how consumers and non consumers of the alternatives are distributed unevenly across the geographical categories. Domestic meat seems to be important in Libreville, large and coastal towns, with few households elsewhere consuming domestic meat. Sea fish is an important resource everywhere, with a very large proportion of households in Libreville consuming sea fish. Freshwater fish is consumed by a small proportion of households in all categories[9]. Poultry appears to be an important food for households

[9] The towns on large freshwater deltas where freshwater fish is consumed in larger quantities than elsewhere (Lambarene, Ombooue and Coastal villages) are most likely swamped in the coastal and large town categories by the low proportion of freshwater fish consumption in the capital, which is also coastal (Table 5.2).

in the larger towns and Libreville. It is also worth noting that overall the only meat/fish type that was consumed more often than not in all geographical categories was sea fish, which supports the contention that this is an important food resource across Gabon.

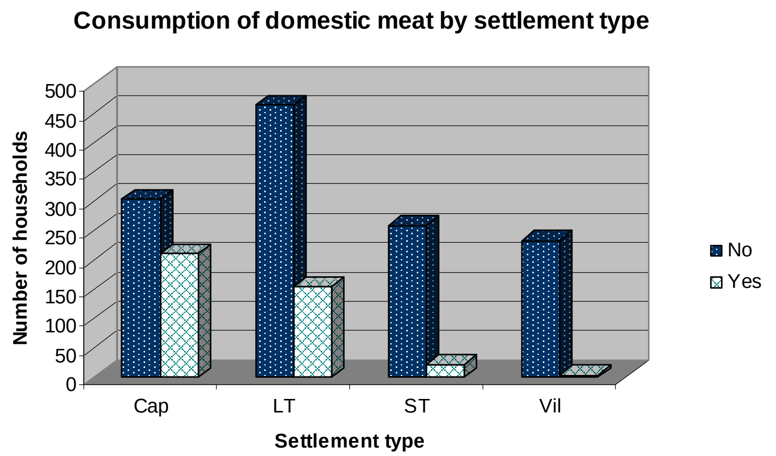


Figure 5.4 Chart showing the distribution of consumers and non-consumers of domestic meat by settlement type.

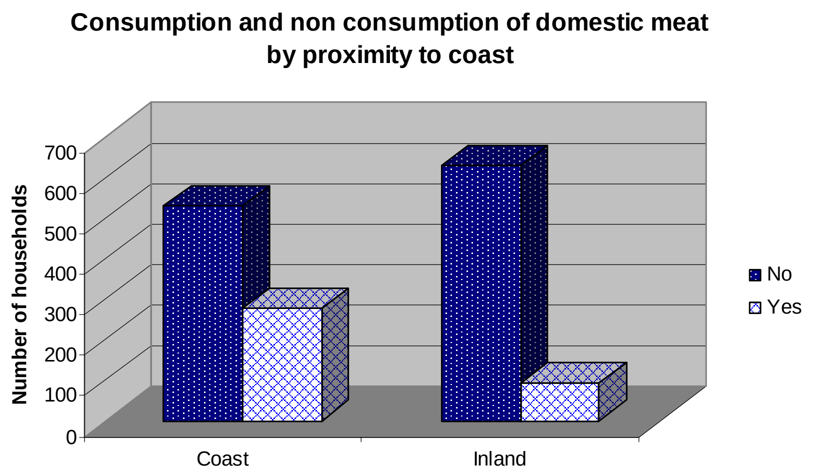


Figure 5.5 Chart showing the distribution of consumers and non-consumers of domestic meat by coastal/inland category.

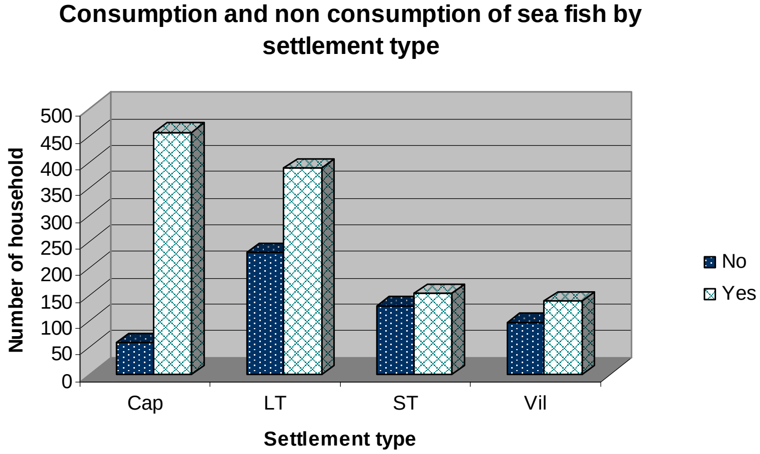


Figure 5.6 Chart showing the distribution of consumers and non-consumers of sea fish by settlement type.

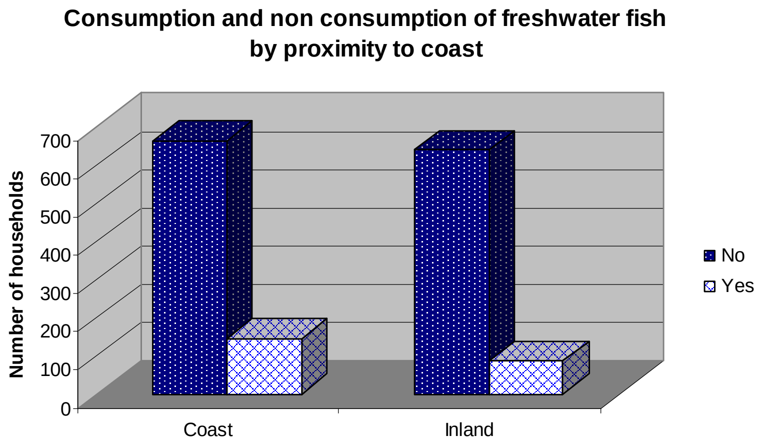


Figure 5.7 Chart showing the distribution of consumers and non-consumers of sea fish by coastal/inland category.

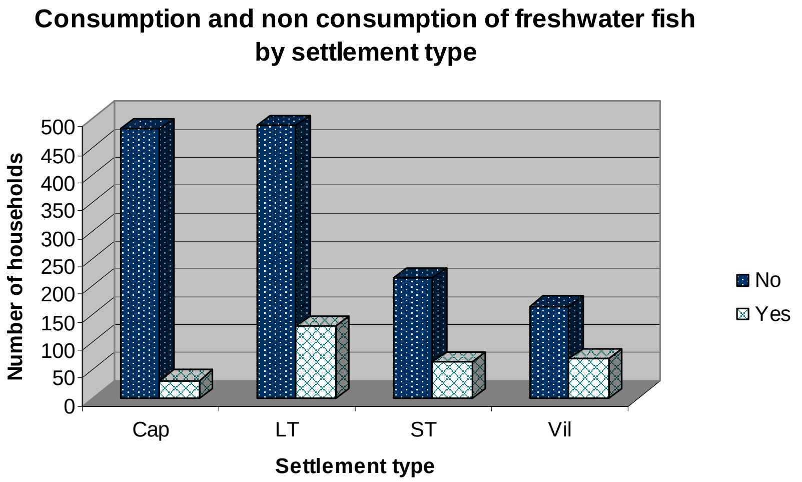


Figure 5.8 Chart showing the distribution of consumers and non-consumers of freshwater fish by settlement type.

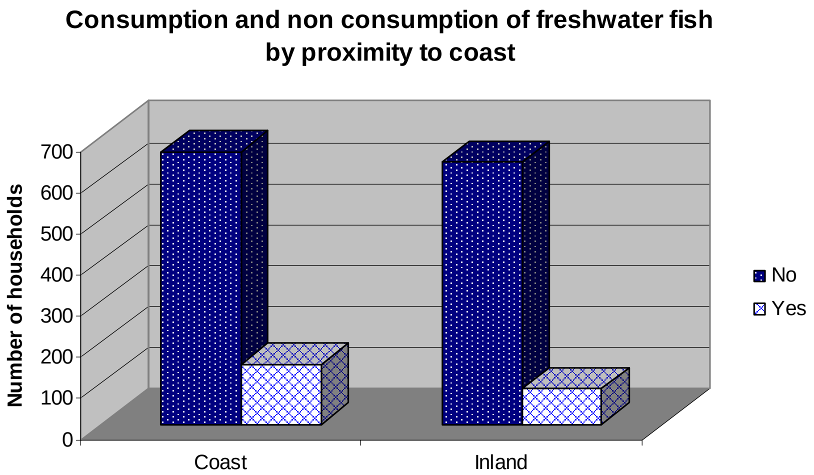


Figure 5.9 Chart showing the distribution of consumers and non-consumers of freshwater fish by coastal/inland category.

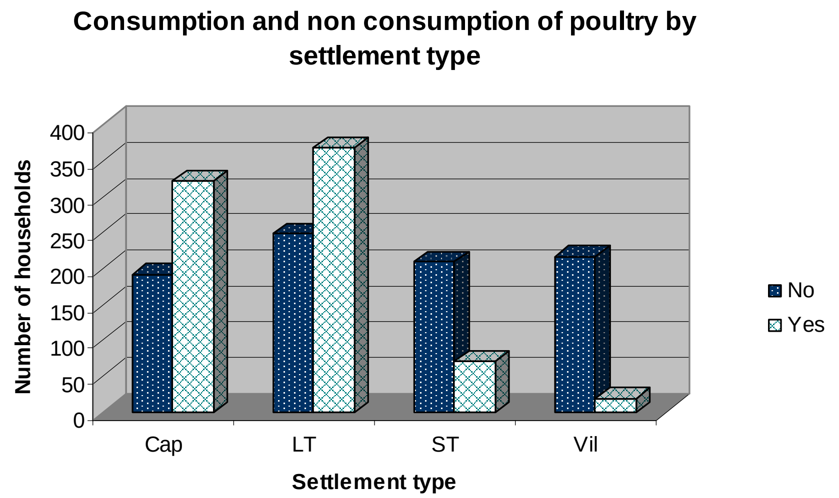


Figure 5.10 Chart showing the distribution of consumers and non-consumers of poultry by settlement type.

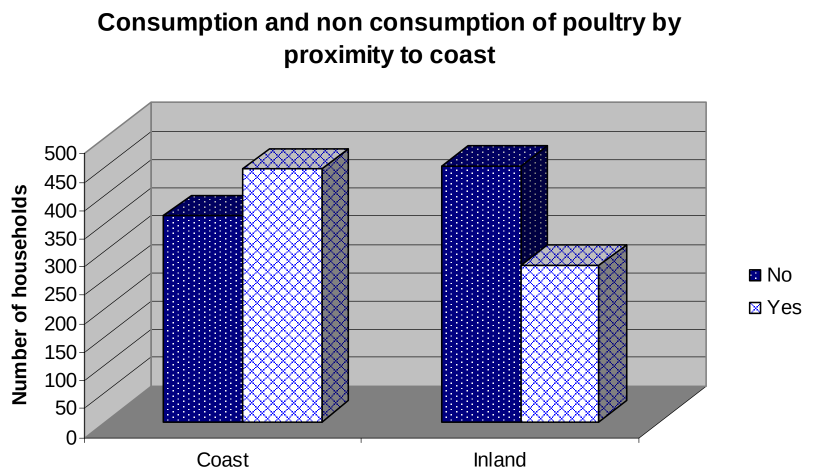


Figure 5.11 Chart showing the distribution of consumers and non-consumers of poultry by coastal/inland category.

Consumption of all alternatives were significantly associated with consumption of bushmeat in χ^2 tests (Table 5.8). The direction of trends indicate that for domestic meat, sea fish and poultry, households consuming bushmeat ate the alternative less often than expected. For freshwater fish the association is the opposite.

Table 5.8 Results of tests of association of bushmeat and alternative consumption/non consumption.

Meat/fish consumption	χ^2 [10]	**p**	Direction of association
Domestic meat	37.5889, df = 1	p<<0.001	Eating bushmeat less likely to eat domestic meat
Sea fish	8.8211, df = 1	p< 0.001	Eating bushmeat less likely to eat sea fish
Freshwater fish	12.7913, df = 1	p< 0.001	Eating bushmeat more likely to eat freshwater fish
Poultry	37.0892, df = 1	p<<0.001	Eating bushmeat less likely to eat poultry

5.3 Relationships between explanatory variables and quantities in consumption

Removing zero values for consumption of bushmeat yields a data set within which the effect of geographic factors, socioeconomic variables and consumption and price of alternatives on amount of consumption can be investigated.

5.3.1 Effects of socioeconomic categories and alternatives on bushmeat consumption quantity

Out of the subset of bushmeat consuming households, mean consumption amounts between geographical categories were found to be significantly different, along with mean consumption amounts between house types (Table 5.9). Wealth, income and employment and education levels showed no difference in mean bushmeat consumption amount.

Pairwise correlations of bushmeat consumption amount and consumption amounts of alternatives indicate that consumption of alternatives is not related to consumption of bushmeat, except in the case of freshwater fish, where less bushmeat is consumed with higher consumption amounts of freshwater fish (Figure 5.12).

[10] Yates' continuity correction was employed for all two-by-two tables.

Table 5.9 Results of tests of differences in means and correlations of bushmeat quantities consumed and geographical and socioeconomic categories.

Explanatory variable	Mean[11] kg per AME per day (95% range)	Statistic	p
Settlement type			
Capital	0.189 (0.019-0.731)	$F_{(3,315)} = 2.71$	<0.05
Large Town	0.257 (0.030-1.151)		
Small Town	0.279 (0.026-1.014)		
Village	0.301 (0.035-1.379)		
Coastal/inland			
Coastal	0.206 0.031-1.211)	$t_{302} = -3.47$	<0.001
Inland	0.295 (0.035-1.379)		
Wealth		Spearman rank correlation	ns
Income		Spearman rank correlation	ns
Employment and education level			
Male employment		One-way anova	ns
Male education		One-way anova	ns
Female employment		One-way anova	ns
Female education		One-way anova	ns
House type		$F_{(2,216)} = 3.101$	<0.05
A	0.297 (0.0120-0.764)		
B	0.243 (0.030-1.155)		
C	0.260 (0.0354-1.379)		

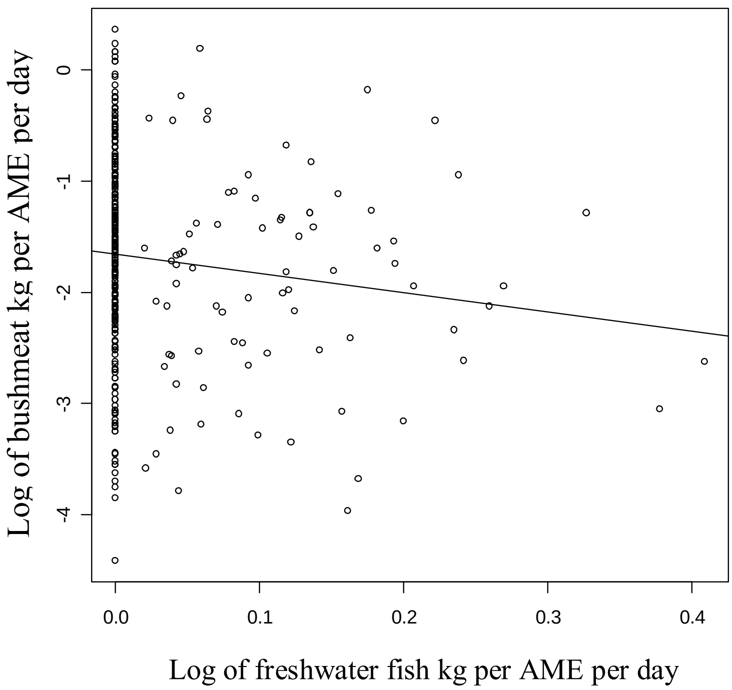


Figure 5.12 Graph showing relationship of freshwater fish consumption quantity and bushmeat consumption quantity. Spearman rank correlation rho = -0.136, p<0.05.

[11] Means do not reflect overall consumption means as positive values only are used.

Correlation of bushmeat consumption quantity and price of bushmeat showed a negative relationship (Figure 5.13), where less bushmeat is consumed at higher prices. Correlations of bushmeat consumption with prices of alternatives showed no relationship except freshwater fish, where more bushmeat is consumed at higher prices of freshwater fish (Figure 5.14).

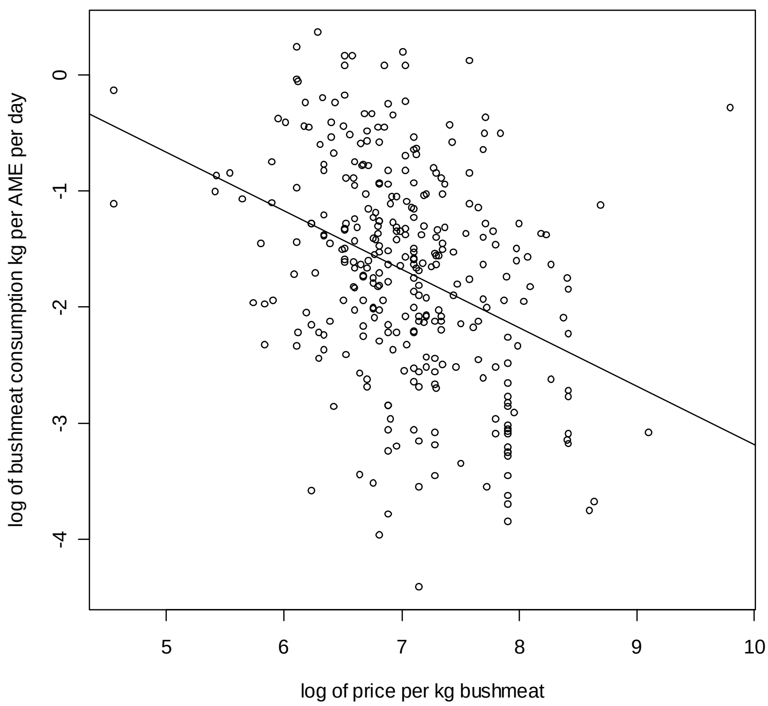


Figure 5.13 Graph showing the relationship between consumption quantity and price of bushmeat. Spearman rank rho = -0.375, p<<0.001.

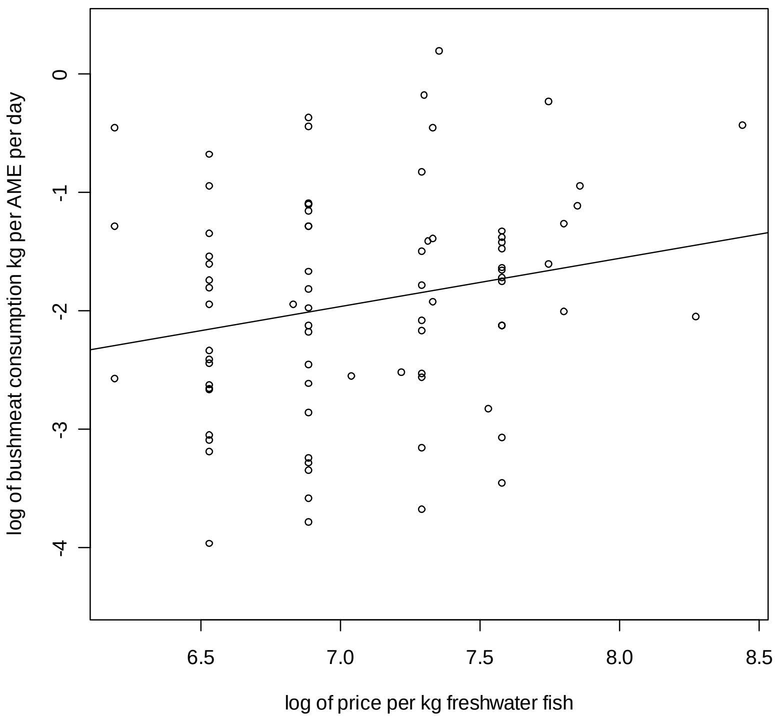


Figure 5.14 Graph showing relationship of bushmeat consumption quantity and price of freshwater fish. Spearman rank rho = 0.232, p<0.05.

To describe the variation in bushmeat consumption amount a generalised linear model of all variables with *a priori* reasons for presumed importance was built. Both geographical categorisations, price per kg of bushmeat and freshwater fish and consumption amount of freshwater fish were the covariates in the maximal model, quadratic terms were included. The minimum model described consumption quantity of bushmeat as a function of price per kg of freshwater fish and settlement type, all terms were highly significant. The model was significant ($F_{(4,75)}=4.58$, $p<0.01$) but overall explained only a small amount of variation in amount of bushmeat consumed by consumers ($r^2=0.15$). It is notable that of the chosen set of variables, price of freshwater fish was the only price/alternative predictor of bushmeat consumption.

5.3.2 Analyses of relationships between price, wealth and consumption within location

Given that prior studies have focussed on the general patterns across broad geographical regions or the urban-rural divide, the variations in quantity of bushmeat consumed with price and wealth will here be addressed according to geographical category, to see if there are discernible patterns that differ between these categories as indicated above in the calculated consumption volumes.

To investigate the within region variation in consumption quantity with price and wealth, the data set was broken down to each settlement type category. Models initially contained number of survey days this but was removed where found not to significantly affect consumption quantity. Quadratic terms were fitted to account for any discernible non-linear trend in variation of consumption quantity.

Libreville: The regression of price of bushmeat against consumption quantity indicated that there was a significant negative relationship between price and consumption, as price increases, consumption quantity decreases (Figure 5.15). The model only describes a small amount of the variation in consumption quantity, indicating influences not accounted for by this model ($F_{(1,34)}$=4.32, $p< 0.05$, adjusted r^2=0.09). The regression of wealth against consumption quantity found no significant relationship. Quadratic terms were non-significant in all cases.

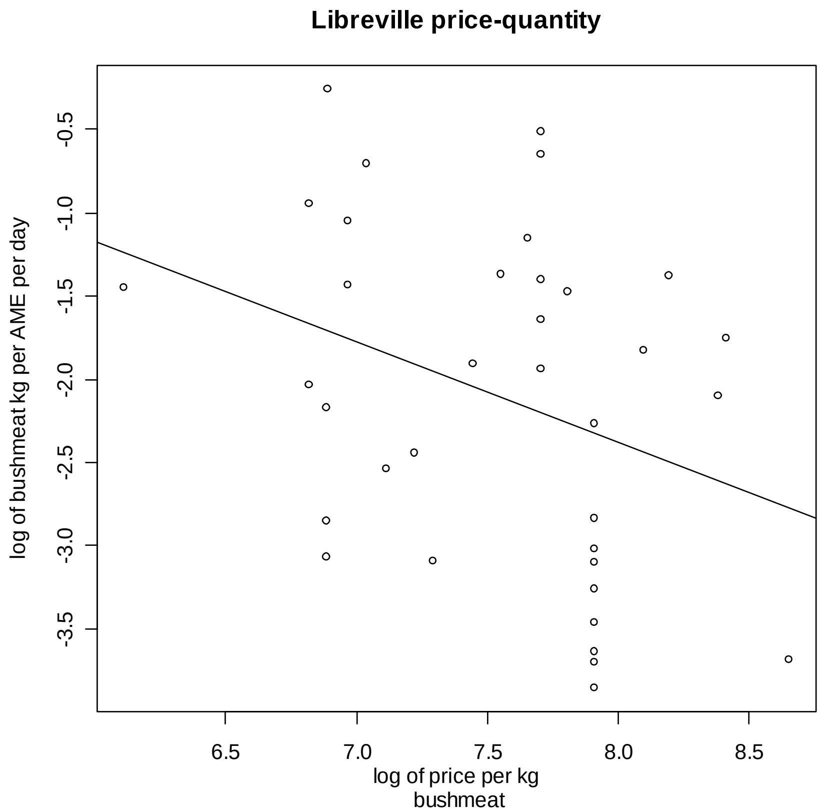


Figure 5.15 Graph showing the significant negative relationship between price and consumption quantity of bushmeat among consumers in Libreville.

Large Towns: Regression of price of bushmeat against consumption quantity indicates that there is a significant linear relationship, although the model explained only a small portion of the variation in consumption quantity ($F_{(1,101)}$ =12.87, p<0.001, r^2= 0.10) (Figure 5.15). There was no significant relationship of wealth and consumption quantity.

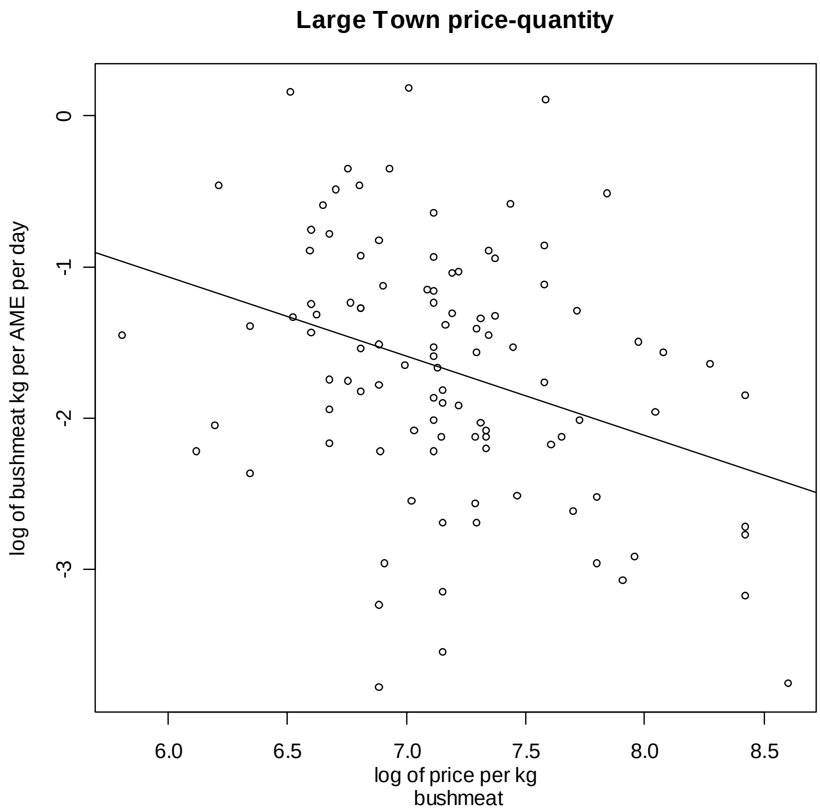


Figure 5.16 Graph of relationship between consumption quantity and price of bushmeat in large towns.

Small Towns: The model describing consumption quantity with price retained linear, quadratic and interaction terms between price, price squared and number of survey days and explained a greater amount of variation in consumption quantity than for other regions ($F_{(7,65)}$ = 4.011, p<0.001, adjusted r^2 = 0.23). Graph is not shown here as model prediction line is difficult to visualise on two axes. Wealth also showed no significant relationship

Villages: The regression of price and consumption quantity simplified to include only the linear price term and explained a fair proportion of consumption quantity variation but was highly significant ($F_{(1,105)} = 27.7$, $p<<0.001$, adjusted $r^2 = 0.20$) (Figure 5.17). Wealth explained no variation in consumption quantity.

Figure 5.17 Graph of the relationship between consumption quantity and price of bushmeat in villages.

5.4 Origin and composition of bushmeat in consumption

5.4.1 Composition of bushmeat in household consumption

Overall 31 species were recorded in the household survey (for a full list see Appendix I) with the few standout important species accounting for the majority of consumption (Table 5.10). It is notable here that the most consumed species, red river hog, are partially protected under Gabonese law, and the giant pangolin is totally protected.

Bushmeat consumed in the survey was made up of almost 91% artiodactyls and rodents with few other Orders playing any significant part (Figure 5.18).

Table 5.10 Contribution of important species to biomass in consumption.

Species	% of overall biomass in consumption
Red river hog	21.8
Blue duiker	19.6
Brush tailed porcupine	19.5
Duiker unknown	13.4
Bay duiker	7.3
Moustached guenon	2.8
Giant pangolin	2.1
Peter's duiker	2.1

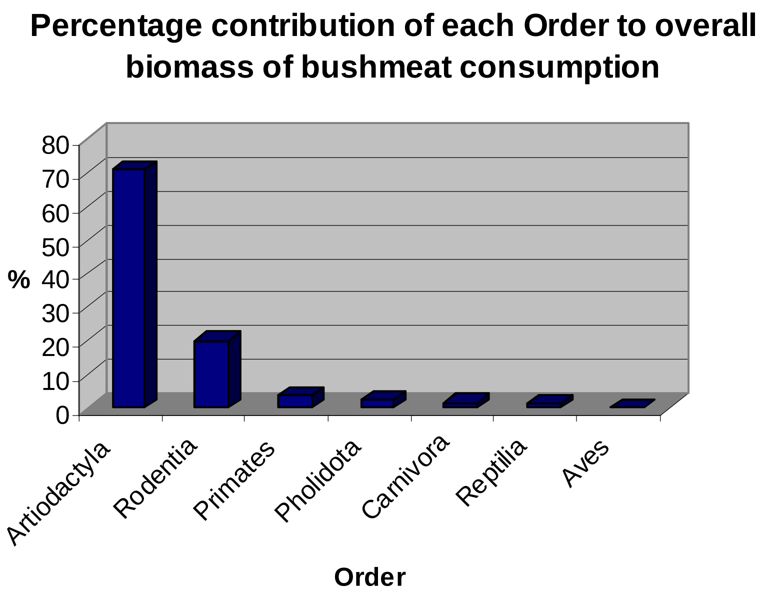


Figure 5.18 Chart showing the relative contributions of the seven important Orders of bushmeat species to the overall biomass.

5.4.2 Origin of bushmeat

Table 5.11 and Figure 5.19 illustrate the modes of acquisition in the overall sample. Most bushmeat is bought, but a not insignificant portion is received as gifts or through activities of family members. Bushmeat in the overall sample and the Libreville sample show the same pattern of acquisition, with almost half of all bushmeat that is bought (49.9%) coming from other towns or villages. A significant proportion of cash purchased bushmeat is obtained from markets (30.4%) but it is worth noting that this is far from a majority and a small portion of consumption.

Table 5.11 How bushmeat consumed by households was acquired.

How obtained	% of total sample
Bought	67.6
Gifted	14.4
Family	18.0

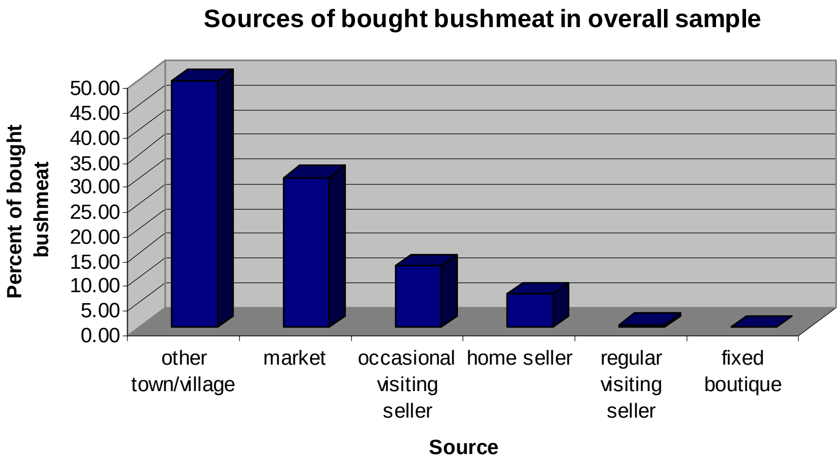


Figure 5.19 Chart showing the variety of sources of bushmeat that is bought in the whole sample and the relative proportions of bushmeat obtained from each source.

6 Comparison of volumes and composition of trade in markets and consumption

Summary

The concluding section of the analysis consists of a characterisation of markets in Libreville and uses market and consumption data to compare what is apparent about the bushmeat trade from these two sections within it. Volume and composition are compared. In order to extract trends for comparison, a complete set of markets from a given region where consumption data was also taken must be used. All seven of the permanent markets in Libreville were sampled, so these will form the basis of the case study to investigate market characteristics and extract trends in body size, proportions of Orders and protected species turning up at the various markets. The markets are Premier Campement, Akebe, Mont-Bouet, Nkembo, Oloumi 1, Oloumi2 and PK5. Research questions to be addressed are:

6.1 Volume of trade and consumption

Using the average annual estimated biomass of bushmeat sold at the seven markets, the estimated annual trade of bushmeat through the permanent markets of Libreville in a given year is 372,222 kg or 372.2 metric tonnes per year (
Table 6.1).

In section 5.1 the volume of consumption of bushmeat in 2002 for Libreville was estimated to be 2,148.0 – 2,814.4 metric tonnes. There is clearly a large discrepancy here.

Table 6.1 Average estimated annual biomass and total estimated biomass traded in the permanent markets in Libreville.

Market	Average annual biomass (kg)
Premier Campement	24181
Akebe	31253
Mont-Bouet	62390.2
Nkembo	24449.7
Oloumi 1	77048
Oloumi 2	109367
PK5	43533
Total Estimated Annual Biomass	**372,221.9**

6.2 Comparing composition

93 kg of bushmeat was consumed by households in Libreville during the survey with only 10 species consumed (Table 6.2). Porcupines are by far the dominant species in Libreville consumption (red river hog dominated the overall sample), with a lesser proportion of artiodactyls, the difference mostly made up by the greater proportion of rodents. This list includes species that are protected under Gabonese law and are IUCN red listed (forest elephants are partially protected under Gabonese law and are IUCN listed as vulnerable[12]). The relative importance of the seven important Orders to the composition of consumption in Libreville are shown in Figure 6.1. A rank correlation of the 15 species that make up top the 10 by percentage in markets and in consumption shows that the two do correlate to some degree, but looking at the figures indicates some key differences (Table 6.2). Five of the top ten species in markets are missing in consumption, including number one (dwarf crocodile), and several of the top ten consumed species are a lot lower on the list of biomass in markets (buffalo, cane rat, Afep pigeon). See Appendix VI for a list of most popular species by biomass by individual market in Libreville.

[12] IUCN recognises African elephants as a single species, so this categorisation is likely to underestimate the threat to forest elephants, whether or not they are a separate species.

Table 6.2 Contribution of important species to biomass of bushmeat consumed in Libreville, and the contribution of those species to the biomass at markets in Libreville. The association in the relative ranks of these species is significant, rho=0.82, p<0.01.

Species	*% of overall biomass in Libreville consumption*	*Rank*	*% biomass in markets in Libreville*	Rank
Brush tailed porcupine	36.9	1	12.5	2
Red river hog	19.5	2	8.0	4
Blue duiker	17.6	3	10.6	3
Moustached guenon	7.1	4	1.2	15
Bay duiker	5.1	5	7.3	5
Forest elephant	4.2	6	1.6	14
Forest buffalo	3.8	7	0.5	24
Cane rat	3.4	8	0.1	33
Peter's duiker	2.0	9	3.7	8
Afep pigeon	0.4	10	0.0	78
Dwarf crocodile	NA	NA	21.3	1
Mandrill	NA	NA	5.7	6
Water chevrotain	NA	NA	4.4	7
Black colobus	NA	NA	3.4	9
Putty-nosed guenon	NA	NA	3.3	10

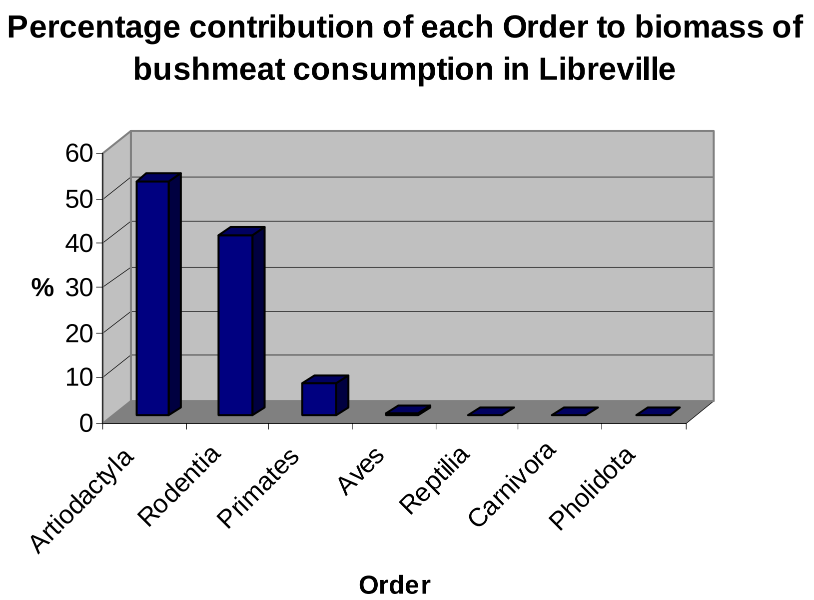


Figure 6.1 Chart showing the relative contributions of the seven important Orders of bushmeat species to the overall biomass of consumption in Libreville.

6.3 Characterising Libreville markets and their composition

6.3.1 Relative importance of seven Orders to market assemblages

Figure 6.2 shows the relative contribution of each Order to the total biomass at each market. To ascertain whether the differing distributions of Order can be said to be characteristic of these markets, the variation in percentage contribution to monthly biomass was modelled in a generalised linear model with order, market, month and year, simplifying to describe the variation as a function of market, order and month, with some significant interactions between market and order[13]. The model described a high degree of variation in the percentage contribution to monthly biomass (adjusted r^2=0.86) and the model was highly significant ($F_{(46,322)} = 51.36$, $p<<0.001$).

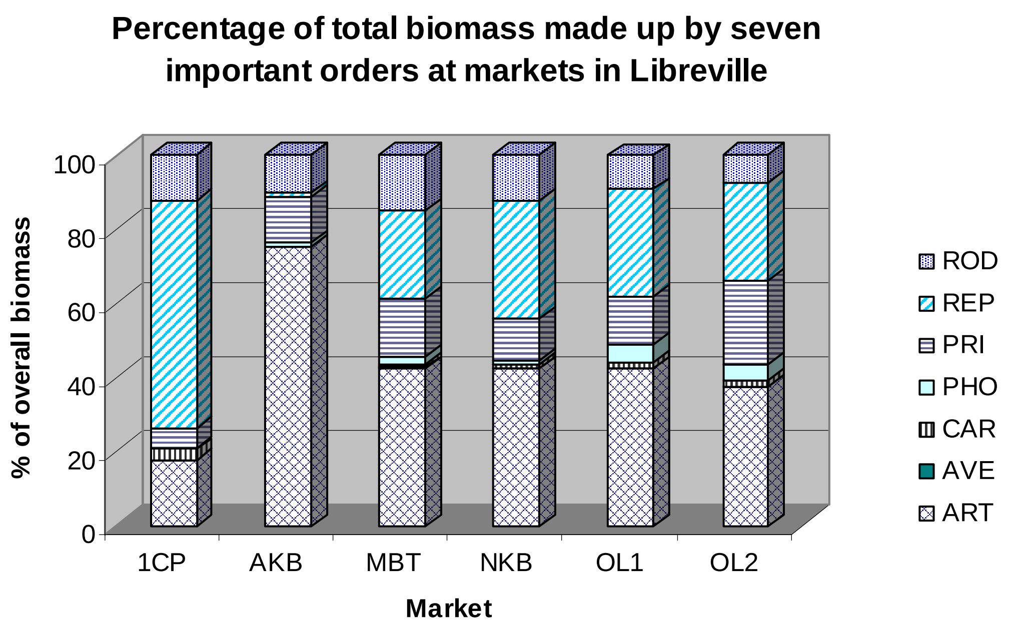


Figure 6.2 Chart showing the contrasting importance of the seven orders at the Libreville markets. Reptiles appear to be more important at Premier Campement, and Akebe and PK5 are heavily dominated by Artiodactyls.

That market and order contribute to the model is unsurprising, given the degree of variation in biomass between markets as shown previously, and the differences in

[13] Interactions were limited to two-way between market and order as any further would have over-parameterised the model. The basis for presuming the importance of this set of interactions is inspection of the data and the hypothesis that markets differ in their proportions of orders.

proportions of orders as Figure 6.2 shows. That month also contributes to the model indicates there is some variation in importance of the different orders according to month, or some variation in the biomass according to month, perhaps indicating some element of seasonality that previous analyses were not sensitive enough to detect. Months aggregated to three groups, with January, April, May, June, July forming a group, February, August, September and October forming a group and March remaining singular[14]. Interactions are the part of the model which will show which market-order combinations are noteworthy for their combined explanatory power. Significant interactions are those indicating proportions of reptiles at all markets differ to those at Premier Campement, and PK5 differs in its proportion of primates to Premier Campement.

6.3.2 Protected status under Gabonese law

Figure 6.3 shows how the Libreville markets differ in the proportion of overall biomass made up of species protected under Gabonese law. A model was built using monthly values of percentage of biomass of each category as the response. The minimum adequate model describing the variation in this variable contained no random effects (glm), but interactions were significant between totally protected and Akebe, totally protected and PK5, partially protected and Akebe, partially protected and PK5, and not proteced and Mont-Bouet. Levels of status and market could not be combined. The model was highly significant and explained a high degree of variation in the response variable (adjusted r^2= 0.89, $F_{(24,233)}$= 89.65, p<<0.001).

[14] November and October did not contain enough data points to provide estimates and so were removed from analyses.

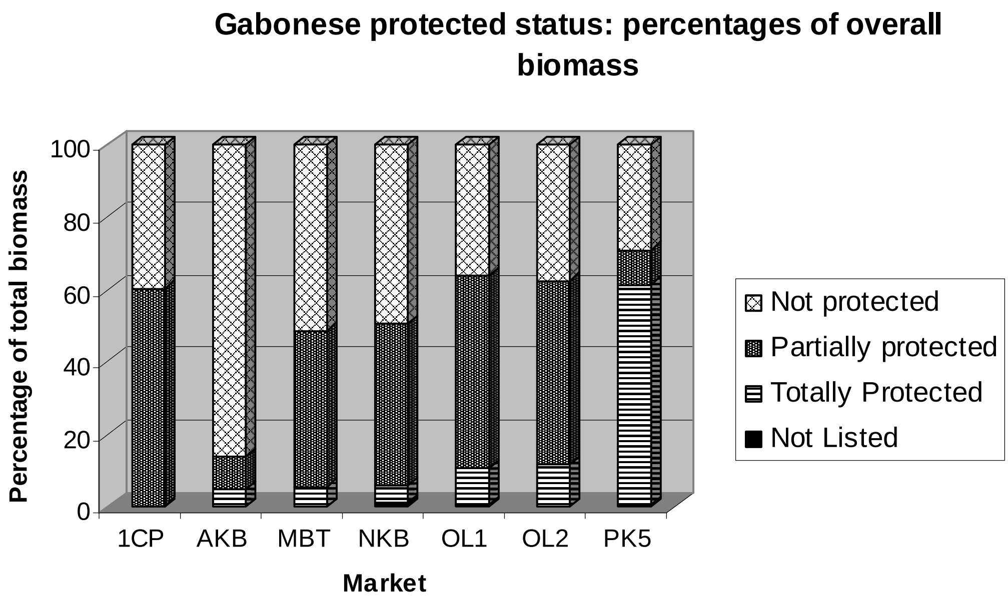


Figure 6.3 Chart showing differences according to market in proportion of overall biomass made up of protected species.

6.3.3 IUCN conservation status

Figure 6.4 shows the proportions of overall biomass at each market made up by species under each IUCN red list status. To investigate the relationship between status, market and percentage of biomass, a model was built using monthly values of percentage biomass for each status of each month as the response. Removing interaction terms and removing either of the main effects significantly changed the model for the worse. Attempts to combine levels and simplify the model through stepwise deletion were unsuccessful – all combinations of levels with similar mean estimates produced a model that was significantly worse. Significantly different to not listed were critically endangered, data deficient, endangered, lower risk/conservation dependent and vulnerable. In markets only Akebe was different to Premier Campement. Significant interactions were many (see Appendix IV for details). Overall the model showed high explanatory power (adjusted r^2 = 0.82, $F_{(52,443)} = 44.44$, $p << 0.001$).

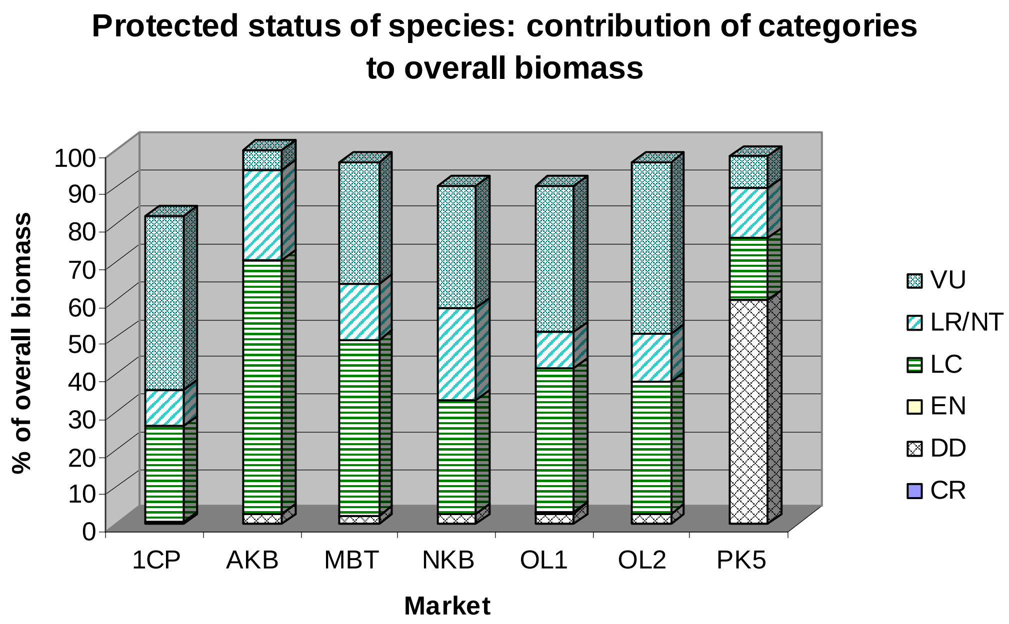


Figure 6.4 Proportions of biomass according to IUCN conservation status at markets in Libreville. This chart indicates that vulnerable species comprise a large part of the trade at most markets except Akebe and PK5.

6.3.4 Average body size of species appearing at markets

Average body size here is used as a proxy for intrinsic rate of increase (these two characteristics are related). Higher average body size of species in a market indicates larger bodied, slower reproducing species are present to a greater extent. Monthly values of average body size of species were used as the response variable in a mixed effects model, as a function of market with random effects of year, month and market remaining in the model. Variance components of year (16.9%), month within year and market within month within year (29.9% and 53.2% respectively) were all high, indicating significant effect of hierarchical structure in the data. Main effects of market were highly significant ($F_{(4,30)}$= 8.6, $p<0.001$). Levels of market grouped as shown in Figure 6.5, where two groups appear to emerge, with larger average size species at Nkembo, Oloumi 1, Oloumi2 and PK5 and smaller average size species at Premier Campement, Akebe and Mont-Bouet. Coefficients table for this model is listed in Appendix IV.

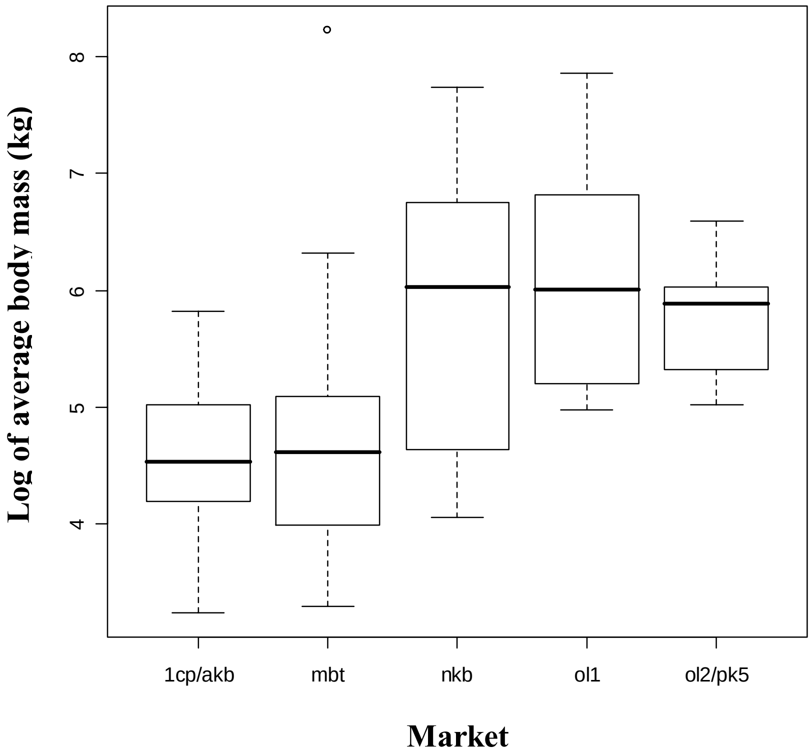


Figure 6.5 Graph showing groupings of market according to average body mass of species.

6.4 Origin of bushmeat in Libreville consumption

That there seems to be a large discrepancy between composition and volume of bushmeat in markets and consumption may in part be explained by looking at the origin of bushmeat in consumption. Table 6.3 shows that the majority of bushmeat consumed in Libreville is obtained by cash purchase, however figure 6.6 shows that of the cash purchases, only 25% is purchased from markets. Bushmeat in the overall sample and the Libreville sample show the same pattern of acquisition, with almost half of all bushmeat that is bought (49.9% overall and 47.9% in Libreville) coming from other towns or villages.

Table 6.3 How bushmeat was acquired by households in Libreville.

How obtained	*% of Libreville sample*
Bought	82.4
Gifted	17.2
Family	0.4

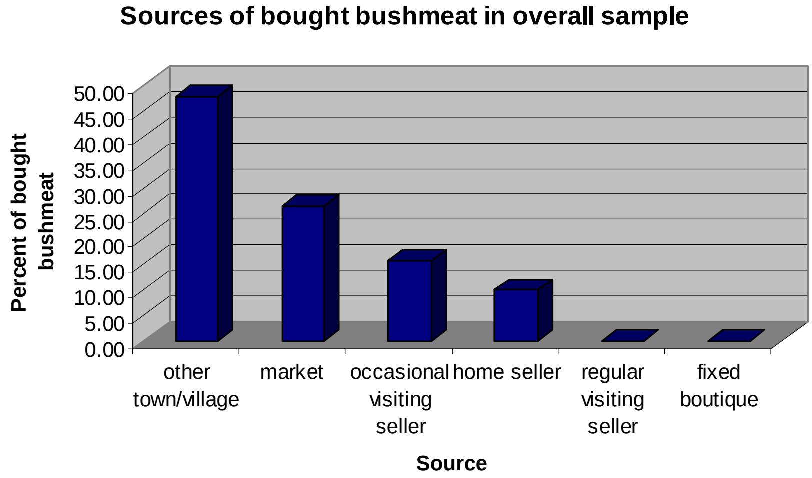


Figure 6.6 Chart showing the variety of sources of bushmeat that is bought in Libreville and the relative proportions of bushmeat obtained from each source.

Of the households consuming bushmeat in Libreville 16.6% say it came from Mont-Bouet, 7.9% state Oloumi and 2.0% say PK5 was the source. No other permanent markets in Libreville were the stated source of any of the bushmeat in this survey. Species bought in the markets were brush-tailed porcupine (52.4%), blue duiker (25.2%), red river hog (16.4%), bay duiker (4.5%) and forest elephant (1.5%).

7 Discussion

7.1 Market trends: indicators of supply and depletion in the bushmeat trade

Decreases or increases in trade volumes coupled with changes in prices in bushmeat markets can indicate whether supply is failing to meet demand (Fa, 2007). However, to fully investigate the forces governing the supply and demand of a commodity, information concerning the market for alternatives and wealth and income of consumers is needed. Supply, and whether there is a shortfall, is a crucial element to know with regards to trade in wildlife, as a restriction in supply could be coming from increasing scarcity of the resource, i.e. population depletion. The trends through time and space observed in the bushmeat markets in Gabon in this study are difficult to interpret with regards to what they indicate about supply and demand within the bushmeat trade, primarily due to uncertainty about the catchment areas that are supplying the markets and a lack of information regarding alternatives and consumer socioeconomics.

It appears from this dataset that the overall biomass being traded through a selection of markets in the period 2000-2004 decreased, but without a concurrent change in price the supply and demand implications of this are weak. The only price differences appear to be between cheap and expensive markets rather than change in price over time. This may only reflect the higher standard of living of the locality of the expensive markets (Carrefour Monaco in Oyem and Mont-Bouet in Libreville) and the higher price of bushmeat in urban as opposed to rural locations (Wilkie et al., 2005). To indicate depletion the decreasing volume would likely be coupled with an increase in price, and defining whether there was a supply shortfall would require an econometric analysis over the same time period including factors related to substitutes, their prices, consumer incomes etc. Milner-Gulland and Clayton (2002) suggest that the increased distance traders travelled to obtain wild pigs, coupled with their higher price and decreased numbers, was consistent with depletion of wild pigs in the forest. Without knowing if there are changes in the distance hunters travel, or the areas they use or similarly with traders who supply markets and the effort to obtain the market supply, making inferences about depletion is inadvisable. Including this information in market surveys where possible is a necessity in future market studies in order to infer depletion in animal populations.

There is no evidence in this data set to indicate that a 'hunting down the size classes' is taking place over time at any of the markets used here over 4 years. Cowlishaw et al. (2005b) suggest that market profiles in Takoradi, Ghana, indicate larger bodied animals have been historically over-exploited and depleted in the market's catchment area. In order to clarify if the findings in the present study are real stability in average body mass or an artefact of the analysis (four years may not be long enough to detect a change), detailed knowledge of the catchments supplying the markets would be needed. A depletion of larger bodied species through over-hunting would be evident in market assemblages over time only if the catchment was consistent. As shown in Milner-Gulland and Clayton (2002), depletion was not detected in the markets due to traders increasing distance travelled, even though there were suggestions that depletion was taking place in the forest. Differences in average body size of species between markets, as observed in this study, could indicate that the proportion of protected species is higher, or that the trade is coming from a healthier ecosystem, or even both. The results from this study with regards to changes over time in biomass, price and average body size of species in markets are of limited utility as indicators of supply and demand forces or depletion in animal populations.

The trading profile of Carrefour Monaco in Oyem stands out for the reason that it is large scale and on the higher end of both the price and diversity scales, and the only market with this profile outside of the capital. The market trends at Carrefour Monaco are opposite to elsewhere, with increased volume and decreased price of bushmeat. These findings could indicate perhaps that the market is being flooded, possibly in response to demand from across the border. Oyem is the only major town other than Libreville in the North of Gabon and strategically placed close to the border with the relatively wealthy country of Equatorial Guinea. It is thus in a prime position for trade routes across the border. It is noteworthy that oil revenues in Equatorial Guinea increased in value from $190 million in 2000 to $3.3 billion in 2006 (World Bank, 2008). Data is not available on whether the trade in bushmeat has risen over this time period in Equatorial Guinea. As most of the population and the new found wealth are concentrated in the city of Bata, which is far from the Oyem region border with Gabon, the association between rising trade in bushmeat in Oyem and rising wealth of Equatorial Guinea can not be presumed to exist (UN, 2008). It is, however, worth monitoring, as there could be biodiversity impacts for Northern Gabon if this association is real.

7.2 Market trends: seasonality

Biases according to any month or aggregation of months in the biomass of bushmeat, prices or species composition could be reflecting any of a variety of changes taking place over the year elsewhere in the commodity chain. Possibilities are:

- changes in hunting effectiveness or effort as a consequence of wet or dry season
- changes in hunting effectiveness as a result of differential vulnerability, for example in breeding or birthing seasons or movement of prey
- changes in demand for bushmeat through the year according to cultural events such as religious festivals
- changes in incentives to sell bushmeat on the part of the market trader, for example in response to enforcement in the form of inspections or seizures
- changes at earlier points in the commodity chain leading to market in the relative benefits to the hunter of selling or keeping hold of harvested animals

The apparent lack of seasonality in market assemblages found here indicates that there is no evidence to support any of these possible ecological, cultural or economic changes having any effect on the bushmeat trade, or at least the part of it that is concentrated in markets. Fa et al. (2004) compared estimates of composition and volume on the basis of different sampling methods from data on five markets in West and Central Africa. Their results suggest that, although a large sample of markets is needed to make useful inferences on a regional level, seasonality did not appear to affect the accuracy of estimates of composition or volume. This is consistent with results in this study, which indicate that uneven sampling of months across the year is not an issue that will affect the validity of results in comparing between markets. Although important for this dataset, this has wider implications for the study of bushmeat markets. It may be the case that within the same geographical zone where effects of seasonality are likely to be consistent, market surveys need not sample within the same season for comparisons to be made.

There is no difference in the biomass sold between the open and closed hunting seasons in Gabon. All hunting and trading in hunted animals is banned by Gabonese law between mid September and mid March every year. Enforcement of this ban in the form of seizures, fines or other penalties theoretically should tip the cost-benefit balance on the part of traders in favour of not transgressing the law in order not to incur the costs. Traders (wholesalers and market sellers) clearly have no incentive to restrict the supply of bushmeat in the closed season, indicating that any enforcement of this ban is ineffective. The ineffectiveness of enforcement must also continue further back down the commodity chain to the hunters, but it is difficult to extrapolate operations in the whole bushmeat trade from what is sold in markets, as this study finds the market trade to be only a small portion of the overall trade.

There seems to be little strong evidence that inspections and seizures are an effective control measure for bushmeat markets in Gabon. This contrasts with findings from elsewhere such as with law enforcement effects on the illegal sale of babirusa in Indonesia (Clayton et al., 1997). This study on wild pig and babirusa hunting and trading found that check points on the road and enforcement in the market reduced both the numbers of babirusa bought by traders and numbers sold in markets. The effect of inspections in Libreville is inconclusive. Indications are that there was a general decrease in the biomass sold in months following inspections at Mont-Bouet, however this should be treated with caution. Longer term data would be useful here, to clarify if there is a link between the changes in biomass and the enforcement activity rather than other forces not accounted for here. A seizure in Oyem, where all the bushmeat was confiscated by police, had little effect on sellers, given that the biomass sold continued to rise during 2001. However, the rising trade was in the open season, and the seizure occurred at the end of the closed season. It would be useful to contrast the rising trend indicated here with any observations following seizures at the outset or during the closed season, however, there are no other seizures at any market from which data was collected during the study period. Enforcement activities may have greater and more noticeable effect if they were more regular, as at

Mont-Bouet. A final caveat here is that monitoring the biomass sold only gives a rough indication of response of sellers to interventions. It would also be useful to monitor the numbers of protected species through time to indicate if there is any effect on what is sold even though there is no discernible effect on how much, although monitoring trade of protected species, which is illegal, is unlikely to be straightforward.

7.3 Determinants of consumption

Location seems to have more effect on determining quantity of consumption of bushmeat than socioeconomics in Gabon. The location of a household significantly predicts the consumption quantity of bushmeat. It is noteworthy that socioeconomic status and location are confounded here, as the relative effects could not be separated, but with wealth having no discernible relationship to consumption quantity (overall or within settlement category), and income categories showing little significant difference in mean consumption amounts, this indicates that it is more likely that location is a bigger driver of consumption than socioeconomics. The wealthier and higher socioeconomic classes are less often consumers of bushmeat, but among consumers socioeconomics has little to do with quantity. Other studies have focussed on consumption within a given location. For example, East et al. (2005) use a study of consumption and preferences in Bata, Equatorial Guinea, to indicate that income, ethnicity and nationality are key determinants of consumption of preferred foods, including bushmeat. The present study finds that within-location relationships of socioeconomic characteristics and bushmeat consumption quantity are not as strong as the effect of type of settlement. This means that measures to mitigate negative effects of the bushmeat trade that are settlement type-specific may be necessary in Gabon.

Consumption patterns observed here for Gabon have some important implications for bushmeat mitigation policies. There are development issues, substitute issues and issues about where to concentrate controls to affect the most worthwhile change. Although not statistically significant, there is evidence to indicate that consumption in rural areas seems to follow a parabolic curve in relation to income, where the lowest and highest income categories consume less than the middle, as found in South

America by Wilkie and Godoy (2001). This supports the contention that development aims and conservation aims should be co-ordinated in rural areas in order to ensure that increases in wealth do not increase pressure on biodiversity by increasing bushmeat consumption (Wilkie et al., 2005; Brown, 2007).

There seems to be a behaviour shift with regards to bushmeat consumption between villages and small towns. Consumption declines with increasing price everywhere as would be expected of a normal good. The pattern of bushmeat consumption quantities follow the pattern more like that of a luxury good than a normal or staple everywhere but the villages, in that they have more of a tendency to increase with increasing income category. However, as these differences were not significant, interpretation of this should be treated with caution.

7.4 It all comes down to the price of fish…

The sensitivity of consumption to price indicates that an increase in bushmeat prices may affect a decrease in consumption, for example through taxation or controls in supply. As a mitigation strategy, this must be combined with the provision of alternatives to make up for the nutritional shortfall. However, in contrast to other studies (e.g. Wilkie et al., 2005; Brashares et al., 2004) this study finds no relationship with alternatives that would indicate substitutability with bushmeat except for freshwater fish. The negative relationship in the consumption quantities of bushmeat and freshwater fish, and the effect increased price of freshwater fish on bushmeat consumption, indicate that these two commodities are related. Earlier findings from Gabon that fish and bushmeat are related did not distinguish freshwater fish and sea fish (Wilkie et al., 2005) so it is unsurprising that this has not been reported previously. The productivity of freshwater fisheries in Gabon is unlikely to be able to provide for the deficit in animal protein that would be caused if people could no longer afford bushmeat.

Discussion of links between bushmeat and fisheries has become a popular trend in the literature in terms of substitutability and co-management strategies (e.g. Brashares et al., 2004; Cowlishaw et al., 2007). It has been suggested that decreasing consumption of bushmeat could lead to increases in consumption of fish, which may only serve to shift the biodiversity crisis from over-exploitation of forest resources to over-exploitation of fisheries. This may be the case in Gabon at localities where freshwater fish is important, however, the linkage with sea fish as found in Ghana is not detected here (Brashares et al., 2004) and the predicted increased pressure on fisheries as a result of bushmeat control may not be as extreme as is commonly thought.

7.5 So, who ate all the crocodiles?

It is clear from these analyses that bushmeat markets are representative of a different section of the bushmeat trade to household consumption. Other studies have shown that markets show a subset of the bushmeat trade in that there is a huge discrepancy between market species composition and the composition of hunter catches. Davies et al. (2007) found hunter catches and markets in Sierra Leone to have vastly differing proportions of ungulates and primates. Allebone-Webb (2007) found that species profiles of village harvests and markets in both villages and urban centres were significantly different. These studies are useful for situating the utility of market data in a relevant context, showing that markets are not representative of harvests. The present is the first comparing the profiles of markets and consumption to assess their utility as indicators.

The volume discrepancy between what is consumed in Libreville and what is traded is very large. The reasons for this are partly explained by the fact that people do not obtain the majority of bushmeat consumed in households from markets. That this is true for the whole sample (Gabon-wide) indicates that the miss-match seen between markets and consumption in Libreville probably translates to elsewhere in Gabon. East et al. (2005) report that of a sample of households in Equatorial Guinea only half of the bushmeat in household consumption that was obtained through cash purchase was bought in markets. There are regional differences in this finding, in some places (e.g. Ghana, Cowlishaw et al., 2005a) the majority of the trade does pass through markets. This is an indication that there are not universal rules for the utility of market data, and that markets may be used more accurately as indicators of the bushmeat trade in, for example, Ghana than in Gabon or Equatorial Guinea. The question remains with regards to the discrepancy in composition; if what is sold in the markets in Libreville is not consumed by households in Libreville, where is the trade demand coming from?

Only ten wild animal species were consumed out of a sample of 515 households over seven months in Libreville in 2002. There is correlation between popular market species and consumption species, however, of the ten most popular species at the markets, five did not appear in consumption at all. Most notable of these is the dwarf crocodile, which constituted around 21% of the biomass sold in Libreville over the study period and yet is not among the ten species found to be consumed. This could be methodological, as in the survey was not large enough to detect all of consumption, but this is unlikely with the large randomised sample. It is thus indicated that consumption studies do not capture all of the trade, (and vice-versa; markets do not capture all of consumption), even though consumption accounts for a larger biomass than markets. Of the 70% of bushmeat in household consumption in Gabon that is cash-purchased, almost 50% comes from another town or village. This may explain why sales in Libreville markets do not match consumption. East et al. (2005) also found that a large proportion of bushmeat in household consumption (26%) was obtained outside Bata, the city in which the study was conducted. What is consumed in any settlement is thus probably not representative of a local catchment or local markets, and therefore consumption studies must be treated with caution; consumption may indicate drivers of extraction, but should not be used to assess sustainability of hunting in the local area.

The contrasting characters of markets in Libreville lend further support to the conclusion that market data can not be usefully interpreted without the aid of information regarding the catchment area. This study found differences in average body size of species at different markets. This could mean that there are differing levels of depletion, if the markets have suppliers from different catchments. It could also mean that there are differences in the body size of species on which the trade of that particular market is based. There are differences in scale and composition that could indicate specialisation, for instance at Premier Campement a customer can be assured of the availability of reptile meat, whereas at Akebe the more popular duikers, porcupine and red river hog will always be available. This is a level of sophistication in the trade that is not often accounted for in market surveys, but in cases such as this where there are several markets in the same town, market surveys would have to account for specialisation of markets if any trends in body size were to be used to indicate sustainability.

7.6 Allocating resources to control bushmeat

Market surveys and consumption studies are popular in the study of bushmeat for various reasons, chief of which appears to be the trade-off made between investment of effort in getting the data and the accuracy of the data (Fa, 2007). The indications gained from these types of study may be of limited use in assessing sustainability or changes in forest animal populations, but where they can be of great use is in indicating the priority areas for control and where the scarce resources for alleviating the conservation problems associated with bushmeat would be most efficiently used. For instance, proportions of protected species can indicate if the most pressing issue is of protecting rare and endangered species. As Kumpel et al. (2007) suggest, there is little evidence for a luxury trade based on endangered species in Bata, so resources would be better directed tackling bushmeat in general rather than particular species. Where consumption studies indicate differential importance of bushmeat among socioeconomic categories or between regions, concentrating resources on reducing bushmeat use where it is not a necessity is more likely to have less impact on the poor.

The most prominent species in consumption in Gabon – red river hog, blue duiker and brush-tailed porcupine – are not threatened or rare. To invest resources in controlling the hunting or trade in these species is therefore not a priority. It would be more useful in the case of these popular non-threatened species to ascertain their level of productivity and a sustainable harvest rate in order to monitor possible impacts of the trade on these species. But even this is not an area of great urgency.

There is a case for leniency on the bushmeat trade in rural areas. It is apparent from the market analyses that rural bushmeat markets have much smaller proportions of protected species, red listed species and generally lower species diversity. In the villages bushmeat is obviously a staple commodity for the poor, with the section of the population in income category 1 (extreme poverty; World Bank, 2008) in rural areas comprising 16-17% of the population and consuming 23-24% of the bushmeat. It is certainly the case that there may be depletion caused by the rural trade in some areas (e.g. Coad, 2007), but there are other sections of the trade that potentially require less effort to affect control and need more urgent attention, such as the part of the trade that is comprised of rare and endangered species.

Rare and endangered species tend to appear in larger markets which are more diverse. An example to draw on would be the presence of the Red Listed dwarf crocodile (listed as vulnerable, IUCN, 2007) in the number one spot in five out of seven markets in Libreville. Forest elephant is a species that is consumed in greater amounts in Libreville than would be expected on the basis of its rarity and vulnerability. It is lower on the preference list than, for instance, porcupine (Schenck et al., 2006) but the observation that people are eating it more than expected indicates that there may be a degree of preference acting, people are choosing to eat elephant where other species are available. Directing control effort towards Libreville markets may have minimum impact, given that market inspections and seizures apparently have little effect on the behaviour of sellers and that people only obtain ~20% of bushmeat from markets in Libreville, and more often obtain it from another town or village. In general, the most effective strategy for the conservation of the rare and endangered bushmeat species would be to concentrate controls on enforcement in protected areas, thereby maintaining populations of rare and endangered species, and leave the fast reproducers for people to eat. This is consistent with Bennett et al. (2006) who state that the over-exploitation of larger-bodied more vulnerable and endangered species is of great concern, and there is much more potential for sustainable use of more resilient and rapidly reproducing species, such as duikers and cane rats.

7.7 Directions for future research

Questions that still need to be addressed with regards to bushmeat in Gabon have been raised in the course of this study. Foremost of these is the question of substitutes.

This study has cast doubt on the substitutability of fish in general, and indicated that the only alternative that seems a candidate, freshwater fish, is limited in its ability to supply a large number of people. There is therefore a great deal of importance in clarifying the importance of finding substitutes, and developing strategies to deal with the possibility that there are no viable substitutes in Gabon. Issues raised in this study that could be taken further are those relating to seasonality in markets and the effects of enforcement on species composition. The latter is worthwhile as ineffective enforcement is a waste of resources and investigating this could indicate how enforcement in Gabon may be more effective, for example looking at the timing of seizures. Investigating seasonality and its effects could improve comparability in market datasets and enable comparison of existing data across broad geographical regions. Bushmeat in general is an issue far from solved, despite the mass of research regarding extraction, trade, consumption and potential mitigation measures. The most pressing issue in bushmeat is that of practical application of the theory and putting into practice recommendations from research. It remains crucial to form institutional links between researchers, conservation organisations, governments and local organisations so that routes to implementing mitigation measures are open.

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Appendix I

List of species appearing in market and consumption data

IUCN (2007) status codes are LC: least concern; LR/LC: lower risk/least concern; LR/CD: lower risk/conservation dependent; LR/NT: lower risk/near threatened; VU: vulnerable; EN: endangered; CR: critically endangered; DD: data deficient.

Common Name	***Latin Name***	***Order***	***IUCN Status***	***Gabonese Protection Status***
Aardvark	*Orycteropus afer*	Tubulidentata	LC	Total
African Civet	*Civettictus civetta*	Carnivora	LR/LC	Not protected
African Giant Squirrel	*Protoxerus stangeri*	Rodentia	LC	Not protected
African Palm Civet	*Nandinia binotata*	Carnivora	LR/LC	Not protected
African Pygmy Squirrel	*Myosciurus pumilio*	Rodentia	DD	Not protected
African Python	*Python sebae*	Reptilia		Partial
Agile Mangabey	*Cercocebus agilis*	Primates		Not protected
Albino Monkey		Primates		Not listed
Allen's Squirrel Galago	*Galago alleni*	Primates	LR/NT	Total
Anomalure unknown	*Anomalurus spp,*	Rodentia		
Bay duiker	*Cephalophus dorsalis*	Artiodactyla	LR/NT	Not protected
Beecroft's anomalure	*Anomalurus beecrofti*	Rodentia	LC	Not protected
Black Colobus	*Colobus satanas*	Primates	VU	Not protected
Black-fronted duiker	*Cepholophus nigrifrons*	Artiodactyla	LR/NT	Not protected
Blotched Genet	*Genetta tigrina*	Carnivora	LR/LC	Not protected
Blue duiker	*Cephalophus monticola*	Artiodactyla	LR/LC	Not protected
Bongo	*Tragelaphus euryceros*	Artiodactyla	LR/NT	Partial
Brush-tailed Porcupine	*Atherurus africanus*	Tubulidentata	LC	Not protected
Bush duiker	*Cephalophus grimmia*	Artiodactyla		Total
Bushbuck	*Tragelaphus scriptus*	Artiodactyla	LR/LC	Partial
Calabar angwantibo	*Arctocebus calabarensis*	Primates	LR/NT	Total
Cameleon	*Sphenodon punctatus*	Reptilia	LR/LC	Not protected
Cane Rat	*Thryonomys swinderianus*	Rodentia	LC	Not protected
Central African Linsang	*Poiana richardsoni*	Carnivora	LR/LC	Not protected
Chimpanzee	*Pan t. troglodytes*	Primates	EN	Total
Crowned Eagle	*Stephanoaetus coronatus*	Aves	LC	Total
Crowned Guenon	*Cercopithecus pogonias*	Primates	LR/LC	Not protected
De Brazzas Monkey	*Cercopithecus neglectus*	Primates	LR/LC	Not protected
Demidoff's Galago	*Galago demidoff*	Primates	LR/LC	Total
Duiker Unknown		Artiodactyla		Not listed
Dwarf Antelope	*Neotragus batesi*	Artiodactyla	LR/NT	Not protected
Dwarf Crocdile	*Osteolaemus tetraspis*	Reptilia	VU	Partial
Elegant needle-clawed galago	*Euoticus elegantulus*	Primates	LR/NT	Total
Emin's Rat	*Cricetomys emini*	Rodentia	LC	Not protected
Fish Eagle	*Haliaetus vocifer*	Aves		Total
Forest Buffalo	*Syncerus caffer nanus*	Artiodactyla	LR/CD	Partial
Forest Elephant	*Loxodonta cyclotis*	Artiodactyla	VU	Partial

Forest Snail		Mollusca		Not protected
Forest tortoise	*Kinixys erosa*	Reptilia	DD	Not protected
Gaboon Viper	*Bitis gabonica*	Reptilia		Not protected
Galagal unknown		Primates		Not listed
Gambian Rat	*Cricetomys gambianus*	Rodentia	LC	Not protected
Giant Hog	*Hylochoerus meinertzhageni*	Artiodactyla	LR/LC	Partial
Giant Otter Shrew	*Potamogale velox*	Insectivora	LC	Not protected
Giant Pangolin	*Manis gigantea*	Pholidota	LR/LC	Total
Golden Cat	*Profelis aurata*	Carnivora	VU	Partial
Great Blue Turaco	*Corythaeola cristana*	Aves	LC	Not protected
Green Squirrel	*Paraxerus poensis*	Rodentia	LC	Not protected
Grey Parrot	*Psittacus erithacus*	Aves	NT	Partial
Grey Pelican	*Pelecanus mufescens*	Aves		Total
Grey-cheeked Mangabey	*Lophocebus albigena*	Primates	LR/LC	Not protected
Guereza Colobus	*Colobus guereza*	Primates	LR/LC	Not protected
Hartlaub's Duck	*Pteronetta hartlaubii*	Aves	LC	Not protected
Hippopotamus	*Hippopotamus amphibius*	Artiodactyla	VU	Total
Hornbill	*Hornbills*	Aves		Not protected
Kob	*Kobus defassa*	Artiodactyla		Total
Lady Burton's Rope Squirrel	*Funisciurus isabella*	Rodentia	LC	Not protected
Leatherback Turtle	*Dermochelys coriacea*	Reptilia	CR	Partial
Leopard	*Panthera pardus*	Carnivora	LC	Total
Lion	*Panthera leo*	Carnivora	VU	Total
Long-snouted mongoose	*Herpestes naso*	Carnivora	LR/LC	Not protected
Long-tailed Pangolin	*Uromanis tetradactyle*	Pholidota	LR/LC	Not protected
Lord Derby'sAnomalure	*Anomalurus derbianus*	Rodentia	LC	Not protected
Manatee	*Trichechus senegalensis*	Artiodactyla	VU	Total
Mandrill	*Mandillus sphinx*	Primates	VU	Partial
Marsh mongoose	*Atilax paludinosus*	Carnivora	LR/LC	Not protected
Mongoose	*Bdeogale nigripes*	Carnivora	LR/LC	Not protected
Mongoose	*Mangouste*	Carnivora		Not protected
Monitor lizard	*Varanus niloticus*	Reptilia		Partial
Moustached Guenon	*Cercopithecus cephus*	Primates	LR/LC	Not protected
Nile Crocodile	*Crocodylus niloticus*	Reptilia	LR/NT	Partial
Ogilby's duiker	*Cephalophus ogilbyi*	Artiodactyla	LR/NT	Total
Palm-nut Vulture	*Gypohierax angolensis*	Aves	LC	Partial
Peter's duiker	*Cephalophus callipygus*	Artiodactyla	LR/NT	Not protected
Potto	*Perodicticus potto*	Primates	LR/LC	Total
Putty-nosed Guenon	*Cercopithecus nictitans*	Primates	LR/LC	Not protected
Ratel (Honey Badger)	*Melivora capensis*	Carnivora	LR/LC	Not protected
Red Cheeked Rope Squirrel	*Funisciurus leucogenys*	Rodentia	DD	Not protected
Red Duiker	*Cephalophus spp.*	Artiodactyla		Not protected
Red river hog	*Potamochoerus porcus*	Artiodactyla	LR/LC	Partial
Red-capped Mangabey	*Cercocebus torquatus*	Primates	LR/NT	Not protected
Red-legged Sun Squirrel	*Heliosciurus rufobrachium*	Rodentia	LC	Not protected
Ribboned Rope Squirrel	*Funisciurus lemniscatus*	Rodentia	DD	Not protected
Sacred Ibis	*Threskiornis aethiopica*	Aves	LC	Partial
Serval Cat	*Felis serval*	Carnivora		Partial
Servaline Genet	*Genetta servalina*	Carnivora	LR/LC	Not protected
Sitatunga	*Tragelaphus spekii*	Artiodactyla	LR/NT	Partial
Slender Mongoose	*Herpestes sanguinea*	Carnivora	LR/LC	Not protected

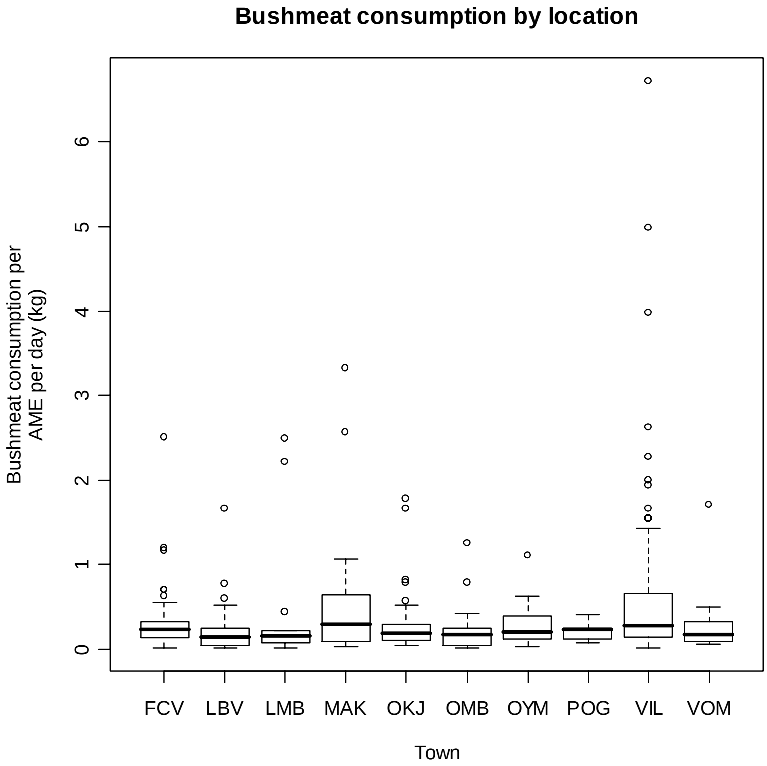
Southern Reedbuck	*Redunca arundinum*	Artiodactyla	LR/CD	Total
Southern Talapoin	*Miopithecus talapoin*	Primates	LR/LC	Not protected
Spot-necked Otter	*Lutra maculicollis*	Carnivora	LC	Not protected
Sun-tailed Guenon	*Cercopithecus solatus*	Primates	VU	Total
Swamp Otter	*Aonyx congica*	Carnivora		Not protected
Tree Hyrax	*Dendrohyrax arboreus*	Hyracoidea	LC	Total
Tree Pangolin	*Manis tricuspis*	Pholidota	LR/LC	Not protected
Unknown Bird		Aves		
Unknown Pangolin		Pholidota		
Water Chevrotain	*Hyemoschus aquaticus*	Artiodactyla	DD	Total
Waterbuck	*Kobus ellipsiprymnus*	Artiodactyla	LR/CD	Total
Western lowland gorilla	*Gorilla g. Gorilla*	Primates	CR	Total
Western Palm Squirrel	*Epixerus ebii*	Rodentia	DD	Not protected
White-bellied duiker	*Cephalophus leucogaster*	Artiodactyla	LR/NT	Not protected
Wild boar	*Sus scrofa*	Artiodactyla	LR/LC	Not protected
Yellow-backed duiker	*Cephalophus sylvicultor*	Artiodactyla	LR/NT	Partial
Black guinea-fowl	*Agelastes niger*	Aves	LC	Not protected
Rhinoceros viper	*Bitis nasicornis*	Reptilia		Not protected
Piping hornbill	*Bycanistes fistulator*	Aves	LC	Not protected
Black-casqued hornbill	*Ceratogymna afrata*	Aves	LC	Not protected
Slender-snouted crocodile	*Crocodylus cataphractus*	Reptilia	DD	Partial
Western bronze-naped pigeon	*Columba delegorguei iriditorques*	Aves	LC	Not protected
Afep pigeon	*Columba unicincta*	Aves	LC	Not protected
Saddle-billed stork	*Ephippiorhynchus senegalensis*	Aves	LC	Partial
	Francolinus latbami	Aves	LC	Not protected
Scaly francolin	*Francolinus squamatus*	Aves	LC	Not protected
	Gavial	Reptilia		Partial
Thomas' galago	*Galago thomasi*	Primates	LR/LC	Total
Ibis	*Ibis ibis*	Aves		Partial
Helmeted guinea-fowl	*Numida meleagris*	Aves	LC	Not protected
African spoonbill	*Platalea alba*	Aves	LC	PAR
African side-necked turtle	*Pelomedusa sp*	Reptilia		Not protected
White-headed vulture	*Trigonoceps occipitalis*	Aves	VU	Not protected
Nile soft-shelled turtle	*Trionyx triunguis*	Reptilia		Not protected

Appendix II

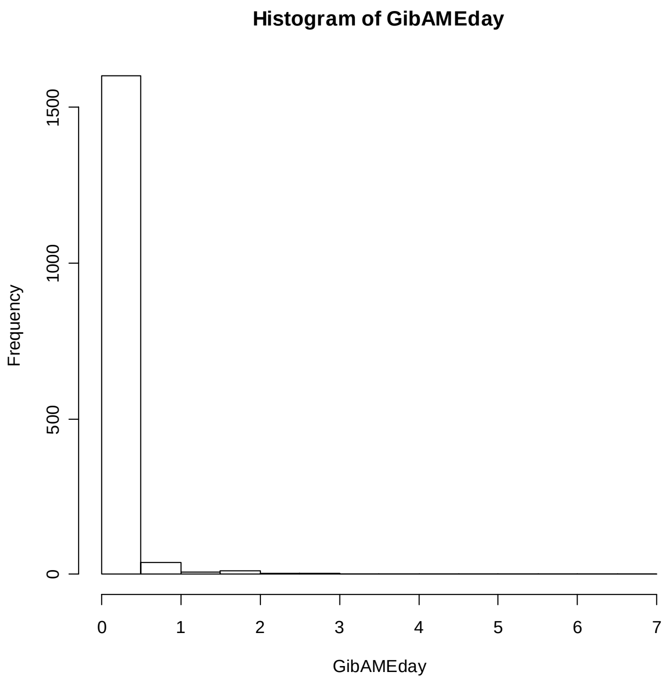
Details of truncation of socioeconomic and consumption dataset.

The raw data consisted of records of each item consumed in each household on each survey day. For a number of items, weights had not been calculated. Data was refined as follows: weights were calculated for records with missing weights where possible (from a weight for the same item or average weight for the same item or similar item), remaining missing weights were excluded along with any items consumed on the same day by the same household, effectively eliminating that consumption day. After truncation of the data, 1649 households (out of 1672) remained in the dataset with 5004 consumption days (an average of 3.26 consumption days per household). All records of crevettes and insects were eliminated due to their negligible proportion in consumption.

Consumption was aggregated by household on the basis of number of AMEs present in the household, number of survey days and biomass of consumed bushmeat and alternatives. Data were investigated for outliers. The graphs below indicate that some truncation of the data for analysis would be advisable (A.II 1and A.II 2).



A.II 1 Graph showing consumption amounts of bushmeat by town, where the y axis is not logged it is clearly visible that some per AME per day values are questionable.



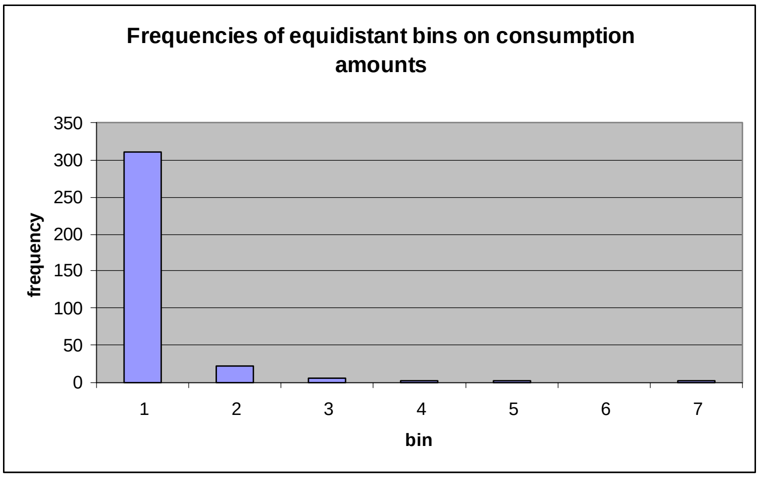
A.II 2 Histogram of the distribution of the bushmeat consumption per AME per day variable.

Truncation details and rationale are as follows:

A.II 2 shows the frequency distribution of the per AME amounts of bushmeat consumption (x axis is consumption per AME per day in kg) and illustrates the long thin tail that the data shows. This is likely to cause problems later on in analyses with overdispersion, as well as making it difficult to represent a realistic mean consumption. Values of bushmeat consumption were traced back to the raw data and checked. 23 households out of 342 positive consumption records were suspicious, examples include:

- A household in 'Vil' location containing 0.879 AMEs consumed an entire 17kg duiker
- A household in 'Vil' location containing 5.595 AMEs consumed (allegedly) one entire Sitatunga
- Two households in Franceville (11.229 and 21.106 AMEs) and two in Makoukou (6.755 and 7.997 AMEs) each consuming an entire red river hog
- A household in 'Vil' containing 3.837 AMEs consumed an entire 17.73kg duiker
- A household in Okondja with 0.879 AMEs consumed an entire blue duiker

A.II 3 shows, using positive bushmeat consumption values only, how the data points are distributed across equidistant categories – in this case each 'bin' is equivalent to a boundary of 1 kg. Truncating to <1.5kg excludes all the households with questionable consumption quantities, leaving all of bin 1 and half of bin 2.



A.II 3 Consumption amounts of bushmeat distributed across equidistant bins.

Appendix III

AME calculation: energy requirement details

Adult Male Equivalent units (AMEs) were calculated on the basis of converting the energy requirements of a person of a given age and sex into the proportion of an adult male their energy requirement represents. Energy requirement values used are shown in A.III 1.

A.III 1 Recommended Levels of Energy Intake (Calories/day).

Age	*Males*	*Females*	*Age*	*Males*	*Females*
<1	785	741	12	2180	1974
1	1307	1107	13	2297	2029
2	1456	1255	14	2397	2087
3	1604	1397	15	2449	2143
4	1729	1546	16	2528	2143
5	1812	1698	17	2618	2150
6	1910	1785	18<30	2987	2183
7	1992	1771	30<60	2928	2186
8	2056	1835	60+	2018	1834
9	2066	1810			
10	2088	1901	Pregnant		+ 285
11	2152	1914	Lactating		+ 500

These recommendations are based on reference weight data for Mozambique (James and Schofield, 1994) and include energy needed to maintain weight as well as energy necessary for occupational and “socially desirable” activities. Occupational activities are assumed to be characteristic of a rural population in a developing country, i.e. requiring moderate to heavy energy expenditures.

Appendix IV

Coefficients tables of all models in analyses

4. Market Data Analysis

4.1.1 Biomass and Price

Model of monthly biomass as a function of year and market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	3.49470	0.04042	< 2e-16 ***
year12002/4	-0.12629	0.04156	0.00264 **
year12003	-0.40911	0.08255	1.38e-06 ***
newMkt8AFE	0.24760	0.07500	0.00111 **
newMkt8CM	0.54633	0.06407	1.85e-15 ***
newMkt8CZB	0.69060	0.11882	2.00e-08 ***
newMkt8FCV	0.09698	0.05855	0.09897 .
newMkt8LMB	0.33450	0.11324	0.00346 **
newMkt8LMP	0.15391	0.10228	0.13372
newMkt8LOU	0.60499	0.19782	0.00248 **
newMkt8MBT	0.18211	0.05626	0.00138 **
newMkt8MEK	0.36240	0.11918	0.00263 **
newMkt8MOA	-0.68631	0.08898	3.48e-13 ***
newMkt8NDJ	-1.14888	0.27758	4.86e-05 ***
newMkt8NKB	-0.04098	0.08845	0.64359
newMkt8OL1	0.28971	0.11139	0.00989 **
newMkt8VOB	0.21303	0.19947	0.28664

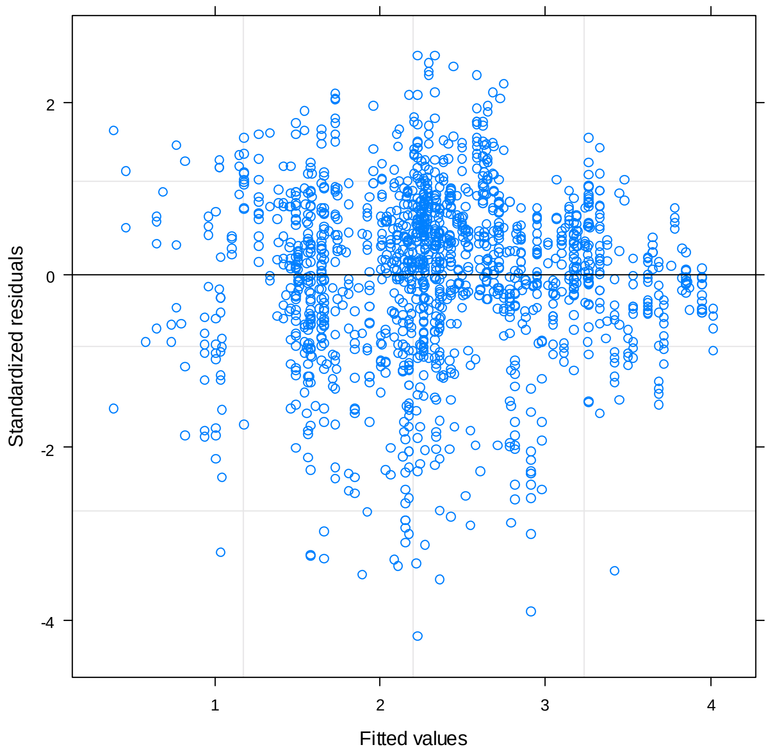
Model of monthly price per kg as a function of year and market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	2.79797	0.02244	< 2e-16 ***
years22001	-0.05315	0.0155	0.000711 ***
mktNew18MBT/ol2/ol1/AKB/ndj	0.42858	0.02522	< 2e-16 ***
mktNew18CM/klm/moa	0.36377	0.02633	< 2e-16 ***
mktNew18LOU/vob/czb/lmp/lmb	0.18895	0.03085	3.59e-09 ***
mktNew18FCV/KMR/okj/MSQ/nkb	0.25947	0.02379	< 2e-16 ***

4.1.2 Species composition

Model of monthly biomass by Order as a function of market

Term	*Value*	*Std.Error*	*DF*	*p-value*
(Intercept)	3.196598	0.055608	1397	0
mkt10CM	0.681861	0.042221	1397	0
mkt10CZB	0.612891	0.086289	1397	0
mkt10LMB	0.305917	0.087279	1397	0.0005
mkt10LMP	0.095007	0.085739	1397	0.268
mkt10LOU	0.592297	0.137147	1397	0
mkt10MBT	0.357126	0.037357	1397	0
mkt10MEK	0.382722	0.086082	1397	0
mkt10MOA	-0.62244	0.069987	1397	0
mkt10MSQ	-0.07202	0.219332	1397	0.7427
mkt10NDJ	-0.81492	0.282396	1397	0.004
mkt10OKJ	-0.07569	0.044139	1397	0.0866
mkt10OL1	0.388431	0.07869	1397	0
mkt10PK5	0.112472	0.118096	1397	0.3411
OrderCodeAVE	-2.68094	0.068317	1397	0
OrderCodeCAR	-1.68438	0.046359	1397	0
OrderCodePHO	-1.60679	0.045026	1397	0
OrderCodePRI	-0.99941	0.043629	1397	0
OrderCodeREP	-1.03671	0.047106	1397	0
OrderCodeROD	-0.90125	0.043412	1397	0



A. IV 1 Model plot for biomass by order model

Porcupine model – monthly biomass as a function of market

Term	*Estimate*	*Std. Error*	*p*	
(Intercept)	3.8475	0.1339	<2e-16	***
MarcheCodeCM	2.5964	0.166	<2e-16	***
MarcheCodeFCV	1.8969	0.1601	<2e-16	***
MarcheCodeMBT	2.8218	0.1588	<2e-16	***
MarcheCodeOKJ	2.0153	0.166	<2e-16	***

Blue duiker model – monthly biomass as a function of market

Term	*Estimate*	*Std. Error*	*p*	
(Intercept)	5.8693	0.0922	< 2e-16	***
MarcheCodeCM	1.0196	0.1156	5.33E-15	***
MarcheCodeFCV	0.0133	0.1124	0.9059	
MarcheCodeMBT	0.6028	0.1118	3.07E-07	***
MarcheCodeOKJ	0.2609	0.1156	0.0256	*

Red river hog model – monthly biomass as a function of market and year

Term	*Estimate*	*Std. Error*	*p*	
(Intercept)	7.0493	0.0835	< 2e-16	***
year22002	-0.4914	0.1103	1.71E-05	***
year22004	-0.3416	0.14	0.016	*
marketCM	-1.4375	0.1304	< 2e-16	***
marketMBT	-0.8835	0.1198	1.44E-11	***
marketOKJ	-1.0252	0.1325	1.99E-12	***

Cane rat model – monthly biomass as a function of market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	2.1833	0.1083	20.16 < 2e-16 ***
market3CM	1.5054	0.1503	10.02 1.35e-15 ***

4.3 Trends in bushmeat markets through time and space

4.3.1 Biomass and Price

Annual biomass as a function of year and market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	11.1845	0.1157	96.658 < 2e-16 ***
year12002-4	-0.4047	0.1237	-3.272 0.00515 **
mktcm	0.6554	0.1694	3.870 0.00151 **
mktfcv	-0.3126	0.1694	-1.846 0.08479 .
mktokj	-0.5329	0.1694	-3.146 0.00666 **

Average price per kg (annual) as a function of market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	7.06241	0.05720	< 2e-16 ***
market2cm/mbt	0.43039	0.09044	0.000157 ***

4.3.3 Average body mass

Monthly species average body mass as a function of market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	2.41999	0.04309	< 2e-16 ***
newMkcm	-0.64755	0.05523	< 2e-16 ***
newMkfcv	-0.47288	0.05302	1.87e-15 ***
newMkmbt/okj	-0.85313	0.04846	< 2e-16 ***

5 Socioeconomic and consumption data analysis

5.1.1 Volumes of bushmeat consumption

Model of bushmeat consumption quantity as a function of income category and settlement type

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	-6.64907	0.309605	< 2e-16 ***
SetTypeLT	0.245268	0.379948	0.51867
SetTypeST	1.027813	0.382334	0.00726 **
SetTypeVil	1.562009	0.346149	6.86e-06 ***
IncomeCat2	0.060873	0.61921	0.9217
IncomeCat3	0.279466	0.406531	0.4919
IncomeCat4	0.057015	0.325415	0.86094
SetTypeLT:IncomeCat2	0.51079	0.746818	0.4941
SetTypeST:IncomeCat2	0.427095	0.775559	0.58192
SetTypeVil:IncomeCat2	0.129003	0.718466	0.85753
SetTypeLT:IncomeCat3	0.007532	0.508928	0.98819
SetTypeST:IncomeCat3	0.641991	0.613701	0.29567
SetTypeVil:IncomeCat3	-0.0639	0.577074	0.91185
SetTypeLT:IncomeCat4	0.385923	0.405123	0.34093
SetTypeST:IncomeCat4	1.088514	0.458146	0.01762 *
SetTypeVil:IncomeCat4	-0.23452	0.425229	0.58136

5.3.2 Analysis of relationships between price, wealth and consumption quantity of bushmeat

Model of consumption quantity of bushmeat as a function of settlement type and price of freshwater fish

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	-8.5902	1.9513	3.5e-05 ***
SetTypeLT	1.2469	0.4609	0.008445 **
SetTypeST	1.5481	0.4911	0.002329 **
SetTypeVil	1.7234	0.4855	0.000669 ***
log(PricekgPed)	0.7357	0.2564	0.005344 **

Large town – consumption quantity of bushmeat as a function of price of bushmeat

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	2.1015	1.0586	0.049832 *
log(PricekgGib)	-0.5276	0.1471	0.000517 ***

Small town consumption quantity of bushmeat as a function of price of bushmeat, price squared and number of survey days

Term	*Estimate*	*Std. Error*	*Pr(>|t|)*	
(Intercept)	-439.761	214.3909	0.0443	*
log(PricekgGib)	194.5981	88.4821	0.0314	*
I(log(PricekgGib)^2)	-28.2827	12.0962	0.0225	*
Days	130.8249	73.3194	0.079	.
log(PricekgGib):I(log(PricekgGib)^2)	1.347	0.5476	0.0166	*
log(PricekgGib):Days	-57.8376	30.1238	0.0592	.
I(log(PricekgGib)^2):Days	8.3822	4.1005	0.045	*
log(PricekgGib):I(log(PricekgGib)^2):Days	-0.3988	0.1849	0.0347	*

Village – bushmeat consumption quantity as a function of bushmeat price

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	2.8120	0.8455	0.00121 **
log(PricekgGib)	-0.6575	0.1249	7.56e-07 ***

6 Comparison of volumes and composition of trade in markets and consumption

6.3 Characterising Libreville markets and their composition

Libreville markets – percentage biomass as a function of market, month and Order

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	-4.72073	0.419005	< 2e-16 ***
MarcheCodeAKB	0.86557	0.53515	0.106764
MarcheCodeMBT	0.873541	0.429767	0.042914 *
MarcheCodeNKB	0.952747	0.351348	0.007053 **
MarcheCodeOL1	0.829966	0.451187	0.066760 .
MarcheCodeOL2	0.92239	0.372323	0.013747 *
MarcheCodePK5	1.88001	0.372503	7.52e-07 ***
OrderCodeCAR	1.623184	0.53515	0.002617 **
OrderCodePHO	1.027302	0.53515	0.055785 .
OrderCodePRI	1.871915	0.53515	0.000535 ***
OrderCodeREP	3.369795	0.53515	9.94e-10 ***
OrderCodeROD	2.113202	0.53515	9.65e-05 ***
OrderCodeZRT	2.41504	0.254448	< 2e-16 ***
month82/8/9/10	0.141546	0.039672	0.000415 ***
month83	-0.20014	0.061004	0.001149 **
MarcheCodeAKB:OrderCodeCAR	NA	NA	NA
MarcheCodeMBT:OrderCodeCAR	-1.03675	0.547087	0.058982 .
MarcheCodeNKB:OrderCodeCAR	-1.24211	0.520495	0.017591 *
MarcheCodeOL1:OrderCodeCAR	-0.79083	0.574338	0.169486
MarcheCodeOL2:OrderCodeCAR	-0.94448	0.526358	0.073691 .
MarcheCodePK5:OrderCodeCAR	-1.36857	0.601881	0.023635 *
MarcheCodeAKB:OrderCodePHO	-0.48485	0.658898	0.462357
MarcheCodeMBT:OrderCodePHO	-0.00297	0.546433	0.995666

MarcheCodeNKB:OrderCodePHO	-0.63605	0.499787	0.204063
MarcheCodeOL1:OrderCodePHO	0.282378	0.574338	0.623296
MarcheCodeOL2:OrderCodePHO	0.061625	0.526358	0.906871
MarcheCodePK5:OrderCodePHO	-1.14016	0.552259	0.039767 *
MarcheCodeAKB:OrderCodePRI	-0.28274	0.647662	0.662729
MarcheCodeMBT:OrderCodePRI	0.190127	0.546027	0.727918
MarcheCodeNKB:OrderCodePRI	-0.26043	0.496255	0.600092
MarcheCodeOL1:OrderCodePRI	0.003963	0.574338	0.994499
MarcheCodeOL2:OrderCodePRI	0.172534	0.526358	0.743284
MarcheCodePK5:OrderCodePRI	-1.18473	0.526358	0.025072 *
MarcheCodeAKB:OrderCodeREP	-2.11411	0.715179	0.003346 **
MarcheCodeMBT:OrderCodeREP	-1.02585	0.546027	0.061181 .
MarcheCodeNKB:OrderCodeREP	-1.20349	0.496255	0.015852 *
MarcheCodeOL1:OrderCodeREP	-1.11177	0.574338	0.053775 .
MarcheCodeOL2:OrderCodeREP	-1.20467	0.526358	0.022744 *
MarcheCodePK5:OrderCodeREP	-2.7335	0.535082	5.57e-07 ***
MarcheCodeAKB:OrderCodeROD	-0.58765	0.647662	0.364903
MarcheCodeMBT:OrderCodeROD	0.005093	0.545949	0.992563
MarcheCodeNKB:OrderCodeROD	-0.63219	0.496255	0.20361
MarcheCodeOL1:OrderCodeROD	-0.39648	0.574338	0.49049
MarcheCodeOL2:OrderCodeROD	-0.7062	0.526358	0.180649
MarcheCodePK5:OrderCodeROD	-1.28537	0.526358	0.015144 *
MarcheCodeAKB:OrderCodeZRT	0.377764	0.444774	0.396324
MarcheCodeMBT:OrderCodeZRT	0.490521	0.27644	0.076938 .
MarcheCodeNKB:OrderCodeZRT	NA	NA	NA
MarcheCodeOL1:OrderCodeZRT	0.278848	0.328973	0.397273
MarcheCodeOL2:OrderCodeZRT	NA	NA	NA
MarcheCodePK5:OrderCodeZRT	NA	NA	NA

Libreville markets – percentage biomass as a function of Gabon protection status and market

Term	*Estimate*	*Std. Error*	*p*
(Intercept)	-2.12487	0.18432	< 2e-16 ***
GabonStatusCodeINC	0.38045	0.24511	0.121966
GabonStatusCodeINT	0.07163	0.26226	0.785007
GabonStatusCodePAR	1.63663	0.22666	7.21e-12 ***
GabonStatusCodePAS	1.37706	0.12874	< 2e-16 ***
MarcheCodeAKB	0.57684	0.15608	0.000273 ***
MarcheCodeMBT	-0.07157	0.21349	0.737727
MarcheCodeNKB	0.12033	0.14249	0.39926
MarcheCodeOL1	-0.05803	0.14958	0.698412
MarcheCodeOL2	-0.0349	0.16156	0.829175
MarcheCodePK5	-0.1378	0.16156	0.39459
GabonStatusCodeINC:MarcheCodeAKB	NA	NA	NA
GabonStatusCodeINT:MarcheCodeAKB	-0.24986	0.26051	0.338495
GabonStatusCodePAR:MarcheCodeAKB	-1.55557	0.22074	2.03e-11 ***
GabonStatusCodePAS:MarcheCodeAKB	NA	NA	NA
GabonStatusCodeINC:MarcheCodeMBT	-0.25181	0.27835	0.366585
GabonStatusCodeINT:MarcheCodeMBT	0.4102	0.28484	0.151174
GabonStatusCodePAR:MarcheCodeMBT	-0.22153	0.25242	0.38105
GabonStatusCodePAS:MarcheCodeMBT	0.29012	0.17004	0.089306 .

GabonStatusCodeINC:MarcheCodeNKB	-0.24226	0.22848	0.290108
GabonStatusCodeINT:MarcheCodeNKB	0.19037	0.24084	0.430088
GabonStatusCodePAR:MarcheCodeNKB	-0.31346	0.2015	0.121153
GabonStatusCodePAS:MarcheCodeNKB	NA	NA	NA
GabonStatusCodeINC:MarcheCodeOL1	-0.07909	0.25667	0.758244
GabonStatusCodeINT:MarcheCodeOL1	0.6465	0.2493	0.010106 *
GabonStatusCodePAR:MarcheCodeOL1	-0.0345	0.21154	0.870576
GabonStatusCodePAS:MarcheCodeOL1	NA	NA	NA
GabonStatusCodeINC:MarcheCodeOL2	NA	NA	NA
GabonStatusCodeINT:MarcheCodeOL2	0.66749	0.26383	0.012064 *
GabonStatusCodePAR:MarcheCodeOL2	-0.07266	0.22848	0.750777
GabonStatusCodePAS:MarcheCodeOL2	NA	NA	NA
GabonStatusCodeINC:MarcheCodePK5	NA	NA	NA
GabonStatusCodeINT:MarcheCodePK5	1.69429	0.26383	7.43e-10 ***
GabonStatusCodePAR:MarcheCodePK5	-0.95791	0.22848	3.92e-05 ***
GabonStatusCodePAS:MarcheCodePK5	NA	NA	NA

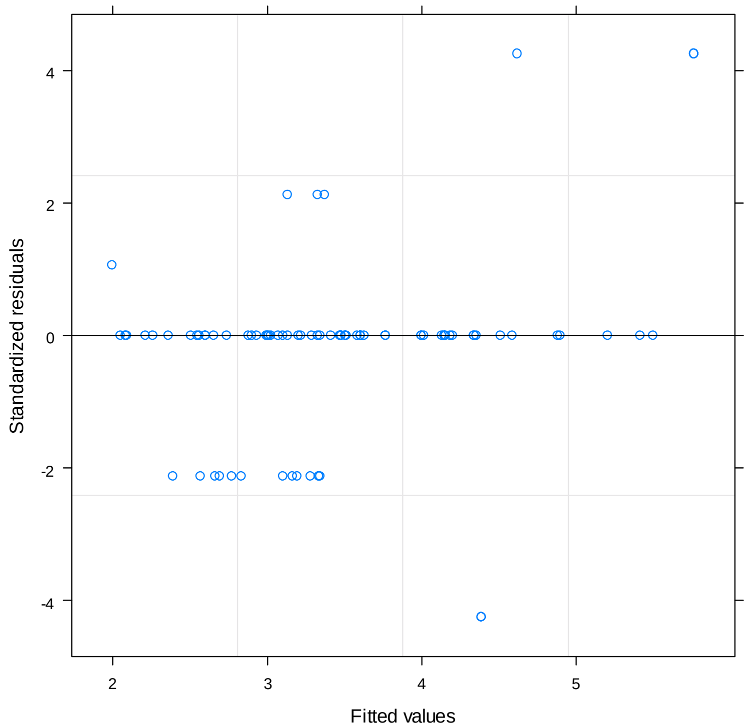
Libreville markets – percentage biomass as a function of IUCN conservation status and market

Term	***Estimate***	***Std. Error***	***p***
(Intercept)	-2.31838	0.290152	1.18e-14 ***
statusCR	-2.10987	0.438668	2.08e-06 ***
statusDD	-1.16565	0.410337	0.004709 **
statusEN	-1.20388	0.438668	0.006308 **
statusLC	0.524906	0.410337	0.201493
statusLR/CD	-1.2652	0.502558	0.012170 *
statusLR/LC	0.571685	0.410337	0.164255
statusLR/NT	0.372827	0.410337	0.364061
statusVU	1.603719	0.410337	0.000107 ***
MarcheCodeAKB	-1.57515	0.410337	0.000142 ***
MarcheCodeMBT	-0.51345	0.297499	0.085066 .
MarcheCodeNKB	0.042975	0.315428	0.89169
MarcheCodeOL1	-0.01982	0.329001	0.951988
MarcheCodeOL2	-0.49224	0.355362	0.166699
MarcheCodePK5	-0.72475	0.374584	0.053649 .
statusCR:MarcheCodeAKB	NA	NA	NA
statusDD:MarcheCodeAKB	2.387342	0.542824	1.37e-05 ***
statusEN:MarcheCodeAKB	NA	NA	NA
statusLC:MarcheCodeAKB	1.42222	0.535013	0.008138 **
statusLR/CD:MarcheCodeAKB	NA	NA	NA
statusLR/LC:MarcheCodeAKB	2.79801	0.535013	2.62e-07 ***
statusLR/NT:MarcheCodeAKB	2.138545	0.535013	7.51e-05 ***
statusVU:MarcheCodeAKB	-0.17083	0.535013	0.749645
statusCR:MarcheCodeMBT	1.061689	0.45459	0.019963 *
statusDD:MarcheCodeMBT	1.044242	0.420476	0.013380 *
statusEN:MarcheCodeMBT	0.314305	0.469895	0.503918
statusLC:MarcheCodeMBT	0.684576	0.42036	0.10412
statusLR/CD:MarcheCodeMBT	0.77203	0.518564	0.137256
statusLR/LC:MarcheCodeMBT	1.257487	0.42036	0.002931 **
statusLR/NT:MarcheCodeMBT	0.707969	0.420476	0.092938 .
statusVU:MarcheCodeMBT	0.057485	0.420476	0.891318

statusCR:MarcheCodeNKB	NA	NA	NA
statusDD:MarcheCodeNKB	0.556493	0.446083	0.212869
statusEN:MarcheCodeNKB	-0.84183	0.61328	0.17055
statusLC:MarcheCodeNKB	-0.13822	0.444651	0.756067
statusLR/CD:MarcheCodeNKB	0.004573	0.593346	0.993854
statusLR/LC:MarcheCodeNKB	0.192341	0.444651	0.66554
statusLR/NT:MarcheCodeNKB	0.551115	0.444651	0.215841
statusVU:MarcheCodeNKB	-0.39444	0.444651	0.375513
statusCR:MarcheCodeOL1	NA	NA	NA
statusDD:MarcheCodeOL1	0.790639	0.465278	0.089968 .
statusEN:MarcheCodeOL1	NA	NA	NA
statusLC:MarcheCodeOL1	-0.16873	0.465278	0.717038
statusLR/CD:MarcheCodeOL1	0.120854	0.564546	0.830588
statusLR/LC:MarcheCodeOL1	0.627287	0.465278	0.178284
statusLR/NT:MarcheCodeOL1	-0.01982	0.465278	0.966035
statusVU:MarcheCodeOL1	-0.23701	0.465278	0.610724
statusCR:MarcheCodeOL2	NA	NA	NA
statusDD:MarcheCodeOL2	1.037191	0.502558	0.039616 *
statusEN:MarcheCodeOL2	NA	NA	NA
statusLC:MarcheCodeOL2	0.093225	0.502558	0.852921
statusLR/CD:MarcheCodeOL2	1.157013	0.59227	0.051387 .
statusLR/LC:MarcheCodeOL2	1.015888	0.502558	0.043835 *
statusLR/NT:MarcheCodeOL2	0.647466	0.502558	0.1983
statusVU:MarcheCodeOL2	0.469036	0.502558	0.351174
statusCR:MarcheCodePK5	NA	NA	NA
statusDD:MarcheCodePK5	3.658145	0.516329	5.51e-12 ***
statusEN:MarcheCodePK5	NA	NA	NA
statusLC:MarcheCodePK5	0.469398	0.516329	0.363788
statusLR/CD:MarcheCodePK5	0.516658	0.626799	0.410224
statusLR/LC:MarcheCodePK5	0.393605	0.516329	0.446278
statusLR/NT:MarcheCodePK5	0.986459	0.516329	0.056711 .
statusVU:MarcheCodePK5	-1.03258	0.516329	0.046127 *

Libreville markets – species average body mass as a function of market

Term	***Value***	***Std.Error***	***p-value***
(Intercept)	2.445594	0.299921	0
marketnew1mbt	0.626649	0.259984	0.0223
marketnew1nkb	1.344448	0.308669	0.0001
marketnew1ol1	1.275912	0.311736	0.0003
marketnew1ol2/pk5	1.250823	0.314954	0.0004



A. **IV 2 Model plot for Libreville markets average body size model**

Appendix V

Table of estimates of annual biomass and average price per kg of bushmeat at markets

Town	*Market*	*Year*	*Estimated Annual Biomass (kg) Bushmeat*	*Average price per kg Bushmeat (fcfa)*
Libreville	Premier Campement	2000	19076	1564
		2001	29286	1656
	Akebe	2000	31253	1916
	Mont-Bouet	2000	76769	2156
		2001	110457	1819
		2002	58899	1769
		2003	31702	1969
		2004	34124	1802
	Nkembo	2000	21566	1587
		2001	36766	1726
		2002	15017	1354
	Oloumi 1	2000	77048	1361
	Oloumi 2	2000	109367	2082
	PK 5	2001	43533	1378
Franceville	Pottos	2000	70198	1255
		2001	54257	1474
		2002	27131	1530
		2003	19298	1675
		2004	33158	1601
		2006	33156	1588
Koula-Moutou	Koula-Moutou	2002	21479	1319
	Koula-Moutou Ravitaillement	2002	25839	1422
Lambarene	Lambarene	2002	148658	938
		2003	30339	1654
		2004	55387	1129
	Port	2002	39497	909
		2004	42124	1012
Makoukou	Afane	2000	71067	882
		2001	77126	948
		2002	32138	979
		2004	47682	961
	Afane Ravitaillement	2001	40101	841
	Cite Zaotab	2001	87327	1212
		2002	207460	1554
	Loua-Loua	2001	106159	2370
		2002	160511	1941
Mekambo	Mekambo	2000	28506	1934
		2001	109301	903
Moanda	Moanda	2000	8732	994
		2001	7726	1543
Ndjole	Ndjole	2001	2661	1550
Okondja	Mosquee	2001	40594	1517
	Gare Routiere	2000	33476	1721
		2001	35994	1327
		2002	28155	1259
		2004	41850	1415
		2006	34827	1180
Oyem	Carrefour Monaco	2000	98373	2326
		2001	122078	1636
		2002	119157	1454
		2004	115051	1387
Obiri Village	Obiri Village	2002	46398	1156

Appendix VI

Table showing Libreville markets and the most popular species by percentage of biomass.

Market													
Premier Campement		Akebe		Mont-Bouet		Nkembo		Oloumi 1		Oloumi 2		PK5	
Species	% of biomass	Species	% of biomass	Species	% of biomass	Species	% of biomass	Species	% of biomass	Species	% of biomass	Species	% of biomass
Dwarf crocodile	43	Blue duiker	39.6	Dwarf crocodile	21.3	Dwarf crocodile	23.2	Dwarf crocodile	26.6	Dwarf crocodile	23.6	Water chevrotain	60.0
African rock python	17.9	Peter’s duiker	23.1	Brush-tailed porcupine	14.5	Bay duiker	17.5	Red river hog	15.9	Red river hog	10.9	Brush-tailed porcupine	7.9
Brush-tailed porcupine	10.7	Brush-tailed porcupine	10.0	Blue duiker	12.1	Brush-tailed porcupine	11.8	Brush-tailed porcupine	8.5	Black colobus	7.6	Bay duiker	7.3
Blue duiker	7.8	Red river hog	7.5	Bay duiker	7.7	African rock python	8.5	Duiker unknown	6.9	Brush-tailed porcupine	7.0	Dwarf crocodile	5.0
Bay duiker	4.8	Putty-nosed guenon	4.6	Red river hog	7.1	Blue duiker	6.4	Giant pangolin	4.7	Mandrill	6.3	Peter’s duiker	4.2
Peter’s duiker	3.9	Moustached guenon	4.4	Mandrill	6.7	Red river hog	6.0	Blue duiker	3.9	Peter’s duiker	5.4	Blue duiker	3.0
Black colobus	3.4	Water chevrotain	3.0	Putty-nosed guenon	3.7	Mandrill	5.1	Black colobus	3.8	Blue duiker	5.3	Sun-tailed guenon	2.0
African civet	2.2	Forest elephant	2.2	Black colobus	3.1	Peter’s duiker	4.1	Mandrill	3.4	Sun-tailed guenon	4.8	Putty-nosed guenon	1.6