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The Dynamics of a Bushmeat Hunting System Under Social, Economic and Environmental Change

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Declaration of Originality

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James McNamara, October 2013.

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Abstract

The trade in bushmeat for human consumption is an important source of income and food for many people in tropical Africa. Yet it also represents one of the most significant threats to the persistence of wildlife. This threat has been exacerbated in recent decades as the trade has become increasingly commercial in nature, and previously pristine habitats have been degraded due to agriculture and extractive industries. These agricultural, production landscapes are increasingly the face of rural Africa, particularly West Africa. Understanding how economic and landscape-level pressures influence hunting behaviour in these production landscapes will be critical to developing effective management policies that are able to address both development and conservation agendas.

This study uses a unique 26-year dataset, collected in the Atwemonom market in Kumasi, Ghana, to examine the spatio-temporal dynamics of the bushmeat trade in the region. A multidisciplinary, multi-scale approach is adopted to present a holistic overview of the trade. Four analyses are presented. Firstly, a framework is developed to assess the degree to which the trade is driven by the demands of the consumer, or the behaviour of the hunter. Secondly, an econometric supply and demand model based on available market data is tested and implemented to analyse the drivers of supply and demand in the commercial system. Thirdly, a spatial model is designed to explore how the biophysical characteristics of the landscape influence what is harvested, from where it is harvested and how this has changed over time. Finally, the findings of these three approaches are used to inform a scenario analysis that explores the socioeconomic factors determining a hunter's willingness to adapt their behaviour in light of changing incentives to participate.

The findings highlight the importance of the production landscape for supporting the bushmeat trade in the region and present evidence that suggests the trade around Kumasi may be defined more by drivers of supply (hunter behaviour) than demand (consumer preference). This raises concerns about the effectiveness of demand side management. The results emphasise the need for

integrated approaches to bushmeat management that consider the full range of social, economic and environmental drivers.

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Chapter 1

Introduction

1. Introduction

1.1. Problem statement

The commercial bushmeat trade in West Africa is an established livelihood activity that is deeply entrenched in the rural economy. As a financial activity, the motivations to participate in the commercial trade differ from those of the subsistence hunter and are defined both by the opportunity costs of engagement as well as environmental factors (Brashares *et al.* 2011). Thus, the context within which hunting decisions are made may be viewed as being embedded in a complex socio-ecological system (Duraiappah & Naeem 2005). There is growing awareness that if we wish to manage these systems more sustainably and more effectively, it is critical we develop holistic and interdisciplinary methods that are able to take account of the broader processes defining people's decision making (Berkes *et al.* 2003; Díaz *et al.* 2006; Nicholson *et al.* 2009). The findings of such analyses represent an important source of evidence, both to understanding complex dynamics of the system (such as feed-backs that may lead to interventions producing counter intuitive results) and to helping develop more sustainable bottom-up management policies based on empowering the user base rather than dictating to it.

The challenge of conserving biodiversity in many regions of Africa is complicated by poor governance, and high levels of poverty (Smith *et al.* 2003). Traditional reliance on natural resources, particularly among the poorest (Robinson & Bennett 2002; Adams *et al.* 2004), means that management is a priority both for conservationists and development agencies alike (Davies 2002). Forecasts for climate change in the region suggest an increase in extreme weather events, a reduction in the growing seasons of key crops, and an intensification of vector borne diseases may become more likely (Conway 2009). Such developments are likely to place additional pressure on people and resources, making the need for solutions that consider the broader contexts of these system much more critical (Young *et al.* 2006; Rands *et al.* 2010; Sala *et al.* 2000; Sachs *et al.* 2009; Watson *et al.* 2012; Warren *et al.* 2013). Bushmeat, the meat of wild animals, is a particularly valuable resource provided by tropical African ecosystems that has a long history of human use. It represents an important subsistence and economic activity, particularly for those on the edge of the cash economy, who frequently have few employment options and are less able to escape from poverty traps due to a lack of education, skills or access to capital (Robinson & Bennett 2002; de Merode *et al.* 2004; Carter & Barrett 2006). However, the bushmeat trade is largely recognised as unsustainable, and is acknowledged as among the major threats to tropical forest biodiversity (Bowen-Jones, Brown & Robinson 2003). Overexploitation by hunters has been attributed to the declines, and localised extinctions of species in a number of cases (Struhsaker & Oates, J 1995; Brashares *et al.* 2001; Barnes 2002). Many bushmeat species also play an important role in seed dispersal and pollination (Wright *et al.* 2000; Brodie & Gibbs 2009). Loss of large mammals from forest environs impacts the structure and functioning of ecosystems leading to an alteration in productivity that may have consequences for challenges of global concern, such as climate regulation and carbon sequestration (Brodie & Gibbs 2009; Morris 2010). In recognition of this fact, the trade in bushmeat been recognised by the IUCN as one of the world's most pressing conservation problems (Mainka & Trivedi 2002).

The bushmeat trade sits within a network of dynamic processes and is influenced by a range of drivers that act at multiple scales. Hunters' participation in the trade is determined by local-level drivers such as their socioeconomic profiles (de Merode *et al.* 2004) and the opportunity costs associated with their livelihood choices (Brashares *et al.* 2011; Schulte-Herbrüggen 2011). Globalisation, and the associated improvements in access to markets and technology, change the incentives associated with hunting (Kramer *et al.* 2009). Urban demand is driving the commercialisation of the bushmeat trade; as a consequence, the wealth and preferences of urban consumers exert a strong influence on the dynamics of the trade (Falconer 1992; Bowen-Jones & Pendry 1999; Brashares *et al.* 2004; Fa *et al.* 2009). At the same time, many landscapes in the tropical world have undergone dramatic changes in recent decades, with significant loss of native forests as timber and agriculture industries have expanded (Benhin & Barbier 2004; Norris *et al.* 2010). These landscape-level changes alter species composition, hunter behaviour and, ultimately, the productivity and sustainability of bushmeat extraction (Wilkie & Carpenter 1999; Jerozolimski 2003; Robinson & Bennett 2004). In addition, the personal or cultural importance of hunting may influence an individual's willingness or desire to adapt to external pressures.

The trade in bushmeat can therefore be defined by a range of drivers that influence both supply and demand. If managers are to develop appropriate strategies for managing such a complex socio-ecological system, multi-disciplinary, multi-scale approaches will need to be adopted that are able to consider the full range of drivers and their interactions (Milner-Gulland 2012). Management strategies that fail to take such an integrated approach will risk failure, as they are unlikely to be able to predict the responses of resource users to change, nor where change may be best made to encourage desirable behaviour (Albrechtsen *et al.* 2007; Carpenter *et al.* 2009; Milner-Gulland 2012). Although theoretical models have explored various aspects of the integrated socio-ecological dynamics of hunting systems (Damania *et al* 2005; Ling & Milner-Gulland 2006), empirical analyses that analyse the drivers of supply and demand are few, due often to the lack of long-term high-resolution data (Macdonald *et al.* 2011). This study aims to address this gap.

1.2. Aims and objectives

It is widely acknowledged that there is no simple solution to the problems associated with the bushmeat trade, and that successful conservation management will require an integrated approach addressing both supply and demand (Robinson & Bennett 2002; Davies 2002; Milner-Gulland, Bennett & SCB WIld Meat Group 2003; Bennett *et al.* 2007). If integrated approaches are to be successful, it is necessary to develop analyses that consider bushmeat hunting within the context of the socio-ecological systems of which it is part. To understand these systems, it is first necessary to break them down into their component parts.

In its simplest form, we break this system down into three core inter-linked components (figure 1.1): (1) the behaviour of the hunter, defined by (2) The dynamics of the market and (3) The landscape and biophysical attributes that define the trade. It should be noted that cultural and traditional uses of hunting are also likely to play an important role in defining hunting behaviour and may alter the perceived opportunity costs of participation. Although the model presented in figure 1.1 does not explicitly depict these drivers, they will be considered in a contextual manner in the following thesis.

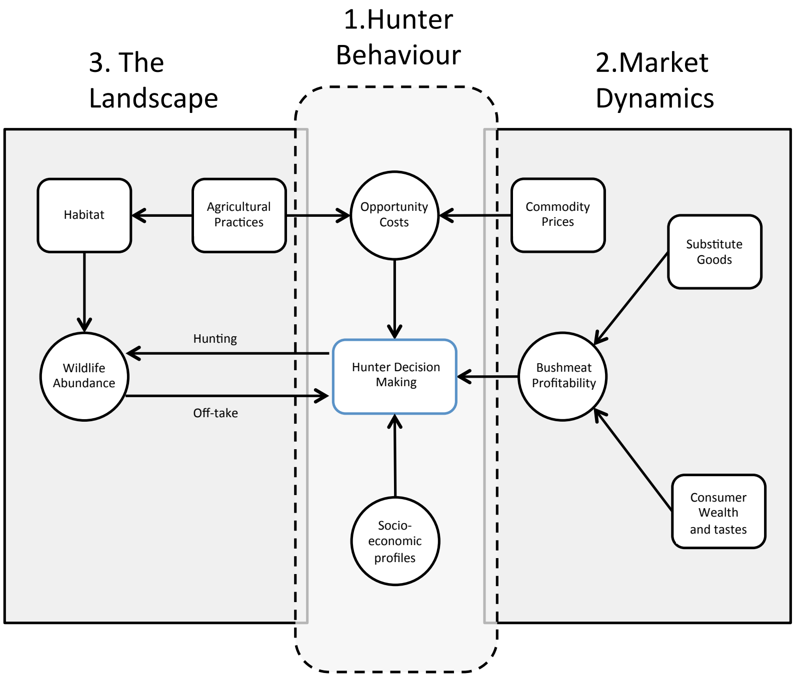

Figure 1.1: A conceptual diagram describing the fundamental processes that may define the commercial bushmeat trade in Kumasi. Circles represent incentives that influence hunter decision-making. Rectangles represent drivers, or consequences of drivers. Lines represent the direction of effect.

Using the bushmeat trade in the city of Kumasi, Ghana, as a case study, the following research aims to develop an innovative and multidisciplinary approach to analysing the socio-ecological context of bushmeat hunting, that is both dynamic (how does the trade evolve in both time and space?) and cross-sectoral (how does the broader context of the system influence behaviour?). It aims to understand the mechanics of the system in order to (1) critically analyse management options within the context of an improved understanding of system behaviour and (2) make predictions about the future evolution of the system in the light of global environmental change.

Adapting novel methodologies from the social, ecological and economic science, these research aims are addressed through the following objectives:

1. What are the drivers of the commercial trade in bushmeat?
2. How do the livelihood dynamics and socioeconomic profile of resource users influence their behaviour, and
3. How do the dynamic biophysical attributes of the landscape define the trade?

Chapter 2

Research background and case study

2. Research background and case study

2.1. Study Area

2.1.1. Ghana

Ghana, which takes its name from the ancient Kingdom of Ghana, one of the great Sudanic states that flourished in sub-Saharan Africa up to 11th Century AD, is situated in West Africa (Gocking 2005). It has three land borders: Côte D'Ivoire to the west, Burkina Faso to the north and Togo to the East. There are six primary ethnicities in the country, of which the Akan are the largest group, representing 53% of the population. Other major ethnicities include Ewe (12%), Mole Dagbani (12%), Ga-Dangme (10%), Guan (4%) and Gurman (3%). The Akan themselves consist of numerous sub-groups, of which the Asante (based in the Ashanti Region) and Fanti (in the Central region) are the largest (Ghana Statistical Service 2008). It is estimated that more than 60 local languages are spoken in the country, of which Twi, the language of the Asante and Akuapem, is the most widely spoken.

Ghana has one of the strongest economies in the west African sub-region , with a total annual GDP second only to Nigeria, and the highest GDP per capita (IMF 2013b). It has a primarily agricultural economy, with cocoa representing the main export commodity, although mineral resources, notably gold and more recently oil, are valuable components of the national balance sheet (Breisinger et al. 2009). Politically it has been relatively stable for the past 20 years, with a multi-party democratic system. This has made it an attractive option for foreign investment, particularly compared to the relatively turbulent political administrations of its neighbours (Gocking 2005). Although 30% of the population are still defined as living in poverty (living on less than $1.25 per day), the country's strong economy and stable political environment has allowed it to attain lower-middle income status, and the government has set a target to attain middle income status by 2015 (IMF 2013a).

2.1.2. Study area

This research focuses on hunting in and around the Ashanti region of Ghana, with a focus on the commercial trade that passes through the Atwemonom bushmeat market, located in the city of Kumasi. The Ashanti region is located in the tropical forest zone of southwest Ghana. It is one of the wealthiest and most populous regions in Ghana, as a result of its rich agricultural land and forest reserves that support productive cocoa and timber industries (Bediako 2008; Ghana Statistical Service 2008). In addition to Kumasi, research was conducted in four rural communities around the city. Jachie and Kwaman in the Ashanti Region (6.57N,-1.52W and 6.98N, -1.27W respectively), Anyimaye in the Brong-Ahafo Region (6.69N, -2.77W), and Kofiekrom in the Western Region (5.80N, -2.26W), see figure 2.1. The area was visited on three research trips, between April and June 2010, May and June 2011 and May to June 2012.

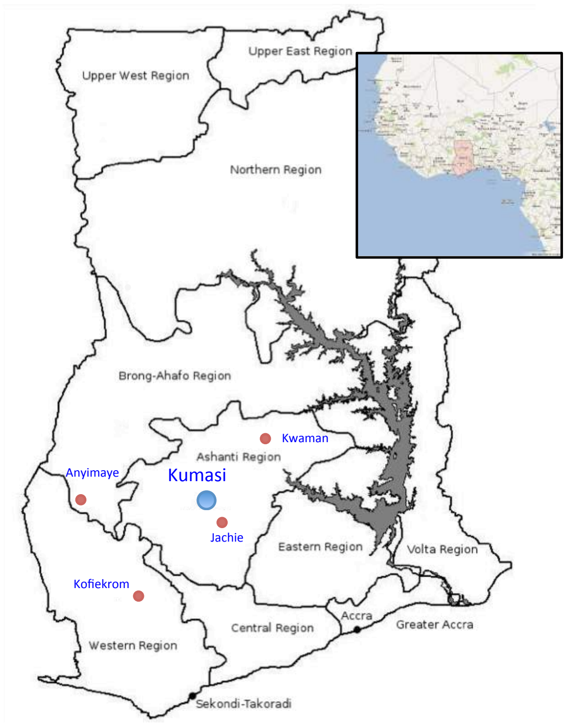

Figure 2.1 A map of Ghana and its regions, and location of the study sites, Kumasi, Jachie, Kwaman, Kofiekrom and Anyimaye

2.1.3. Climate and geography

The study area lies within the Upper Guinean Forest Global Biodiversity hotspot, which extends east from Guinea through Liberia, Cote D'Ivoire, Ghana and Togo (CEPF 2000). The ecosystem is ranked 5th among 25 global hotspots identified by Conservation International and is considered an area of high conservation and biodiversity importance (CEPF 2000; Myers et al. 2000). The climate is tropical, with average temperatures ranging from 22^{0}C to 31^{0}C, and average annual rainfall of 1,402mm with 10 days of rain per month, averaged over the past 30 years (Ghana Meterological Association 2013). There are four seasons: a long dry season (November to March) associated with the Harmattan, a dry wind from the Sahara that blows across the country from the northeast (Gocking 2005; McSweeney et al. 2008), a long wet season (from April to July), followed by a short dry season (August) and a short wet season (August to October).

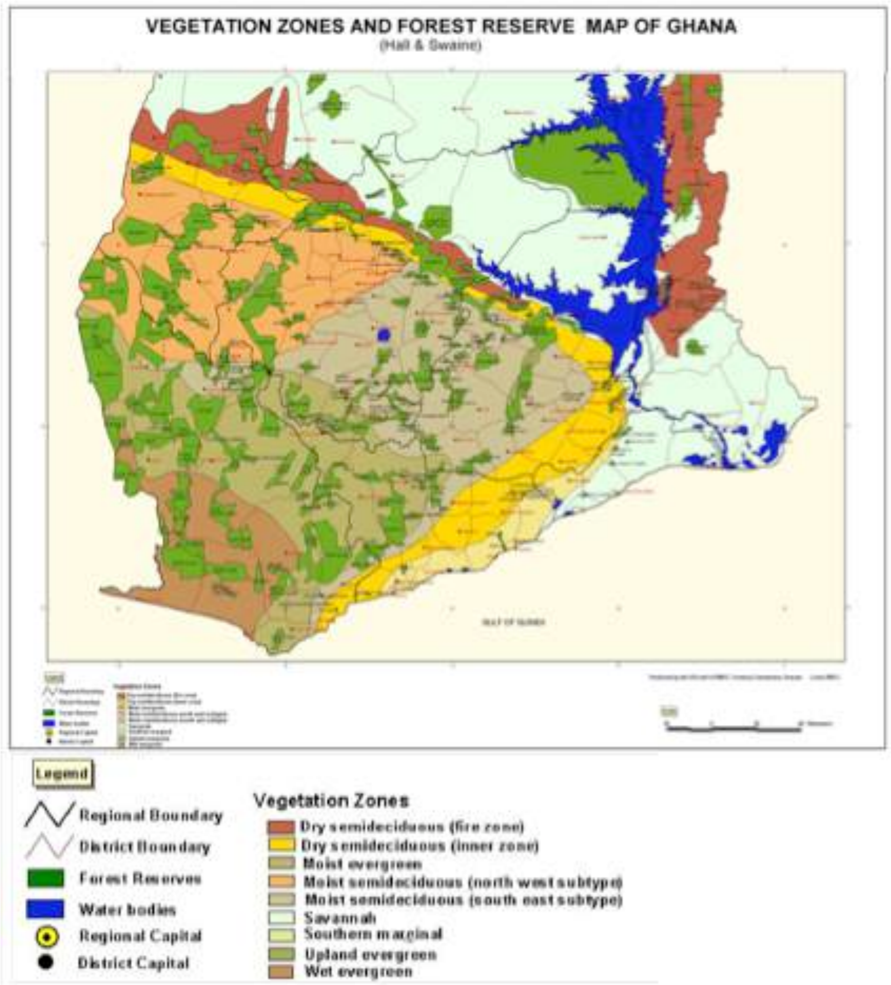

Figure 2.2 Map of the ecological zones in southern Ghana (Forestry Commission 2003)

In reality, the seasons are variable, and dominated by the Inter-Tropical Conversion Zone (ITCZ) which oscillates between the northern and southern tropic over the course of the year (McSweeney et al. 2008). The southwest of the country receives the highest level of rainfall, which declines as one moves towards the northeast. This rainfall pattern creates clearly defined differences in the ecological zones across the country (figure 2.2). The Ashanti region straddles three primary eco-zones: the dry semi-deciduous in the north; the moist semi-deciduous in the centre; and the moist evergreen in the southwest (Forestry Commission 2003).

2.1.4. Agriculture and the landscape

Agriculture is the mainstay of the rural economy. The most recent Ghana Living Standards Survey (GLSS), conducted in 2005, indicated that 61.4% of households are involved in agricultural enterprises (Ghana Statistical Service 2008), and 37% of the average household income was derived from agricultural activity (Trades Union Congress (Ghana) 2004). Cocoa and maize are the primary cash crops in the Ashanti Region, accounting for 95% of the total harvest value in 2005 (Ghana Statistical Service 2008); see table 2.1.

Table 2.1 Summary data of agricultural production of the seven main crops grown in the Ashanti region, ranked by value. Data relates to 2005. Sources, (Ghana Statistical Service 2008; SRID 2010; COCOBOD 2013)

Crop	Value (million cedi)	Production (tonnes)	Land Area (km2)	Households involved
Cocoa	405	90,535	245,685	651,009
Maize	154	183,032	113,639	1,212,037
Cassava	8.3	1,226,931	120,324	1,216,927
Plantain	7.1	600,595	65,623	1,032,758
Rice	6.0	9,926	5,264	25,952
Yam	2.5	230,367	18,146	281,583
Cocoyam	2.2	638,942	96,777	534,951

The expansion of agriculture, especially cocoa, and the timber industry has been one of the main drivers of forest loss in the region (Benhin & Barbier 2004; Braimoh 2009). Between 1977 and 2004, the area of land set aside for the cultivation of the seven main agricultural crops (including cocoa) in the Ashanti Region more than doubled, from 0.2 to 0.5 million hectares (Ghana Statistical Service 2012). This expansion has come at a price, and it has been suggested that as much as 20% of the forested land present in 1990 had been converted to other land types by 2005 (FAO 2010), while as much as 80% of Ghana's forest may have been cleared during the last century (Opoku 2006; Awanyo 2007).

Much of the remaining intact tropical forest in Ghana lies in forest reserves or protected areas. Within the Ashanti region, only 6.8% of protected forest areas are not managed for timber production. Outside of these reserves, land is largely devoted to low-intensity agricultural production (Benhin & Barbier 2004). Thus the landscape is almost entirely characterised by production and human disturbance.

2.1.5. Hunting and wildlife management

The impact of land conversion, coupled with high levels of hunting, has had a dramatic impact on wildlife across Ghana (Struhsaker & Oates, J 1995; Barnes 2002; Brashares 2003; Schulte-Herbrüggen et al. 2013). There have been a number of documented local extinctions, with perhaps the best known being that of Miss Waldron's red colobus (Oates et al. 2000; McGraw & Oates 2002), although similar, lesser known cases are available regarding other species, such as the white-neck rock fowl (Marks et al. 2004).

Despite these dramatic declines, wildlife hunting remains an important part of the livelihood portfolio for many rural households, and bushmeat a highly desired consumer good in both rural and urban markets. Household surveys conducted in communities around Kumasi in 1990 indicated that, on average, 14% of households were involved with hunting (Falconer 1992). This aligns well with surveys conducted in 2002 and 2004, also in the Kumasi area, which indicated that approximately 15% of households were involved in hunting (Crookes et al. 2007). Although estimates of the value of the trade are difficult due to its largely informal nature, research has conservatively suggested the annual trade could be worth in excess of $US350 million (Ntiamoa-Baidu 1998).

Hunting is regulated by the Wildlife Conservation Regulations (Government of Ghana 1971, 1983, 1988, 1989) which impose a strict ban on hunting of all species except the grasscutter (Thryonomys swinderianus) between 1 August and 1 December each year, a period referred to as the "closed season". For the remainder of the year, from December through to July, hunting is permitted for all species except those listed as schedule 1 in the Wildlife Conservation Regulations. For a full set of schedules and species covered by this legislation, see Appendix A. Additional controls are present in the form of hunting licences. Hunters are required to apply for a hunting licence every year. The licence stipulates the number of animals of each species that can be taken. Although Wildlife Division officials work closely with hunters to ensure that licences are up to date, monitoring offtake in line with licence requirements is extremely difficult and rarely attempted in practice. Hunting with a gun is the only legally permitted method. However, a variety of other practices are commonly used, including traps (usually wire snares) and dogs.

There are two main types of protected area that have strict conditions of use associated with them. Forests Reserves, which are managed for commercial timber extraction, and Wildlife Reserves, which include National Parks. Wildlife reserves are fully protected and no extraction of any kind is permitted. Forest reserves allow certain types of extraction in addition to commercial logging. Villagers are free to harvest forest products, such as firewood or cane, but the harvesting of commercial timber and bushmeat is strictly prohibited (Bockhorst 2010).

2.1.6. Study sites

Kumasi and the Atwemonom market

The capital of the Ashanti region is Kumasi, Ghana's second largest city, capital of the Asante Kingdom, and the throne of the Asante King, with a population of approximately 1.5 million people (Ghana Health Service 2010). Kumasi is often considered the commercial capital of Ghana, and its open-air Central Market rivals Onitsha in Nigeria as one of West Africa's largest markets. In addition to timber, it is renowned for the local trade in artisan goods and vehicle engineering (World Bank 2000). As well as the sprawling and diverse Central Market, Kumasi is also home to the Atwemonom bushmeat market. The name "Atwemonom" means "fresh duiker meat" in the local dialect, Twi, ("Otwe" is the Asante name for the Maxwell duiker, Philantomba maxwellii), and it serves as the primary market for fresh bushmeat in the city. It is also one of the oldest formal bushmeat markets in Ghana and as such is well established in the local economy (Falconer 1992). The market is primarily supplied by local hunters from the surrounding communities (Hofmann et al. 1999; Shanti-Alexander

2011). As household refrigeration is uncommon, hunters tend to bring the meat directly to market from the hunt, with the bulk usually arriving in the early morning as hunters end their night-time hunts. What is unsold is either stored for sale the following day, or smoked and dried and sold to traders at the Central Market. Atwemonom is a wholesale market, supplying restaurants and street vendors of the city as well as members of the public.

Trade within the market is controlled by a small, closely connected group of traders, many of whom are linked by family (Falconer 1992). Traders are exclusively female (the few men who work in the market are responsible for preparing the fresh meat prior to it being sold) and the market is run by a group of senior "market ladies". The traders inherit their business from their mothers, in accordance with Akan tradition and the same is true for the owners of the bushmeat chopbars (cafes) which operate from the market. For those not associated with the market through family or close business associations, entry into the trade at Atwemonom is difficult.

There is a strong patron-client relationship in which hunters will preferentially trade with specific market ladies with whom they have working relationships. The market traders will support this loyalty through loans to the hunters, either for hunting supplies or in times of hardship. These loans the hunter repays through meat. The relationships are fluid however; if a hunter's usual trading partner is not present when he arrives, he is free to sell to another trader. Hunters report that although prices vary day to day, they are broadly speaking comparable between traders. It is the relationship, rather than price competition, that bonds supplier to distributer. The market ladies and Wildlife Division officials who have worked with the market over the years claim that almost all fresh bushmeat entering Kumasi for commercial trade passes through Atwemonom. This is a claim supported by research in the market in 1990 (Falconer 1992). Consequently, a wealth of information can be readily obtained with permission of the "Queen Mother" who heads the market.

A potential lack of internal competition raises concerns about market failure, which would have consequences for the planned econometric analysis in this study if the prices set by the market were independent of supply and demand (Krugman & Wells 2006). However, there is good evidence to support the argument that, despite its dominance, the Atwemonom market is not exempt from competition. Discussions with hunters serving Kumasi highlighted that a number of alternative trade options were frequently utilised and, except in the case where bushmeat was sold directly to the consumer, that prices were equivalent or even better in alternatives markets (such as the main transport hubs and satellite towns through which the hunters passed to access the central markets). Hunters are free to and do use these trade routes. The ability of Atwemonom to shift a large amount of stock, and the relationship between hunter and trader, which provide the hunter with access to credit, maintains its prominence in the trade of the city. Although hunters may not choose traders on price alone, they are being compensated for this choice through the lenient repayment of credit, and thus there remains a degree of internal competition depending on the terms of credit provided.

Previous studies of the market have shown that prices change on a daily basis (Falconer 1992; Ntiamoa-Baidu 1998). Although no formal stock assessment was made during this study, anecdotal evidence from traders and our own casual observations during our time in the market provided no evidence of unsold stock. If anything, long-term price trends suggest that current supplies fall short of fully satisfying demand. Thus it is assumed for the purposes of this study that the market is competitive.

Study villages

Four study villages were surveyed during the course of this work: Jachie and Kwaman in the Ashanti Region, Anyimaye in the Brong-Ahafo Region, and Kofiekrom in the Western Region. All four communities were identified from the Kumasi data as suppliers of the Atwemonom bushmeat market. All communities were Akan, with Jachie, Kwaman and Kofiekrom being traditionally Asante, and Anyimaye predominantly Akuapem. Jachie and Kwaman have regular transport connections to the district capital Kumasi and are 12km and 48km from the city centre, respectively. Hunters from these communities are known to trade bushmeat regularly with the city market. The two remaining communities, Anyimaye and Kofiekrom are more remote, 130km and 120km from Kumasi, respectively. Access to large urban centres is difficult, and roads are seasonally impassable. Both Anyimaye and Kofiekrom are situated within easy walking distance of large forest reserves. Anyimaye neighboured the Bia Tano and Bonsam Bepo Reserves, while Kofiekrom bordered the Bura River Reserve. The habitat quality of the two former reserves is relatively degraded, while the quality of the latter reserve is good (Ghana Forestry Commission 2012). Hunters in Anyimaye and Kofiekrom trade almost exclusively with the local market, except on rare occasions when they travel to the city for family or work matters (figure 1.1). Communities were selected, in consultation with Wildlife Division officials, to provide a cross section of hunters, both those who regularly participated in the urban trade and those that did not, who were willing to participate in the study.

2.1.7. Market data

Species composition

Between 1978 and 2004, officials from the Ghana Wildlife Division regularly surveyed the daily trade passing through Atwemonom. Data were collected as hunters arrived at the market. The market has a central preparation area, where, following the transaction between hunter and market lady, the bushmeat is prepared and divided up to be returned to the market ladies for sale. This central processing system allowed observers to monitor efficiently the trade passing through the market. Information was recorded on the species, carcass weight, wholesale price received by the hunter and location from where the hunter had come. The dataset therefore represents a spatially explicit record of the commercial trade passing through the market over a 26-year period.

The full dataset represents 86,365 records made over 4,965 days and 268 months, covering 26 years from May 1978 to June 2004. There are a number of important caveats covering the data that need to be considered for analysis. The first of these arises due to the presence of the annual closed season. During this time, only grasscutters can be legally traded. Although other species are recorded in the data during this period, discussion with members of the team who monitored the market indicated that the recording of banned species (i.e.

illegal trade) was unlikely to be reliable. In short, as the monitoring team required the trust of the market ladies to operate, there was an incentive to ignore elements of the illegal trade. For this reason, data from the closed season was excluded from the following analysis. The resulting dataset, covering only the open season, consisted of 67,438 records, over 3,335 days and 180 months. Table 2.2 summarises the species break down of the data.

A second caveat applies to the species records. Just as observers turned a blind eye to illegal trade during the closed season, so they also reported turning a blind eye to trade in schedule 1 species, which are fully protected by law at all times of the year. During personal observation of the market in 2011, a number of schedule 1 species were openly traded, including pangolin species, *Manis spp.,* and the African civet, *Viverra civetta.* Neither of these species is common in the market data recorded between 1978 and 2004. Indeed, there is only one recorded pangolin transaction in 26 years. It is therefore unlikely that the market data represents a true record of the trade in schedule 1 species.

The final caveat relates to the composition of the trade, which is strongly skewed towards the seven most common species that constitute 94% of the trade by volume. The sharp divide between the abundance of these seven common species and the remainder presents problems for detailed statistical analysis of the long-term trade in many species. This discrepancy may be due to a number of factors such as consumer preference (demand) or local abundance (supply). It should be noted that price is unlikely to be a factor as many of the less abundant species are among the most valuable measured on both a per carcass and per kilo basis. Consequently, the following analysis is limited to analysing the trade in the seven most common species on the market, namely the grasscutter, maxwell duiker, royal antelope, bushbuck, black duiker, brush-tailed porcupine and giant rat.

Table 2.2 Summary of data of records from the Atwemonom Market, Kumasi during the open season (December – July inclusive), between May 1978 and June 2004. Species are sorted according to the number of records. All weights are fresh carcass weights. Prices are deflated to 2004 using the Consumer Price Index (CPI). Prices and weights are averaged over the entire time period.

Species	Latin Name	Records	Weight (kg)	Price (Cedi/kg)	Price (Cedi/ carcass)
Grasscutter	*Thryonomys swinderianus*	17470	4.03 *(1.7)*	15.91 *(5.2)*	67.0 *(22.9)*
Maxwell duiker	*Cephalophus maxwelli*	14008	7.31 *(1.74)*	12.68 *(3.8)*	90.6 *(27.0)*
Royal antelope	*Neotragus pygmaeus*	8425	2.90 *(1.42)*	15.86 *(7.2)*	33.3 *(16.2)*
Bushbuck	*Tragelaphus scriptus*	8147	36.17 *(12.8)*	8.08 *(3.2)*	271.6 *(104.9)*
Black duiker	*Cephalophus niger*	7029	19.01 *(4.7)*	9.60 *(2.9)*	179.4 *(48.8)*
Brush-tailed porcupine	*Atherurus africanus*	4637	3.28 *(1.3)*	14.65 *(5.1)*	47.9 *(16.6)*
Giant rat	*Cricetomys* gambinus.	3722	1.05 *(0.7)*	12.41 *(5.0)*	12.9 *(9.4)*
Long-nosed mongoose	*Herpestes naso*	519	0.78 (*0.5)*	12.96 *(7.9)*	9.2 *(8.6)*
Mona monkey	*Cercopithecus mona*	495	3.14 *(1.8)*	14.08 *(7.6)*	41.5 *(23.2)*
Ground squirrel spp	*Xerus* spp.	456	0.9 *(2.4)*	15.82 *(16.3)*	11.8 *(16.8)*
Francolin	*Francolinus* spp.	455	0.5 *(0.2)*	21.89 *(17.1)*	9.6 *(7.7)*
Palm civet	*Nandinia binotata*	439	2.3 *(0.7)*	16.1 *(7.2)*	35.7 *(15.7)*
African civet	*Viverra civetta*	346	7.5 *(3.8)*	13.1 *(11.4)*	92.9 *(65.2)*
Forest genet	*Genetta maculata.*	285	2.1 *(0.7)*	13.7 *(5.4)*	27.8 *(10.7)*
Red-flanked duiker	*Cephalophus rufilatus*	231	9.5 *(3.3)*	11.86 *(4.1)*	106.3 *(31.2)*
Bay duiker	*Cephalophus dorsalis*	132	12.2 *(1.6)*	10.86 *(3.18)*	125.0 *(43.9)*
Marsh mongoose	*Atilax paludinosus*	124	2.3 *(4.0)*	11.43 *(6.8)*	23.8 *(23.9)*
Spot-nosed monkey	*Cercopithecus petaurista*	122	3.6 *(1.8)*	12.4 *(4.7)*	41.9 *(19.5)*
Flying squirrel	Anomolurus pelii	67	1.41 *(0.46)*	10.8 *(6.6)*	13.5 *(6.3)*
Red river hog	*Potamochoerus porcus*	63	44.8 *(13.0)*	8.2 *(2.8)*	356.7 *(169.3)*
Gambian mongoose	*Mungos gambianus*	20	1.1 *(0.8)*	14.6 *(9.1)*	12.4 *(6.8)*
Common duiker	*Cephalophus sylvicapra*	18	7.6 *(2.1)*	13.5 *(4.7)*	99.5 *(20.7)*
Genet spp.	*Genetta spp.*	14	2.0 *(0.6)*	12.4 *(4.5)*	24.5 *(9.9)*
Slender mongoose	*Herpestessanguineus*	12	2.2 *(0.8)*	11.6 *(3.5)*	23.6 *(7.0)*
Kob	*Kobus kob*	5	35.6 *(10.1)*	12.0 *(5.5)*	429.1 *(213.2)*
Tree hyrax	Dendrohyrax dorsalis	5	1.9 *(0.3)*	9.0 *(1.8)*	16.8 *(5.6)*
Cape hare	*Lepus capensis*	5	1.8 *(0.4)*	18.0 *(5.7)*	32.0 *(8.4)*
Yellow-backed duiker	*Cephalophus sylvicultor*	4	52.7 *(46.3)*	9.0 *(5.9)*	318.3 *(225.0)*
Tree squirrel spp	*Sciuridae spp*	2	0.6 *(0.1)*	8.4 *(2.1)*	4.7 *(1.7)*
Fruit bat spp	*Eidolon spp*	2	11.0 *(4.2)*	17.5 *(NA)*	140.1 *(NA)*
Egyptian mongoose	*Herpestes ichneumon*	2	2.1 *(0.1)*	4.8 *(0.3)*	10.0 *(0.0)*
Green monkey	*Chlorocebus sabaeus*	2	3.3 *(1.8)*	14.4 *(9.0)*	38.8 *(3.9)*
Side striped squirrel	*Sciuridae spp*	2	0.2 *(NA)*	24.9 *(NA)*	5.0 *(NA)*
Oribi	*Oreibia ourebi*	1	7.0 *(NA)*	10.9 *(NA)*	76.4 *(NA)*
Pangolin	*Manis* spp.	1	2.0 *(NA)*	NA *(NA)*	NA *(NA)*
Tree pangolin	Manis tricuspis	1	7.0 *(NA)*	12.2 *(NA)*	85.0 *(NA)*

Market trends

The distribution of observation days throughout the study period is not consistent (figure 2.3). Observation effort in the latter half of data, from 1995 onwards is notably lower, with only 16 days monitored in 1997. Only two months were surveyed during the 1978 open season, hence the low observation rate.

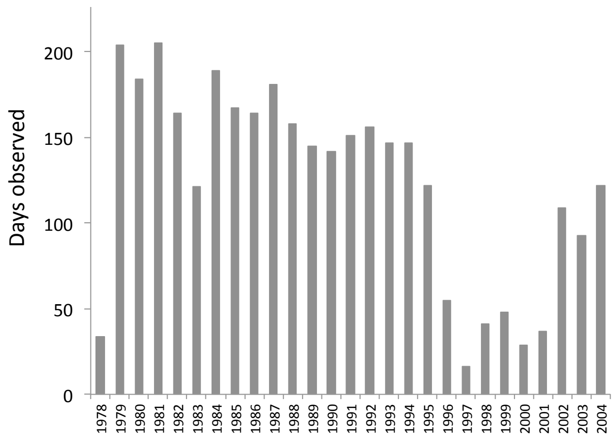

Figure 2.3: Number of days during the open season on which Wildlife Division staff visited the market

Overall trade volumes entering the market increased in the latter part of the sample period, both in terms of the average number of carcasses and biomass entering the market per day (figure 2.4).

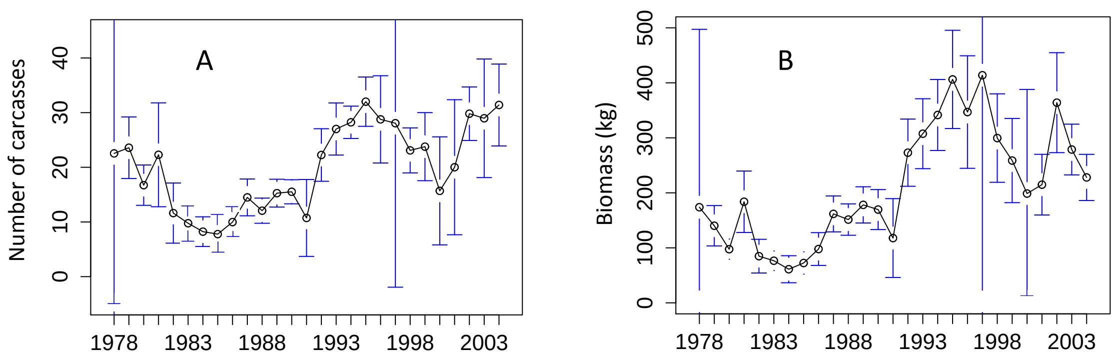

Figure 2.4: Trade passing through the market, measured in terms of A - the average number of carcasses recorded per day and B - the average weight of bushmeat entering the market per day. All data are calculated from the Open Season.

The apparent decline in biomass recorded in 2003 and 2004, which coincides with a stable trade in terms of number of carcasses, may be due to changes in the species composition entering the market, as rodent species such as the grasscutter begin to dominate and fewer ungulates are recorded. This is evident both in terms of species composition and the rodent to ungulate ratio (figure 2.5).

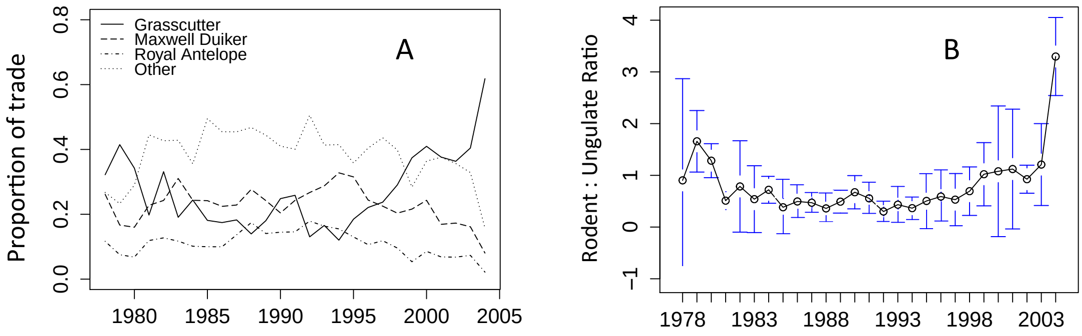

Figure 2.5: Changes in the composition of the trade. A - Ungulates and other species appear to decline in the latter stages of the survey period while grasscutters make up an increasingly large proportion of the trade (measured in terms of number of carcasses) from 1995 onwards. B – the Rodent to Ungulate ration shows a sharp increase in the latter part of the survey.

In addition to apparent changes in species composition, a clear intra-annual pattern in trade volumes in observed: notably that there are two peaks in trade volumes, a large peak in January and February, and a second smaller peak in June and July (figure 2.6).

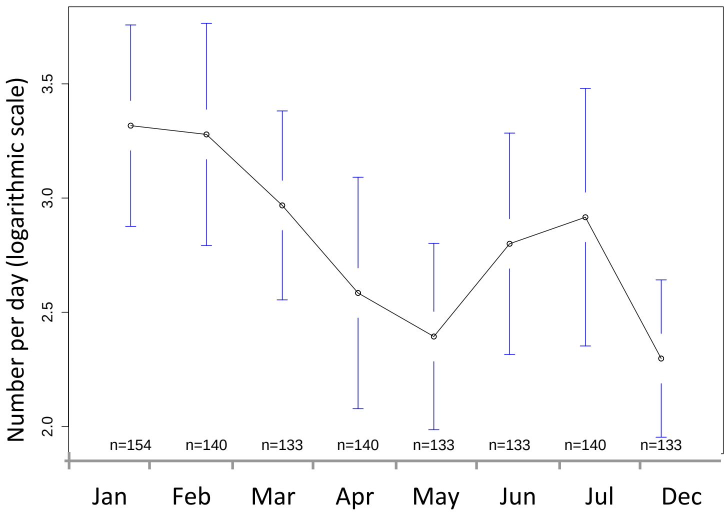

Figure 2.6: Seasonal variation in trade volumes (measured in terms of average number of carcasses passing through the market per observation day)

In terms of market prices, there was no significant change in the average price per carcass received by the hunter (figure 2.7). Such analysis is however complicated by the underlying changes in species composition that may hide significant inter-species differences. These dynamics will be explored in more detail in Chapter 4.

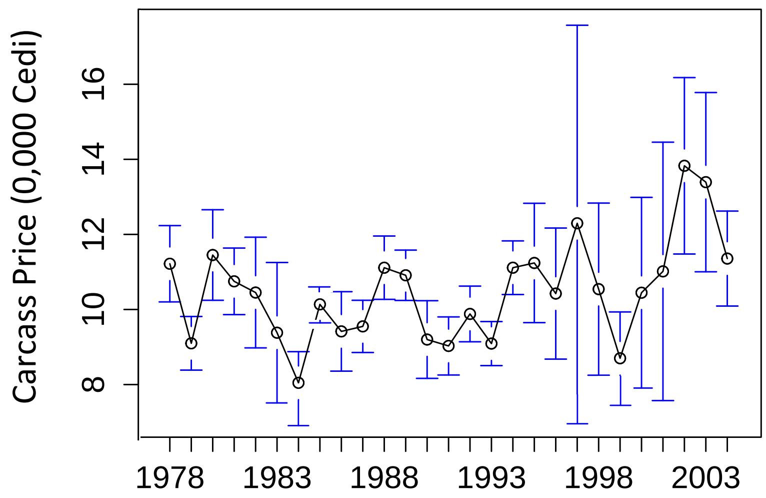

Figure 2.7: Variation in average per carcass price received by the hunter. Per carcass price is an average across all trade (total mass traded divided by the total value). Statistical testing suggested differences were not significant.

2.1.8. Urban protein consumption

101 Consumers in Kumasi were surveyed in 2011 to examine patterns of protein consumption among urban consumers to inform analysis of the drivers of demand. Fish was the most commonly consumed (86%) most preferred protein (60%) among urban consumers (figure 2.8). Although consumed regularly by a relatively small proportion of consumers (16%), bushmeat was the next most preferred protein.

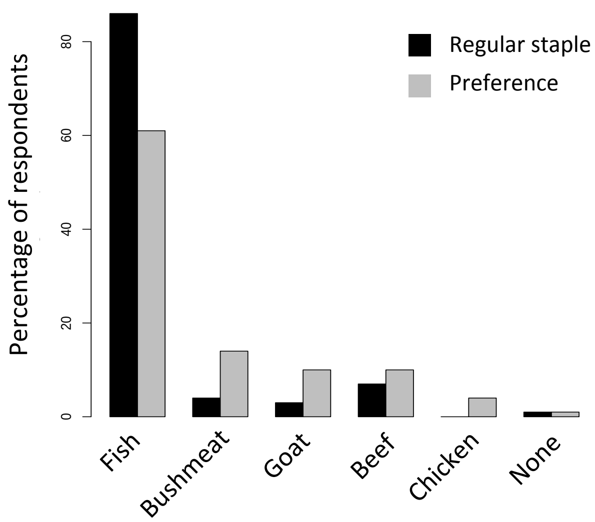

Figure 2.8: Urban consumers protein consumption behaviour. N = 101.

Breakdown of fish and bushmeat consumption behaviour highlighted the importance of marine species of fish (versus freshwater species), notably herrings and red fish (table 2.3).

Table 2.3: Most commonly consumed fish species among urban consumers in Kumasi (N = 101). The type of fish denotes whether the species is a marine (M) or freshwater (F) species.

Common name	Scientific name	Type	Percentage of respondents
Herrings	*Clupea spp.*	M	33
Red Fish	*Lutjanus spp.*	M	31
Mud Fish	*Protopterus, Parachanna spp.*	F	14
Mackerel	*Trachurus spp.*	M	10
Tilapia	*Cichlid spp.*	F	5
Pola	*Unknown*	M	2
Tuna	*Thunnus spp.*	M	1
Cassava fish	*Pseudotolithus spp.*	M	1
No preference	NA	NA	2

The grasscutter was the most commonly consumed type of bushmeat in line with previous research in the market (Falconer 1992; Ntiamoa-Baidu 1998), followed by the maxwell duiker, giant rat and bushbuck (table 2.4).

Table 2.4: Stated preference for difference bushmeat species among urban consumers in Kumasi (N = 101).

Bushmeat species	Percentage of respondents
Grasscutter	72
Maxwell's Duiker	20
Giant Rat	4
Bushbuck	2

2.1.9. Thesis outline

The thesis has the following structure:

Chapter 2: Research background and case study

An overview of hunting in the Ashanti Region, the local culture, Kumasi and the Atwemonom market are presented, in addition to background information on consumer preferences and market prices in the city.

Chapter 3: Is the Atwemonom bushmeat market supply or demand driven?

This chapter seeks specifically to address the question whether the trade in the region is defined more by the drivers of demand or supply. It sets out to do this by presenting a detailed overview of hunter and consumer behaviour, and analysing these in the context of the market.

Chapter 4: Drivers of supply and demand in a mature bushmeat market in Ghana, West Africa

This chapter presents an econometric analysis of the drivers of supply and demand, using data collected at the Atwemonom market over a 26-year period. In addition to analysing the drivers of the market, it also investigates how a major bushfire event in the 1980s affected the commercial bushmeat trade.

Chapter 5: The rise of the rodent: Spatial dynamics of a bushmeat hunting system

This chapter uses satellite imagery from two time periods, 1986 and 2002, and a time-series analysis of trends in the market data between 1978 and 2004, to investigate how landscape characteristics influence bushmeat trade volumes and trade composition. Market data from the Atwemonom market are used to characterise the trade, while classified satellite imagery is used to define features of the landscape, which might determine changes over time in the volume and type of trade emanating from particular areas.

Chapter 6: Exploitation, inflation and deforestation – What the future holds for bushmeat hunting in the Ashanti Region

This chapter analyses how the socioeconomic profiles of hunters influence their willingness to adapt their hunting behaviour in the face of changing incentives. Using scenario analysis, hunters are asked how they would hypothetically respond to future scenarios of change.

Chapter 7: Discussion

The findings of Chapters 3 – 6 are drawn together and synthesised, and their implications explored.

Chapter 3

Is the Atwemonom bushmeat market supply or demand driven?

3. Is the Atwemonom bushmeat market supply or demand driven?

3.1. Introduction

Bushmeat hunting is one of the oldest livelihoods utilised by man. However, its use sits in the context of shifting economic and environmental conditions and, as a consequence, its role for both consumers and hunters can be seen to change over time. Expansion of agricultural lands and an increasing human population have resulted in loss of habitat and increased pressure on natural resources (Fimbel *et al.* 2001; Braimoh 2009). Increasing national wealth and migration into urban centres have increased urban demand (Bowen-Jones & Pendry 1999; Breisinger *et al.* 2009), heralding a shift from traditional subsistence hunting to a trade that is now more commercial in its nature in many areas (Ntiamoa-Baidu 1998; Crookes *et al*. 2005). Meanwhile, improved access to agricultural markets, the introduction of new crop varieties and improved technology have altered the opportunity costs of hunting (Damania et al. 2005; Kramer et al. 2009).

Thus it can be assumed that the modern urban bushmeat market is characterised by a range of drivers that exert pressure on both supply and demand (Ling & Milner-Gulland 2006). If successful management strategies are to be implemented, it is critical that the processes that define these drivers are well understood (Nicholson *et al.* 2009). Much recent research in the literature has focused on trying to identify the processes governing supply (hunting behaviour) and demand (consumer behaviour). What has been missing from the literature, however, is any attempt to distinguish which of these processes (supply or demand) dominates and defines the trade. Being able to elicit such information is of particular value for managers seeking to identify where in the commodity chain interventions are best made. For example, if demand is driving the trade and hunters are responding to market prices, then initiatives to reduce demand or devalue bushmeat may be effective. This might be realised by increasing the availability of alternative protein sources to encourage consumers to switch to cheaper alternatives (Brashares *et al.* 2004; Mahama & Mohammed 2003), educating consumers through public engagement activities to attach stigma to bushmeat consumption, or flooding the market with farm-reared bushmeat to reduce its value (GTZ 2009). Conversely, if the trade were supply driven, then engaging with hunters to reduce their reliance on hunting would be more effective. Approaches often advocated include the development of alternative livelihood options (Bowen-Jones 2002) or investment in human capital to reduce poverty (Robinson & Bennett 2002). The options available to managers are well known. What are needed are novel methods to help make decisions about which interventions are likely to be effective (Ling et al. 2002).

The following analysis seeks to address this need, by developing and testing a framework based on simple concepts from the economics literature, to explore the extent to which the bushmeat trade around the city of Kumasi, Ghana, is driven by supply or demand, and to provide managers with evidence as to which interventions are likely to be effective. The bushmeat market in Kumasi provides a valuable case study for testing this framework due to a long history of bushmeat research in the region (Falconer 1992; Ntiamoa-Baidu 1998; Hofmann et al. 1999; Shanti-Alexander in press), which allows a historical perspective to be taken over three decades. The city is located in the Upper Guinean Forest Ecosystem, a biodiversity hotspot that has experienced severe degradation, such that only 15% of its original area remains intact, 1.5% in forest reserves (CEPF 2000; Myers *et al.* 2000). Thus the management of the legal hunting trade to preserve unprotected areas is of high conservation concern.

Microeconomics, which is concerned with the behaviour of producers and consumers in individual markets, posits that the relationship between price and the quantity demanded is based on a set of choices that maximizes the utility of the consumer, and that rational, profit-maximizing firms will produce at some level in accordance with demand (Besanko & Braeutigam 2010). Under this principle, changes in demand use the price mechanism to signal to firms to change what they produce. Markets that adhere to this principle are considered examples of demand driven markets (Blanchard et al. 2010).

However, the notion that individual markets are always demand driven was challenged by Ghosh (1958). He considered the case where, due either to resource limitations or some central control mechanism (such as rationing), the supply curve was inelastic and unable to respond to a change in demand. In such circumstances this led to "demand outstripping supply", where the factors associated with production (supply), rather than consumption (demand), set prices and defined consumption patterns. This proposal was highly contentious, and the technical formulation and plausibility of the model he proposed continue to be debated today (Mesnard, date unknown; Oosterhaven 1988, 2012; Dietzenbacher 1997; Guerra & Sancho 2011; Manresa & Sancho 2012). While there is as yet no agreement between the proponents and opponents of Ghosh's approach, even among the more vocal critics there is general agreement that a supply-driven approach can, under appropriate circumstance, offer value for identifying the processes that define the market Giarratani 1980; Oosterhaven 1988).

Other examples of markets that may be described as supply driven are those associated with industries that have a stable and high demand and which have few barriers to entry. Examples include prostitution and street vending. The decision to participate in these types of industries may be largely independent of price, with suppliers choosing to move in or out of the trade depending on the quality and availability of alternative income streams (Rankin 2000). Such industries are prone to considerable fluctuations in supply, despite relatively constant demand.

Traditionally, commercial bushmeat markets are often assumed to adhere to a demand driven regime, whereby hunters respond to market prices to meet consumer demand (Milner-Gulland E.J. & Clayton L. 2002). The corollary has been that if the bushmeat trade is driven by demand, then policies that seek to alter demand, and ultimately price, are a key mechanism to manage the trade. However, the trade potentially exhibits a number of characteristics associated with supply driven markets: limited exploitable resources, low barriers to entry (depending on the type of hunting adopted) and strong demand that has led to the development of a reportedly exclusive luxury market in some instances, all typify the trade, to a greater or lesser degree.

Using the bushmeat trade in the city of Kumasi, Ghana, as a case study, the following analysis presents a systematic framework, based on four key principles summarised from the economics literature, to examine the degree to which the trade is supply or demand driven (table 3.1). The characteristics are: 1) resource condition, 2) hunter behaviour, 3) consumer behaviour and 4) price behaviour.

Table 3.1: Conceptual framework for evaluating the bushmeat market under a demand and supply driven regime, broken down by resources (wildlife), producer behaviour, consumer demand and price behaviour.

Assumption	**Demand-driven** Demand determines price	**Supply-driven** Supply determines price
1) Bushmeat resources	Resources should be sufficient to meet demand	Resources may be insufficient to meet demand
2) Hunter behaviour	Hunters respond to price signals from the market, changing supply in response to price	Hunters move in an out of the trade independently of price signals from the market.
3) Consumer behaviour	Consumer choice defines patterns of consumption.	Supply-side dynamics define consumer behaviour.
4) Price behaviour	Prices are set by demand. An increase in demand will lead to an increase in price and quantity.	Prices are set by supply. An increase in supply will lead to a decrease in price.

By testing a series of predictions related to each of these four steps, and relating the findings to what we expect to observe in either a demand or supply driven market, we can draw conclusions about what is driving the trade (table 3.2). This framework is intended to use the kind of data that is commonly available in the bushmeat literature, without the need for the detailed long-term economic data that is usually required to estimate formal supply and demand relationships accurately, but which are rarely available for the informal markets system that characterise many artisanal trades. We use the framework to test whether the bushmeat trade in Kumasi is supply or demand-driven, using four general predictions. We predict that:

Table 3.2 Research structure as defined by the four framework tests. Predictions, associated tests and data sources are presented for each of the framework tests. In the data sources section, literature refers to one of the six peer-reviewed pieces of literature that form the basis for historic comparison, be it government publications or peer-reviewed articles. Primary data refers to data collected in the field as part of this study

Framework tests	Prediction	Sub predictions and tests	Data sources
Resource condition	Resources show signs of depletion.	***Trade composition***	
		1. Market level. Increase in proportion of the trade represented by less vulnerable taxonomic groups such as rodents.	Market surveys – Literature and primary data collection.
		2. Village level. First hand hunter reports reflect a comparable compositional change to one dominated by less vulnerable taxonomic groups.	Hunter surveys – primary data collection.
		Catch per unit effort	
		3. Average distance travelled per hunt increasing and catch per unit effort in decline.	Hunter surveys – Literature and primary data collection.
Hunter behaviour	Hunters move in and out of the market independently of price signals.	***Short-term (intra-annual)***	
		4. Hunting activity seasonal, defined not by the price of bushmeat, but by other factors associated with hunters' livelihoods, namely the agricultural seasons.	Hunter surveys, rural focus groups and bushmeat trader surveys – primary data.
		Long-term (inter-annual)	
		5. Participation in the trade trends independently of market signals (price) and the relative value of bushmeat (measured relative to inflation, national minimum wage and the price of alternatives).	Household and hunter surveys – Literature and primary data collection. Economic indices from national organisations.
Consumer behaviour	Consumer spending patterns defined by supply rather than demand.	***Consumer spending patterns***	
		6. Frequency of bushmeat consumption in decline due to high prices and lack of availability and frequency of consumption of cheaper alternatives increasing.	Consumer surveys – Literature and primary data collection.
Bushmeat prices	Prices are set by supply, not demand.	***Seasonal changes***	
		7. Periods of peak supply correlate to low prices and vice versa. There will be no evidence that consumer demand for bushmeat fluctuates.	Bushmeat trader surveys and market surveys from the literature.

3.2. Methods

3.2.1. Study area

Kumasi is Ghana's second largest city, with an estimated population of 1.5 million people (Ghana Health Service 2010). Kumasi is home to the Atwemonom bushmeat market, one of the oldest and largest bushmeat markets in Ghana, fed by the historically rich forests of the region (Falconer 1992). Atwemonom is the only formal market for fresh bushmeat in central Kumasi. Thus the trade passing through this market may be considered indicative of the general trade in the city. Other main central markets include Kejetia, which also doubles as the transport hub of the city, and Racecourse Market, the main market for livestock. These four markets comprise the trading centre of Kumasi and lie within easy walking distance of each other in the central business district known as Adum.

Two rural communities were surveyed, Jachie and Kwaman (Shanti-Alexander *et al.* in press), lying 20km to the southeast and 65km to the northeast of Kumasi respectively. Urban surveys were conducted in the regional capital, Kumasi (figure 3.1).

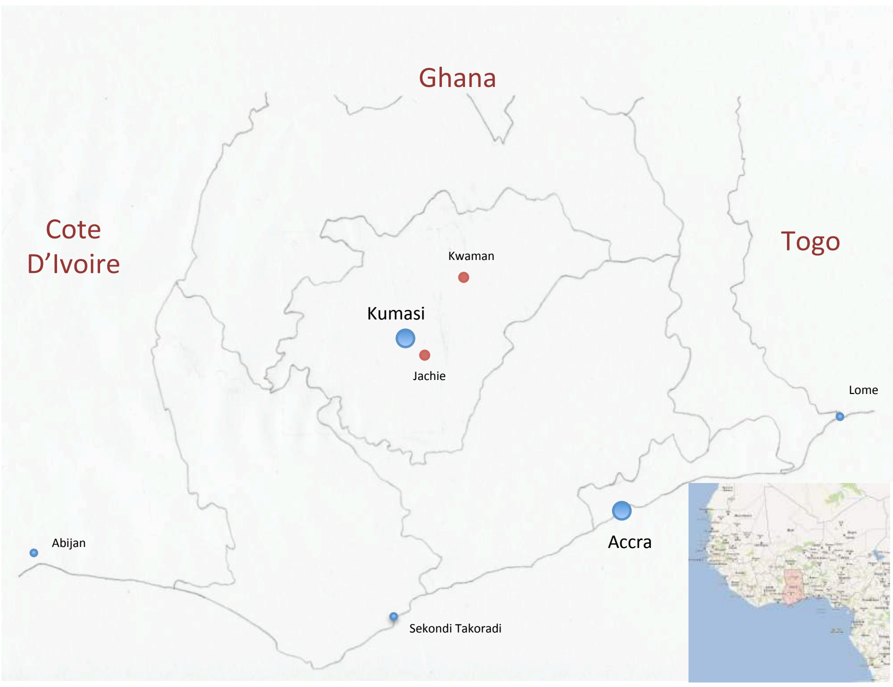

Figure 3.1: Map showing the three study locations: Kumasi and villages of Jachie and Kwaman

The decision to select the two rural communities was based on:

- Advice from Ghanaian Wildlife Division (GWD) staff (who have been working with hunters and communities in the region over may years),
- The historic involvement of each community in the bushmeat trade – the GWD conducted regular surveys of the Atwemonom market from 1978 until 2004. Jachie was ranked 12th and Kwaman 168th out of more than 1000 identified source locations.
- Willingness of the hunters and wider community to participate.
- History of research (hunting in Kwaman was studied in detail by Hoffman (1999), allowing direct comparison to be made between communities)

3.2.2. Data Collection

We used a combination of primary data (collected during two field seasons between April and June in 2010 and 2011) and secondary data from the literature, to evaluate how our four predictions had changed over time, 1) resource condition, 2) hunter behaviour, 3) consumer behavior and 4) price behaviour. Table 3.3 summarises the survey statistics.

Rural surveys

Rural surveys in Jachie and Kwaman were of two types: we used purposive sampling to obtain information from hunters, and we carried out a general survey of households within the village, selected using systematic samples.

Data were collected through structured and semi-structured interviews. Prior to commencing formal survey activities, focus groups were held in each village with a small number of individuals, typically 8 to 12. Questions focused on aspects of village life and livelihoods, such the main crops grown for cash and for food, when the associated harvest and planting seasons were and what time of the year was associated with the lean season. Individuals were selected from senior members of the hunting community, who were well placed to answer questions as the heads of their respective households. Information from the focus groups helped inform the more detailed one-on-one surveys conducted with hunters and households.

Household surveys (Appendix B1) recorded household demographics, livelihood activities, protein consumption patterns and perceptions about the bushmeat trade (Jachie N = 90, Kwaman N = 87). Surveys were conducted with the head of the household and usually took place in the early morning and early evening to fit into the daily work schedule. A systematic sampling approach was used with a sampling interval of approximately 10 households to ensure the full geographical area of the village was covered by the survey. Where the head of the household was not present, or unwilling to take part, the next available house was selected.

Hunter surveys (Appendix B2) focused on livelihood activities, trading activities and hunting behaviours (Jachie N = 23, Kwaman N= 28). Hunters were identified using three methods: household surveys, members of the hunting associations (where applicable), and the snowball method where known hunters were asked to identify other hunters. For the purpose of this study, hunters were defined as those who viewed hunting as one of their livelihood activities, whether for food or income. They hunted across a range of landscapes outside the boundaries of their own farms, using a range of techniques. Individuals who trapped on their farms as a means of pest control or for opportunistic subsistence were not included in the hunter survey, although their hunting practices were explored as part of the household survey. Such individuals seldom traded or gained direct economic benefit from their activities and usually perceived hunting to be a complement to farming (Shanti-Alexander *et al.* in press).

Urban surveys

Urban surveys were of three types. Firstly, short, semi-structured interviews based on a random sampling technique targeted general members of the public, recording meat consumption. Secondly, semi-structured interviews were targeted to bushmeat traders, both chopbar owners and wholesale market traders. Thirdly, surveys of the meat markets in the city (bushmeat, livestock and fish) were conducted to compare prices. The combination of consumer and trader was chosen to build up complementary data on the trade from different perspectives in the commodity chain.

Consumer surveys (Appendix B3) recorded patterns of protein consumption and preferences. Surveys were conducted in the four main central markets: Central Market (N = 35), Racecourse Market (N = 30), Kejetia (N = 16), and the streets between (N = 20). Surveys were kept short and simple to encourage participation, with 6–12 questions depending on whether or not an individual consumed bushmeat.

Trader surveys (Appendix B4) targeted wholesale traders in Atwemonom and chopbar owners throughout the city, and recorded information on bushmeat prices, availability and seasonal trends (wholesale traders N = 11, chopbar restaurants N = 6).

Market surveys consisted of a one-week survey of the Atwemonom bushmeat market in June 2011 to complement similarly timed surveys from earlier studies, Falconer (1992). Data were gathered on price, weight and species traded. Fish and livestock markets were surveyed in the Racecourse Market. Data were gathered on price.

Table 3.3 Summary of surveys conducted in each location. Distances and areas were calculated using Google Earth. *Consumer surveys were with households in the rural areas and bushmeat buyers in the market in Kumasi. **Includes both chopbar operators and wholesale bushmeat traders.

Location	Community Area (km^2)	Distance from Kumasi (km)	Hunter surveys	Consumer surveys	Trader surveys
Jachie	1.25	20	23	90	NA
Kwaman	0.92	65	28	87	NA
Kumasi	NA	NA	NA	101*	17**

Secondary data

Secondary data were gathered from the literature. Seven pieces of literature are used for these analyses, reporting the status of the bushmeat trade in: 1982 (Dei 1989), 1990 (Falconer 1992), 1993 (Ntiamoa-Baidu 1998), 1995 (Hofmann, Ellenberg & Roth 1999), 1999 (Hofmann, Ellenberg & Roth 1999), and 2002 (Crookes *et al.* 2007). These historical perspectives complement our own data to allow an assessment to be made of change over three decades. Additional data on economic indices, such as exchange rates and the consumer price index, were collected from international and national institutions including the International Monetary Fund, World Bank and Ghana Statistical Service.

3.2.3. Data analysis and prediction tests

Primary data are presented alongside comparable historic data selected from the literature. All information relating to 2011 represents primary data.

Resource condition

Resource condition was assessed through two metrics. 1) Trade composition and 2) catch per unit effort.

Trade composition: Changes in the composition of the trade was examined using market data collected in the Atwemonom market in three years: 1990, 1993 and 2011. This information is cross-referenced with firsthand hunter reports, gathered during our primary data collection in 2011, to validate the degree to which hunters corroborate the trends that are evident in the market data. This method was implemented to address, in so far as possible, concerns that market data may not always be an accurate measure of what is actually being harvested (Allebone-webb *et al.* 2011). As part of this process, hunters were asked to list those species that they caught frequently, and those that they used to catch but no longer did (or which were notably less frequent). Each time a species was mentioned it received a score in either the present or absent category. The totals for each species in each category (present or absent) are presented as a percentage of all scores in the relevant category. Thus an estimation of the relative scarcity of each species, from the perspective of the hunter, was made. Hunters' responses were unrestricted and they were free to list as many species as they wished (although in reality this number never exceeded 4 per category) in order to allow an honest picture of hunting at the village level.

Catch per unit effort: It is assumed that if the resource is depleted, hunters' catch per unit effort will be low. Estimates of the length of the average hunting trip is available from a number of studies in the Ashanti region over four periods; 1982, 1993, 2002 and 2011. Catch data are only available from one comparative study in 2002. Where possible, catch per unit effort is presented as the average number of animals caught per hour spent hunting. Comparison of the proportion of hunters in Kwaman, who believed that there had been a decline in bushmeat, between 1995 and 2011, using data from the literature, is also presented to provide a coarse perspective on the change in hunting success rates over this period.

Hunter behaviour

Short-term, intra-annual: We examined how hunters allocated their time throughout the year and explored whether variation was due to factors associated with the bushmeat market, agricultural seasons, or other external influences. Variation in hunting pressure was quantified by asking hunters to name the months when they hunted most (the peak months) and the months when they hunted least (the low months). To test whether the effort exerted was significantly different between seasons, hunters were asked to identify how many trips they might expect to engage in and how many animals per week they expected to catch in both the low and high seasons. Standard univariate statistical tests are used to analyse the differences. Hunters' motivations for acting as they did were explored through the hunting surveys. Seasonal trends reported were verified through surveys of bushmeat traders.

Long-term, inter-annual: Hunter participation (measured in terms of the proportion of active hunters in a community at any one time) was examined over three time periods: 1995, 2002 and 2011. This is contrasted with the change in the relative value of bushmeat over the same period to assess whether hunters are responding to price. An estimate of bushmeat value is made by comparing the normalised, real price of bushmeat, relative to the Consumer Price Index (a proxy for the cost of living), national minimum wage (national earnings), real price of cocoa (the most important cash crop) and the price of substitute goods (in this case, fish, the most commonly consumed protein). While not without its caveats, this "value estimation" is intended to place changes in bushmeat prices in the context of other key price indices to determine how the relative value, and hence price incentive associated with the trade, has changed.

Consumer behaviour

Consumer demand: Data are not available to accurately quantify how demand for bushmeat has changed over time. Based on our prediction that supply is unable to meet current levels of demand, we look for evidence that consumers are being priced out of the market due to shortfalls in supply. Patterns of consumption are compared over three time periods: 1990, 1993 and 2011. We measure changes in consumption behaviour using four metrics: 1) the proportion of consumers who eat any bushmeat, 2) the proportion of consumers who eat bushmeat regularly (defined as once a week or more), 3) stated preferences for bushmeat and 4) willingness to pay more for the bushmeat they consume. Changes in patterns of consumption are contrasted with changes in the real price of bushmeat. If the market is supply limited, and consumers are being priced out of the market, a reduction in consumption would likely be associated with an increase in the real price. Further, we ask consumers who report no longer eating bushmeat (but who have done so in the past) why they have made this choice, to ascertain whether price, preference, health, religion or some other factor played a role.

Bushmeat prices

We expect to see high prices associated with seasonal periods of low hunter engagement and low supply; low prices with high hunter engagement and high supply. We examine two long-term market studies conducted in Kumasi in 1990 and 1995 for evidence on price and supply peaks and hunter engagement. We reference this to reports gathered from hunters and traders during our 2011 survey season to corroborate this relationship qualitatively.

3.3. Results

3.3.1. Resource condition

Trade composition

Although differences in the timing and length of the surveys means care needs to be taken making comparisons, analysis of available historical data suggests that the profile of the trade entering Atwemonom market is relatively stable with the bulk being represented by nine species of ungulate and rodent (table 3.4).

Table 3.4: Comparison of changes in market composition (measured in terms of numbers of carcasses entering the market per day) in 1990, 1993 and 2011 at the Atwemonom Market. Data are presented for the 9 species which were most commonly traded in 1990. Falconer (1992) surveyed 12 days in April, 9 days in May and 6 in June. Ntiamoa-Baidu (1998) surveyed 6 days in March and our study surveyed 6 days in May. **Codes:** D – decrease, I – Increase in relative abundance between surveys. N/P – Not present during survey.

Species	April - June 1990 *(Falconer 1992)*			March 1993 *(Ntiamoa-Baidu 1998)*			May 2011 *(Current study)*		
	%	Rnk	Chg.	%	Rnk	Chg.	%	Rnk	Chg.
Grasscutter	48.3	1	-	26.2	1	-	62.4	1	-
Maxwell duiker	14.2	2	-	22.1	2	-	5.0	5	D
Bushbuck	10.6	3	-	12.4	3	-	6.0	4	D
Black duiker	6.9	4	-	11.0	5	D	0.7	8	D
Royal antelope	5.4	5	-	7.9	6	D	2.6	7	D
Red flanked duiker	4.0	6	-	N/P	-	D	0.2	12	D
Giant rat	3.8	7	-	4.3	7	-	9.6	2	I
Brush-tailed porcupine	3.7	8	-	11.4	4	I	4.3	6	D
Ground squirrel	0.4	9	-	N/P		-	7.2	3	I
Proportion of total	97%			95%			98%		

However, closer inspection of the data suggests an underlying shift in composition with a gradual increase in the importance of smaller species such as the giant rat *Cricetomys gambianus,* ground squirrel *Protoxerus stangeri* and grasscutter *Thryonomys swinderianus,* and a decrease in larger ungulates such as the black duiker *Cephalophus niger* and to a lesser degree the bushbuck

Tragelaphus scriptus. The ratio of ungulates to primates declines markedly between the 1990 (1.4) and 2011 (5.8).

Cross-referencing these market data with hunter observations gathered during primary surveys supports these trends. The seven most common species in our one-week market survey in 2011 were all identified as being regularly caught by hunters in our survey. The one notable decline in the market data, the black duiker, was the species most commonly reported by hunters as now being absent (figure 3.2). Primates account for just 2% and pangolins 1% of reported catch. The bushbuck was the only large ungulate (mean body mass > 20kg) reported as common by some hunters, although conflicting opinions on its presence suggest it may be becoming scarcer.

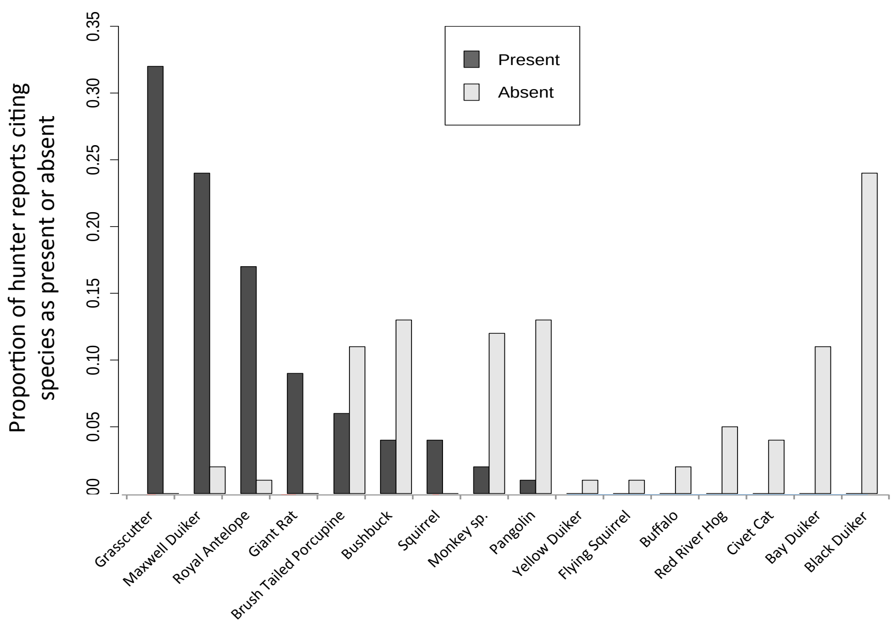

Figure 3.2: Proportion of hunter reports citing particular species as being present or absent in their catch. Present refers to species caught frequently. Absent refers to species that used to be caught regularly but are now rare or absent entirely.

A similar survey conducted in 2002 by Crookes et al. (2007) asked hunters which species they caught most regularly in three villages around Kumasi. Hunters reported a greater diversity of species, although their findings were still dominated by rodents and ungulates (78%). Four species reported in Crookes et al. (2007) but absent in our survey were the black duiker, flying squirrel, African civet and francolin.

Catch per unit effort

There was unanimous consensus among hunters that bushmeat species were in decline and that it was necessary to hunt for longer and travel further than in the past. Table 3.5 summarises estimates of average hunting trip length and, where available, catch per unit effort estimates over four time periods.

Table 3.5: Summary of average hunting trip length and catch per unit effort over time. All study locations were in the Kumasi area. Figures given in parentheses are standard deviations. * Decline in catch per unit effort is significant to the 95% level.

Period	Average hunting trip length (hrs)	Catch per trip (number of animals per trip)	Catch per unit effort (number of animals per hour)
1982 *(Dei 1982)*	3.6	NA	NA
1993 *(Tutu 1993)*	4.4	NA	NA
2002 *(Crookes 2007)*	5.6 *(3.3)*	1.97 *(1.2)*	0.35 *(0.15)*
2011 *(Shanti-Alexander in press)*	7.7 *(3.1)*	1.95 *(1.5)*	0.19 *(0.12)**

The average time spent hunting by hunters in the Kumasi area appears to have increased by almost 114% in the 30 years since the study of Dei et al. (1982). Catch data are only available from Crookes et al. (2007) and Shanti-Alexander (2011), thus an estimate for catch per unit effort, measured in terms of catch per hour, can only be calculated from these data. The decline in catch per unit effort of 46% from 2002 to 2011 is significant to the 95% level ($t = 0.73$, d.f = 73, $p = 0.02$). Further evidence that resources may be becoming stressed lies in accounts provided by other researchers. In 1995, (Hofmann, Ellenberg & Roth 1999) reported that 98% of hunters perceived bushmeat success to be in decline. 70% believed this to be due to dwindling resources. Shanti-Alexander (2011) found all hunters reported a decline in success and reported the increasing difficulty they faced in securing a successful catch. One hunter was quoted as saying:

"It used to be that before I had even left to start the hunt, they would be starting the fire to cook the meat"

While such statements need to be taken in context, these anecdotes illustrate the point that, whether entirely attributable to depletion or not, hunters perceive there to have been a dramatic change in resource availability.

3.3.2. Hunter behaviour

Short-term, intra-annual

22% of hunters surveyed in 2011 reported hunting all year round. Hunting was a strongly seasonal activity for the other hunters, and all hunters, including those who hunted all year round, reported a peak season and low season during the year (figure 3.3). Reported levels of effort and success, measured in terms of trips per week and animals caught per week, were all significantly different between peak and low hunting seasons (Kwaman trips per week, V = 196.5, P = 0.00064, Kwaman animals per week, V = 325, P = 1.29×10^{-5}, Jachie trips per week, V = 140, P = 0.0028, Jachie animals per week V = 120, P = 0.00068).

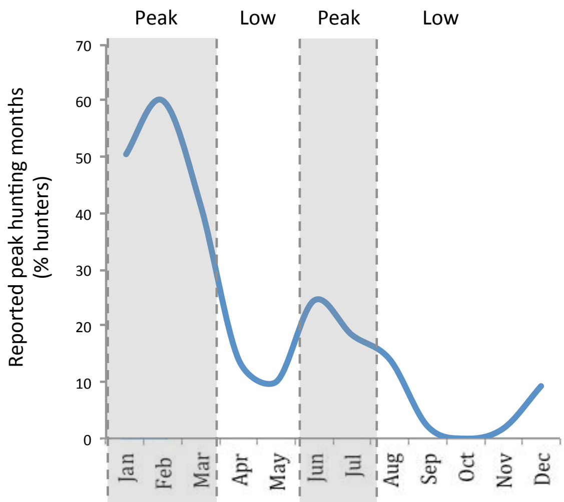

Figure 3.3: Plot of reported peak hunting months in both communities.

All hunters gained income from other sources as well as hunting, with farming being the primary income generator for most (Jachie 52%, Kwaman 71%). 94% of hunters engaged in agriculture to some degree. 80% stated that agricultural activities were the primary reason why they chose to hunt more in the peak season. This was broken down into reduced labour commitments during the months from January to March, when labour commitments associated with harvesting and planting were low (47%), and hunting to protect their crops, in particular the maize crop, which ripens in June (33%). The remaining 20% said that favourable environmental conditions linked either to the seasons or to perceived prey abundance explained their hunting strategy. No hunter mentioned any aspect associated with the bushmeat market as a reason for allocating effort as they did. Seasonal engagement in the trade appears to be driven by characteristics associated with the chosen livelihood portfolio. Bushmeat traders confirmed seasonal fluctuations in the trade in line with hunter reports.

Long-term, inter-annual

Relative engagement in hunting appears to have declined over the last decade. Household surveys in 1990 conducted in communities around Kumasi indicated that on average 14% of households were involved with hunting (Falconer 1992). This aligns well with surveys conducted in 2002 and 2004, also in the Kumasi area, which indicated that approximately 15% of households were involved in hunting (Crookes *et al.* 2007). A more recent study (Shanti-Alexander *et al.* in press) found that only 4% of households were engaged in hunting.

Over a comparable period bushmeat has consistently been the most expensive protein available on local markets (Asibey 1987; Falconer 1992; Ntiamoa-Baidu 1998). In 1990 Falconer (1992) found that fresh bushmeat was on average 39% more expensive than beef and 51% more than goat. The market surveys conducted in 2011 found this difference had increased; the wholesale value of a kilo of grasscutter meat was 67% more than the retail value of a kilo of goat, 108% more than beef and 488% more than a kilo of fresh sardines.

Data on profit margins between protein substitutes was not available. However analysis of the marginal increase in bushmeat prices between 1990 and 2011 (using the wholesale price of a single grasscutter carcass as an indicator) shows that the real price of bushmeat increased by 313%, significantly greater than the national minimum wage, 61%; the real price of cocoa, 153%; and the price of herring, the most commonly consumed protein according to our survey of 101 consumers in Kumasi, 180%.

To elaborate on these figures, in 2011 the price a hunter could expect for a single grasscutter carcass was 57% more than a worker on the national minimum wage could expect to earn in a week. In 1990 it was 30% less. According to the Ghana Statistical Service, inflation between 1990 and 2011 was 4,930%. Over the same period, the raw price of the average grasscutter carcass increased by four times this rate. While this comparison presents only a simple comparison of prices, ignoring external production costs such as fuel that might potentially impact hunters' profit margins, it highlights how the consistent rise in bushmeat price has exceeded those of similar commodities. The implication is that the relative value of bushmeat is greater in 2011 than it was in 1990 but that participation in the trade has declined.

3.3.3. Consumer behaviour

Consumer demand and spending

Comparison of historical consumer surveys suggests that the proportion of the population who regularly eat bushmeat has changed little over recent decades; in 1993 Tutu et al. (1993) found that bushmeat was the primary protein source for 2-5% of respondents, similar to our own findings of 4% in 2011. While regular bushmeat consumption appears steady, the number of people who eat bushmeat in any form appears to have declined. Preference and willingness to pay (defined simply as whether a consumer would be happy to pay more for the bushmeat they consume) have also declined sharply, while there has been a marked increase in the consumption of and preference for fish (table 3.6). Consumer preference has been shown to be linked to what is most readily available on local markets (East *et al.* 2005). The fall in preference may therefore be linked to the lack of availability and high price of bushmeat. Scarcity and price were the most frequently quoted reasons for not eating more bushmeat in 1993 (Tutu, Ntiamoa-Baidu & Asuming-Brempong 1993). In our own survey, 100% of respondents who had stopped eating bushmeat in the previous year cited cost as the reason.

Table 3.6: Comparison of consumer tastes. **1990**: (Falconer 1992) study area: Kumasi and surrounding communities; **1993** (Tutu, Ntiamoa-Baidu & Asuming-Brempong 1993) study area: Accra (capital), Mankesim (town, Central Region) and Doryum (village, Ashanti Region); **2011**, primary data collected during consumer surveys, May – June 2011, study area: Kumasi and surrounding communities.

Consumption characteristic	**1990 N = 262**		**1993 N = Unknown**		**2011 N = 278**	
	Bushmeat	Fish	Bushmeat	Fish	Bushmeat	Fish
Eat (any)	95%	NA	NA	NA	82%	100%
Eat (most freq)	NA	NA	2% - 5%	55% - 77%	4%	86%
Prefer	61%	NA	40% - 70%	10% - 32%	14%	61%
Willing to pay more	>55%	NA	NA	NA	32%	NA

Bushmeat consumption would therefore appear to remain important for a small proportion of the population, but price increases are increasingly pricing consumers out of the market, which may be reflected in a reduction in preference.

3.3.4. Bushmeat prices

Seasonal changes

Two previous studies of the Atwemonom market found supplies varied seasonally, with a peak from January to March, a decline in April and May and then a rise again in June (Falconer 1992; Hofmann, Ellenberg & Roth 1999). Falconer (1992) found prices to be correspondingly higher in the low season than in the peak season. Relative price markups in the low season for four main species were 67% (grasscutter), 29% (Maxwell duiker), 60% (black duiker) and 114% (bushbuck). Surveys of bushmeat traders in 2010 and 2011 confirmed this trend anecdotally. These seasonal fluctuations align well with allocation of effort reported by hunters in our 2011 survey of hunting communities, with periods of low hunting activity correlating with high prices and vice versa. There is no evidence among consumers that bushmeat demand follows the same seasonal pattern as hunting activity. The suggestion is therefore that seasonal price trends are driven by the seasonal participation in the trade by hunters, and hence by availability of bushmeat in the market.

3.4. Discussion

Bushmeat hunting has had a dramatic impact on wildlife in many parts of Ghana (Oates *et al.* 2000; Brashares, Arcese & Sam 2001). This loss of wildlife represents a three-fold threat, not only to the hunted species themselves, many of which are becoming increasingly marginalised in fragmented forest reserves and the few remaining patches of primary forest (Myers *et al.* 2000; Tan *et al.* 2009), but also for sections of society who rely on hunting for their incomes and wellbeing (Adams *et al.* 2004), and the ecosystem of which bushmeat species are an integral part (Brodie & Gibbs 2009). The management of hunting, as with other natural resources, is therefore necessary both from a conservation and development perspective. Understanding the processes that drive the trade is an important step in developing appropriate management strategies (Ling & Milner-Gulland 2006; Nicholson *et al.* 2009; Macdonald *et al.* 2011).

This work sets out and tests a framework that examines the bushmeat trade around Kumasi, from the perspective of the market, in order to ascertain what is driving the trade. Specifically, it aims to characterise the nature of supply and demand by explicitly considering the behaviour of the hunters and consumers involved in the trade. The tests of our predictions provide good evidence in support of our hypotheses that the trade around Kumasi is defined more by characteristics associated with supply-side dynamics than demand-side dynamics (table 3.7). The analysis also suggests that the supply-driven nature of the trade has become more marked in recent years as the resource has become more depleted.

Resource depletion is likely to be a significant contributor to the supply-limited scenario observed in the Kumasi market. The effect of resource limitation on price in hunting systems has been reported elsewhere in Africa. Hearn & Morra (2001) found that limited resources and unmet demand was likely to be responsible for high prices in Equatorial Guinea, and Kamins et al. (2011) found that vendors of bats in various locations across Ghana, including Kumasi, reported that demand frequently outstripped supply.

Table 3.7: Evaluation of results against predictions based on the market evaluation framework presented in table 3.2

Prediction	Sub predictions and tests	Result	Comments
Resources show signs of depletion.	***Trade composition*** 1. Market level. Increase in proportion of the trade represented by less vulnerable taxonomic groups such as rodents.	✓	1. Dramatic increase in the rodent to ungulate ratio between 1990 and 2011.
	2. Village level. First hand hunter reports reflect a comparable compositional change to one dominated by less vulnerable taxonomic groups.	✓	2. Hunter reports align closely with trends observed in the market data. Rodent species and small ungulates dominate the trade.
	Catch per unit effort 3. Average distance travelled per hunt increasing and catch per unit effort in decline.	✓	3. Significant decline in CPUE between 2003 and 2011. Anecdotally a 114% increase in distance travelled over 30 years. It should be noted the decision to travel further may be to harvest more, however hunters' report catches are in decline.
Hunters move in and out of the market independently of price signals.	***Short-term (intra-annual)*** 4. Hunting activity seasonal, defined not by the price of bushmeat, but by other factors associated with hunters' livelihoods, namely the agricultural seasons.	✓	4. Strongly seasonal pattern in hunting effort. 80% reported this was due to agricultural commitments
	Long-term (inter-annual) 5. Participation in the trade trends independently of market signals (price) and the relative value of bushmeat (measured relative to inflation, national minimum wage and the price of alternatives).	✓	5. Relative value of bushmeat has increased over the past 21 years compared to three indices (cocoa price, fish price and national minimum wage). Proportion of households engaging in hunting over the same period is in decline. Two caveats: Production costs that may reduce profit per animal were not considered and; the absolute number of hunters participating was not considered.
Consumer spending patterns defined by supply rather than demand.	***Consumer spending patterns*** 6. Frequency of bushmeat consumption in decline due to high prices and lack of availability, frequency of consumption of cheaper alternatives increasing.	✓	6. The proportion of regular consumers appears stable. The proportion of the population who eat bushmeat is in decline. Price is the main factor that defines this decision. Preference and frequency of consumption of cheaper alternatives has risen.
Prices are set by supply, not demand.	***Seasonal changes*** 7. Periods of peak supply correlate to low prices and vice versa. There will be no evidence that consumer demand for bushmeat fluctuates.	✓	7. Anecdotal evidence suggests bushmeat prices are at a premium when supplies are low. Price fluctuations are large (>100% for some species). There is no evidence from consumers that demand is seasonal. More detailed econometric modeling is needed to define the relationship between supply and demand and price.

There are a number of important caveats that should be highlighted when interpreting the results. For example, the change in composition observed both on markets and among hunters might be due in part to an increasing reliance on pest species, many of which are rodents. This reliance on pest species is reported by hunters and evidenced by the peak in hunting during the ripening of the maize crop in June. A focus on agricultural pests would influence both the seasonal participation trend and the market composition.

In addition, the supply and demand functions have not been comprehensively defined, thus precise evaluation of how the supply and demand relationship has evolved over time has not been possible. However, substantial detailed data are required for such estimations (Epple 1987), which are unlikely to be available for many bushmeat market systems. Estimates of how the relative value of bushmeat has changed over time do not consider bushmeat production costs and hence there has been no attempt to quantify how the actual profitability of hunting has changed relative to alternative income streams. Such an estimate would be extremely valuable when analysing participation in the market. Nor has it been possible reliably to estimate how long-term supplies of bushmeat entering the market have changed. Participation in the trade is measured in relative terms. However populations will have increased over the period covered by this study. Although relative engagement has declined, absolute engagement may have remained constant or increased. The data required to make such an estimate is not prohibitive; unfortunately local population data needed to make such calculations were not available for the study sites over the study period. On an individual level, the results of the tests that are presented need to be interpreted with caution. However, where possible, multiple tests have been conducted for each framework step, and collectively the results provide a robust picture of how the trade has evolved over time. The framework itself presents a systematic approach to analysing market characteristics using the kind of information that is often available for such markets.

The fact that relative engagement in hunting has declined despite significant increases in its apparent value suggests that a decline in bushmeat price, at least if these declines are marginal, may also have little effect. These findings raise doubts about whether demand-side initiatives, such as consumer education campaigns, will effectively lead to a reduction in hunting pressure. The one exception might be if government intervention formally regulated the trade, keeping wholesale prices artificially low, while inflating retail prices through the application of a bushmeat tax or similar instrument. Such a policy would almost certainly be deeply unpopular among consumers and suppliers alike, and almost impossible to enforce due to the informal, open access nature of the trade.

The logical conclusion is that supply-side interventions may be more effective; however, with limited scope significantly to alter the fundamental nature of rural livelihoods so as to break the seasonal pattern of income and labour associated with agriculture, what opportunities do these findings present? The link between agriculture and hunting suggests that hunting plays two roles: firstly, as an activity during the early part of the year when agricultural labour commitments are low and hunters have more time on their hands, and secondly, as a method of protecting agricultural incomes from losses arising from pest damage during the period around June, when crops such as maize are ripening. Crop pests tend to be abundant, fast-growing, non-threatened components of the farm-bush matrix, and therefore not as vulnerable to extirpation from over-harvest as forest-dwelling species (Rowcliffe *et al.* 2003). The importance of crop pests in Ghanaian markets has been reported previously by Falconer (1992) and Bojo (1996). Cowlishaw et al. (2005) in their study of the Takoradi bushmeat market concluded that the farm matrix might play an important role in supporting a sustainable bushmeat trade. Yet despite the recognition of the benefits of the farm-bush matrix for bushmeat in the literature, historically Ghanaian farmers have not considered crop pests to be advantageous (Bojo 1996) and although there have been calls for the production of wildlife to be explicitly considered in land planning (Asibey 1977), to date wildlife harvesting as a land-use remains off the political agenda in the forest zones of Ghana.

The small-scale individual nature of agriculture in Ghana makes the human modified landscape naturally amenable to wildlife friendly policies (Fischer *et al.* 2008), while the benefits associated with improved resilience and adaptive capacity that would be realised in multi-use landscapes are arguably of greater importance for communities heavily reliant on agriculture, where productivity and value are susceptible to environmental and economic shocks (Holling & Meffe 1996; Tscharntke *et al.* 2005). In order to integrate wildlife production into land planning, however, it is necessary to understand which components of the fauna can persist in the human modified landscape and what their characteristics are (Norris 2008). Our analysis of the trade suggests that the most valuable bushmeat species, the grasscutter, is also the most abundant in trade. It is also the species most commonly associated with crop damage and thus the ideal species for co-production of bushmeat and crops. The time at which harvesting this species is most useful from a pest control perspective is the maize season in June, which is also the lean season when agricultural income is low. Explicit consideration of the value of bushmeat in land-planning exercises would be a first step to assessing the benefits it provides and assessing any changes in land use that would be required to maximise income and reduce livelihood vulnerability throughout the year.

Policies that engage with hunters and farmers to promote the benefits of wildlife-agricultural co-production may also have the dual benefit of complementing existing policies that seek to protect and enforce the no-take status of the few remaining intact forest reserves. For example, conservationists might work with hunters to improve the efficiency of traps for crop pests, reduce the costs of transport to market (e.g. through a cooperative), or to support them in marketing them as products of wildlife-friendly farming, in return for commitments not to hunt less resilient species in forest areas. By raising the economic returns from activities that can be readily incorporated into existing livelihood strategies, conservation initiatives designed to enforce no-take zones, which are often viewed with skepticism by local communities, being associated with the loss of opportunity rather than its promotion, may be attractive to resource users.

The results of this study should not be taken as an indication that demand does not play a role. While in the short term, evidence of the market's supply driven nature is persuasive, a distinction should be made between short-term and long-term market drivers. In the long term, regardless of hunters' seasonal livelihood strategies, if the human population continues to grow and unless demand for bushmeat falls, consumption can only increase. Ultimately, management that fails to consider both sides of the trade is unlikely to provide the complete solution. However, if markets can be managed and manipulated through policies that complement rather than seek to control and dictate to existing behaviours and institutions, then the dual objectives of promoting local value from local resources while conserving scarce and endangered and species should be more achievable.

Chapter 4

Drivers of supply and demand in a mature bushmeat market in Ghana, West Africa.

4. Drivers of supply and demand in a mature bushmeat market in Ghana, West Africa

4.1. Introduction

The bushmeat trade in much of West Africa has seen significant change over the last century. While likely a primarily subsistence-based activity originally, today the bushmeat trade represents a large well-established economic activity in many countries (Falconer 1992; Bowen-Jones & Pendry 1999), providing an important source of income as well as food for hunters and their households, many of whom exist on the margins of the cash economy (Asibey 1974; Davies 2002; de Merode, *et al.* 2004; Kumpel *et al.* 2010). The economic importance of the trade is substantial. Estimates of annual bushmeat production range from 400,000 tonnes in Ghana (with an estimated value of $US350 million dollars; Ntiamoa-Baidu 1998a) to 1 – 5 million tonnes in the Congo Basin (Wilkie & Carpenter 1999; Fa, Peres & Meeuwig 2002). The scale of the trade becomes evident when one considers that, in Ghana, annual commercial production of marine and freshwater fish between 1991 and 1998 averaged 407,000 tonnes, while commercial livestock production averaged 57,600 tonnes (SRID 2010).

High bushmeat prices on the urban market are frequently considered to be one of the main drivers of the unsustainable trade in bushmeat (Wilkie & Carpenter 1999; Bowen-Jones & Pendry 1999; Fa *et al.* 2000; Fa *et al.* 2009). Despite the economic significance of bushmeat and the increasingly recognised importance of the urban trade as a driver of unsustainable hunting behaviour, there have been few analyses that have used econometric techniques (the application of statistical methods to analyse economic phenomena) for analysis of the bushmeat markets. One such example is Rentsch & Damon (2013) who presented a detailed analysis of the cross price elasticity of demand for bushmeat in the Serengeti. Although the tools of econometrics and ecology do not differ greatly in principle (Armsworth *et al.* 2009), one of the key benefits of adopting such approaches is the ability to analyse and interpret behaviour according to economic theory, offering different lines of enquiry and interpretation.

Such methods have been successfully applied in a range of natural resource markets, including local fish markets in the USA (Angrist *et al.* 2000), the ivory trade Japan (Milner-Gulland 1993) and the shark fin trade in Hong Kong (Clarke 2003). One of the biggest barriers to implementing such studies for informal markets in the developing world, such as the bushmeat trade, is the lack of long-term data necessary for robust analysis. However, the need for such analysis is great. These markets represent tightly coupled socio-economic systems, where the behaviour of the hunter, consumer and their environment are often inextricably linked. Developing models of such markets, consistent with economic theory, represents a valuable tool for improving our understanding of the processes that drive the trade; challenges that are of vital significance with regard to informing the development of appropriately targeted and effective management strategies for both conservation and development (Nicholson *et al.* 2009).

Markets can be expected to be self-regulating and in equilibrium, on the assumption that supply equals demand and that stocks clear; or in other words, under the assumption of perfect competition. Economists' interests in understanding these markets led to the development of statistical methods for modelling systems of simultaneous equations that describe both supply and demand (Tinbergen 1930; Haavelmo 1943). In their simplest form, these supply and demand relationships are linear and described in terms of the principle that supply equals demand, where the quantity of a good demanded is defined by its price and the price of an alternative, or substitute good, while the quantity supplied is defined by its price and some variable that encapsulates the production cost. In reality, many markets are highly complex, and although assumptions of perfect competition and linearity are not unrealistic (Graddy 1993; Stoker 1993) many markets may not be subject to perfect competition (for example oligopolistic or monopolistic markets) or linearity in the demand or supply functions. In practice, relaxing the requirements of perfect competition and linearity in applied systems introduces complexity in solving simultaneous supply and demand equations (Goldfeld & Quandt 1968) and requires knowledge of the true nature of competition that can be difficult to gain in real-world systems (Bresnahan 1982; Klemperer & Meyer 1989).

Bushmeat markets have been used to examine a variety of characteristics of the trade, from wildlife depletion to spatial and temporal dynamics, and consumer, hunter and trader behaviour (Falconer 1992; Juste *et al.* 1995; Fa *et al.* 2004; Crookes *et al. 2*005; East *et al.* 2005; Macdonald *et al.* 2011; Allebone-webb *et al.* 2011). These studies represent a rich source of literature from which to understand the potential drivers of supply and demand in bushmeat markets.

Using the commercial bushmeat trade in the Atwemonom market in the city of Kumasi, Ghana, as a case study, we develop a monthly simultaneous supply and demand model for the market, the first if its kind for a bushmeat system, based on the simplifying assumptions of perfect competition and linearity. Although we acknowledge that this assumption may be a simplification, it is based on knowledge of the market structure and operation, namely that the market clears and appears to operate in a competitive fashion (Chapter 2 & 3), suggesting such assumptions are a reasonable starting point for a preliminary analysis. Four models are tested. The first model considers all species traded. The second and third models focus on those two taxonomic groups that make the most important contribution to the trade, namely (2) ungulates, and (3) rodents (selected on the basis that they form the majority of the commercially traded species), which contribute 56% and 40% of the total volume of all biomass traded between 1978 and 2004 (Chapter 2). The fourth considers the most important species within the rodent subset, namely (4) the grasscutter, or giant cane rat, *Thryonomys swinderianus,* which is also the most commonly traded species on the market, contributing more than 45% of the records (number of animals) traded in 1990 (Falconer 1992) and 63% of records in a one week survey 2011 (Appendix C1). The decision to distinguish models by taxonomic group was made on the basis that while hunting is generally a non-selective activity, where specific species are rarely targeted (Hofmann *et al.* 1999), different taxa may exhibit different elasticities of supply. We may therefore expect to see difference in the ability of different stocks to respond to price signals generated in the market. For example, Rowcliffe *et al.* (2003) suggest that an index of the ratio of rodents to ungulates may be a good proxy for depletion due to the higher resilience of rodents to hunting pressures. Grasscutters are prevalent in the market, and are both the most preferred among consumers, the most valuable in terms of price per kilo and are also frequently hunted due to their being a crop pests as well as for bushmeat (chapter 3). They may therefore show different dynamics to species that are hunted specifically for trade.

Atwemonom is the primary market for fresh bushmeat in the city, and one of the oldest formal bushmeat markets in Ghana (Falconer 1992). In addition, it has been the focus of a number of previous studies on hunting in the region, and as such, represents an excellent case study for market analysis due to the relative abundance of reliable information on its structure and operation (Falconer 1992; Ntiamoa-Baidu 1998b; Hofmann *et al.*1999). Model variables are selected with reference to economic theory, the bushmeat literature and personal experience of the study site gained over three field seasons between 2010 and 2012. Data requirements for the model are underpinned using a unique 27-year dataset collected between 1978 and 2004 as part of a long-term market survey of the Atwemonom bushmeat market in Kumasi by the Ghana Wildlife Division.

In addition to assessing the drivers of the trade, we present the results of two further analyses. Firstly, we compare the relative price elasticities of supply of different species groups to test the hypothesis that if bushmeat resources are depleted as indicated by the qualitative assessment presented in Chapter 3, the supply of rodents is likely to be more elastic than the supply of ungulates, based on their faster reproduction and growth rates meaning they will be more likely to sustain high levels of hunting pressure (Robinson 2000; Rowcliffe *et al.* 2003). Secondly, we look for evidence in the market data to support the hypothesis that a major bushfire event in the 1980s dramatically impacted hunting for a number of subsequent years. Bushfires in Ghana represent a major threat, not just to agriculture and pastoralist systems, but also to native biodiversity (Kusimi & Appati 2012). Between 1982 and 1984, much of the country was affected by a series of devastating and extensive bushfires, considered by many to be the worst in living memory (Arthur & Arthur 2011). The Food and Agricultural

Organisation (FAO) estimated that as much of 50% of vegetation cover and 35% of croplands were destroyed in parts of the country. In a survey of hunters around Kumasi, bushfires were the most frequently cited threat to hunting offtakes, and many older hunters referred often to the fires of the 1980s as being at the root of the perceived decline in bushmeat today (Chapter 2). The scope of the data from the Atwemonom market presents a unique opportunity to examine evidence of the impact of major fire events on the bushmeat trade. Quantifying the impacts of such effects is particularly important in light of forecasts that predict increases in the intensity and frequency of bushfires due to climate change (Biringer 2003; Kalame *et al.* 2009).

4.2. Methods

4.2.1. General approach

The analysis is based on data collected on a daily basis in the Atwemonom market in Kumasi between 1978 and 2004 by members of the Ghana Wildlife Division. The data include records on species, trade volumes and price. The bushmeat trade in Ghana is a legal activity for non-schedule 1 species, except during a 4-month closed period between 1 August and 1 December, when the hunting of all species except for the grasscutter is prohibited (Wildlife Conservation Regulations, 1971). Due to data reliability concerns, records from the closed season were excluded from analysis (Crookes *et al.* 2005).

A monthly simultaneous supply and demand model is developed which forms the basis for subsequent analysis. The trade is broken down into four sub-groups: total trade volumes, rodents, ungulates and the grasscutter. An additional analysis investigates evidence of how a major bushfire event in the early 1980s impacted supply and demand dynamics. Our methods are broken down into four sections. First we outline a general model of the bushmeat market based on economic theory (Section 4.2.2). Secondly, we present a conceptual model of the bushmeat market based on evidence from the literature and personal experience of the study system (Section 4.2.3). Thirdly, we discuss model parameterization (Section 4.2.5), and finally, we validate the model (Section 4.2.6).

4.2.2. The General Model

Within our market, let p_t denote the price of bushmeat, q_t denote the quantity of bushmeat traded, and x_t denote a vector of covariates that characterise the market at time t. Assuming perfect competition, supply and demand are in equilibrium, and thus the supply and demand functions, which are a function of both price, p_t, and the market covariates, x_t, can be assumed to be equal:

$q_t^s(p_t;\ x_t) = q_t^d(p_t;\ x_t)$ (4.1)

Where $q_t^s(p_t;\ x_t)$ is the supply function and $q_t^d(p_t;\ x_t)$ is the demand function. On this basis, we can specify our simultaneous supply and demand model according to:

Supply: $q_t^s = \beta_p^s p_t + \beta_x^s x_t + \varepsilon_t^s$ (4.2)

Demand: $q_t^d = \beta_p^d p_t + \beta_x^d x_t + \varepsilon_t^d$ (4.3)

Market clears: $q_t^s = q_t^d = q_t$

Where $\beta_p^s \geq 0$ and $\beta_p^d \leq 0$, based on economic theory predicting that the gradient of the demand curve be negative, or downward sloping, while the supply curve gradient be positive or upward sloping. This is in line with the standard assumption that consumer demand will fall as prices rise, while suppliers will increase production in response to price rises. Equations (4.2) and (4.3) are referred to as the *structural equations* of our model.

When solving this system of equations, there are three primary considerations that need to be addressed: identification, endogeneity and efficiency. The problem of identification arises from the fact that if we were to simply observe a number of equilibrium positions of p_t *and* q_t, in relation to a hypothetical variable z_t which influences demand (such as income) we would only be able to reveal the supply curve and could infer nothing about the shape of the demand curve. Thus, if we are to be able to identify both the supply and demand curves, it is necessary to distinguish a set of unique covariates that are associated with shifting either demand, or supply, but not both. The vector of covariates x_t described in equations (4.2) and (4.3) can therefore be described in terms of three components: x_t^s are exogenous supply shifters that influence supply and not demand; x_t^d are exogenous demand shifters that influence demand and not supply, while x_t^c are the market controls, exogenous variables that influence both supply and demand. Thus equations (4.2) and (4.3) can be rewritten in the more specific form:

Supply: $q_t^s = \beta_p^s p_t + \beta_{x,c}^c x_t^c + \boldsymbol{\beta_{x,s}^s x_t^s} + \varepsilon_t^s$ (4.4)

Demand: $q_t^d = \beta_p^d p_t + \beta_{x,c}^c x_t^c + \boldsymbol{\beta_{x,d}^d x_t^d} + \varepsilon_t^s$ (4.5)

The second issue is that of endogeneity. A consequence of the fact that price is determined by supply is that price, p_t, is not a stochastic variable uncorrelated with the error term, ε_t. This is a violation of the assumptions of the classic linear regression model, and will result in any inferences made by ordinary least-squares being both biased and inconsistent (Maddala & Lahiri 1992). The solution to this is to use instrumental variables to estimate exogenous forms of both price and demand that can be substituted into equations (4.4) and (4.5) and solved. Based on the assumption that $q_t^s = q_t^d$, equations (4.4) and (4.5) can be set to equal each other and solved to estimate $\hat{p}_t$. Similarly, as p_t is equal in both equations, the same equations can be rearranged such that p_t is the dependent variable, and solved to estimate $\hat{q}_t$. The equations used to estimate $\hat{p}_t$ and $\hat{q}_t$ are known as the *reduced form* equations (equations (4.6) and (4.7)).

Price: $\hat{p}_t = \beta_{x,c}^c x_t^c + \beta_{x,s}^s x_t^s + \beta_{x,d}^d x_t^d + \varepsilon_t^s$ (4.6)

Quantity: $\hat{q}_t = \beta_{x,c}^c x_t^c + \beta_{x,d}^d x_t^d + \beta_{x,s}^s x_t^s + \varepsilon_t^s$ (4.7)

IVs: $z_t = (x_t^c, x_t^s, x_t^d)$,

In this way, $\hat{p}_t$ and $\hat{q}_t$, – being now described purely in terms of the exogenous instrumental variables (IVs), and thus being themselves exogenous – can be substituted back into equations (4.4) and (4.5) for unbiased estimation of the structural equation coefficients, $\beta_p^s, \beta_x^s, \beta_p^d, \beta_x^d$. This process of dual estimation is known as Two Stage Least Squares (2SLS).

The final consideration with regard to estimation is efficiency. In describing the same system using two differently identified models, we have necessarily restricted the parameters in each model, and thus they cannot be thought of as being efficient (Stock & Watson 2012). Indeed, when considering how best to solve a set of simultaneous equations, it is usually not satisfactory to try and determine each of the equations separately without regard to the restrictions that each equation may impose on the other (Haavelmo 1943). A solution to this is to use Seemingly Unrelated Regression (SUR), where both of the structural equations (4.4) and (4.5) are solved jointly under the assumption that their errors are correlated. Adopting this approach ensures that the full range of regressors are considered in estimating the structural equation coefficients, thus ensuring no restrictions are placed on the model. This combination of IV and SUR methods is known as three staged least squares (3SLS) and should produce estimates of the structural equation coefficients that are unbiased, consistent and efficient (Lin 2005).

4.2.3. A conceptual model of the Atwemonom Market

To develop an appropriate model of the bushmeat market in Atwemonom, it is first necessary to define the system and distinguish those variables associated with demand, supply, and both (the market controls). In categorising the market, we make a number of assumptions to simplify the system. We consider supply in terms of those factors that influence hunter behaviour in the rural setting, while demand is defined in terms of the urban consumer. We do not consider rural demand in our analysis, as this does not play a direct role in the functioning of the Atwemonom market.

On the supply side, many hunters in the humid tropics are primarily engaged in agricultural activities (Bojo 1996; Shanti-Alexander et al. *in press*). Thus, hunting activity has been shown to be influenced by both seasonal variation in agricultural incomes (Schulte-Herbrüggen 2011), labour demands associated with harvests (Brashares *et al.* 2011) and the need to protect crops against pests at certain times of the year (Tutu *et al.* 1993; Smith 2005; Shanti-Alexander *in press*). The most significant cost associated with hunting is the purchase of a firearm. The initial capital outlay associated with this expenditure is significant (Crookes *et al.* 2007), although other, less capital intensive hunting methods are also used, such as wire-snare trapping and dog hunting (Shanti-Alexander *et al.* in press). Additional costs associated with production include the purchase of cartridges and batteries or fuel for night-time hunting (Hofmann *et al.* 1999) and the cost of transporting bushmeat to market (Brashares *et al.* 2004; Cowlishaw *et al.* 2005a). Other considerations that play a role in a hunter's decision to participate include seasonal variation during the annual wet and dry seasons, which, as well as defining the agricultural seasons, influences the penetrability of the landscape for hunters (Juste *et al.* 1995). On the demand side, in addition to the availability of alternatives such as fish and livestock (Asibey 1987; Falconer 1992; Brashares *et al.* 2004), consumer income has been shown to be a driver of bushmeat consumption (Wilkie *et al.* 2005; Fa *et al.* 2009).

Both supply and demand are likely to be influenced by macroeconomic and demographic drivers such as population growth and the cost of living. Rising urban populations are likely to increases demand and drive prices up (Bowen-Jones & Pendry 1999). Population estimates suggest that the population of the Ashanti region has more than doubled over the last 20 years (Ghana Statistical Services 2012). Although data are not available on rural population estimates, it would be reasonable to assume that this regional growth in population would be correlated in both rural and urban regions. With regard to the cost of living, bushmeat has long been considered among the most expensive forms of protein in urban centres in Ghana (Asibey 1987; Falconer 1992; Ntiamoa-Baidu 1998a; Shanti-Alexander 2011), while hunters have been shown to rely on hunting during the lean season, when income from agriculture is low and food stuffs are expensive (Schulte-Herbrüggen 2011), and during other times of hardship (Shanti-Alexander 2011). Increases in the cost of living, such as the price of daily consumables like food and fuel, as measured by the Consumer Price Index, may be expected to incentivise hunting among hunter communities while shifting urban demand towards less expensive goods. Figure 4.1 summarises these hypothesised associations in the form of a conceptual diagram of the commercial bushmeat market.

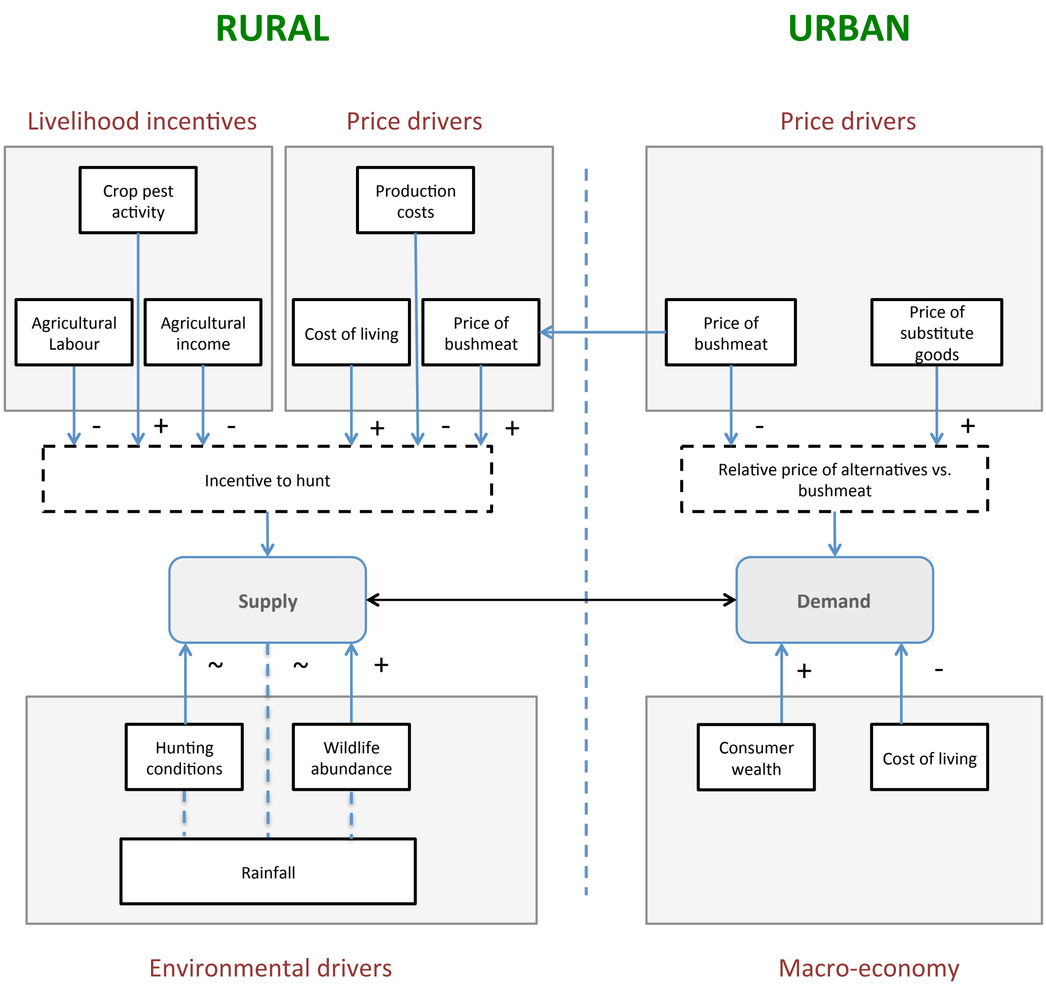

Figure 4.1: A conceptual model describing the drivers of supply and demand. Drivers are loosely grouped into different categories. Supply: (1) hunter livelihood dynamics, (2) the rural market and macroeconomy and (3) the environment. Demand: (1) The urban market and (2) the macroeconomy. Arrows show the direction of action. The symbols represent the effect of an increase in any given driver on the quantity of bushmeat supplied or demanded, be it positive, (+), negative, (-), or uncertain (~).

4.2.4. Data processing

Bushmeat data

The dataset was cleaned to remove outliers using plots of weight against price. Recorded weights were compared to the maximum reported adult weights in Silva & Downing (1995) and Huffman (2012). Allowing for regional variation in species body mass, and possible weighing errors in the market data, any entries with values over 50% greater than the maximum reported were considered individually and revised or removed accordingly. Where it was apparent that price data had been entered incorrectly (such as a misplacement of a decimal point) corrections were made, otherwise the entry was removed. The refined data set represents 60,310 records, collected over 3,331 days, 180 months and 27 years. 3,128 records, representing 4.9% of the original dataset, were deleted due to missing or incorrect data (either weight, price or both). Normalised values for price and quantity were generated to take account of variation in observer effort between months. Price was described in terms of the average price per kilogram in a given month and deflated with CPI using 2004 as a baseline. Quantity was described in terms of the average number of individuals recorded per "record day", where "record day", refers to the number of days the market was observed in the relevant month. Controlling for variation in sampling effort in this way has been shown to be appropriate for this particular dataset (Crookes *et al.* 2005).

4.2.5. Exogenous regressors

Eight exogenous regressors were defined in line with the conceptual model presented in figure 4.1 (summarised in table 4.1), and categorised according to whether they were supply shifters, demand shifters or market controls.

Supply shifters

Four variables are associated exclusively with supply side dynamics: agricultural income, agricultural labour, pest incidence and rainfall. The Ghana Meteorological Society supplied monthly rainfall data collected at weather stations in Kumasi. Agricultural income and labour were calculated with reference to production and harvest activity of the seven main cash and food crops grown in the Ashanti region: cocoa, maize, cassava, plantain, yam, cocoyam and rice (Ghana Statistical Service 2008). Agricultural income was calculated according to equation 4.8.

$$I_t = \sum_t^c A^c \emptyset_t^c P_t^c \tag{4.8}$$

$t = 1, \ldots, T \; and \; c = \; individual \; crops$

Where t represents a monthly interval, I_t is the total monthly income from all crops at time t; A^c is the annual production in kilograms of a crop c; $\emptyset_t^c$ is a production coefficient that represents the proportion of the total annual production of a crop c sold at time t and P_t^c is the deflated price per kilo of a crop

c at time t as recorded in Kumasi's Central Market. For the food crops, the Ghana Statistical Services supplied data on total annual crop production for the Ashanti region. The Statistics Research Information Directorate, a sub-division of the Ministry of Food and Agriculture, supplied monthly data on market prices, based on regular surveys of Kumasi's Central market. The production coefficient was derived from seasonal selling behaviour (the proportion of farmers selling agricultural produce in any given month) as reported in the Ghana Living Standards Survey (Ghana Statistical Service 2008). Production and price data for cocoa was supplied by COCOBOD, the state organisation in charge of the Ghana cocoa industry. Specific selling information was not available for cocoa. It was assumed that since cocoa is not stored locally it is sold shortly after harvest, and thus that selling and harvest are aligned. This assumption is in line with the findings of cocoa research in the region (Schulte-Herbrüggen 2011).

Agricultural labour commitments were calculated according to equation 4.9.

$$L_t = \sum_t^c H_t^c C^c \qquad (4.9)$$

$t = 1, \ldots, T \; and \; c = \; individual \; crops$

Where L_t represents total labour commitments across all crops at time t; H_t^c is a seasonal variable representing the harvest of crop c at time t; and C^c is the total area of land under cultivation for crop c in any given year in the Ashanti region. C^c is included as a weighting factor to ascribe greater labour demands to those crops which are more widely grown. For the sake of simplicity it is assumed that the labour associated with the harvest of each crop is equal.

The relative incidence of crop pests (particularly grasscutters) is proxied by the maize season, H_t^{maize}, based on consistent reports that it is during the ripening of the maize crop that pest predation is of greatest concern to farmers (Shanti-Alexander *et al.* in press; Falconer 1992).

Demand shifters

Two variables were associated exclusively with demand side dynamics: the availability of alternatives to bushmeat, and consumer income. In the absence of long-term price data on livestock, fish price was used as a proxy for "substitute goods". Seasonal fluctuations in fish supply have been shown to be a significant predictor of bushmeat consumption and harvesting in Ghana (Brashares *et al.* 2004). Gross Domestic Product (GDP) per capita was selected as a proxy for "urban wealth" and sourced from the World Bank Data Bank (World Bank 2013). GDP per capita was only available on an annual scale, therefore intra-year fluctuations were simulated using a moving average model averaged over a period of one year.

Price per kilo of herring was selected as a proxy for fish price, based on the results of previous market and consumer surveys that highlighted it as both the cheapest and most commonly consumed protein on the Kumasi market (Chapter 2). Because herring prices in the model should be representative of fish supplies to domestic (versus international) markets, herring prices were taken from landing data at two ports close to Kumasi (in Central and Western Regions), harvested by artisanal fisheries that supplied local markets using all gear types. These data were provided by the Fisheries Commission, who also advised on the use of these landing data as the most appropriate for present purposes. Unfortunately, there were 9 months in the dataset (5% of the sample) for which herring prices were missing. In these cases, anchovy prices were used to estimate the herring prices. Monthly herring prices were closely correlated to anchovy prices (Pearson's correlation coefficient, R = 0.95), and the two-step Engle-Granger cointegration method was used for the process of extrapolation (equation 4.10).

$$F_t^s \sim F_t^a + \theta + \varepsilon_t \qquad (4.10)$$

$t = 1, \ldots, T$

Where F_t^s represented the logged price per kilo of sardines at time t, F_t^a the logged price per kilo of anchovy at time t, θ is a short run time trend that is the interaction between month and year and ε_t is the error. All prices were deflated using CPI to a 2004 baseline. The Engel-Granger method tests whether two time series, in this case F_t^s and F_t^a, are co-integrated, based on the fact that if they share a common stochastic drift, a linear combination must be stationary. Thus the two-step method involves regressing one variable upon the other, and testing the estimated residuals, $\hat{\varepsilon}_t$ for stationarity (i.e that their mean and variance remain statistically constant over time) using an Augmented Dickey Fuller Test for a unit root. The relationship described in equation 4.10 was shown to be stationary to the 95% confidence interval (lag = 8, DF = -3.51, p = 0.043), where DF is the Dickey Fuller test statistic and the null hypothesis is non-stationary. A lag of 8 was selected, since in the absence of the four closed season months (Aug – Nov), one "data year" covers 8 months. The predicted values of $\hat{F}_t^s$ were well correlated with the originals, F_t^s (Pearson's correlation coefficient, R = 0.97).

Market controls

Two market control variables were defined: the cost of living and population growth. The relative increase in the Consumer Price Index month on month was used as a proxy for changes in the cost of living (Mankiw 2000). The Ghana Statistical Service supplied annual population estimates for the Ashanti region, which were smoothed using a moving average model averaged over a period of one year.

Excluded variables

Two variable groups were excluded from the final analysis, both of which relate to the supply side of the market: wildlife abundance (resource condition) and hunter production costs. With regard to wildlife abundance, no suitable data were available. With regard to production costs, these can be broken down into two general categories: direct production costs (firearms, cartridges, batteries) and indirect costs (transporting produce to market). In the first case, as village blacksmiths produce most firearms locally, no long-term data were available on manufacturing costs. Nor were price data available for cartridges or batteries. However, this issue may not be as problematic as might be assumed on first consideration. In their study of hunting in the region, Hofmann *et al.* (1999), concluded that although firearms are expensive and likely to act as a barrier to those wishing to enter the trade (Crookes *et al.* 2007), once purchased the ongoing costs of participation (cartridges and batteries) are relatively low, particularly for commercial hunters where the price of bushmeat far outweighs the marginal equipment costs associated with these items. An additional consideration in this regard is the strong client-patron relationship in operation in the Awtemonom market, where traders assist hunters with short-term loans for equipment, which can be repaid in meat. Thus there are existing local finance schemes to help hunters with capital expenditure needed to hunt. Capital costs of production are therefore unlikely to represent a barrier for those already participating in the trade. They are likely, however, to act as a barrier to those who wish to enter. In reality, there are a number of lower-expenditure options available such as snare traps and dogs, which require minimum investment.

In the second case, transport costs are known to be one of the most important sources of expenditure for small-scale traders in developing countries (Badiane & Shively 1998) and the link between transport and bushmeat prices has been demonstrated previously (Cowlishaw *et al.* 2005a). There are two points worth raising in this regard. Firstly, hunters surveyed around Kumasi indicate that they are able to incorporate the costs of transport into the wholesale trade price at market. Thus, while transport is likely to be a significant determinant of price, it is unlikely to influence decisions on whether or not to participate in the trade. Secondly, a logical proxy for transport costs is the price of fuel. While data are available on global oil price, the link between global oil and regional fuel prices in Ghana is likely to be distorted due to the presence of historic fuel subsidies (Boafo-Arthur 1999). While the National Petroleum Authority of Ghana keeps records of pump prices, these records are only available on an irregular basis from 1989. Thus in the absence of reliable, long-term in-country data, fuel prices are not explicitly considered in the following analysis. Nevertheless, it should be noted that fuel prices are among the goods used to construct the monthly Consumer Price Index, which is incorporated in the model as a market control indicator of the costs of living. Model variables are summarised in table 4.1.

While the lack of data on capital costs (fuel and production), is unfortunate, it is unlikely to represent a critical exclusion in the model considering the broader context. Lack of data on wildlife populations is potentially a greater shortfall, particularly if the resource is limited. The inclusion of such data is not a strict requirement, however, and they have been excluded from similar supply and demand analyses in the fisheries sector (Angrist, Graddy & Imbens 2000)

4.2.6. Model validation

The supply and demand model described in equations (4.4) and (4.5) was parameterised according to the variables described in table 4.1. Logs were taken of bushmeat price, quantity and fish price. The endogenous relationship between quantity and price was tested with the Hausman Wu test to validate the requirement for an instrumental variable (IV) approach. The test uses an F-test to compare the distributions of two variants of the structural equations: one using the raw data for p_t and q_t, the other the estimates, $\hat{p}_t$ and $\hat{q}_t$, generated from solving the reduced form equations, (4.6) and (4.7). The null hypothesis, of no statistically significant difference between the models, was rejected (supply model: F = 0.003, p=<$2.2x10^{-16}$, demand model: F = $1x10^{-4}$, p = <$2.2x10^{-16}$), and thus endogeneity was assumed.

To validate the selected variables and test whether the IV methodology as presented in table 4.1 is likely to have adequate statistical power to identify the supply and demand functions, the reduced form relationships (equations (4.6) and (4.7)) were estimated, and F tests used to test deviations from the null model, for the model in its entirety, and the exogenous variable groupings (supply shifters, demand shifters and market controls). Results suggest that the instruments, $z_t = (x_t^c, x_t^s, x_t^d)$, are well correlated (Appendix C2) with both price and quantity, both jointly (p-value <0.001 for all models), and individually, except on two occasions where the market controls have poor explanatory power (the all-rodent and grasscutter models), suggesting that the drivers behind the rodent market (of which grasscutters make up 67%) may be somewhat independent of the macro-economic variables of population and inflation (CPI). Points of note are that on the supply side, periods with high levels of agricultural labour are associated with low trade volumes and high market price; while on the demand side, GDP per capita is positively associated with both price and trade volumes. Overall, the instruments appear strong (have good explanatory power) and credible (that their inclusion is justified in theory).

Table 4.1: Summary of model variables selected for inclusion in the monthly supply and demand model. Summary statistics are presented, along with the time trend and literature associated with the selection of each variable as a proxy for the market drivers (as identified in the conceptual model of the system). The trend is the coefficient on month when each variable is regressed on month and a constant and is included as a simple indication of the stationarity of the data over time. Figures in parentheses are standard errors. Significance codes, * 5%, ** 1% and *** 0.1%.

Category	Market driver	Model variable	Symbol	Units	Mean	S.D	Trend	Literature
Response	Bushmeat volume (all species)	Average number of animals per day	*P*	No/day	19.1	9.58	$4.4\text{x}10^{-3}$*** *($6.3\text{x}10^{-4}$)*	NA
Endogenous	Bushmeat price (all species)	Average price per kilogram	*N*	000' GHC /Kg	10.6	3.08	$-1.7\text{x}10^{-3}$*** *($3.1\text{x}10^{-4}$)*	(Wilkie & Carpenter 1999; Bowen-Jones & Pendry 1999)
Market controls	Cost of living	Relative change in CPI	*C*	None	0.03	0.04	$-1.2\text{x}10^{-4}$** *($4\text{x}10^{-5}$)*	(Falconer 1992; Brown & Williams 2003; Schulte-Herbrüggen 2011)
	Population	Ashanti region population	*A*	Millions (people)	2.74	0.69	0.01*** *(0.0001)*	(Brashares *et al.* 2001; Wittemyer *et al.* 2008)
Supply shifters	Agricultural income	Income proxy	*I*	GHC	261	121.1	1.53*** *(0.089)*	(Damania *et al.* 2005; Schulte-Herbrüggen 2011)
	Agricultural labour	Labour proxy	*L*	Km^2	293	78.6	0.71*** *(0.075)*	(Tutu *et al.* 1993; Hofmann *et al.* 1999; Brashares *et al.* 2011)
	Crop pest activity	Seasonal time trend (maize harvest)	*M*	None	0.38	0.23	$-7.1\text{x}10^{-5}$ *($2.6\text{x}10^{-4}$)*	(Tutu *et al.* 1993; Smith 2005; Shanti-Alexander, *in press*)
	Rainfall	Total monthly rainfall	*R*	Millimetres	102	89.2	0.07 *(0.102)*	(Falconer 1992; Juste *et al.* 1995; Barrett & Arcese 1998)
Demand shifters	Price of alternative	Fish price (herring, price per kilo)	*F*	000' GHC /Kg	2.93	1.20	0.24 *(1.41)*	(Brashares *et al.* 2004; Wilkie *et al.* 2005)
	Urban wealth	GDP per capita	*W*	\$US / unit population	233.4	23.4	0.24*** *(0.021)*	(East *et al.* 2005; Fa *et al.* 2009; Brashares *et al.* 2011)

An augmented Dickey-Fuller test for a unit root, conducted over a lag period of 8, to align with one data year, verified that all models were stationary, for all species (supply DF = -3.76, p = 0.02, demand DF = -3.6, p = 0.04), for ungulates (supply DF = -3.3, p = 0.07, demand DF = -3.9, p = 0.02), for rodents (supply DF = -4.2, p <0.01, demand DF = 4.5, p <0.01), and for grasscutters (supply DF = -4.5, p <0.01, demand DF = -5.9, p <0.01), where DF is the Dickey Fuller test statistic and the null hypothesis is non-stationary.

Pearson's Correlation tests highlighted four potentially problematic correlations between the explanatory variables. Agricultural income and labour were positively correlated (r=0.62) and population was positively correlated with agricultural income (r=0.51), labour (r=0.56) and GDP per capita (r=0.54) (Appendix C3). Variance inflation factor tests suggested that the agricultural labour and income were likely to be most problematic (VIF labour = 3.1, income = 2.5, all other variables < 2.5). Exclusion of either income or labour from the model, however, led to a failure to identify the demand function according to economic theory ($\beta_p^d > 0$) and a marginal reduction in the explanatory power of the model as indicated by $\bar{R}^2$. Thus the original variable set was maintained. However, caution was adopted when interpreting the model relationships involving these explanatory variables.

Durbin Watson tests for serial autocorrelation indicated significant positive autocorrelation in the residuals for all models (appendix C4). Scrutiny of the auto- and partial correlation functions confirmed an autoregressive relationship, of the form AR(1) or AR(2) (Appendix C5). Although the parameter estimates should not be affected by the presence of autocorrelation, the standard errors, and hence model inference, may be biased. To take account of this effect, robust standard errors were calculated using a heteroskedasticity and autocorrelation consistent (HAC) covariance matrix, based on the "Arellano" methodology, to reduce the likelihood of a false positive (Arellano 1987; Andrews 1991; Zeileis 2004).

4.2.7. The bushfires of 1982

To test whether the catastrophic bushfires of late 1982 and early 1983 impacted the commercial bushmeat trade, a Chow Parameter Stability test was run to test for a structural break in the market data around this period. The assumption underlying this process was that the fire event would result in a sudden change in the data (the structural break) and that for a number of years after the fire, there would be prolonged impact as wildlife populations recovered, and that this break in the data would differentiate the behaviour of the model pre and post fire. Additional evidence to suggest a prolonged period of disruption post 1982 fire lies in the fact that there was a series of less major fire events in late 1983 and 1984 (Arthur & Arthur 2011). Changes in the behaviour of the model were contrasted by running a regression for the whole sample, and two sub-samples, selected according to where the break is believed to occur. The resulting model distributions are tested for evidence that the coefficients in the two subsamples differ from those of the full sample. The model used as the foundation for the test was a linear OLS regression of average monthly trade volumes against the matrix of covariates described in table 4.1 (equation 4.11). The full sample covered the period 1979 to 1985, while the two subsamples covered a period of 3.5 years each from 1979 – 1982 (mid) and 1982 (mid) to 1985. The full sample focused specifically on the period either side of the fire events so as to maximise the likelihood that any significant differences in the mode were due to the fire, and not other environmental or economic events that may be present over the period from 1978 to 2004. The decision on where to place the break was made based on literature describing the fires, reporting that they commenced in mid-1982 at the start of the dry season (Ampadu-Agyei 1988; Arthur & Arthur 2011).

General equation: $v_t = \beta'_x x'_t + \varepsilon_t$ (4.11)

Test statistic: $\frac{RSS^f - (RSS^{S1} + RSS^{S2})}{(RSS^{S1} + RSS^{S2})} \cdot \frac{T-2k}{k}$

Where v_t represents the normalised monthly trade volumes, x'_t represents the matrix of covariates (see table 4.1), ε_t are the model residuals, RSS^f is the residual sum of squares for the full sample, RSS^{S1} is the residual sum of squares for the first subsample (1979 – 1982), $RSS^{S2}$is the residual sum of squares for the second sub-sample (1982 – 1985), T is the number of observations in the full sample and k is the number of regressors. The test statistic is compared against the F distribution. Differences between sub-groups were analysed by fitting the supply and demand relationships to the two subgroups, and solved according to the 3SLS methodology described previously.

4.3. Results

4.3.1. The supply and demand model

The supply and demand functions that emerge from the three-stage least-square regression appear to be well identified in all models, with $\beta_p^s \geq 0$ and $\beta_p^d \leq 0$ (table 4.2). Supply appears to be elastic in all models except ungulates, with the supply of rodents, and particularly the grasscutter, being most elastic to changes in price. This result aligns well with the hypothesis that depletion may be altering the composition of the trade away from ungulates to one dominated by rodents. It also highlights inter-taxon differences in the price elasticity of supply that may be indicative of a decline in ungulate numbers as suggested by the historical analysis of the Atwemonom market (Chapter 3). Conversely, demand in all models is elastic with the exception of rodents and the grasscutter.

Generally, the influence of the regressors on supply and demand is in line with the hypothesised relationships (figure 4.1). With regard to drivers of supply, agricultural labour is negatively associated with supply across all models. A word of caution should be expressed here due to the potentially confounded relationship between agricultural income and labour. Since these variables cannot be separated statistically, flows of income may equally be negatively correlated with hunting behaviour. However, the positive relationship between income and labour suggests that these flows are likely to materialize in tandem, and thus the evidence for the influence of the agricultural cycle on hunting behaviour appears robust, regardless of the precise mechanism involved. The model results also indicate a significant relationship between the maize season (a proxy for pest control) and both grasscutter and rodent off-take, but not all bushmeat off-take.

On the demand side, GDP per capita is strongly associated with increased demand for all bushmeat products. Interestingly, and counter to expectation, there was no relationship between fish price and bushmeat supplies.

Table 4.2: Results of three-stage least square regression. The time interval of the regression is one month. The response variable for all models is quantity, described as the ln of the mean number of animals recorded on the market per day in any given month. Four models are presented, (1) all species traded, (2) ungulates, (3) rodents and (4) grasscutter. Standard errors are given in parentheses. Significance codes * 5%, **1% and ***0.1%.

	All Species	**Ungulates**	**Rodents**	**Grasscutter**
		Supply Model		
Intercept	-12.2*** *(2.64)*	-4.34 *(3.04)*	-31.0*** *(4.26)*	-34.9*** *(4.34)*
ln(P)	1.49*** *(0.28)*	0.63 *(0.32)*	3.27*** *(0.44)*	3.62*** *(0.45)*
I (ag.income)	-7.05 $x10^{-4}$ *(6.05* $x10^{-4}$*)*	-6.50 $x10^{-4}$ *(5.58* $x10^{-4}$*)*	-9.65 $x10^{-4}$ *(6.95* $x10^{-4}$*)*	-8.13 $x10^{-4}$ *(7.32* $x10^{-4}$*)*
L (ag.labour)	-2.42 $x10^{-6}$** *(8.41* $x10^{-7}$*)*	-2.08 $x10^{-6}$** *(7.92* $x10^{-7}$*)*	-3.03 $x10^{-6}$** *(1.11* $x10^{-6}$*)*	-3.75 $x10^{-6}$** *(1.19* $x10^{-6}$*)*
M (pest activity)	-0.052 *(0.21)*	-0.087 *(0.19)*	0.55* *(0.27)*	0.57* *(0.28)*
R (rainfall)	-3.05E-05 *(5.42E-04)*	-3.17E-05 *(4.98E-04)*	-6.77E-04 *(6.15E-04)*	-8.41E-04 *(6.61E-04)*
C (cost of living)	1.24 (1.19)	3.11** (1.15)	-2.28 (1.61)	-3.14 (1.60)
A (population)	8.03E-07*** *(1.22E-07)*	6.10E-07*** *(1.26E-07)*	8.57E-07*** *(1.49E-07)*	9.48E-07*** *(1.50E-07)*
		Demand Model		
Intercept	7.73* *(3.82)*	16.5** *(5.45)*	-2.58 *(5.69)*	-4.36 *(5.65)*
ln(P)	-1.07* *(0.52)*	-2.02** *(0.72)*	-0.18 *(0.72)*	-0.0546 *(0.71)*
W (wealth)	0.023*** *(0.0049)*	0.018*** *(0.0054)*	0.027*** *(0.0061)*	0.029*** *(0.0063)*
F (fish)	0.037 *(0.093)*	0.149 *(0.12)*	0.025 *(0.10)*	-0.018 *(0.11)*
C (cost of living)	1.36 *(0.88)*	4.43*** *(1.12)*	-3.05** *(1.18)*	-3.65** *(1.22)*
A (population)	-2.47E-07 *(1.73E-07)*	-4.12E-07* *(2.32E-07)*	-9.62E-08 *(1.58E-07)*	-6.91E-08 *(1.63E-07)*

Of the market controls, population growth is positively correlated with supply, but largely unimportant for demand, except in the case of the ungulate model where a significant negative correlation was reported. The cost of living, proxied by the relative change in CPI from month to month, plays a somewhat mixed role. Although it is unrelated to supply or demand in the general model, it does have taxon-specific effects. Specifically, a positive correlation with both supply and demand in ungulates, the latter being contrary to expectations, and a negative correlation with demand in rodents, in line with expectations. This rather complex relationship will be revisited in the discussion.

4.3.2. The bushfires of the 1980s

Results of the Chow Parameter Stability test confirmed a break in the market data in 1982, the first year when dramatic bushfires swept through much of the country (F = 2.43, d.f. = 25, p = 0.035), illustrated in Figure 4.2.

A Wilcoxon signed rank test of the monthly average trade volumes in the 3.5 years prior and post the bushfires highlighted a decline from an average of 20.6 (s.d=8.3) animals per day to 8.6 (2.4), (W = 573, n = 28, p <0.01). Models of the supply and demand relationships over this period were poorly identified, however, and failed to identify a positive price coefficient on the supply side, $\beta_p^s < 0$, during the 3.5 year period from mid-1982 to mid-1985 (Appendix C6).

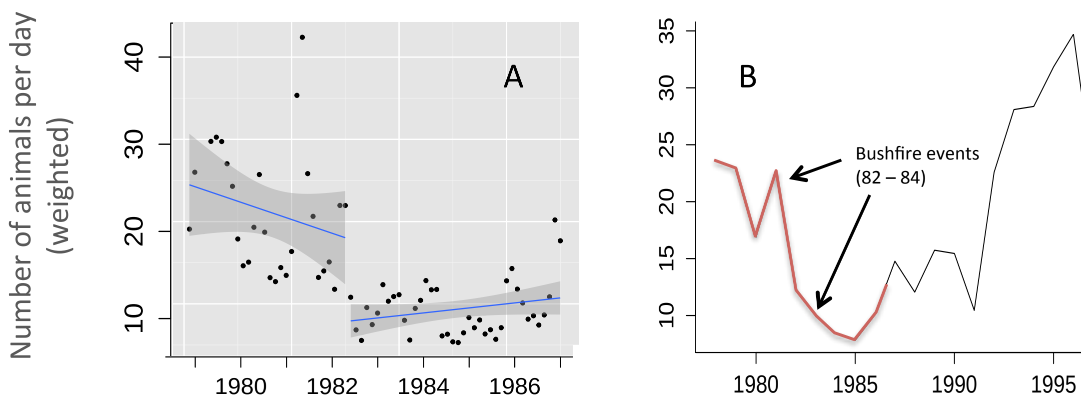

Figure 4.2: Graphical analysis of the market data during the period before and after the 1982 – 1984 bushfires. Plot A presents a monthly analysis of the 3.5 year period immediately prior to the fires and the 3.5 year period immediately following. Two linear regressions are plotted, with 95% error bars, to highlight the break. Linear regressions represent trade volumes regressed against time. Plot B highlights how the tested data sample in A appears in a larger sample of the data. Data in B are summarised annually, resulting in the differences in the scales of the y-axis on each graph.

A longer regression sample from 1982 – 1989 was better identified, and significant (p<0.05), although the significance of the individual model variables remained extremely poor. Although this latter regression suggested that bushmeat supply was less elastic in the period after the fire than before (pre-82, β_p^s = 1.87; post-82 $\beta_p^s = 1.04$) the generally poor explanatory power of the model suggests that extreme caution should be adopted when making any inferences.

4.4. Discussion

4.4.1. The model and the market

The specified supply and demand model appears robust on a number of counts. In addition to the supply and demand functions being correctly identified according to economic theory ($\beta_p^s \geq 0$ and $\beta_p^d \leq 0$), the testing of the selected instruments showed that both the supply, demand and market shifters were significant predictors of price and volume (Appendix C2). These findings suggest that the assumptions of perfect competition and linearity may not be far from reality, at least when long-term market behaviour is examined over the full period from 1978 to 2004. However, the model is not without its flaws. Data limitations restrict what can be included, particularly in regard to bushmeat alternatives (no livestock data were available), hunter production costs, and an explicit component that is able to capture the condition of the resource (i.e. wildlife abundance). Incorporating a descriptor of resource condition is not a strict requirement. Similar analyses of fisheries markets have omitted such data (Angrist, *et al.* 2000). However, these studies have often focused on resources that are considered relatively abundant. Where there are resource limitations in place, such as may be suspected in the case of bushmeat, resource condition has been found to be a significant predictor of supply (Lin 2005). In addition, our model poses inherently difficult challenges in the ability statistically to separate key variables, namely agricultural income and labour. Despite these caveats, the model appears relatively well specified and statistically robust, and highlights a number of consistent features.

4.4.2. General observations

The estimated supply and demand functions align well with commonly accepted drivers of supply and demand in the region, namely that agricultural activities and population pressure play an important role in defining supply (Tutu *et al.* 1993; Brashares *et al.* 2011; Chapter 3), while demand is most strongly influenced by consumer wealth (Bowen-Jones & Pendry 1999; Fa *et al.* 2009; Godoy *et al.* 2010). More novel trends appear when individual taxonomic groups are analysed. There are good reasons for considering different taxa in isolation. In addition to representing different resource pools, failure to differentiate taxa in any market analysis assumes that both supplier and consumer see the market in a similar way. However, this is unlikely to be true. Although hunting in the tropics is frequently non-selective (Hofmann *et al.* 1999), there are exceptions. Grasscutters, which are targeted by hunters during specific agricultural cycles are one such example (Shanti-Alexander *et al.* in press). Conversely, bushmeat consumption is highly selective, both in terms of preferences and price (Falconer 1992; Fa *et al.* 2002). Therefore, while production is generally non-selective, consumption is more discerning where bushmeat may be viewed as a range of products, differentiated by price and taste (East *et al.* 2005). Both of these factors are likely to play an important role in defining the more subtle dynamics of the trade.

In regard to this first point, that species represent separate resource pools, our results show clear differences in elasticities of supply, with grasscutters, the most commonly traded species, being most elastic. The price elasticity of supply of ungulates, whose market share is in decline, is relatively inelastic (Chapter 3). There are two possible reasons for this discrepancy. Either hunters are choosing not to trade ungulates, despite the price signals being generated by the market, or they are unable to source them in sufficient numbers. As ungulates often command higher per carcass prices than rodents due to their size (Falconer 1992; Macdonald *et al.* 2011), the former suggestion appears unlikely. Thus, it seems most likely that the variation in supply elasticities between groups is an indication of variation in the condition of the underlying resource. The analysis also supports the hypothesis that grasscutter and rodent supply is closely correlated with the maize harvest, when the protection of crops is a priority for farmers (Tutu *et al.* 1993; Hofmann *et al.* 1999).

Demand for grasscutters and all rodents was relatively inelastic, unlike demand for ungulates and bushmeat generally. One explanation may be that it reflects the strong consumer preferences for these species, particularly the grasscutter (Falconer 1992; Chapter 2). The phenomena whereby highly desired goods exhibit inelastic price elasticities of demand is a recognised phenomena in other markets (Stigler & Becker 1977). Strong demand, combined with limited supplies is arguably the mechanism that led to the wholesale price for a single grasscutter carcass more than doubling in the 12 months between June 2011 and June 2012 (Chapter 3).

There are also trends highlighted in the results that may be analysed with reference to the selective nature of consumer demand. CPI is negatively correlated with demand for rodents in line with predictions (that, as an expensive good, demand for bushmeat would decline as the cost of living rose). However, it positively correlated with demand for ungulate species. As these may represent a marginally less expensive form of bushmeat (Chapter 2), it may be possible that consumers switch species, selecting cheaper alternatives during periods when the cost of living is high. This assumption aligns with the assertion that bushmeat represents a "multi-commodity" to the consumer, but further research is needed to examine whether such a hypothesis is plausible.

The lack of a correlation between fish price and trade volumes was surprising. Evidence in the literature suggest that hunting in other parts of Ghana increases during times when fish supplies are low (and hence prices are high Brashares *et al.* 2004). Reasons may lie in differing consumer tastes in the Kumasi market, or a flaw on the part of the data to proxy accurately for monthly fish prices. It should be noted that fish represents only one alternative commodity. The inclusion of other alternatives, such as livestock, would be a valuable addition to analyses, and may represent a more accurate proxy the influence of alternative goods on bushmeat demand (Rentsch & Damon 2013).

4.4.3. The 1982 – 84 bushfires

There was good evidence of an abrupt structural break in the market data during the period of the 1982-84 bushfires. This supports the hypothesis that the fires that swept the country during this period had real and quantifiable effects on the commercial bushmeat trade, reducing the trade volume by more than 50% in the period that followed. The failure of the supply and demand model to describe the data satisfactorily during this period prevents more detailed analysis, other than to suggest tentatively that there was a reduction in the elasticity of supply following the fires, a characteristic that might be indicative of a resource under pressure. There are a number of explanations as to why the model might have failed to describe accurately market activity during this period. Firstly, the number of data points in the pre- and post-fire periods are on the border of what is statistically acceptable when one considers the number of variables in the model (Crawley 2007). Secondly, it is not unreasonable to assume that the assumptions of linearity and perfect competition may not be valid, either over the relatively short time scales under observation, or due to the potentially dramatic impact that the fires may have had on the market. In the first case, analysing the market at a finer resolution (daily as opposed to monthly) may increase statistical power, although this poses problems with obtaining comparable daily data for the other variables in the model. In the second case, implementing methods that allowed the assumption of linearity and competition to be relaxed may benefit the model.

4.4.4. Concluding remarks

This analysis represents a novel analysis of a bushmeat hunting system, which, despite the potentially simplistic assumptions of market behaviour, produces results largely in line with expectations. The study highlights the importance of considering taxon-specific effects when considering the drivers of supply and demand, and presents the first quantified evidence of the impact of extreme natural events such as bushfires on the commercial bushmeat trade. The model framework presented here indicates a number of interesting opportunities for future development, such as relaxing the assumptions of perfect competition and linearity. These may improve the ability of the model to separate the often closely intertwined drivers of supply and demand. New developments in the field of spatial econometrics (Baltagi 2008) could be combined with land-use change analysis to add a further layer of understanding of the complex dynamics that define these informal markets.

Chapter 5

The Rise of the Rodent:

Spatial dynamics of a bushmeat hunting system

5. Rise of the rodent: Spatial dynamics of a bushmeat hunting system

5.1. Introduction

Production landscapes are dynamic in both time and space. Population growth, urbanisation, changing patterns of land use and intensification of agriculture influence landscape productivity and associated ecosystem services. Understanding these dynamics is important for designing effective conservation and land management strategies that take account of the trade-offs between different ecosystem services that may be degraded or enhanced by different approaches (Anderson *et al.* 2009; Armsworth *et al.* 2012). Bushmeat is an important benefit provided by ecosystems in the tropics. However habitat loss and overhunting have modified landscapes and degraded biodiversity leading to dramatic declines in wildlife in many regions. This degradation is particularly evident in many parts of West Africa (Brashares *et al*. 2001; Norris *et al.* 2010).

In the following analysis, we explore how the spatio-temporal dynamics of a production landscape in Ghana have influenced the commercial bushmeat trade in the region over a 16 year period. We identify four landscape level patterns that are likely to influence the dynamic of the trade in time and space and be important for the management of bushmeat hunting systems. These are 1) habitat disturbance, 2) protected areas, 3) hunting pressure and 4) distance to market.

Habitat disturbance is likely to play a fundamental role in the spatial characteristics of the trade. There is evidence that disturbed landscapes such as secondary forests can, under certain circumstances, be more productive than undisturbed climax vegetation, particularly in tropical rainforests where the opening up of the canopy and improved browsing conditions can be beneficial to certain species (Robinson & Bennett 2004). Forest mosaics interspersed with food crops and mixed agricultural landscapes, can harbour a high concentration of edible foods, of particular benefit to more robust generalist species such as small ungulates, and species off-take in these semi-disturbed landscapes can surpass those of less disturbed, primary forest (Uhl *et al.* 1990; Jorgenson 2000). Robinson & Bennett (2004) provide a thorough examination of the literature in this regard and present a hypothetical framework for how supply (characterised by biotic productivity) and demand (defined in terms of off-take) may vary across a disturbance gradient.

Protected areas may also influence spatial patterns of exploitation and species-specific harvest patterns. Fa et al. (2006) found an inverse relationship between bushmeat harvests per capita and distance from protected areas in 89 urban and rural bushmeat markets in Nigeria and Cameroon. There were good indications that harvest rates of many species were greater closer to the national park boundaries, with certain species, such as primates and large ungulates, being particularly susceptible. While hunting off-reserve may represent a perfectly legal trade in many countries, the incentive for hunters in depleted landscapes to exploit relatively untapped reserves remains a real threat to wildlife conservation objectives, particularly in countries with poor governance and enforcement (Smith *et al.* 2003).

Densely populated areas are likely to experience greater levels of hunting pressure (Robinson & Bennett 2004). Unsustainable hunting reduces stocks and leads to falls in catch (Robinson *et al.* 1999; Albrechtsen *et al.* 2007). Areas exposed to sustained levels of high hunting pressure are therefore likely to experience significant declines in catch and commercial trade volumes over time.

The distance a community is from market also plays an important role in defining the spatial characteristics of the trade. Brashares *et al.* (2011) found consistent evidence that bushmeat was more expensive in settlements further from the source of capture. The effect of this price gradient was an increased incentive for hunters close to more lucrative urban markets to trade their catch, rather than consume it at home. In their study of a commercial bushmeat market in Equatorial Guinea, Allebone-Webb *et al.* (2011) found evidence of trade filters that influenced what species were brought to market depending on the isolation of the sources. Trade from isolated communities maximised trader profits, i.e. the most valuable species per kilo were sourced from such locations. Conversely, trade from communities with more direct market access maximised hunter profits, i.e. species with the greatest carcass price were more likely to be traded. If trade filters such as those observed in Equatorial Guinea were present in the Kumasi catchment area, it would be reasonable to assume there would be spatial differences in trade volumes of certain species, based on their weight – value relationship.

As urban centres expand, local resources are depleted and previously isolated communities are connected, the size of a market's catchment area, indicated by the distance meat travels to market, may grow. The change in a market's catchment area is one metric often used to describe the evolution of the trade, as hunters exploit ever more remote resources, or new actors enter the trade (Clayton *et al.* 1997; Milner-Gulland & Clayton 2002; Crookes *et al* 2005). In a detailed analysis of a commercial bushmeat market on Bioko Island, Albrechtsen *et al.* (2007) found good evidence that such increases were associated with faunal depletion, as prices, volumes, distance travelled and market composition all showed marked difference between two time periods that were broadly in line with expectations under depletion.

All four of these patterns (habitat disturbance, protected areas, hunting pressure, and distance to market) may not only affect the volume of bushmeat traded, but also the species composition of the trade, as specialist and larger, less fecund species that are more sensitive to environmental and anthropogenic pressures are extirpated (Naughton-Treves *et al.* 2003), to be replaced by smaller, more resilient, generalist species such as rodents (Fa *et al.* 2000; 2007). Such changes are evident in many commercial markets which are increasingly dominated by species of rodents and small ungulates better able to persist in human influenced landscapes (Falconer 1992; Hofmann *et al.* 1999; Crookes *et al.* 2005). Over time, locations that are susceptible to levels of human encroachment are therefore likely to experience significant shifts in species composition, relative to less heavily hunted locations (Green and Sussman 1990; Robinson *et al.* 1999; Fitzgibbon *et al.* 2000; Jorgenson, 2000; Robinson & Bennett 2004).

Thus complex processes, linking the biophysical attributes of the landscape with the socio-spatial characteristics of the human populations exploiting it, define the spatial dynamics of these hunting systems. A logical conclusion is that if the landscape defines the trade, appropriate land management has the potential to represent a powerful tool for managing it. Any management strategies that seek to alter land use to promote key benefits, however, will necessarily involve trade-offs between conflicting objectives (Armsworth *et al.* 2012). If appropriate land management decisions are to be made in the context of bushmeat hunting, it is essential that the consequences of changing patterns of land-use on wildlife, and on human use of wildlife, be understood.

Using the bushmeat trade in the city of Kumasi, Ghana, as a case study, we analyse the spatio-temporal dynamics of the commercial bushmeat trade in the region in relation to shifting patterns of land-use over a 26-year period. The landscape around Kumasi has been subject to intense conversion over the past decade, and is primarily defined by agriculture, with much of the remaining intact tropical forest confined to forest reserves and protected areas (Braimoh 2009). In addition, a long running study of the Atwemonom bushmeat market in Kumasi between 1978 and 2004 means long term spatially explicit data is available on the bushmeat trade. We test hypotheses in four key areas (table 5.1):

1. Habitat disturbance. Harvest rates may be higher in landscapes categorised by intermediate levels of disturbance. In addition, generalist species, better able to persist in more heavily disturbed landscapes, may dominate the trade from these areas.
2. Protected areas. We test whether there is any relationship between trade volumes and the presence of reserves, and whether species-specific differences exist.

3. Hunting pressure. We examine how trade volumes originating from heavily hunted areas change over time, and measure changes in species composition through changes in the ratio of rodents to ungulates.
4. Distance to market. We examine how distance from market influences the species composition of the trade, and the volume of the trade.

Table 5.1: Spatio-temporal characteristics of the landscape-bushmeat system and their associated hypotheses and predictions

Spatial characteristic	Summary description	Hypotheses and predictions	References
Habitat disturbance	Harvest rates and biological production are expected to vary with changes in human-induced disturbance in the landscape. We examine whether communities whose surrounding landscapes are categorised by intermediate levels of disturbance supply more bushmeat to the commercial market than either more or less disturbed landscapes.	1. **Bushmeat off-take will be greatest in semi-disturbed landscapes**. 1a. Bushmeat volumes will be quadratically related to level of disturbance. 1b. Trade volumes of generalist species, such as rodents, will be less sensitive to higher levels of disturbance than other species groups.	Robinson & Bennett (2004)
Protected areas	Protected areas (PAs) may act as refuges for wildlife, particularly those species that are more susceptible to disturbance. Research suggests that harvest rates of certain species, such as primates and ungulates, may be higher in communities close to PAs. Protected areas may be associated both with illegal hunting within the reserve, and spillover effects whereby hunting in neighbouring areas benefits from wildlife emigrating outside the reserves.	2. **Bushmeat off-take of certain species will be higher in communities close to PAs.** 2a. PA presence will be positively correlated to ungulate trade volumes, and uncorrelated with rodent trade volumes.	Fa *et al.* (2006)
Hunting pressure	High levels of hunting pressure may reduce standing wildlife biomass and alter species composition towards smaller bodied mammals.	3. **Heavily hunted areas will experience reduced harvest rates and altered species composition**. 3a. Trade volumes from areas with a high density of hunting communities will decline over time. 3b. The ratio of rodents to ungulates, supplied from heavily hunted areas, will increase over time.	Rowcliffe *et al.* *(*2003);Lopes & Ferrari (2000); Naughton-Treves *et al*. (2003); Jorgenson (2000)
Distance to market	Distance to market represents a potential barrier to participating in the commercial trade, representing a substantial cost. This may influence both the species that are brought to market and the degree to which otherwise productive landscapes participate in the trade. Over time, as resources become depleted and urban demand grows, we would expect the incentives to exploit more distant resources to increase.	4. **Over time the catchment area of the commercial market will increase.** 4a. Distance to market will be negatively correlated to trade volumes, although this effect will change reduce over time. 4b. Catchment area of the market will increase over time.	Crookes *et al.* (2005); Allebone-webb *et al.* (2011); Albrechtsen *et al.* (2007; Brashares *et al.* (2011)

5.2. Methods

5.2.1. General methodology

Bushmeat market data, collected at Atwemonom in Kumasi between 1978 and 2004 by staff from the Ghanaian Wildlife Division, were used to identify the communities (sources) supplying bushmeat to the market. Data were available on multiple individual transactions on a given day, including the species, weight, price, method of capture and location from which the traded item was sourced (see Chapter 2). For the purpose of the following discussion, a "source" is defined as a community, located within the Kumasi catchment area, that supplies bushmeat to the Atwemonom market. GIS methods were used to generate maps describing the spatial characteristics of the landscapes around each source. Data was obtained from a variety of resources (described below). The relationship between a source's spatial characteristics and associated trade volumes were then analysed using a mixture of univariate and multivariate statistical methods (figure 5.1).

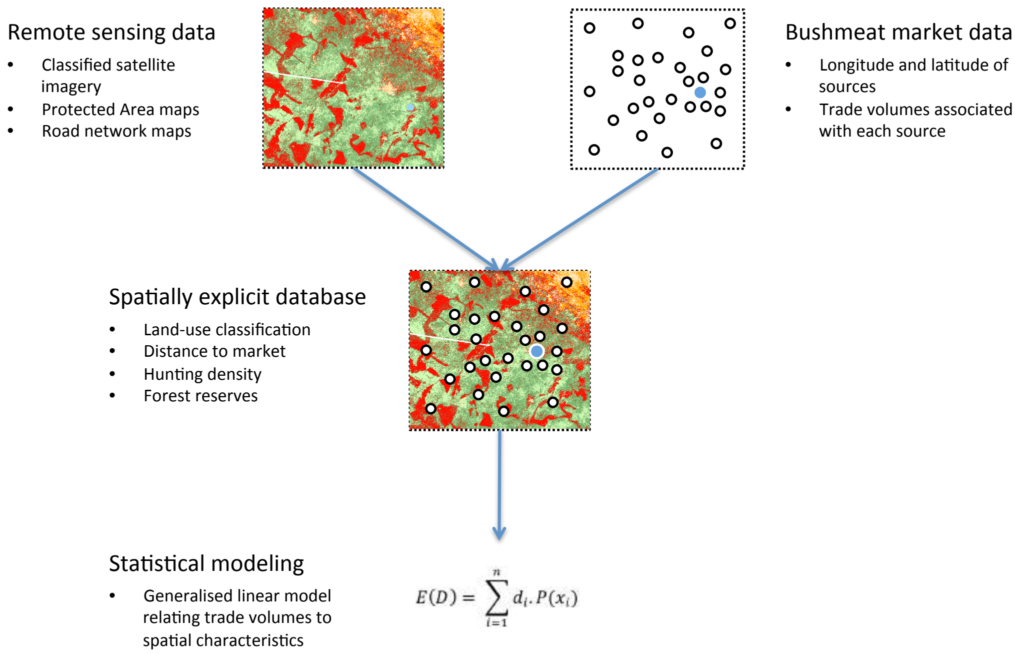

Figure 5.1: Schematic diagram of the methodology adopted underlying the statistical analysis

5.2.2. Bushmeat trade volumes

The full market dataset consisted of 67,271 records covering 3,343 days recorded over 27 years from 1978 to 2004. All data relate to the open season, which runs for 8 months from December to July, during which hunting is permitted for all species, except those classified in schedule 1 (Wildlife Conservation Regulations 1971). Each record in the dataset relates to a single carcass, for which information on species, source location, weight and price were recorded, where possible. Of these records 46,769 have sources (village names) associated with them. Sources were geographically located in a two-part process. First, the dataset was reviewed for errors in consultation with the Ghana Wildlife Division (GWD) staff member who was responsible for the original collection. With reference to a regional map, purchased from the Land Division Office in Kumasi, the geographic locations of the major sources were coarsely identified and, where necessary, ambiguous spellings and typos corrected to refine the data. Secondly, fine-grain geographic coordinates were assigned using a database of village locations in the region, compiled by the Land Survey Department and purchased from the Centre for Remote Sensing and Geographic Information Services (CeRGIS). These data were reviewed in ArcGIS, projected in UTM WGS 1984, and the boundary of the Kumasi market catchment area, representative of the entire dataset, was defined.

Ideally, the four hypotheses under test would explore the patterns of covariation between the bushmeat trade and the relevant landscape-level predictors across all years from 1978 – 2004. However, land cover and therefore habitat disturbance (hypothesis 1) could only be quantified for two years, when sufficiently high-quality satellite images were available. Meanwhile, protected area coverage (hypothesis 2) and distances to market (hypothesis 4) were expected to stay relatively constant across years. Consequently, our analysis focused on the bushmeat trade in those two years when land cover could be quantified, namely 1986 and 2002 (see below). The only exception to this approach was for the analysis of changes in catchment area (prediction 4b) and species composition, in which the full dataset could be used. Consequently, two spatially explicit databases were produced from the market data. First, a database containing all market records relevant to the 1986 and 2002 time periods; second, a general database containing records from all years, to be used in defining the long-term evolution of the catchment area over time. In both databases, records were summarised in terms of their locations, and aggregated bushmeat volumes defined by the number of carcasses at the species level.

Two hunting seasons were included for both 1986 and 2002 to align with the dates when available satellite images were taken, and to maximise data for analysis. For 1986, records cover the period from December 1985 to July 1986 and December 1986 to July 1987; similarly for 2002, records run from December 2001 to July 2002 and December 2002 to July 2003 (table 5.2). Variation in observer effort between hunting seasons was controlled for by expressing bushmeat volumes in units of carcasses per day. This method of normalising the data treats all days as equal in terms of daily observer effort, which at the seasonal scale is considered a reasonable assumption.

Table 5.2: Summary statistics of bushmeat records successfully georeferenced.

	Land-use Analysis Model		**Catchment Analysis**
Data	**1986**	**2002**	**All years**
Period covered	Dec 85 – Jul 86 & Dec 86 – Jul 87	Dec 01 – Jul 02 & Dec 02 – Jul 03	Open Season, 1978 – 2004
Total Records	4647	2875	46,769
Geo-referenced	4437	2771	43,550
Percentage of records identified	95.5%	96.4%	93.1%
Unique Sources / Locations	203	167	389
Mean volume per source, kg per day *(C.V)*	23.4 (C.V=157)	17.3 (C.V= 161)	11.7 (C.V=189)
Median volume per source, kg per day	8	5	5

5.2.3. Measuring hunting pressure

In order to calculate a spatially explicit measure of hunting pressure in the catchment (hypothesis 3), the scaled and summarised bushmeat source data were imported into ArcGIS 10 and projected in UTM WGS 1984 to produce a layer for analysis. A 7km-radius buffer zone was produced around each source to represent the effective hunting radius. 7km was chosen based on the lower boundary derived from previous surveys of 53 hunters in two communities around Kumasi where the average distance travelled to hunting grounds was 7.7 ±4.8 km (Shanti-Alexander 2011). Sources with less than 3 individual records were excluded to avoid anomalous data that might skew the model. The cut-off value was low due to the data being heavily skewed towards smaller records (table 5.2), and therefore was selected as a compromise to avoid losing excessive data, while controlling for anomalies. These data were further refined by merging sources within 2km of each other to produce more distinct sub-groups for analysis. This was done to minimise discrepancies in the data in which two or more neighbouring sources sharing more than 90% of the same catchment area (defined by the 7km buffer) might be associated with substantially different bushmeat volumes. The differences in volumes between villages in these cases was more likely to be associated with the livelihood characteristics of the communities or trader habits than differences in the landscape. Merging data for communities sharing almost identical landscapes therefore minimised data bias.

Hunting pressure was defined in terms of the overlap between the hunting zones of neighbouring sources in ArcGIS. Thus, an isolated village with no neighbours, and whose 7km hunting radius overlapped with no other source, would have a base level 1. A village with many neighbours, and whose hunting buffer intersected with many neighbours, could end up with a value many multiples of this. This approach was adopted as a measure of relative hunting intensity around a particular source. Competition for resources around hunting communities with many neighbours (who were also identified in the market data as hunting), may be expected to be greater than in areas with few hunting communities, and consequently such areas may be more depleted.