

# Survey of the Status of the Leopard (*Panthera pardus*) In Sub-Saharan Africa



R.B. Martin and T. de Meulenaer

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TERMS OF REFERENCE

- (i) To collect and collate the best available data relating to the status and distribution of the leopard in sub-Saharan Africa.
- (ii) To collect and analyse recent historical data relating to conservation and exploitation status, in order to assess changes in the number of leopards killed.
- (iii) To assist individual governments, if appropriate, by providing an outline management plan for utilisation/protection of the species.
- (iv) To make recommendations as to how the species in sub-Saharan Africa should be protected or exploited in connection with CITES.

The project was undertaken from the 1st November 1986 to the 31st March 1987, during which period we visited Benin, Botswana, Burundi, Cameroun, Central African Republic, Congo, Ethiopia, Gabon, Ghana, Ivory Coast, Kenya, Malawi, Rwanda, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Uganda, Zaire, Zambia and Zimbabwe. Owing to the limited period for the survey it was not possible to spend more than 2-7 days in each country.

A report (Doc.6.21) was presented in draft form to the 6th Meeting of the Parties to CITES in Ottawa in July 1986 and comments and criticism were solicited from as many sources as possible. This final report includes revisions arising from those criticisms which we felt were valid, and acknowledges and discusses other comments which were not necessarily heeded in the final version.

This report is the final requirement of the contract.

# ABSTRACT

Evidence is presented for the theory that leopard densities are unaffected by harvesting unless the rate of offtake exceeds some threshold. Either leopard populations can sustain the harvest to which they are being subjected, in which case their numbers remain the same, or they can not - in which case they go extinct. Thus if leopard are present in an area, then their **status** is such that they are generally at the maximum density at which they could occur.

There is no practical method to count leopard directly on any large scale. However, predator densities are ultimately limited by their food resources and these in turn are limited in Africa mainly by rainfall. An indirect method of assessing leopard numbers has been used which relies on the relationship between leopard densities, rainfall and the amount of suitable habitat. When the technique is applied to Kenya, which is the only country in Africa where independent detailed estimates have been made for leopard populations (Hamilton 1981), we obtain identical results for the overall estimate, confidence limits and the populations in individual regions within Kenya.

Our final estimates after correction for certain West African countries show a leopard population in sub-Saharan Africa of approximately 700,000 animals, with confidence limits of 600,000 - 900,000.

We have estimated the number of leopards which might have been killed for the fur trade from 1950-1986 in Africa as a whole and in 5 regions within Africa. A population model was used to simulate the effects which these harvests might have had on the numbers of leopard. We find that the harvest would have had a negligible effect on the total population even if the peak offtake were as high as 61,000 animals in 1969.

However, in the East and North of sub-Saharan Africa had the populations been as low as predicted in this survey, and the peak harvest as high as 15,000 in both regions, the leopard would have gone extinct in both regions in about 1970. This would have happened before any of the protective measures which were introduced in the mid-1970s could have made any difference. The fact that they are not extinct is explained by far higher leopard populations in the recent past when there was more available



habitat. In neither region could leopard numbers return to the 1950 level. The rate of habitat degradation is such that the population would have been forced from a level of 100,000 animals in North Africa in 1950 to a new level of 50,000 now - even if there had been no fur trade .

In very few cases can the current number of leopards being killed in any country be accurately stated, largely as a result of government policies which make illegal trade inevitable. The present offtake is estimated at about 6,000 leopard per year, of which 4,000 are illegally killed. Sport hunting accounts for about 1,000 animals, protection of livestock a further 2,500 and trade 2,500. In most countries the offtake is well below a sustainable harvest from the leopard in unprotected areas.

No countries have exceeded their quotas for the export of leopard skins but Botswana and Zimbabwe require higher quotas if the present system is to be continued.

Leopard populations have high intrinsic growth rates and can sustain offtakes exceeding 10%. However the technical basis for management is of secondary importance when it is considered that the available range for leopard will decrease by half in the next 20 years and so will the number of leopard. This requires pragmatic policies for a species which lives mainly outside protected areas. The decline can be legally exploited to produce returns of about US\$30 million annually, or the animal can be made worthless. Those who are anxious that Africa protect all leopards at all costs should be prepared to pay the opportunity costs.

Private citizens will destroy leopard and trade in the skins illegally if there are no legal channels. The problem has been solved in Botswana by allowing citizens to kill leopard to protect their livestock and to trade legally in the skins. Contrary to expectations, this does not result in wholesale slaughter and there is little wastage of valuable products. There is a need for other African governments to develop appropriate institutions in their countries.

In deciding on which CITES appendix the leopard should be listed, the key issue is whether the species is currently threatened with extinction. If its status is presently satisfactory but it is possible that trade might jeopardise this, then it belongs on Appendix II.

Our estimate for the number of leopard in Africa is in excess of 700,000. Noting that the species is a carnivorous predator at the top of the food chain, **it cannot be considered threatened with extinction.** This is a necessary and sufficient condition for the leopard to be moved off Appendix I.

Other matters affecting the issue are discussed, but it is emphasized that these are secondary. Arguments in favour of Appendix I status include the "look-alike" problem, the principle of "positive listing", the existence of certain locally endangered leopard populations in Africa and the fear that the harvest for the fur trade might reach the levels of 20 years ago. Against these can be set disadvantages to legitimate wildlife industries, the loss in potential income to Africa, and the fact that Appendix I has been undesirably compromised by the introduction of a quota system.

If trade controls under CITES are effective, there are no good reasons why Appendix II status for the species should be any worse than Appendix I. To believe otherwise can be interpreted as a direct slight on African Party States. The Convention loses its credibility when species which are not threatened with extinction are included on Appendix I. We realise that aesthetic principles are involved but, as far as possible, the CITES forum should be totally objective over matters of trade and extinction.

If the species is moved to Appendix II, it is recommended that both quotas and the present tagging system are retained as controls. The main reason for quotas is to encourage positive management in Africa. The quotas should be seen as an upper limit to the number of leopard which each producer country regards as a safe harvest rather than an exact estimate of the numbers of leopard likely to die in any calendar year. As in the case of elephant, these quotas should be advised to the Secretariat and the Parties duly notified.

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---



### BACKGROUND TO THE SURVEY

This is the fifth survey of leopard in Africa since 1976. Myers (1976) carried out a survey lasting two years (1972-73) and concluded that excessive hunting for the international fur trade had depressed leopard populations in several parts of Africa. He recommended that the leopard remain for the foreseeable future on Appendix I of CITES under complete protection. Eaton (1978) made estimates of the total number of leopard in Africa based in part on densities derived from Myers' work and arrived at various "minimum", "conservative" and "realistic" estimates ranging from a quarter to a half-million animals. Teer and Swank (1978) carried out a survey based on interviews in several countries in Africa and arrived at a similar conclusion to Eaton - that the leopard was not an endangered species, and should not remain on Appendix I of CITES. Both of the latter studies were mainly concerned with the question of whether the United States should allow the import of leopard sport hunting trophies. Hamilton (1981) addressed the status of leopard (and cheetah) in Kenya and concluded that illegal hunting had reduced numbers, but that the population was recovering since the decline of the fur trade. He recommended that the leopard remain on Appendix I of CITES, but that there was no reason why legally acquired hunting trophies should not be exported from Africa.

It is not our intention to get involved in the controversy which these four studies have generated. Time has moved on and circumstances have changed. However, it is justifiable to ask whether there is a need for yet one more survey, particularly a short consultancy. A major reason for the controversy surrounding previous works has been the lack of quantitative data on which conclusions have been based. This is not necessarily the fault of the authors: it is very difficult to assess numbers of the African leopard and, in general, the costs of doing so do not justify the effort.

The current study cannot ignore history nevertheless. An examination of the events leading up to this survey is important to identify the questions which now need to be asked about leopard in the context of the CITES forum. An outsider entering the discussion at this stage might be confused about what the key issues are (as we were) unless he understood how they have arisen. There follows below a brief outline of the important events relating to the leopard and CITES during the past twenty years.

- 1967: The number of leopard skins entering the fur trade was considered excessive and began to attract attention. Paradiso (1972) reports 9556 skins entering the United States in 1968 and 7934 in 1969. The CITES did not exist.
- 1969: The United States passed its Endangered Species Act of 1969, which prohibited the importation of live or dead animals, or the parts and products thereof, for any species listed under this Act.
- 1972: In March the leopard was listed as an Endangered Species in the United States. The implications were considerable. It caused the collapse of the leopard fur trade in the US and it prevented US sport hunters from importing leopard trophies.
- 1973: In Feb-March the Convention on International Trade in Endangered Species of Wild Fauna and Flora was negotiated in Washington D.C. (although it did not become effective until July 1975). The leopard was placed on Appendix I of the Convention at this time, although many African countries were not represented at the meeting.

In December, the United States modified their Endangered Species Act to include, in line with Appendix II of CITES, a category of Threatened Species in addition to Endangered Species.

The sport hunting lobby in the US began to exert pressure for the leopard to be classified as a Threatened Species.

- 1976: The 1st Meeting of the Parties to CITES took place in Berne.

Myers' study was published by IUCN.

- 1978: Eaton's study was published, sponsored by Safari Club International.

Teer and Swank's study, sponsored by the US Fish and Wildlife Service, was published by Safari Club International.

The US Scientific Authority for CITES decided that the management programme for Botswana met the necessary criteria for the US to permit the importation of leopard hunting trophies from that country (DOI 1982), notwithstanding the species' Appendix I status under CITES. Politically, singling out Botswana was perhaps a poor move.

It is perhaps important to note here that there is nothing contained in the Articles of CITES which prevents the importation of sport hunting trophies into any country. Article III of the Convention provides for this, given that the Scientific Authorities in both the exporting and importing States are prepared to state that it does not affect the survival of the species (Paragraphs 2(a) and 3(a)), the specimen has been legally taken (Paragraph 2(b)), and it is not to be used primarily for commercial purposes (Paragraph 3(c)).

The United States' problems with imports were very much a function of their own legislation which exceeded the requirements of CITES. However, this had the potential to affect Africa considerably, since a large number of American sport hunters visit Africa.

- 1980: In March the Department of the Interior in the US proposed to reclassify the leopard to Threatened status under its Endangered Species Act of 1973 (DOI 1980). This would allow the import of hunting trophies, but would continue to ban the commercial fur trade. The Agency called for comment from interested parties.

Over a thousand communications were received (DOI 1982), some 90% of them opposed to the reclassification. Amongst these were EAWS (1979), Myers (1980a & 1980b), Traffic (1980a), Schaller (1980), Fund for Animals (1980), and Defenders of Wildlife (1980). We mention the above to illustrate that **any proposal** which seeks to exploit the leopard is likely to be met by considerable opposition on technical and/or emotional grounds.

- 1981: Hamilton's study was received by the US Fish and Wildlife Service and decisions regarding the proposed reclassification of the leopard to Threatened status were delayed to allow further responses to Hamilton's findings.
- 1982: The reclassification of leopard to Threatened status in the US was published in the Federal Register on the 28th January 1982. The new status for leopard applied only to Gabon, Congo, Zaire, Uganda, Kenya and all countries to the south of these. In the remainder of Africa the leopard remained Endangered.

1983: At the fourth Meeting of the Conference of the Parties to CITES in Botswana, a Resolution was passed granting export quotas for leopard skins to Botswana (80), Kenya (80), Malawi (20), Mozambique (60), Tanzania (60), Zambia (80) and Zimbabwe (80). This resolution set a precedent and it is worth examining the reasons for it, since provisions already existed within CITES for export of hunting trophies.

Several reasons are apparent. For the first time, agreement was obtained to export skins of leopard killed in the defence of life and property, rather than just sport hunting. The resolution recognises that the Parties do not desire the commercial market for leopard skins to be reopened, but allows the export of single skins as personal possessions and tourist souvenirs. However, whilst this might appear new, in fact it is not. Provisions are made in Article III (Para. 3(c)) of the Convention for imports of such items if the Management Authority of the importing country is satisfied they are not primarily for commercial purposes.

The prime explanation for this resolution, as we see it, is to address an inherent problem in the provisions of Article III of the Convention. In granting an export permit for an Appendix I specimen, the Scientific Authority in the State of export is required to certify that the export of the specimen will not endanger the survival of the species (Para. 2(a)). This ought to be a necessary and sufficient condition for the importing State to accept the specimen, all other conditions being met. However, Paragraph 3 of the same Article states that before an import permit can be granted, the Scientific Authority of the importing State must also certify that the specimen will not endanger the survival of the species, and the Management Authority must further certify that the specimen is not to be used primarily for commercial purposes.

The countries who proposed the Resolution were not satisfied that Article III was being applied in its intended spirit. They assumed that if their Scientific Authority were to state that the survival of the species would not be affected by the export, the matter should not require reconfirmation by the Scientific Authority in the importing State. They assumed further that if specimens were legally taken in their countries it should be unnecessary for the Management Authority in the importing State to verify that the specimen would not be used primarily for commercial purposes.

Thus the main reason for quotas for leopard on Appendix I was to obtain tacit acceptance by importing States that, up to a certain number of specimens, there was no need for superfluous bureaucratic controls which were prejudicing the wildlife industry in their countries. Furthermore there was an implicit warning that certain prerogatives entrenched in the Convention should not be used by the West to dictate to the Third World.

It was agreed that the whole Resolution would be reviewed at the next Meeting of the Parties in 1985. Many Parties were concerned in principle with the acceptance of quotas for an Appendix I species which, by definition, is threatened with extinction.

1985: The 5th Meeting of the Parties in Buenos Aires saw an aggressive initiative on the leopard issue proposed by Zimbabwe, Zambia and Tanzania. Three alternative proposals were tabled:

1. That the leopard should be transferred to Appendix II of CITES (Zimbabwe and Zambia).
2. That quotas for leopard on Appendix I would be set by the Management Authority and communicated to the CITES Secretariat, who would in turn notify the Parties (Zimbabwe).
3. Increased quotas of leopard were requested by Tanzania (250), Zambia (300) and Zimbabwe (350).

These countries were persuaded to accept the last resolution and their quotas were increased as requested.

In supporting the Zimbabwe submission, Child (1984) argued the case mainly on the grounds of an increased quota required for sport hunting. The previous quota of 80 was barely adequate to meet the needs of safari hunting on State Land, and did not cover the requirements of a growing wildlife industry on private land. It posed no threat to an estimated population of 35,000 leopard and was a preferable alternative to having the animal destroyed as vermin on commercial cattle ranches and in communal lands.

Again, the Parties requested that the matter be reviewed at the next Meeting, when better scientific data should be presented. For this reason the CITES Secretariat initiated the present survey.

(xx)

The present situation can be summarised as follows. There is a considerable reluctance amongst many Parties to see the leopard transferred to Appendix II of the Convention despite some evidence from previous studies that the species is not threatened with extinction.

To some extent the Convention has been compromised by granting quotas for the exploitation of a species which is, by definition, threatened with extinction. While provisions exist for export of sport hunting trophies and personal possessions of Appendix I specimens without the need to resort to quotas, they are cumbersome and politically unacceptable to a group of African countries. Quotas were established as a solution to these problems.

There is a fear that the situation which pertained in the late 1960s and early 1970s could recur, when large numbers of leopard skins entered the world fur trade.

The stand which the US takes on the leopard issue is important. It is clear that the US played a major part through its own Endangered Species Act in determining the future of the leopard trade and sport hunting at the time when CITES was in its inception. The US Fish and Wildlife Service has been responsible for initiating many of the studies mentioned in this report. At the same time the US has perhaps overemphasized the sport hunting aspects of leopard exploitation and lost sight of other issues.

A great deal of clarification is still needed. The following questions can be posed which define the main issues and to which this report attempts to provide answers.

- How many leopard are there in sub-Saharan Africa ?
  - Given this number and present trends, is the species in danger of extinction ?
  - What effect has the trade in leopard skins had on the population in individual countries and Africa as a whole ?
  - How many leopard are being killed annually ?
  - What is a sustainable harvest from a leopard population ?
  - What is the opportunity cost to African countries of not exploiting their leopard populations ?
  - If leopard are exploited, what is the optimum management system ?
-

## **1. STATUS AND DISTRIBUTION OF LEOPARD**

### **1.1 A POPULATION MODEL FOR LEOPARD**

One of the objectives of this consultancy was to advise wildlife agencies in African countries on the management of leopard. We constructed a population model to simulate the effects of various types of exploitation. Most of the results of this modelling are presented in the following chapters on harvesting and management, but one of the outcomes is so fundamental to understanding the status of leopard that it needs to be introduced at the outset.

The model simulates the population dynamics of a large, solitary, territorial carnivore. Given an area of natural habitat with prey present, a leopard population left to its own devices will stabilise at some unknown saturation density. To simulate this we have used a modified Leslie Matrix birth-pulse model in which density dependence is achieved through a classical control system operating on the survival of the population. The details of the model are given in **Appendix 1**.

The model falls into the "Complete Compensation" category as defined by Caughley (1985), in which population size is unaffected by harvesting unless the rate of offtake exceeds some threshold. How appropriate is the complete compensation model for leopard ? Caughley (pers. comm.) states that before accepting it, he would like to see a clear demonstration that sustained yield hunting did not lower density permanently below the saturation level. We had neither the time in this study nor an available leopard population to carry out such an experiment. Caughley (op.cit.) states that to test whether the complete compensation model is appropriate for a species all that is required is to subject a population to two different levels of harvesting pressure. If there is no difference in the average density of animals under the two treatments then the population fits the model. We have no knowledge of such an experiment ever being carried out on leopard under scientific monitoring conditions, but there is evidence from the field to support complete compensation.

- The Matetsi Safari Area (4,300 sq.km) in Zimbabwe was originally a block of commercial cattle ranches before it was expropriated by the Government in 1974 for wildlife exploitation. Prior to the Government takeover, leopard had been heavily hunted in the area with the object of extermination, but this had been unsuccessful. When the area was put under safari hunting it was felt advisable to begin with low hunting quotas to allow the population to recover. Over a ten year period the

hunting quota has been increased from 12 to 28 leopard. Trophy quality, hunter effort and numbers of leopards on baits have been monitored. The trophy quality (based on skull dimensions) has remained more or less the same over the 10 year period, but the average age of the trophies has increased from 3.2 years in 1976 to 5.4 years in 1984. Hunter effort has not changed and the success rate on safaris is about 75%. The population estimate for the area is 800-1,000 leopard, so that the hunting offtake represents a harvest of 1.5% in 1975 which has risen to 3.5% in 1986. Our model predicts that this level of offtake is well below the maximum sustainable (which would be about 10%). The increase in age of trophies is compatible with a population which was heavily harvested up until 1974, perhaps above a sustainable offtake, and was then subjected to a reduction in hunting pressure leading to an adjustment of the age pyramid. There has been no observable decline in the population over the period 1975-1987 during which the hunting harvest has more than doubled (Booth, 1987).

- Hamilton (1981 p108) states that moderate hunting may stimulate breeding and thereby compensate for the loss of animals removed from the population. He quotes the resilience of the leopard population of Narok, where such a mechanism must have been operating to allow a professional hunter to take 3 large male leopards from the same tree in Block 60 in 3 consecutive safaris within a period of 3 months. We do not believe an increase in breeding is a necessary condition to compensate for the loss of animals: it requires only that animals which would have dispersed into less favourable habitats no longer disperse.
- A Forest Officer (Allan) based in the Gwaai River area of Zimbabwe in the 1950s shot 20 leopards outside his house. Initially, on taking up residence in the government accommodation, he was pleased to have a leopard available for regular viewing in the garden. However, after he had lived in the house for some time, the leopard took his pet dog and he decided to eliminate it. In the next few years 20 leopard were shot in the garden. If the leopard is regarded as a population of one, then it was maintained at saturation density before and after he began hunting (G.F.T. Child, pers.comm.).
- The Tashinga staff camp of Matusadona National Park is situated in a small area of "Jesse" thicket which contains a resident population of 5 or 6 leopard. These leopard caused no problems in close proximity to humans until about 1976 when pet dogs were introduced and conflict began. From 1976-1982 a leopard was shot every year but there was no detectable decrease in the population. After 1982 problem leopard were translocated to a nearby safari area to be hunted (Russell Taylor, pers.comm.).



- On Lone Star Ranch in Zimbabwe (280 sq.km) over the period 1972-81 three leopards were taken annually for safari hunting. Leopard numbers appeared so high by 1982 that the quota was increased to six and has been held at 5-6 to date. There has been no difficulty in obtaining this doubled harvest and no detectable decrease in the number of leopard (Clive Stockil, pers.comm.). (According to our model, this could only be possible with a population density greater than 1/6 sq.km which is quite feasible for the area concerned.)
- Willie Engelbrecht (pers.comm.), a professional hunter in Botswana, has frequently taken 5 male leopard in one hunting season out of a single territory of about 5 x 10km in the Jackie's Pan area of the Kalahari. This, and the incidents to follow, indicate a very rapid replacement rate of territorial leopard and, by implication, a constant population.
- A professional hunter, Roy Carr-Hartley (pers.comm.), reports taking 4 territorial males from a single tree in one hunting season.
- John Varty, owner of Londolozi Game Reserve bordering onto the Kruger National Park can recall no period when leopard have been more or less numerous over 40 years. In the first 20 years when his family owned the farm, leopard were shot regularly. When it became a Game Reserve hunting ceased but there appeared to be no change in leopard density.

The complete compensation model explains many of the commonly heard remarks on the resilience of leopard populations. It requires the presence of a "shadow" population in the same area which is normally subject to high mortality in the form of transient males dispersing and cubs being killed by dominant males. When the territorial animals are removed this shadow population (or an adjacent population) rapidly replaces numbers. Perhaps the major form of mortality in leopards (apart from juvenile mortality) arises from surplus leopard being forced into marginal habitats where they either starve or are killed by other predators, including humans. For the purposes of this report, we assume that the complete compensation model is a fair representation of the processes at work in leopard populations.

When populations are subjected to harvesting, it is normal to expect various reduced population densities dependent on the level of harvest. This is not the case when complete compensation operates. Either the population can sustain the harvest, in which case it remains at the same density (or rapidly returns to the same density after an initial dip), or it can not - in which case it crashes to extinction. No harvest rates result in stable population levels below the saturation density.

A corollary to this model is that, if leopard are present in an area, then they are at the saturation density. This is a bold statement and we will qualify it shortly. But the implication is quite clear. Generally, the indication of leopard presence in an area can be taken to mean they are at the saturation density - which is a very important conclusion. The first requirement of this consultancy was to examine status. The status of leopard, wherever they occur, is such that they are at the maximum number at which they could occur: that, or they are on the path to extinction.

Occam's Razor would suggest that it is asking too much to postulate that over a wide area many leopard populations are in the temporary state of decline to extinction. According to our model, any population which is being harvested at a rate which predicts extinction gets there very fast. In fact, it does so at an accelerating rate. We have little doubt there are many leopard populations which have been subjected to harvests beyond the sustainable level. But what would tend to happen in cases like this is that such a harvest could not be sustained up to the point of extinction. The effort required to produce a large catch when the population is low becomes prohibitively high and it is not economic to continue (Hamilton 1987 p14-15). Having been once reduced, the population may be kept at a lower density by sporadic harvests which prevent its recovery to the original saturation level and this could be regarded as a second unstable equilibrium point for leopard populations. However, we doubt that this a very general condition. Any relaxation of pressure will result in a rapid population recovery.

The complete compensation model casts serious doubts on a certain type of report on leopard status which begins with a statement in the early pages explaining how it is impossible to count leopard, but the author has no hesitation later in the same report in declaring assertively that leopard are declining in a number of places. Our first reaction to this, even without the help of the model, is to ask "if you can't count the animals, how can you state they are declining?". The model makes a much stronger refutation: it predicts that if leopard are present in an area, they are likely to be at the maximum density possible. An alternative low level equilibrium situation might exist in a few cases where leopard are under extreme pressure.

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## 1.2 LEOPARD NUMBERS

There is no practical, direct method to count the leopard in any country (Myers 1976 p17), let alone on a regional or a continental scale. Eaton (1978) attempted to assess leopard populations in Africa, but came under fierce criticism (Hamilton 1981 p93-94, Defenders of Wildlife 1980, etc.). Not all this criticism is justified: despite weaknesses in the data, it should be recognised as the first attempt to define the order of magnitude of leopard populations. In an attempt to avoid the guesses which have bedevilled earlier work, we have used an objective method based on a relationship between leopard densities, habitat type and rainfall.

### 1.2.1 Relationship between leopard densities and rainfall

"One expects animals to live at higher densities in richer and more productive habitats than they do in marginal and unproductive ones; and there is no reason to doubt that food is for most species the ultimate determinant of population density."

(Wynne-Edwards 1970 p425)

Predators are ultimately limited by their food resources. Whilst density dependent carnivores may use territory as a proximate regulating mechanism, the causal factor is food supply (Murray 1979 p45 & p68). Sunquist (1981 p52) states that the major factor influencing home range sizes (and hence density) for tigers lies in the seasonal distribution and abundance of prey. Schaller (1972 p368) refers to prey populations regulating the density of predators in the Serengeti. Bertram (1978 p106) states that larger territories permit larger prides of lions because more prey is included.

Other factors obviously influence density. Seidensticker et al. (1973 p53) noted that the densities of resident mountain lions in breeding populations were below the level which might be expected if food supply was the only consideration. They conclude that the density of mountain lions is a function of vegetation, terrain, prey numbers and the vulnerability of the species to factors which affect its successful breeding. The presence of other predators also has an effect. Seidensticker (1976), in considering the coexistence of tiger and leopard in Royal Chitawan Park notes that it is not only the abundance of prey which influences predator numbers but also the size distribution of prey. The regulatory effect of food shortages may also take a long time to affect predator populations. Gasaway et al. (1983 p32) note that when prey populations are reduced it may take timber wolves several years to respond to the shortage.

The relationship between herbivore densities and rainfall in Africa is well established. Coe, Cumming and Phillipson (1976) showed a straight line regression between rainfall and herbivore biomass for a wide range of habitats in Africa. Bell (1982) pointed out that this relationship should be modified by soil nutrient status and that this effect would be most pronounced at higher rainfall values. Parker (1984) developed a relationship between elephants and rainfall taking into account Bell (1982), and this was used by Martin (1985) to predict elephant densities in certain countries. East (1984) developed Coe et al.'s relationship further for individual herbivore species in savanna habitats and distinguished between arid and moist savanna systems to meet the requirements of Bell (1982). Importantly, East also established a positive correlation between carnivore biomass and rainfall. We have examined the relationship between leopard density and rainfall more closely and find a strong correlation ( $r=.95$ ) for 23 data points (**Appendix 2**). The regression between leopard density (numbers/sq.km) and rainfall (cm), assuming suitable habitat, is:

$$\text{Log (Density)} = - 8.344 + 1.342 \times \text{Log (Rainfall)}$$

The relationship may not remain linear at high rainfall values on low nutrient soils. However, East (1982) found that the total biomass of moist savanna species showed a similar relationship to rainfall for both high and low nutrient status soils up to about 1,200 mm of rainfall. Parker's (1984) relationship between elephant and rainfall showed a peak at about 1,500mm of rainfall but more recent work by Parker and Graham (in preparation) suggests that the relationship may, after all, be linear across the range of rainfall values. In the high rainfall tropical forests of West Africa we have used correction factors to reduce densities (pp14), but there may be no scientific basis for this.

#### 1.2.2 Habitat and rainfall

The distribution of leopard in Africa is largely controlled by the amount of suitable habitat. It was argued in section 1.1 that leopard will be present in most habitats at their saturation density.

White (1983) produced a vegetation map for Africa which details some 77 types of natural habitat (**Appendix 3**). Mackinnon & Mackinnon (1986) used this map to review the location of protected areas in Africa. They calculated the area of each vegetation type in each country and quantified the amount of remaining unmodified habitat in each type. We have assigned rainfall values to each vegetation type in each country. A correction factor was assigned to certain vegetation types which are less favourable for leopard than the rainfall values would indicate (e.g. grasslands).

### 1.2.3 Prediction of leopard numbers

The regression was used to predict a density for leopard in the unmodified portion of each vegetation type and this density was reduced where necessary by the correction factor for habitat suitability (1.2.2). We have assumed that "modified" habitat has a lower carrying capacity for leopard because of a reduced amount of prey and a loss of cover. In a countrywide survey of leopard in Zimbabwe, Booth (1986) found that leopard survived in most modified habitats except for certain large agricultural schemes where all natural cover had been removed and prey was virtually absent. In this analysis, the density in the modified portion of each habitat was arbitrarily assumed to be one-tenth that of the density in the unmodified part. Further corrections were made for high human densities in certain areas. Leopard numbers were computed from these densities in each original vegetation type and summed to give the total number of leopard in each country (**Appendix 4**).

A check on the consistency of the results (**Appendix 5**) has been carried out using independent data from FAO (1986) which give the overall amounts of forest and woodland remaining in each country, and mean rainfall figures from Parker (1984). The results are very similar.

The results for each country are summarised in the column headed "Predicted Population" in Table 1 overleaf. We stress that these are **predictions** of the numbers of leopard which ought to be present in each country based on suitable habitat and rainfall. The actual figures depend upon the validity of our assumptions. In the last part of this chapter some estimates are revised.

### 1.2.4 Confidence intervals

The confidence intervals in this analysis are a measure of the uncertainty in predictions caused by the scatter in the regression data, rather than an absolute statement of limits within which populations might lie. Other factors could influence the absolute limits.

Two types of confidence interval can be considered: that for the prediction of an individual leopard population and that for the prediction of the mean value of populations. Both types are dependent on the rainfall value at which the density prediction has been made. The further rainfall values diverge from the mean rainfall of the set of data used in the original regression the wider are the confidence limits. 95% confidence intervals have been calculated according to Snedecor & Cochran (1967 p155). In the table below, confidence intervals are given as a percentage above and below the predicted value of density (nos/sq.km).

TABLE 1: LEOPARD POPULATION ESTIMATES

#	COUNTRY	PREDICTED POPULATION	FACTOR	FINAL POPULATION
1	ANGOLA .....	62,486		62,486
2	BENIN .....	4,915	0.1	492
3	BOTSWANA .....	7,729		7,729
4	BURKINA FASO .....	1,693		1,693
5	BURUNDI .....	495		495
6	CAMEROUN .....	41,896		41,896
7	CENTRAL AFRICAN REPUBLIC .....	41,546		41,546
8	CHAD .....	3,125		3,125
9	CONGO .....	32,394		32,394
10	DJIBOUTI .....	25		25
11	EQUATORIAL GUINEA .....	5,040		5,040
12	ETHIOPIA .....	9,782		9,782
13	GABON .....	38,463		38,463
14	GAMBIA .....	33		33
15	GHANA .....	5,990	0.1	599
16	GUINEA .....	15,689	0.1	1,569
17	GUINEA BISSAU .....	682	0.5	341
18	IVORY COAST .....	9,522		9,522
19	KENYA .....	10,207		10,207
20	LESOTHO .....	420		420
21	LIBERIA .....	5,031	0.1	503
22	MALAWI .....	4,530		4,530
23	MALI .....	3,365		3,365
24	MAURITANIA .....	230		230
25	MOZAMBIQUE .....	37,542		37,542
26	NAMIBIA .....	7,745		7,745
27	NIGER .....	454		454
28	NIGERIA .....	18,963	0.5	9,481
29	RWANDA .....	388		388
30	SENEGAL .....	781		781
31	SIERRA LEONE .....	2,803	0.1	280
32	SOMALIA .....	2,123		2,123
33	SOUTH AFRICA .....	23,472		23,472
34	SUDAN .....	22,035		22,035
35	SWAZILAND .....	805		805
36	TANZANIA .....	39,343		39,343
37	TOGO .....	2,537	0.1	254
38	UGANDA .....	4,292		4,292
39	ZAIRE .....	226,192		226,192
40	ZAMBIA .....	46,369		46,369
41	ZIMBABWE .....	16,064		16,064
	TOTALS .....	757,196		714,105

### Confidence intervals for the prediction of an individual value

Rainfall	100	300	500	700	900	1100	1300	1500	1700	1900	2100	2300	2500mm
Upper CI	103	87	83	82	82	83	84	85	86	87	88	89	89 %
Density	.005	.021	.042	.065	.090	.118	.147	.177	.209	.242	.276	.312	.348
Lower CI	51	46	45	45	45	45	46	46	46	46	47	47	47 %

### Confidence intervals for the prediction of the population mean

Rainfall	100	300	500	700	900	1100	1300	1500	1700	1900	2100	2300	2500mm
Upper CI	48.8	23.6	15.6	13.1	13.5	15.1	17.1	19.2	21.3	23.3	25.3	27.1	28.8 %
Density	.005	.021	.042	.065	.090	.118	.147	.177	.209	.242	.276	.312	.348
Lower CI	32.8	19.1	13.5	11.6	11.9	13.1	14.6	16.1	17.6	18.9	20.1	21.3	22.4 %

Confidence intervals for individual countries have been calculated by using the overall mean rainfall and total leopard population for the country (Table 2). Strictly speaking, these confidence intervals should be based on a summation of upper and lower estimates for each vegetation type within the country but it is doubtful whether such precision is justified. Statistically, it is invalid to sum the upper and lower estimates in Table 2 to obtain confidence intervals for Africa as a whole: the probability of every country being either at the lowest or highest value is negligible.

To evaluate a confidence limit for the entire population of Africa we have grouped all individual vegetation type estimates from each country in Appendix 4 into 200mm wide rainfall classes, ignoring entries of less than 100 leopard. The above confidence intervals for the population mean have been used to obtain an upper and lower limit within each rainfall class. The leopard populations are expressed in thousands and the values for all rainfall classes between 2,200-3,600mm of rainfall have been grouped into a single class at 2,500mm. The results appear below.

### Confidence intervals for the leopard population of Africa

Rainfall	100	300	500	700	900	1100	1300	1500	1700	1900	2100	2500mm
Population	2.4	18.9	26.5	51.8	52.3	148.8	68.2	68.2	58.2	81.4	155.9	21.5
Upper limit	3.6	23.4	30.6	58.6	59.3	171.2	79.9	81.3	70.6	100.4	195.3	27.7
Lower limit	1.6	15.3	22.9	45.8	46.1	129.3	58.2	57.2	48.0	66.0	124.5	16.7

Total Population: 754.1 Upper population: 901.9 Lower population: 631.6

Adjusting these totals proportionally to accord with the final population value of 714,105 leopard in Table 1 we obtain the result that the predicted population should lie between 598,102 and 854,066 leopard.

TABLE 2: 95% CONFIDENCE INTERVALS FOR INDIVIDUAL COUNTRIES

#	COUNTRY	RAINFALL mm	LOWER CI %	UPPER CI %	PREDICTED POPULATION	LOWER LIMIT	UPPER LIMIT
1	ANGOLA .....	1,088	45	83	62,486	34,367	114,349
2	BENIN .....	1,153	45	83	4,915	2,703	8,994
3	BOTSWANA .....	435	45	83	7,729	4,251	14,144
4	BURKINA FASO .....	879	45	82	1,693	931	3,081
5	BURUNDI .....	1,196	45	83	495	272	906
6	CAMEROUN .....	1,572	46	84	41,896	22,624	77,089
7	CENTRAL AFRICAN REPUBLIC .....	1,436	46	84	41,546	22,435	76,445
8	CHAD .....	335	46	87	3,125	1,688	5,844
9	CONGO .....	1,643	46	85	32,394	17,493	59,929
10	DJIBOUTI .....	150	53	103	25	12	51
11	EQUATORIAL GUINEA .....	2,582	47	89	5,040	2,671	9,526
12	ETHIOPIA .....	697	45	82	9,782	5,380	17,803
13	GABON .....	1,871	46	86	38,643	20,770	71,541
14	GAMBIA .....	1,138	45	83	33	18	60
15	GHANA .....	1,326	46	84	5,990	3,235	11,022
16	GUINEA .....	1,911	46	86	15,689	8,472	29,182
17	GUINEA BISSAU .....	1,180	45	83	682	375	1,248
18	IVORY COAST .....	1,434	46	84	9,522	5,142	17,520
19	KENYA .....	528	45	83	10,207	5,614	18,679
20	LESOTHO .....	786	45	82	420	231	764
21	LIBERIA .....	2,731	49	90	5,031	2,566	9,559
22	MALAWI .....	1,057	45	83	4,530	2,492	8,290
23	MALI .....	391	46	87	3,365	1,817	6,293
24	MAURITANIA .....	251	46	87	230	124	430
25	MOZAMBIQUE .....	968	45	82	37,542	20,648	68,326
26	NAMIBIA .....	292	46	87	7,745	4,182	14,483
27	NIGER .....	182	51	103	454	222	922
28	NIGERIA .....	1,300	46	84	18,963	10,240	34,892
29	RWANDA .....	1,103	45	83	388	213	710
30	SENEGAL .....	855	45	82	781	430	1,421
31	SIERRA LEONE .....	2,937	50	92	2,803	1,402	5,382
32	SOMALIA .....	270	46	87	2,123	1,146	3,970
33	SOUTH AFRICA .....	477	45	83	23,472	12,910	42,954
34	SUDAN .....	453	45	83	22,035	12,119	40,324
35	SWAZILAND .....	796	45	82	805	443	1,465
36	TANZANIA .....	905	45	82	39,343	21,639	71,604
37	TOGO .....	1,228	46	84	2,537	1,370	4,668
38	UGANDA .....	1,109	45	83	4,292	2,361	7,854
39	ZAIRE .....	1,613	46	85	226,192	122,144	418,455
40	ZAMBIA .....	1,018	45	83	46,369	25,503	84,855
41	ZIMBABWE .....	677	45	82	16,064	8,835	29,236



#### 1.2.5 Comparison with other estimates

The only country in Africa for which a serious attempt has been made to assess leopard numbers is Kenya (Hamilton 1981 p90). Hamilton estimated the population at 10,000-12,000: our estimate for Kenya, based on a different method is slightly over 10,000. Hamilton stated that he would be surprised if numbers were less than 6,000 or more than 18,000: our 95% confidence limits are 5,500 and 18,300.

Hamilton went further and gave proportions of the total population in each of 8 geographical regions of Kenya. We have estimated the areas of the vegetation types for Kenya in each of these regions and calculated the expected leopard populations in them (**Appendix 6**). Again, the results correspond closely, the greatest difference being 8% in Masailand.

We can find no other estimates for individual countries based on extensive field work.

#### 1.2.6 Individual countries

In discussing individual countries we have grouped them according to the size of their estimated leopard populations.

##### **Countries with less than 1,000 leopard**

These fall mainly into two categories. The first contains small countries such as **Burundi, Gambia, Guinea Bissau, Lesotho, Rwanda and Swaziland**. All of these are fairly densely populated (very densely, in the case of Burundi and Rwanda) and cannot be expected to carry high numbers of leopard. We see no reason to alter any of our estimates for them except perhaps Guinea Bissau. Although we did not visit the country a number of people in Sierra Leone informed us that leopard populations were low throughout the region. If anything our estimate for the Gambia may be too low (Parker (1973) found leopard "extant and widespread"), and our estimates for Swaziland and Lesotho too high (we suspect leopards may have been eradicated in many areas to protect livestock).

The other group are largely desert countries such as **Djibouti, Mauritania and Niger** and the predicted populations are expectedly low.

### Countries with 1,000-10,000 leopard

**Botswana, Namibia, Chad and Somalia** are all arid countries of similar size.

We have no comparative figures for **Botswana** except Eaton's (1978) "conservative population" estimate of 6,646. The wildlife authorities, professional hunters and people in the wildlife industry in Botswana with whom we spoke felt that leopard were widespread and common. They occur on the fringes of all large towns and in the driest parts of the Kalahari.

Joubert & Mostert (1975) report leopard as widespread throughout **Namibia** except perhaps along the extreme coastal portion of the Namib desert. In a questionnaire analysis of commercial farms they received estimates totalling 3,353 animals and suggest this should be taken as the figure for Namibia as a whole. This would be close to the lower value set by our confidence limits. However we feel that allowance should be made for the remainder of the country outside commercial farms (which includes the Kaokoveld, Ovamboland, Damaraland and other large areas).

**Chad** is an unknown quantity. Myers (1976) felt that an estimate of 800 animals by M. Anna (former Director of the Service de Chasse) was too low to account for the annual offtake of leopard skins, and we agree with this. We agree, too, with Myers' comment that the terrain is largely unsuitable for leopard and feel that numbers cannot be much higher than our estimate.

In our calculations for **Somalia** we have reduced Mackinnon & Mackinnon's (1986) figure of 60% for the amount of pristine habitat remaining in vegetation type 42 to 20%, based on discussions with Dr Murray Watson who is carrying out land use surveys in the area at present. The decline in the quality of natural habitats in Somalia suggests that leopard numbers would be low, irrespective of hunting pressures.

Among African countries, **Ethiopia** has always had a reputation for large numbers of leopard. Bolton (1973), when the fur trade was still high, stated that "while under extreme pressure everywhere, this remarkable adaptable animal still manages to survive in every province". Brown (1975) reported that the situation for leopard had not worsened and that the illegal trade in skins was under better control. In our discussions with the authorities in Ethiopia, leopards were thought to be at high densities in Wollega, Illubabor, Kaffa, Sidamo and Gemu Goffa provinces and numbers were reasonable in Shoa, Gondar, Gojjam, Bale and Harrar provinces. The authorities argue that even at the peak of the fur trade in the early 1970s, there appeared to be no decline in leopard numbers. Leopard skin dealers in Addis Ababa maintained that, during the same period, there was

no difficulty in obtaining skins, and prices paid for skins at that time reflected no shortages. An Ethiopian professional hunter, A.N. Roussos, informed us that large trophy leopard were plentiful in all the areas where he hunted except perhaps above the timberline in the high mountains. He had found very little evidence of leopard poaching in recent years and thought this was because the penalties were so high. The leopard has been protected in Ethiopia since 1973, but it is intended to allow sport hunting of the species this year with a quota of about 25 animals. Ethiopia is a very large country, for which an estimate of 10,000 leopard is minimal.

Authorities in **Malawi** report that leopard are common - they even occur in the capital city Lilongwe. V.J. Wilson (pers.comm.), in scrutinising our estimates for various countries, felt that the Malawi figure was low.

Little is known of leopard numbers in **Uganda**, although they occur in the most densely settled areas close to Kampala and are common throughout the country in agricultural land.

The estimate for **Equatorial Guinea** is based entirely on a high density in a single rainforest vegetation type.

**Burkina Faso** and **Mali** both lie in the arid inland part of West Africa and the leopard estimates are more the result of large country areas rather than high densities. Myers (1976) regards both as countries where leopard are likely to disappear by the end of the century because of the southward encroachment of the Sahel. The estimates for these countries are relatively low and we have no information to warrant further discussion.

We now come to a group of West African countries where our predictions are much higher than any local estimates for leopard numbers. They are: **Benin, Ghana, Guinea, Ivory Coast, Liberia, Sierra Leone** and **Togo** (Guinea is included here, although the estimate is over 10,000, as the following discussion is applicable). Because these countries lie in the lowland rainforest region, very high leopard numbers are predicted from the density-rainfall regression. Except for the Ivory Coast, these numbers are far higher than any published figures (except Eaton 1978) and far higher than estimates given to us when visiting the countries. Clearly an anomaly exists which needs examination.

Perhaps the **Ivory Coast** should be discussed first. It is centrally located among the remaining countries and by far the largest. Hoppe (1984) found leopard home ranges to be about 12 sq.km in secondary rainforest in the Tai National Park. This translates into densities above one leopard in 5 sq.km. V.J. Wilson, who has recently completed a survey of duiker in several rainforests in Ivory Coast reports an abundance of prey species and

significant numbers of leopard in Tai National Park. He would not expect densities less than 1/5sq.km in the forests. Poilecot, Lauginie and Sournia (pers.comm.) report leopard in all National Parks in Ivory Coast and state that there is some 30,000 sq.km of undisturbed forest and 150,000 sq.km of unmodified savanna still left in the country. Based on this evidence we feel that the estimate for the Ivory Coast leopard population is not unreasonable. What is unreasonable is that its neighbours should have negligible numbers, when human densities in these countries are not greatly different except perhaps for Ghana at 63 persons/sq.km.

Teleki (1980) estimated that there were no more than 400-500 leopard in Guinea, Sierra Leone and Liberia combined. The estimate was based on some 5,600 miles travelled by vehicle and 900 miles covered on foot. This is not a measure of an intensive search for leopard. One of us has travelled at least 250,000 miles by vehicle in game-rich areas of southern Africa and walked more than 900 miles, but has seen very few leopard in the course of these travels - certainly not enough to begin estimating populations.

Strong (1927) mentioned the leopard as "a rather common species" in **Liberia**, and Jeffrey (1977) mentions the skin trade as being moderate in this country. Robinson (1971) reports leopard as scarce in **Sierra Leone**. Sayer & Green (1984) report few sightings of leopard in **Benin** but state that leopard may well occur in the extensive forests in the centre of the country.

**Benin** and **Togo** have very little rainforest (they lie in the "Dahomey Gap") and are largely savanna countries. The authorities in both countries report leopard as very rare. In Benin they definitely occur in the Pendjari hunting zone, Park "W", in the Trois Rivières forest, and probably in the forests of L'Oueme superieur, Wari Maro and Monts Kouffe. Even in the southern forests some may survive. In Togo leopards are restricted to the National Parks and Protected Forests and are known to occur in Fazao Malfakassa and probably in Keran National Park, Keran Hunting Reserve and Togodo Forest. The authorities estimate between 50-100 leopard in Benin and less than 50 in Togo, although no detailed surveys have been done.

Dr. E.O. Asibey (Chief Administrator, Forestry Commission) regards the leopard as very rare in **Ghana**. He remembers a period when they were plentiful but they started to disappear in the 1950s and now it is unusual to find spoor or traces of leopard. Mr. Manu (Director, Game and Wildlife Department) confirms their presence in Mole National Park, Ankasa Game Production Reserve and the Ejura area in the Ashanti region. He expects that they are also present in the Digya National Park and the Kalakpa Game Production Reserve. However no detailed survey of leopard numbers has been carried out in Ghana.

In Sierra Leone authorities report that leopard are widely distributed but in very low numbers. They definitely occur in Outamba-Kilimi and the Loma Mountains Game Reserves, and in Gola North, East and West Forests. A few may survive in the rainforests south of Freetown and in the Kangari Hills Game Sanctuary. Teleki (1980) estimated no more than 50-100 leopard in Sierra Leone and the wildlife authorities agree with this (although they state that Teleki's survey did not cover all areas suitable for leopard). John Waugh (pers.comm.) feels there may be more.

Myers (1976) felt that the habitat in Guinea was well suited to the widespread survival of leopard in fair numbers and reports that in Liberia leopard are evenly distributed throughout the country except in farming and mining areas. He felt that wherever leopard remain they have no shortage of prey or competition from other carnivores.

The sum total of all the above reports is that they add up to little more than opinions. No serious studies have been made on leopard in any of these countries. It seems, too, that where detailed studies of leopard have been carried out in Africa, invariably densities have been higher than expected at the outset.

We realise the pitfalls implicit in comparing our results with Eaton (1978), since he applied blanket densities to large areas. However, his "conservative estimates" for Ghana, Ivory Coast and Liberia were 5,950, 11,250 and 5,000 respectively: ours are 5,990, 9,522 and 5,031. His "realistic estimates" for Sierra Leone and Guinea were 3,000 and 10,000: ours are 2,803 and 15,689. He gives no estimates for Togo and Benin.

Myers (1976 p49-51) mentions the "Bushmeat" trade in West Africa as a contributory factor towards the leopards reduced status. Despite Myers' forebodings in Ghana in 1973 that large areas could be cleared of small prey species, we observed that the trade was still thriving in 1987. Numerous other people have expressed the view to us that the bushmeat trade was affecting the amount of prey available for leopard. Whilst this may well be so, it is difficult to reconcile the continuous harvesting of small antelope, grass-cutters and other species with a situation where there is nothing left for leopard. At worst we would expect that this leads to larger home ranges because of reduced prey densities.

We refer again to our "Complete Compensation" population model for leopard - if leopard are present in an area then they should be close to the saturation density. The wide distribution reported in many of the above countries is incompatible with very low numbers of leopard - unless the hunting pressure on the species is so great that it is being held

permanently close to extinction in all areas at once. And yet we found very little evidence of extensive killing of leopard. It would be more plausible if the leopard range had been fragmented in these countries and the species wiped out in some of the resulting small islands. But this is not what is being reported. In Benin, Sierra Leone and Liberia leopard are apparently occur widely.

V.J. Wilson (pers.comm.) has drawn our attention to the possibility of some widespread panzootic such as cat-flu or sarcoptic mange which may have been responsible for a general depression in leopard numbers simultaneously over a wide area. A. Archer (pers.comm.) reports a virtual absence of leopard from the Okavango Swamps in Botswana in the early 1970s when there was negligible hunting pressure. Leopard began to increase in 1972 and are now reported to be in very high numbers. However, we have received no information in the course of our travels in West Africa suggesting any such episodic event.

It is possible that there may be departures from the density/rainfall regression in the high temperature/high rainfall situation in West Africa (Cumming pers. comm. and Western 1987), although leopard were once reported as common in these countries. It would be flying in the face of much contrary opinion to ignore everything that has been reported to us in the countries concerned. We have arbitrarily reduced the estimates in the above 6 countries to 1/10th of the predicted value to take into account the fact that leopard numbers may in fact be very low in these countries. The estimate for Guinea Bissau (discussed in the previous section) and Nigeria (discussed in the next section) has been halved for similar reasons.

Bell (pers.comm.) has drawn our attention to the significant demand for leopard skins in West Africa for traditional uses. Leopard skins are highly sought after for chiefs' regalia and decoration in important ceremonies. This demand could perhaps account to some extent for depleted populations in the region.

We are far from convinced that leopard numbers are as low as claimed in these countries. There is no escaping the fact that an anomaly exists - which will not be resolved until some serious field research is done.

#### **Countries with 10,000 to 100,000 leopard**

Cameroun, Central African Republic, Congo, Gabon and Nigeria all fall into the tropical rainforest belt and the numbers are predictably high. We point out that nowhere have we used densities in excess of 1 leopard/4sq.km to obtain these very high totals, except in one limited vegetation type in Nigeria where a density of 1/3sq.km has been used.

In the northern province of **Cameroun** the encroachment of the Sahel has greatly reduced leopard densities, but this is taken into account in our estimates. Leopard are reported as still present in the north-west of the country despite dense human settlement. Leopard numbers are high in the south-west where human numbers are low. The only areas where it is thought that leopard have disappeared are in the west of the country around Mount Cameroun, in the immediate vicinity of Douala and Yaounde, and along main roads linking the large towns. The vast bulk of the leopard population occurs in the southern rainforest zone.

Leopard are still reported as common in the north and north-east of **Central African Republic** and in the rainforest region in the south of the country. Spinage (pers. comm.) reports heavy illegal hunting of leopard during his stay in CAR and mentions a massive poison campaign carried out by the French in the 1950s aimed at eradicating leopard and hyaena which was very successful in many areas. V.J. Wilson (pers. comm.) reports low numbers in the south-east of CAR on a recent field trip, but has no reason to believe that this is general throughout the country.

In the **Congo** leopard are common everywhere except possibly in the Pool area, the extreme south-east and within 50 km of Brazzaville where most wildlife has been eliminated, including all large birds, in pursuit of the bushmeat trade. Densities may be reduced in the swamp forest along the Zaire River in Cuvette (a correction has been made for this). Densities are probably lower inside the National Parks, not because of the presence of other predators, but because of the location of the parks themselves.

Little is known about the leopard in **Gabon**, but the authorities treat it officially as a highly protected animal "menaced by extinction". They agree that it is distributed universally throughout the country except within the immediate precincts of Libreville.

We were unable to visit **Nigeria**. We have halved the estimate for the country for similar reasons to those used for other West African countries, and because of the fragmentation of remaining suitable habitat and high human population densities.

**Angola, Zambia, Tanzania, Mozambique** and **Zimbabwe** lie mainly in the Miombo woodland belt across the southern central part of Africa. All have good leopard populations.

Child (1984) estimated **Zimbabwe's** leopard population at 35,000 animals. This is beyond the upper confidence limit of our estimate, but cannot be entirely ruled out. In a recent questionnaire survey of the country carried out by Vernon Booth it was apparent that leopard still exist in every district and the only areas where it has been eliminated are large commercial agricultural holdings where the natural habitat has been entirely removed.

Smithers and Tello (1976) report leopard widely distributed throughout **Mozambique** and extremely common in undeveloped areas. The animals persist on the fringes of the large cities. Tello (1980) reports the leopard as common everywhere except possibly in the south of the country.

**Zambia**, like Malawi, appears to have an unusually high leopard population. In some parts of the Luangwa Valley densities exceeding several leopard per square kilometre are reported (Dale Lewis pers.comm.) and very high densities exist in the Lower Zambesi Valley National Park. Wilson (1981 p167) reports very small home ranges (10sq.km) for leopard in Miombo woodland in Eastern Zambia which would result in high densities.

**Tanzania** also has a large leopard population. Professional hunters report numerous leopard coming to baits in all areas and a choice of very good trophy animals. All wildlife authorities we spoke to in Arusha and Dar es Salaam regard the animal as extremely common. It is known to occur within 15km of the capital.

We have no current information on leopard in **Angola**. Myers (1976 p31) states that "as recently as the late 1950s, Angola may have had larger populations of leopard than any other sub-Saharan country except Zaire, and that, with comparatively low human population pressure, much of the country should remain relatively undisturbed for the foreseeable future...".

Myers (1976 p55) states that "there are plenty of leopard in the **Sudan** and the number may be as high as the combined totals of Ethiopia, Somalia, Kenya and Uganda". Our predictions match this statement. Professional hunters report very high numbers in the south of the country and traders state that it is not difficult to obtain skins. The wildlife authorities report that numbers have declined drastically in Kordofan and Darfur provinces largely as result of the desertification process. Leopard are still found on the Red Sea coast of Sudan and there have been recent reports from north of Port Sudan of domestic livestock being taken.



The only controversial estimate (according to us) in this group of countries is that for South Africa. On several occasions we have been tempted to reduce it in light of Norton's (1984) estimate of 1,500-4,000 which was endorsed by Brett (1985). The Nature Conservation Division of the Transvaal Provincial Administration also doubts whether numbers could be much higher than a few thousand. Myers (1976) believed that by the end of the decade leopard could have been eliminated everywhere in South Africa except in parks and large reserves, mountain ranges and in forests that still provide plenty of natural food. That decade has passed and Myers prediction has not come to pass. On the contrary there has been a major swing to wildlife as a land use in the Transvaal after the failure of the cattle industry through several droughts. The private game reserves adjacent to Kruger National Park have increased in number and size, and 750 game ranches have been registered with the authorities in the Transvaal. Apart from these areas, leopard still occur close to Pretoria and Johannesburg in unprotected areas, and in numerous other parts of this very large country.

South Africa contains the greatest number of vegetation types of any country in Africa and much of it is ideal leopard habitat. The densities we have used for prediction in these vegetation types are very low indeed. Whilst respecting the ability of South African farmers to eliminate vermin, similar farmers in Zimbabwe have been unable to get rid of leopard after 80 years of warfare. Norton himself states that there are over 500 cases of small livestock taken by leopard every year in the Cape province and that the removal of 20-30 leopards per year makes no impact on the population.

Being well aware of all the arguments advanced by Norton and Brett, we have nevertheless decided to let our estimate stand. We expect it to be criticised, but we advise would-be critics to examine carefully the detailed analysis for each vegetation type in South Africa.

#### **Countries with more than 100,000 leopard**

There is only one. Zaire has over one million square kilometres of pristine rainforest and its leopard population is unlikely to be less than 120,000 or more than 423,000 according to our confidence intervals. It accounts for about one third of the leopard in Africa.

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### 1.2.7 Revised estimates

Our final estimates after correction for certain West African countries (Table 1) indicate a leopard population in sub-Saharan Africa of about 714,000 with 95% confidence limits of 598,000 - 854,000 based on the density/rainfall regression.

To those unfamiliar with leopard in Africa, the numbers may appear very high. They are the result of an indirect estimating procedure which should be checked by field research wherever possible. Although we were unable to carry out any detailed ground surveys in the time available, we found it possible to carry out one simple check in all countries we visited. We ascertained the distance from the centre of each capital city to the nearest recently confirmed location of leopard. In some capitals, such as Lilongwe and Nairobi, there are leopard living in the city centre. In a number of others (Gaborone, Addis Ababa, Maputo, Pretoria, Dar es Salaam, Kampala, Lusaka, Harare) leopard occur immediately on the outskirts of the city. In very few countries is it possible to travel more than 50km from any town before encountering evidence of leopard. Khartoum was the only capital where there were no leopard within a few hundred kilometres. In Mwanza in Tanzania, where every available piece of arable land has been cultivated and most natural habitat has been destroyed, leopard occur in rocky outcrops within 10km of the town centre. The average distance of leopard presence from the centres of 25 capital cities we visited was 40km. When it is considered that the lowest density of leopard would be expected around capital cities, it is not unreasonable to come out with overall densities for sub-Saharan Africa of the order of 1/30 sq.km.

We conclude this chapter with an anecdote from Dieter Rottcher (pers.comm.) which admirably illustrates the commonness of leopard. In the early 1970s an animal trapper in Kenya brought a number of caged animals into Nairobi city centre prior to shipping them overseas. Among the animals was a leopard which unfortunately escaped from its cage. The local press seized on the incident and the trapper was castigated for putting the citizens of Nairobi at risk by releasing a dangerous wild animal into their midst. Public pressure on the individual increased, and it was demanded that he recover the leopard, wherever it was. Reluctantly he set traps throughout the city parks and wooded areas to comply with the general wish. In the first night of trapping he caught four leopard, none of which was the one which had escaped.

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## 2. PAST AND CURRENT EXPLOITATION OF LEOPARD

### 2.1 IMPACT OF THE FUR TRADE

We have estimated the number of leopards killed for the fur trade each year from 1950 to 1986 in Africa as a whole, and in 5 sub-regions of Africa. The leopard population model (Appendix 1) was then used to simulate the effects which these harvests may have had on the numbers of leopard (Appendix 7). The countries comprising each region are defined in Appendix 7.

If the number of leopard dying in Africa were as high as 61,000 animals in 1969, the harvest would have had a negligible effect on the total population. Indeed, it causes no more than a ripple in the total numbers. We have used the population estimate derived from the lower confidence interval (598,000 animals) in the simulation: the effects are even less when the actual estimate is used.

The same is true for the Southern and Central regions of Africa. The estimated harvest hardly affects the population density. In the case of the Western region, if the population were as low as 75,000 animals (which is about the lower confidence interval), the population would have gone through a significant dip during the peak years of the fur trade, but would have survived it. As it is, using the final estimates for all Western countries combined from Table 1 (116,164), the effect of a harvest of 10,000 animals per year is not significant.

The bulk of the fur trade was not spread evenly over sub-Saharan Africa and the Central and Southern regions probably suffered far less than the north and east of Africa. Western Africa may have already been through its nadir by the 1950s (Myers 1976 p64). The effects of the simulation on the Eastern and Northern regions of Africa are very different. In both cases, had the populations been as low as we assume in Table 1, and the harvests as high as we estimate in Appendix 7, the leopard would have gone extinct in 1969 in the North and in 1971 in the East. This would have happened before any of the protective measures which were introduced in the mid-1970s could have saved the situation.

The leopard did not go extinct in either of these regions. This leaves two main alternatives: either we have underestimated the populations or we have overestimated the harvest. (A third possibility is that our model does not provide for enough compensation when harvesting occurs. We have examined this and no amount of compensation could retrieve the situation.)

We have examined how large the populations would have had to have been in order to survive the harvest. In the case of East Africa, if the population were as high as 92,000 animals (which is approximately the upper confidence interval predicted from our analysis), the harvest is accommodated comfortably. At the peak of the fur trade the density is reduced to about 2/3 of its normal value and the population recovers by about 1980. It is important to note that had the harvest not been reduced in 1975, the population would still have been in grave trouble.

In Northern Africa (Ethiopia, Djibouti, Somalia and Sudan) it requires a starting population of 100,000 to survive the sequence of harvests. The upper confidence interval for our estimate is about 58,000 animals. Again, the one certain item of knowledge we do have is that the population did survive. A first reaction to this might be that we should increase our estimates for the populations in these areas. This is not necessarily so.

To a large extent the population estimates are based on the amount of suitable habitat still available for leopard. Jackson (1986) gives loss of habitat as the main factor affecting the status of felids throughout the world. Current rates for loss of natural habitat in Africa are 2-3% (FAO 1986). If natural woodland has been disappearing at a rate of 2% for the past 36 years then the present amount is about half that in 1950 and leopard populations would have been double the current estimate.

This more than accounts for the situation in East Africa (twice the current estimate of 54,000 animals would have handled the harvest quite easily), and it accounts for the situation in North Africa. However, it is important to understand that in neither region could the leopard population return to these 1950 levels. The rate of habitat degradation is such that the leopard population would have been forced down from a level of 100,000 animals in North Africa in 1950 to a new level of 50,000 animals now - even if there had been no fur trade.

Ideally, our simulation should have taken the annual loss of habitat into account, and perhaps in a later exercise we will attempt this. But the important point has been made: in the past 36 years we should have expected the numbers of leopard in Africa to halve - simply on the grounds of habitat loss.

To close this section a few general comments need to be made. We are, in fact, far from satisfied with the estimates for the number of skins entering the fur trade. It seems to us that too many multiplying factors have been used to account for wastage and the death of cubs. At the peak of the fur trade in 1968 the United States imported 9556 leopard skins (Paradiso 1972). Myers (1976), largely on the strength of this figure estimated 5 times as many leopard dying in Africa in the same year. He might be right, but we are uncomfortable with the lack of supporting statistics.

An important point comes out of this modelling. A certain size of harvest implies a certain size of population from which it must come. Persons with a particular viewpoint to make have a tendency to understate the number of leopards in Africa and overstate the harvest from them. We are satisfied that, if these high harvests did take place, then the order of size for the population needed to sustain them has not been overestimated in this report.

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## 2.2 STRUCTURE OF THE EXPLOITATION SYSTEM

Part of our brief was to investigate changes in the number of leopard killed in Africa (presumably with reference to the level of offtake when the fur trade was at its peak). The number of leopard skins entering the international trade is an incomplete index of the number of leopard being killed. We have attempted to clarify the relationship between the number of leopards dying and the various methods by which this can be estimated.

Apart from natural causes, the ways in which a leopard may die are as follows:

- A. Spoorthunting: Leopards may be **legally** hunted for recreation in a number of countries in Africa, both by local residents and international clients. A certain amount of **illegal** sport hunting takes place in the form of "weekend" hunters, mainly ex-patriate, who may take the occasional leopard in some countries, and in the form of overhunting on legal safaris. By this we mean the practice of shooting the first available leopard on safari and, if a better trophy shows up before the end of the hunting trip, it is also taken. The least impressive of the two trophies is either destroyed or disposed of through illegal channels.
- B. Control: This is a euphemism meaning the destruction of any leopards which threaten man and his livestock. In many countries the laws regarding "vermin" are very powerful and there is no conservation agency which will stand in the way of a farmer who feels his livestock are threatened. Control hunting is particularly prevalent in South Africa (Esterhuizen & Norton 1985, Norton 1984), Namibia (Joubert & Mostert 1975), Botswana, Zimbabwe, Kenya and Somalia - to mention but a few countries. Rabinowitz (1986b) describes a similar situation for jaguar in Belize.

Leopard control may be carried out in some countries **legally** by the citizens themselves (e.g. South Africa, Botswana and Zimbabwe), whilst in others it is **illegal** for any person other than staff of the government agency responsible for problem animals to kill a leopard (e.g. Kenya, Malawi, Ethiopia, Somalia). However, it is seldom that such law is workable: control hunting tends to take place regardless of the authorities where livestock is concerned. Even if an individual is caught in the act of such an offence, there are very few courts which would convict him.

- C. Trade Leopards are killed for trade in their skins and other products in most countries at a lesser or greater level dependent on the market. Such killing is generally **illegal**. It seems that the only two countries where it is possible to kill a leopard **legally** for the trade are Zimbabwe and Tanzania.

In Tanzania, the state-owned Tanzania Wildlife Corporation (TAWICO) has killed two leopard in the last few years for the trade. In Zimbabwe, wildlife on private properties may be legally exploited by the landowner for commercial purposes. In the case of leopard, this seldom happens: most skins entering the trade are the result of problem animal control. This too is avoided if the leopard can be taken for sport hunting which is the higher valued use. However, stock raiding leopard are at their most active when cattle are calving during the wet season - which does not coincide with the hunting season. (We note with interest the arguments on this subject advanced by the US Fish & Wildlife Service at the time that they were proposing to reclassify the leopard to Threatened Status (DOI 1982). They tend to suggest that in some way sport hunting will replace problem animal control - which is not correct).

These are the three **primary sources** of leopard products which appear in Fig.1 overleaf, each of which may be divided into a **legal** and an **illegal** component. We now consider the possible destinations for these products.

The end points can be separated into those within the country (**local**), and those outside its borders (**international**). CITES is not involved in the **domestic** transactions, and only becomes an influence when leopard products cross borders.

Within the country skins may end up **legally** or **illegally** in private **homes** or in the hands of **dealers**. **Government** may acquire skins through its own efforts (control) or by confiscation, and some skins may be **wasted**.

Outside the country of origin, again skins may end up **legally** or **illegally** in private **homes** or in the hands of **dealers**. The **government** of the importing country may obtain skins through seizures (in which case they may be wasted).

This gives a simple matrix in which the exploitation system (**Fig.1**) can be analysed. The matter becomes less simple when **secondary sources** are considered. Each of the **local consumers** of skins from the **primary source** may be involved in the export of skins outside the borders of the country and further transactions within the country. To make provision for this, we have included a second array in the lower part of Fig.1.

Fig 1: EXPLOITATION OF LEOPARD

PRODUCERS		CONSUMERS														LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL
		LOCAL						INTERNATIONAL									
		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT					
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS								
										1	2		3	4	5		
PRIMARY SOURCE	LEGAL	SPORT	A														
	CONTROL	B															
	TRADE	C															
	ILLEGAL	SPORT	D														
	CONTROL	E															
	TRADE	F															
SECONDARY SOURCE	LEGAL	HOMES	G														
	DEALERS	H															
	ILLEGAL	HOMES	I														
	DEALERS	J															
	GOVERNMENT	K															

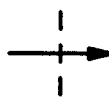
DOMESTIC

→

CITES

TOTAL  
LEOPARD  
KILLED

DOMESTIC



CITES



The titles **legal** and **illegal** in Fig.1 pertain to the transaction in the cell concerned. We are not referring to "illegal homes" or "illegal dealers", but rather to a skin illegally entering a home or the hands of a dealer. We define any transaction as illegal if the leopard product is either illegally obtained or illegally received. Thus within this contingency table, there are certain transactions which by definition cannot occur (e.g. skins obtained illegally for the trade cannot legally be taken by a dealer in cell F2). Cells where an outcome is impossible have been blanked out.

We will now discuss the various situations represented by the cells in the array. This may appear tedious but it is being done for several reasons. Firstly, it shows how difficult it is to obtain a full set of unambiguous data representing the number of leopard which have died in any single country. Secondly, it shows how extremely complex the system has become as a result of all the conflicting procedures which can apply, and lastly it shows how limited the CITES trade aspects are in the full set of possible transactions.

Firstly, we will deal with two cases which do not require discussing for every cell.

Products from any of the primary or secondary sources may be wasted (cells A6-K6). This arises from carcasses not found in the field, from skins allowed to slip, from poor tanning, through destruction of illegal stocks, through losses in shipping and so on. In the table this wastage takes place within the producer country. There is further wastage in the consumer country which has not been shown since it does not add up to any additional deaths of leopard.

Leopard products may at any time be confiscated by the government of the importing country if they have entered illegally (A11-K11). Their end destination will probably be a customs incinerator.

In legal sport hunting skins may find their way into local homes (A1) or (less frequently) into local dealers' hands (A2). The majority of sport hunting trophies are exported to private homes abroad (A7) where it is legal to possess them. Being an Appendix 1 species, under CITES Article III 3(c) leopard skins should not end up in dealers' hands (A8). The next two cells cater for a situation which existed in the United States from 1972-1982, and may exist now in any country which has legislation not aligned with CITES. Despite the fact that a leopard might have been legally taken as a sport hunting trophy in the producer country, it is illegal in a home (A9) or with a dealer (A10) in the importing country.

When animals are legally destroyed to protect livestock (control), the skins will tend to end up in private homes (B1) if there is no provision to sell them legally (e.g. South Africa). If it is legal to sell the skins then local dealers (B2) will acquire most of them (Botswana, Zimbabwe). In some countries (e.g. Zambia, Tanzania), although it is legal for private citizens to kill leopards to protect livestock, they are supposed to surrender the skins to Government (B5). This law is unacceptable to most citizens, so the majority of skins end up illegally in private homes (B3) or with dealers (B4). In Zimbabwe, skins taken on control may be sold directly to private citizens in other countries (B7). According to CITES Conf.4.13 such skins should not to end up in the hands of dealers (B8) but in certain countries they could legally do so. In most cases, however, dealers could only handle them illegally (B10). If the skin of a leopard legally killed on control in Tanzania was not surrendered to the Government but was sold instead to a tourist it would fall into the category B9.

We have mentioned that only two countries appear to kill leopard legally for trade purposes (Tanzania, Zimbabwe). In Zimbabwe's case the resulting skins could end up in any of the cells C1,C2,C7 or C8. In Tanzania, the skins go initially to the Government (C5). They may then be traded, but this would appear in the secondary sources. Cells C9 and C10 cater for the case where, although the skins have been legally taken in the producer countries they would be illegal in the importing country.

By definition the products from illegal sport hunting cannot go legally to homes or dealers locally or abroad. They would tend to be kept illegally in private homes (D3) or go to dealers (D4). Government in the producer country might be successful in confiscating some skins (D5). Skins might be smuggled abroad and end up in homes (D9) or with dealers (D10). An example of this has been reported from the mines in Gabon, where an expatriate worker has illegally shot a leopard for sport, held the skin for some time in the country, and finally shipped it back to France as a personal possession.

Control hunting is illegal for private citizens in many countries and is supposed to be carried out, when necessary, by Government staff. In countries such as Zaire it is impossible for wildlife officials to handle the problem so that the locals make their own arrangements. Because they have broken the law in the first place, the skins are either destroyed or find their way to an illegal destination (e.g. E3,E4,E9,E10).

The illegal trade category arouses the most interest in the CITES context. Skins find their way primarily to local dealers (F4), who become a secondary source for illegal export, although some overseas dealers (F10) once organised their own shipments in the producer countries (e.g. Somalia).

The preceding section dealt with the movements of leopard products arising from the **primary sources**.

The **secondary sources** are the local consumers from the first array but now arranged as rows instead of columns. We have included the secondary sources because, unless one is aware of them, confusion can arise in the analysis of exports. For example, through confiscation Governments in producer countries can become the legal owners of skins which were illegally obtained. Having acquired them, the export becomes legal from the Government source but it reveals no information about their origin.

The first group of transactions in this set covers legal domestic movements of skins between homes (G1), between dealers (H2), and between homes and dealers (G2,H1). In some countries skins may be legally held in homes, but it is illegal to sell them to a dealer (G4). Skins may be legally moved from a home in the producer country to a home abroad (G7) and in some cases legally sold to dealers (G8). In other cases skins which were legally owned in the producer country become illegal when they enter certain importing countries (G9,G10,H9,H10). Legal dealers in producer countries may sell legally to tourists (H7) or overseas dealers in certain countries (H8).

Skins which were illegally obtained by private citizens and dealers continue to be involved only in illegal transactions (I3,I4,I9,I10,J3,J4,J9,J10). Such skins may be "legalised" by obtaining false documentation at some stage in their career, but we have preferred to treat them as illegal because the documentation has been fraudulently issued. Governments in both the producer country and the importing country may be successful in apprehending some of these skins (I5,I10,J5,J10). Governments in the producer country may themselves sell to the local public (K1) or local dealers (K2), or they may sell directly overseas (K7, K8). However, their exports may not be legal either to private citizens (K9) or dealers (K10) in some importing countries.

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### 2.3 MONITORING LEOPARD DEATHS

Given the structure of the leopard exploitation system according to Fig.1, how is it possible to assess, from trade and other data, the number of leopards which are killed ? In Fig.2 we have attempted to identify those cells where it is possible to obtain some useful information.

First of all it must be accepted that the **illegal trade** is virtually impossible to assess. This rules out half of the cells in Fig.1. The only indices are occasional shipments of skins which may be apprehended by customs or the level of poaching activity which may be detected by active wildlife agencies (D5-F5). Because leopard are plentiful outside protected areas, there is little need for the poacher to risk arrest by hunting in national parks. It is easier to find them outside where the level of anti-poaching activity throughout Africa is negligible. The most reliable data comes from the traders themselves, but not all traders are willing to volunteer information.

All of the traders with whom we spoke on this survey, several of whom were heavily involved at the peak of the fur trade, were adamant that controls on the international trade had a very minor impact on their business. Even today they are able to move leopard skins into Europe with no difficulty. One particular trader had recently taken several skins to Europe as personal baggage and returned to Africa with them when he couldn't find a buyer. The traders agree universally that it was only the collapse of the fur market that limited overseas shipments.

For these reasons, it is obviously highly desirable to adopt policies in every country which limit the illegal trade, recognising that strong law enforcement has little chance of working in the case of leopard. This will be discussed further in the next chapter.

The number of leopards killed by **sport hunting** is easy to measure, and in every country we visited these statistics were readily available both for international (A7) and local (A1) sport hunting. It is worth noting that it is far easier to obtain this information from government wildlife agencies than to piece it together from international trade statistics or CITES party members' annual reports.

In most countries, the number of leopards killed on **control** is almost impossible to estimate directly - largely because of the policies adopted by the countries themselves towards control hunting. Wherever it is illegal for citizens to handle problem leopard themselves, invariably there is no information on the number of leopards killed to protect livestock.

We say this fairly categorically. In most of these countries the provision exists for citizens to call on staff of the wildlife agency to kill a problem leopard: however, the very small number of cases reported to us where wildlife staff have actually killed problem leopard is ample proof of the fact that the citizens of the county are managing without them. Thus control by government (B5) may be monitored but, at best, it is an incomplete record.

In some countries it is legal for citizens to kill a problem leopard themselves, but they are required to report the incident immediately and surrender the skin to government (e.g. Zambia, Tanzania and several other countries). As long as there is a trickle of skins to government (B5), wildlife staff believe the process is working. This is an illusion. Because the vast majority of citizens cannot be bothered to report the incident and/or hand over the leopard skin, most leopard are despatched with the minimum of fuss and the skins are either destroyed or traded illegally.

In South Africa problem leopard may be shot by the landholder, provided he reports the incident, and he may keep the skin. This is some way towards a better solution in that it involves the landholder in a minimum of red tape, and provides a partial record of animals killed on control (B5). However, experience in Zimbabwe where the same system was applied for many years showed that only the more conscientious citizens bothered to notify the authorities.

In Zimbabwe problem leopards may killed by any landholder without reference to the government and the skins may be legally traded. This provides no direct record of the number of leopards killed annually and fails to separate leopards killed as problem animals from leopard killed for commercial reasons. However, it is possible to measure the combined number of leopard killed to some extent by the skins received legally by local dealers (A2,B2,G2,H2,K2).

The only country with a simple, reliable system for monitoring the number of leopards killed on control is Botswana. In this country any citizen may kill a leopard to protect his livestock and may obtain an ownership certificate for the skin provided he justifies the killing to a local authority. The skins may then be sold to a limited number of dealers and, of these, Botswana Game Industries (BGI) purchases 90% of the skins. Almost the entire trade can be monitored at the input to the industry (B2). We make further reference to the Botswana system in the next chapter.

**Fig 2: MONITORING OF LEOPARD DEATHS**

# CONSUMERS

		LOCAL						INTERNATIONAL					LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL		
		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT				
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS					
		1	2	3	4	5	6	7	8	9	10	11				
PRODUCERS	PRIMARY SOURCE LEGAL	SPORT	A	*	*			*								
		CONTROL	B		*		*									
		TRADE	C		*		*									
	PRIMARY SOURCE ILLEGAL	SPORT	D				*									
		CONTROL	E				*									
		TRADE	F				*									

SECONDARY SOURCE	LEGAL	HOMES	G		*									
		DEALERS	H		*				*	*				
	ILLEGAL	HOMES	I											
		DEALERS	J											
	GOVERNMENT	K	*	*				*	*					

TOTAL  
LEOPARD  
KILLED

DOMESTIC

CITES

DOMESTIC ———→ CITES

\* - MONITORING POINT

In section 2.2 we pointed out that very few leopards are killed legally for the **trade**. Those killed in Tanzania appear in the records of TAWICO (C5). In Zimbabwe there is no real separation between leopards killed on control and leopards killed for the trade. Whilst it might be thought that the Botswana system automatically leads to some leopard being killed primarily for the trade this is seldom the case. Any individual who persistently attempts to get ownership certificates for more than one or two skins draws attention to his activities and is investigated.

Government sales to private citizens (K1), local dealers (K2), overseas tourists (K7) and overseas dealers (K8) provide some insight into the traffic in leopard skins but are not a complete measure of the number of leopards killed on control or for the trade. In the same way, local dealers sales to overseas destinations (H7,H8) represent only a part of the number of leopards killed. BGI's records for incoming skins are a far better index of the number of leopard killed than any sales.

We conclude this section by noting that in very few cases can the number of leopards dying annually in any country be accurately stated. Statistics on the international trade are not very useful now that the fur trade has collapsed. The best sources of information should be in the producer countries, but the availability of such information is very much dependent on the policies of the country. By adopting a workable system such as Botswana's very little illegal traffic occurs, and the conservation situation can be readily monitored.

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## 2.4 ANALYSIS OF SOME INDIVIDUAL COUNTRIES

We have tried to complete Fig.1 for a few individual countries. The purpose of this exercise is more to show the results of different types of policy than to represent accurately the number of leopard being killed in each country. Information comes from government safari hunting records and transactions of legal and illegal dealers. Some intuition enters into the surmises on the illegal trade. In the case of the sport hunting records we have not used the exact numbers of leopard killed in 1986 but have rounded upwards to give a maximum number that are likely to be taken in the given country in current years. Our motive is simply to put an upper order of magnitude on the numbers of leopard which might be killed in the countries concerned and how they might be killed. No wildlife agencies need take offence at the predictions. Much of the discussion in the previous sections relates to these examples, so it is not our intention to labour the points in great detail.

### Botswana (Fig.3):

About 80 leopard are taken annually in sport hunting and most of the trophies are exported to homes abroad. A maximum of about 100 leopard are killed for livestock protection and most of the skins go to BGI (80), although a few might be retained in private homes. Some illegal sport hunting takes place in the country and, because staff of the wildlife department are unable to accompany all legal hunts, there is bound to be some "double shooting" which gives rise to the numbers in cells D3-D6. We have allowed for a low level of illegal hunting for trade (F3-F6, F9-F11) which does not necessarily occur. A total of slightly over 200 leopards may be killed in the country annually, most of which are legal.

In the lower array we have not attempted to give numbers but have merely indicated with symbols which types of transactions involving leopard skins are possible, common and unlikely. Thus it is possible that skins would move between homes (G1), common that private citizens sell skins to dealers (G2), possible that skins move from homes in Botswana to homes abroad (G3), and unlikely that any skins find their way from private citizens in Botswana legally or illegally to dealers or private citizens abroad (G8,G9,G10). We are not aware of any customs seizures in importing countries (G11-J11). The remainder of the table is self-explanatory.

### South Africa (Fig.4):

Sport hunting accounts for about 40 leopards annually, 25 of which result in exported trophies and 10 in local trophies. We have hypothesized that the odd hunting trophy might find its way to a local dealer for legal resale in South Africa (A2), and a couple might go to an illegal dealer (A4) for resale outside the country. Perhaps 140 leopard are killed



legally and another 60 illegally on control hunting (In SA if a leopard killing is not reported it constitutes an illegal act). We have assumed some illegal sport hunting (D3,D4,D6,D9) of which the wildlife authorities apprehend a couple of culprits annually (D5). There is no legal export of any leopard skins obtained from control and a leopard may not be killed for trade. A low level illegal trade may occur (F3,F4) but government may intercept some of this (F6). We think it unlikely that more than 270 leopards are killed annually, two-thirds of which are legal killings.

The only common transactions likely to take place in the lower table are movements of skins between private citizens (and wastage).

Zambia (Fig.5):

The point we wish to bring out of this example is that leopards killed on control (legally) may be finding their way to illegal destinations (B3,B4) with very few being intercepted by government (B5). In Zambia we received reports of up to 200 illegal skins for sale in Lusaka, and we have assumed this is made up partly of control killings and partly of illegal hunting for the trade.

Largely as a result of the present policy, it is likely that transactions with illegal dealers are common (I4) inside and outside the country (I10). A feature of Fig.5 is the large number of blanked-out cells for legal outlets.

Zimbabwe (Fig.6):

In contrast to Zambia and South Africa, there are very few illegal transactions possible by definition. Of the total number of leopards killings (c.400) less than 10% are illegal. Transactions between legal dealers and overseas tourists are common, and sales to dealers abroad would be common if CITES permitted it. The only criticism we have of the system is that in Zimbabwe the main emphasis goes into monitoring only the exported component for which CITES tags are required: to obtain good statistics on the number of leopards actually killed would involve lengthy surveys of individual farmers and dealers.

West Africa (Fig.7):

This example is not meant to represent any individual country, but merely to point out the result of the type of policy we found in most of the French-speaking countries in Africa. It is generally illegal to kill for sport, control, or the trade and this ensures that 99% of killings and transactions are illegal.

---

Fig 3: EXPLOITATION OF LEOPARD IN BOTSWANA

# CONSUMERS

LOCAL						INTERNATIONAL						LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL								
LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT											
HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS												
1	2	3	4	5	6	7	8	9	10	11											

PRODUCERS	PRIMARY SOURCE LEGAL	SPORT	A	3	2				5	70			80	185		
		CONTROL	B	5	80				20				105			
		TRADE	C										0			
	PRIMARY SOURCE ILLEGAL	SPORT	D			5	3	2	5			0	0	0	15	40
		CONTROL	E												0	
		TRADE	F			2	2	10	5			2	2	2	25	

SECONDARY SOURCE	LEGAL	HOMES	G	P	C				C	P	U	U	U	U
		DEALERS	H	C	P				C	C	C	U	U	U
	ILLEGAL	HOMES	I			U	P	P	C			U	U	U
		DEALERS	J			U	U	P	C			P	P	U
	GOVERNMENT	K	P	C					C	U	U	U	U	U

225

TOTAL  
LEOPARD  
KILLED

DOMESTIC

CITES

C - Common

P - Possible

U - Unlikely

Fig 4: EXPLOITATION OF LEOPARD IN SOUTH AFRICA

PRODUCERS		CONSUMERS														LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL
		LOCAL						INTERNATIONAL									
		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT					
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS						
		1	2	3	4	5	6	7	8	9	10	11					
PRIMARY SOURCE	LEGAL	SPORT	A	10	1		2		2	25					40	180	
	CONTROL	B	100	10		10	5	15							140		
	TRADE	C													0		
	ILLEGAL	SPORT	D			5	1	2	1			1	0	0	10	90	
	CONTROL	E			25	10	5	20				0	0	0	60		
	TRADE	F			3	10	2	5				0	0	0	20		
270																	
TOTAL LEOPARD KILLED																	
SECONDARY SOURCE	LEGAL	HOMES	G	C	P		U		C	P							
	DEALERS	H	P	P				C									
	ILLEGAL	HOMES	I			P	P	P	C				U	U	U		
		DEALERS	J			P	U	P	C				U	U	U		
	GOVERNMENT	K							C						P		
<div>DOMESTIC</div> <div>↓</div> <div>↑</div> <div>CITES</div>																	
C - Common																	
P - Possible																	
U - Unlikely																	

DOMESTIC ———→ CITES

C - Common  
P - Possible  
U - Unlikely

### Fig 5: EXPLOITATION OF LEOPARD IN ZAMBIA

		CONSUMERS											LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL			
		LOCAL						INTERNATIONAL									
		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT					
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS						
		1	2	3	4	5	6	7	8	9	10	11					
PRODUCERS	PRIMARY SOURCE	LEGAL	SPORT	A	5					20	100					125	250
			CONTROL	B			20	50	5	50						125	
			TRADE	C												0	
	ILLEGAL	SPORT	D			5	5	5	5			2	3	0	25	100	
		CONTROL	E														0
		TRADE	F			5	50	10	10			0	0	0	75		
														350			
TOTAL LEOPARD KILLED																	
		<div style="display: flex; align-items: center; justify-content: center;"><div style="text-align: center;">DOMESTIC</div><div style="margin: 0 20px;"></div><div style="text-align: center;">CITES</div></div>															
		<div style="display: flex; justify-content: space-around; margin-top: 10px;"><div>C - Common</div><div>P - Possible</div><div>U - Unlikely</div></div>															

Fig 6: EXPLOITATION OF LEOPARD IN ZIMBABWE

# CONSUMERS

		LOCAL						INTERNATIONAL							LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL									
		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT													
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS														
		1	2	3	4	5	6	7	8	9	10	11													
PRODUCERS	PRIMARY SOURCE LEGAL	SPORT A	8	2			10	180					200	360											
		CONTROL B	100	10		5	10	10	5				140												
		TRADE C	1	8			3	2	6				20												
	PRIMARY SOURCE ILLEGAL	SPORT D			5	1	2			2	0	0	10	30											
		CONTROL E											0												
		TRADE F			4	5	2	4		2	2	1	20												
														390											

TOTAL  
LEOPARD  
KILLED

		LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT	WASTED				
		HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS						
SECONDARY SOURCE	LEGAL	HOMES G	C	C			C	C	U								
		DEALERS H	P	P			C	C	P								
	ILLEGAL	HOMES I					C			U	U	U					
		DEALERS J			U	U	U	C		U	U	U					
		GOVERNMENT K	P	P			C	U	U			U					

DOMESTIC ———→ CITES

C - Common  
P - Possible  
U - Unlikely

Fig 7: EXPLOITATION OF LEOPARD IN WEST AFRICA

# CONSUMERS

LOCAL						INTERNATIONAL						LEOPARDS KILLED	SUBTOTALS LEGAL & ILLEGAL								
LEGAL		ILLEGAL		GOVERNMENT	WASTED	LEGAL		ILLEGAL		GOVERNMENT											
HOMES	DEALERS	HOMES	DEALERS			HOMES	DEALERS	HOMES	DEALERS												
1	2	3	4	5	6	7	8	9	10	11											

PRIMARY SOURCE	LEGAL	SPORT	A									0	1	
		CONTROL	B		1							1		
		TRADE	C									0		
	ILLEGAL	SPORT	D		1					1	0	0	2	99
		CONTROL	E		10	20	0	5		2	3	0	40	
		TRADE	F		10	20	5	10		3	8	1	57	

SECONDARY SOURCE	LEGAL	HOMES	G										
		DEALERS	H										
	ILLEGAL	HOMES	I		P	C	U	C		P	P	U	
		DEALERS	J		U	C	U	C		C	C	U	
	GOVERNMENT		K					P				U	

100  
TOTAL  
LEOPARD  
KILLED

DOMESTIC

CITES

C - Common

P - Possible

U - Unlikely

DOMESTIC ———→ CITES

C - Common  
P - Possible  
U - Unlikely

## 2.5 CURRENT LEVELS OF EXPLOITATION

We have attempted some very crude estimates of the current levels of exploitation for all countries in Africa (Table 3), based on official data (where it was available), reports from traders, and some intuition. In those countries we did not visit the oftakes are no more than informed guesses. We have tended to round numbers upwards so that the table can be regarded as a "maximum likely" situation.

In most countries the estimated offtake is well below a sustainable harvest. The safe potential harvest in Table 3 has been calculated by deducting from the total population estimate all leopard populations in national parks and protected areas where hunting is not permitted, and then calculating a 5% harvest on the remainder of the leopard population. In the next chapter we will justify the choice of 5% as a safe harvest level.

Somalia is the only country which appears to exceed the recommended safe offtake (although the number would not exceed the maximum sustained yield). In Mogadishu we found leopard skins available in the Lido market, and one trader stated he could deliver 40 skins within 24 hours. He claimed his annual turnover was 70 skins in 1986, of which about half went each year to an Italian client who has been purchasing 25-30 skins for several years. This client's order for 1987 was 35 skins. The annual illegal offtake is unlikely to be less than 100 skins (see footnote).

We will deal briefly with the estimates for those countries visited excluding those dealt with in the previous section.

Benin: We found 3 skins for sale in Cotonou of which one was represented as coming from Nigeria. There are no reports of leopard taking livestock, although there were cases of lions doing so. Control is supposed to be done by the wildlife agency but is more likely to be carried out informally. Illegal hunting for leopard is at a low level.

Burundi: We found leopard skins for sale in Bujumbura in street bazaars, but by far the biggest number is held by traders. One trader claimed he was able to supply up to 300 skins at short notice which originated mainly

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Footnote: At the Ottawa CITES Meeting the Somalia delegation objected in writing to the original statements in this paragraph and the figures in Table 3. We have modified the paragraph but not withdrawn it as demanded by Somalia. We are fully aware that the Somalia Government does not sanction the killing of leopards in the country but we cannot ignore the information we obtained during this consultancy. In the first paragraph of this section we have stated our assumptions.

TABLE 3: ESTIMATES FOR THE NUMBER OF LEOPARD CURRENTLY KILLED ANNUALLY

COUNTRY	FINAL POP.	SPORT		CONTROL		TRADE		TOTAL		GRAND	POT.
		LEG.	ILL.	LEG.	ILL.	LEG.	ILL.	LEG.	ILL.	TOTAL	HARV.
ANGOLA .....	62,486	5	5	10	100	0	200	15	305	320	3,056
BENIN .....	492	0	0	0	5	0	5	0	10	10	24
BOTSWANA ...	7,729	80	20	100	0	0	25	180	45	225	261
BURKINA FASO*	1,693	0	0	5	15	0	20	5	35	40	63
BURUNDI ....	495	0	0	0	2	0	3	0	5	5	19
CAMEROUN ...	41,896	0	0	5	20	0	100	5	120	125	1,878
CAR .....	41,546	30	5	5	20	0	100	35	125	160	1,874
CHAD .....	3,125	0	5	5	20	0	50	5	75	80	155
CONGO .....	32,394	0	2	5	100	0	150	5	252	257	1,476
DJIBOUTI ...*	25	0	0	0	1	1	1	1	2	3	1
EQ. GUINEA .*	5,040	0	0	5	10	0	20	5	30	35	235
ETHIOPIA ...	9,782	25	5	5	50	50	100	80	155	235	403
GABON .....	38,463	0	10	5	25	0	60	5	95	100	1,694
GAMBIA .....	33	0	0	0	1	0	0	0	1	1	1
GHANA .....	599	0	0	1	5	0	20	1	25	26	76
GUINEA .....	1,569	0	0	0	10	0	30	0	40	40	76
GUINEA BISSA*	341	0	0	0	3	0	5	0	8	8	17
IVORY COAST.	9,522	0	5	5	15	0	50	5	70	75	371
KENYA .....	10,207	0	5	30	50	0	150	30	205	235	259
LESOTHO .....	420	0	1	5	5	0	2	5	8	13	20
LIBERIA .....	503	0	1	1	5	0	10	1	16	17	20
MALAWI .....	4,530	15	3	2	5	0	10	17	18	35	170
MALI .....	3,365	0	0	5	20	0	30	5	50	55	167
MAURITANIA .*	230	0	0	0	2	0	3	0	5	5	11
MOZAMBIQUE .*	37,542	0	5	0	50	0	200	0	255	255	1,779
NAMIBIA .....	7,745	50	5	100	20	0	20	150	45	195	332
NIGER .....	454	0	2	0	5	0	10	0	17	17	21
NIGERIA .....	9,481	0	10	10	30	0	100	10	140	150	398
RWANDA .....	388	0	0	0	2	0	3	0	5	5	11
SENEGAL .....	781	0	0	1	5	0	10	1	15	16	23
SIERRA LEONE	280	0	0	0	5	0	5	0	10	10	10
SOMALIA .....	2,123	0	0	0	50	0	50	0	100	100	79
SOUTH AFRICA	23,472	50	10	140	60	0	20	190	90	280	1,050
SUDAN .....	22,035	0	0	20	100	0	50	20	150	170	853
SWAZILAND ...*	805	0	0	1	3	0	5	1	8	9	40
TANZANIA ...	39,343	160	20	50	50	10	100	220	170	390	1,827
TOGO .....	254	0	0	0	2	0	3	0	5	5	10
UGANDA .....	4,292	0	5	0	10	0	100	0	115	115	147
ZAIRE .....	226,192	0	10	100	500	0	500	100	1,010	1,110	10,400
ZAMBIA .....	46,369	125	25	125	0	0	75	250	100	350	2,075
ZIMBABWE ...	16,064	200	10	140	0	20	20	360	30	390	710
TOTALS .	714,105	740	169	886	1,381	81	2,415	1,707	3,965	5,672	32,092

\* - country not visited

LEG. - legal

ILL. - illegal

POT.HARV. - potential safe harvest



Zaire, Zambia and Tanzania. When we explained to him that some countries were having problems in exporting skins because of the CITES quota system he offered as a favour to purchase any skins available, although he did not really want them because the market was so poor. He had no difficulty in getting them into Europe - the problem was a market.

Cameroun: Skins were on sale in Douala, Yaounde and Garoua. Many of these were old (perhaps 10 years), and not all originated from Cameroun. Traders estimate 50-150 skins are available annually inside the country. The tannery at Maroua handles leopard skins for much of West Africa. There is an internal demand in Cameroun for skins apart from the international market, and leopard are highly sought after for traditional uses. Last year Cameroun imported skins from Botswana. Some specialised hunting for leopard still occurs.

Central African Republic: There is little interest in leopard as a commercial product, although poaching for wildlife in general is still high. We found no skins on sale in Bangui, but traders in Cameroun and Ivory Coast stated that they often received skins from CAR. It is planned to allow leopard to be shot on safari hunting licence in 1987, although they have been protected since 1967. Conflict with livestock is reported, and citizens are destroying problem leopard.

Congo: Considerable illegal hunting occurs throughout the country, including night shooting with spotlights which is likely to yield significant numbers of leopard. Most of the skins are moved to West Africa, although they are sought after for local traditional uses.

Ethiopia: The Wildlife Conservation Organisation received 200 skins from July 1985 to June 1986 (mostly from confiscations), and there are approximately 400 skins legally registered with private dealers in Addis Ababa and Asmara. Few individual dealers have more than 50 skins. Control hunting is supposed to be done by government but in general the public handle it illegally themselves. There is a steady flow of skins through Ethiopia, and all people interviewed believed that even at the height of the fur trade leopard populations did not decrease significantly. One dealer had handled 400 skins per year at this time and stated that he knew other dealers who had sent individual shipments of up to 600 skins at a time to Europe. He records the market as collapsing totally in 1973 when his turnover dropped to less than 10 skins per year. He had never heard of CITES and was adamant that the leopard skin trade was destroyed by public opinion rather than any trade regulations. He reported sending skins to Djibouti for sale recently but they were "just sitting" in the market.

Gabon: A large commercial bushmeat trade exists, which includes the occasional leopard. There are few conflicts between leopard and domestic livestock because livestock numbers are very low. Skins were available in Libreville but in low numbers. Most of the illegal trade moves to West Africa in the hands of Senegalese and Malians. As in most countries of Francophone Africa, French civil servants and expatriates are reported to buy good skins as well. For this particular market, high quality trophies were imported from Botswana in 1985.

Ghana: There is very little hunting for leopard and reports of the animals are few. There is a high demand for skins for traditional uses in the Ashanti culture, and Ghana would like to import to meet this need.

Ivory Coast: There are reports of leopard/domestic stock conflicts in the north of the country which are probably handled illegally by the local residents (officially the wildlife agency should deal with these problems but there are few examples where this has happened). There is little dedicated leopard poaching, although some get taken on night hunting with spotlights for the bushmeat trade. Skins were on sale in Abidjan, and leopard products play an important part in local traditional culture.

Kenya: Hamilton (1987) reports that conflict with livestock is at a high level in the most heavily populated provinces and there are demands for leopard to be eliminated. We were unable to obtain data from the wildlife department on control problems. A trader from a neighbouring country informed us that he had several significant offers of skins while in Nairobi totalling about 100. We also recieved a report of a shipment of 100 skins leaving Nairobi airport.

Malawi: Two leopard were shot on control by departmental staff in 1986, and we suspect a low level of illegal control and trade hunting. Malawi intends to open safari hunting with a quota of about 15 in 1987.

Rwanda: About 20 skins have been seized by the authorities over the past 10 years, but many of these are from outside the country - mainly Zaire. There are few reports of leopard incidents with livestock and these are usually handled informally by locals.

Sierra Leone: Leopard skins were not on sale in Freetown. Unlike other cat-skins they are reported to be very rare on markets. There are reports of conflict with livestock, and although the wildlife department is supposed to handle such matters there had been no official leopard killing in recent years. Leopard have numerous traditional uses in Sierra Leone.

Sudan: There were 53 skins registered in the market at Omdurman in 1986, and dealers had been instructed to use up their stocks before the ban on leopard products came into effect in January 1987. The government will try to sell any surplus skins abroad after this period. Approximately 20 skins are acquired per year on control by department staff. Leopard skin sandals are highly prized in Sudan as part of the status of high ranking men in Arab dress and may cost up to US\$500. From 1987 onwards it will become illegal to wear them as the government has prohibited the sale or exhibition of items made from spotted cat skins. The department estimates that it issued permits for up to 500 skins at the peak of the fur trade in the 1970s. However, one of the major traders put the figure exported at nearer 2,000 which includes illegal shipments. He confirmed that the trade was now negligible, and complained that the few skins which went to the local tannery were so badly handled that they were worthless.

Tanzania: Departmental staff recover an average of about 46 skins per year on anti-poaching operations (TAWICO data from 1976-1986), a few leopard are shot for the trade by TAWICO, and a maximum of about 160 sport hunting licences may be issued. Skin returns to the Dar es Salaam ivory store average about 50 per year, but the figures do not tally with the TAWICO figures above so we assume that these are additional. We can find no records which correspond with the very high figures claimed by Tanzania for control hunting in CITES Doc. 5.23 Annex 5 (these figures average over 500 annually). Traders in Burundi report that they are receiving significant numbers of leopard skins from Tanzania.

Zaire: It is very difficult to make any estimates for offtakes in Zaire as all leopard transactions are illegal. There are reports from several neighbouring countries about skins received or confiscated, and we were informed that throughout the country rural people carry out their own problem animal control. There is a network of Senegalese and Malian traders operating in the northern part of Zaire and these are reputed to move leopard skins to West Africa. We found leopard skins on sale in the market in Kinshasa.

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Those countries with quotas for the export of skins performed as follows:

**Botswana** has used its entire quota of 80 which is totally inadequate for its requirements.

**Kenya** has apparently exported only 5 skins against its quota of 80 and these went to Swaziland as a coronation gift. There are at present 21 skins held on wildlife stations and 147 skins in the headquarters store which they may well require to export soon.

**Malawi** exported only 5 skins in 1986 but expects to require its full quota of 20 when safari hunting commences this year.

**Mozambique:** we have no data for exports.

**Tanzania** exported 114 leopard hunting trophies in 1986 and we are not certain how many of the additional skins obtained by TAWICO from confiscations, control etc. have actually been exported. The total figure is unlikely to exceed 180 skins which is well under their quota of 250.

**Zambia** did not have the figures available for 1986 exports at the time we visited them but, based on the previous years exports they are unlikely to exceed 150 (quota 200).

**Zimbabwe** has used only 170 of the tags issued for 1986 exports (350). Except for four tourist souvenir skins, all tags went on sport hunting trophies. The wildlife department has been holding back on the issue of tags until it can develop a rational system for allocation to the private sector. We have reports from several game ranchers that they are holding stocks of leopard skins which they are waiting to export.

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The total number of leopard deaths estimated in Table 3 is about 6,000 per year, made up of 2,000 legal and 4,000 illegal. Sport hunting accounts for about 1,000 animals (legal and illegal), control 2,000, and trade 3,000. The estimates are far from reliable.

The value of the harvest is about US\$6 million, assuming that leopards are worth US\$5,000 in the sport hunting industry and US\$500 in the trade. The full value would not have been realised by Africa because most of the animals killed on control hunting would have been wasted. The returns from the illegal trade would also have gone to a very small number of people and not governments or law-abiding citizens. Properly managed, the returns to countries could be a great deal higher.

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### 3. MANAGEMENT OF LEOPARD

Part of our brief in this consultancy was to advise African governments on the management of leopard. From our leopard population model it is possible to give a **technical** basis for management, such as the sustainable offtakes under various treatments of leopard populations. But this is only a part of the subject. There are aesthetic decisions to be made, policies to be decided, institutional arrangements to be set up, and research needs to be met. These issues are more important than the technical matters. People have been managing leopard for years in Africa without the benefit of our population model and they will continue to do so.

There is an immediate fear when the subject of management is brought up that the game utilisation lobby is advocating yet again that only by exploitation will a species be conserved. In the case of leopard, some special interest groups will consider the mere act of discussing management as an indication that the fur trade is likely to be revived, the species will come off Appendix I, and the road is open to wholesale slaughter. This need not necessarily be so. It can do no harm to **talk** about management. The final decisions of individual African governments should be based on an awareness of the technical facts, but these do not constrain them to act in any manner determined by the CITES forum.

It is likely that the available range for leopard will decrease by half again in the next 20 years (see Section 2.1 - North Africa) and, if so, the leopard population will also halve. This can be fought every inch of the way and the conservation world can continue to publish articles on leopards declining everywhere. It will not do much good. How do you manage a species which nobody wants living in their gardens? (Cobb 1981). It is as well to remember that we are not talking about an animal which lives mainly in national parks. It lives mainly **outside** national parks and would not be tolerated in the northern hemisphere. Caughley (1981) stated that "one brown bear in Kent is an overpopulation of brown bears".

Many African governments would like to **manage their leopard populations in the best way possible**. Too often they are constrained by conservation policies they have inherited which are no longer appropriate. Few of them have adequate budgets to protect wildlife in national parks, never mind leopard in unprotected areas. Furthermore they are up against very powerful laws and traditions in the farming areas which give almost unlimited powers to farmers to protect their interests against dangerous animals. For want of some original policies, leopard are being allowed to disappear by default.

This chapter is being written for those wildlife agencies in Africa who are interested in management and who are not content with the present situation.

### 3.1 POLICY

Governments have a sovereign right to adopt the policies they want. If the idea of exploiting leopard is distasteful, a government is at liberty to give the animal ultimate protection. But if it does so, it should at least be aware of the implications, practicality and costs of the chosen path. There seems to be a sort of group syndrome prevalent at the moment where individual countries feel more or less committed to certain types of policy in their countries as a result of resolutions approved in the CITES forum. This should be avoided.

Wildlife decision makers should begin by examining their policies for protected areas and unprotected areas. The four questions which the state has to answer are:

- which wildlife does it want ?
- where does it want it ?
- how much does it want ?
- how does it want to manage it ? (Bell & Clarke 1986)

We would expect that very few would wish to exploit leopard in national parks, being more anxious to uphold a set of internationally accepted standards for them. Having decided this, there remains the rest of their countries to consider. Apart from in West Africa, almost every country has problems with leopard in its farming areas.

In the previous chapter (section 3.4) we compared some policies which work with some which don't. It may gain a wildlife agency some plaudits on the international conservation scene to declare that the leopard is a highly protected species throughout its country but it won't solve a number of problems at home. From our observation of policies which work in certain countries in Africa, we would suggest that the best policy for leopards in unprotected areas is one which does not promote an illegal trade in leopard skins. There may be an inherent danger in allowing the legal exploitation of leopard, but this is the lesser of two evils.

In many countries, it is believed that people have a right to be protected from leopard depredations but unless this is carried out by staff of the wildlife department the result will be uncontrolled exploitation. It is thought to be better that governments carry out control so that the

temptation is removed from peasants. There are two inherent flaws in this system. The first is that the response by government staff is usually too slow to solve the problem. The second is that there is no good reason why the government should get the benefit of the value of the skin. The leopards concerned are a direct cost to particular individuals who have lost livestock, and there is no good reason why the bounty from the sale of skins should accrue to anyone but them.

In South Africa private citizens are allowed to kill problem leopards themselves and to become the legal owners of skins. However, it is illegal to trade in the skins or export them. We would argue that this is a certain way to promote the illegal trade in skins. In some countries the people are more law abiding than others, but generally it is a convenient government illusion that people will respect unworkable laws. Norton (1986, III p13) hints at the possibility that there is some illegal trade resulting from this policy.

In Botswana, where rural people may legally kill leopard to protect their livestock and are allowed to sell the skins for gain this has not resulted in the wholesale slaughter of leopard as predicted. In Kenya where the law prohibits the killing of leopard by citizens, the illegal trade in leopard skins is alive and well.

We advocate a pragmatic policy towards leopard in the rural areas of African countries which accepts the reality that private citizens will control leopard illegally if there are no legal channels, and which provides a means of monitoring the process and judging the severity of the conservation problem.

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### 3.2 INSTITUTIONS

If a country decides to allow rural people to kill leopard themselves and is anxious to ensure that the skins do not enter an illegal market, and leopard do not become extinct, what should it do ?

Botswana have solved the problem through the establishment of private industries which purchase the skins at a fair market price. Botswana Game Industries trains rural farmers in the careful preparation of skins and has established collecting depots throughout the country. There is very little wastage of potentially valuable products. Their records of skin purchases are available to government and the offtake of any species can be gauged from their receipts. If an individual is suspected of destroying an unjustified number of animals he can be easily identified.

In Zimbabwe, landowners may manage their wildlife resources for their own benefit. This has applied mainly to large commercial farmers and the development of the industry in communal lands is in its infancy. Farmers may exploit leopard for trade purposes if they wish, but there is little evidence of this. Leopard are sold for sport hunting, and some are killed to protect livestock. The skins of these leopard are sold to best advantage. We do not necessarily advocate this system for other countries where the bulk of the land is communally owned. Communal resources require a very different approach for conservation. One system which is being tested in Zimbabwe is group ownership and management of wildlife on tracts of communal land (Martin 1986) but it is too early to tell whether it will solve the problem.

We would suggest that governments buy the skins of leopard from rural people at a price high enough to eliminate competition from illegal buyers. This ensures that both the citizens who deserve compensation for stock losses and governments receive a share of the returns. As in Botswana, governments should go further and ensure that villagers are trained in the preparation of skins and that there are sufficient collecting points throughout the country.

Another option for the use of leopard in unprotected areas is sport hunting. But it should not be thought that sport hunting can replace problem animal control or even reduce it. Sport hunters do not usually hunt at the time of year when attacks by leopard on livestock occur, and they don't particularly like to hunt in heavily settled rural areas.

The revenue from sport hunting tends to go entirely to government, even when the leopard are taken in communal lands. In Zimbabwe, all income earned from wildlife in communal lands is returned to district councils - but this does nothing to compensate the individual stockowner who loses animals to leopard. The Defenders of Wildlife (1980) and Myers (1980) are correct in their statements that the income earned from sport hunting in Africa does little for rural peasants - generally it doesn't. The need for institutions to alter this situation is long overdue. Nevertheless, the greatest value attached to leopard lies in sport hunting (next section), and it is a productive land use in unprotected and unsettled areas.

Governments need to do some original thinking on institutional systems which would work in their particular countries, knowing the characteristics of their people, the geography of the country and the present problems.

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### 3.3 SUSTAINABLE OFFTAKES

It may appear somewhat academic to talk about sustainable offtakes from populations which cannot be counted. It seems rather pointless to say that 10% of the population can be harvested when the population size is unknown. This problem was expressed to us by one agency after another when we discussed the exploitation of leopard in various countries.

It is in fact not academic. The costs of counting leopard would be very high and generally cannot be justified. In wildlife management nothing is a certainty, and the standard approach of counting animals and then deciding on a harvest doesn't work with many species. More and more wildlife managers have to rely on indirect indices to assess populations. In Wyoming, the US Fish and Wildlife Service cannot count the numbers of deer before setting hunting quotas so they rely on an indirect method to assess the population (Doug Crow, pers.comm). The sex ratio of adults in the field is estimated by direct observations before and after the hunting season. The offtake is predominantly male deer, so that the change in sex ratio can be used to estimate population size. Combined with a simulation model which will predict the population growth before the next hunting season, management can be very precise.

For leopard similar management approaches must be used. Because of the uncertainties involved, active adaptive management (Holling, 1978) becomes very important. Population size can be guessed, and a certain harvest applied. From a simulation model certain characteristics of both the harvest and the remaining population are predicted. By interactive adjustments to both the simulation model and the harvest over a period of time, and by monitoring the sex ratio of animals in the field and the age of those killed, population size may be quite closely estimated.

In rural farming areas where leopard are likely to be eliminated as a matter of policy, there is little point in talking about sustained yields. However, the offtake should be monitored because it may well provide key data for a simulation model of the effects of a high rate of harvesting on the size and age structure of a population, and the thresholds above which offtakes cannot be sustained. The chances of leopard remaining in such areas will be far greater if the major conservation effort goes into the first two sections of this chapter on policy and institution building than in worrying about sustainable offtakes. Only when the farmers themselves realise the value of the leopard is there likely to be an interest in a sustained yield.

We have used our simulation model to examine three different types of harvesting.

Sport hunting: We examined the sex ratio of trophies from 9 different safari operators in Botswana, Ethiopia, Tanzania, South Africa, Zambia, and Zimbabwe and found that it varied from 26 males:0 females in one place to an equal sex ratio in another. The mean ratio from the data is approximately 3 males:1 female. We have built this selectivity into the model for light harvests but the proportion of females rises when the population is heavily exploited. In the model (Appendix 1) the sex ratio of adults in an unharvested population at the saturation density is already in favour of females (2 females:1 male). We have also built into the model a slight selection by hunters for body size ([Age-2] to the power of 1.33).

Trade hunting: We have assumed that only adults (animals older than two years) are hunted for the trade (the skins of juveniles are too woolly).

Control: All animals in the population are harvested on control including juveniles. This would simulate the effects of (say) a poison campaign, which should take animals in the proportion in which they occur in the population.

In all the simulations it is assumed that the cubs belonging to any breeding female who is killed will also die. Under control killing the situation is a little more complicated. A poison campaign would cause the deaths of many cubs directly and it would be wrong to assume an additional number of cubs dying for every adult female killed - presumably some of the adult females killed will have died with their cubs. We have assumed that only half of the adult females who are killed on control will have cubs which must die in addition to the cubs killed directly.

The maximum sustainable offtakes are very much dependent on the saturation densities at which the populations are specified to exist. This is a result of our assumption that populations have lower intrinsic growth rates in more arid environments. Whilst the assumption may or may not be true (see discussion in Appendix 1), it does have the benefit that the predicted offtakes will tend to be conservative.

The intrinsic growth rates ( $R_{max}$ ), and maximum sustainable offtakes for the three forms of harvest (Sport hunting -  $H_{max}$ , Trade -  $T_{max}$ , Control -  $C_{max}$ ) are given on the next page. It is important to point out that the population cannot stand the given harvest if it is suddenly applied at the

maximum rate (a "step-function"). Although a high harvest causes the population survival to improve to the maximum permitted values, it takes three years for the results of this improved survival to produce more breeding adults. This three year period is critical in setting the initial harvest level, which should not exceed about 80% of the final level.

#### MAXIMUM SUSTAINABLE HARVESTS

Density	.001	.002	.005	.01	.02	.05	.1	.2	.5	1	/sq.km
Rmax	3.3	4.7	6.4	7.8	9.2	10.9	12.2	13.7	15.5	17.0	%
Hmax	6.3	7.7	9.4	10.9	12.0	13.8	15.0	16.3	18.0	19.1	%
Tmax	3.4	4.7	6.4	7.8	9.2	10.9	12.2	13.7	15.5	17.0	%
Cmax	3.0	4.4	6.0	7.2	8.5	10.0	11.3	12.6	14.2	15.8	%

It will be noticed that at any given density the highest harvest is obtained from sport hunting. This is because of the selection for males which has a minimum effect on the breeding success. Leopard are solitary animals and we have no evidence that the killing of a territory-holding male has any effect on the survival of cubs living in the vicinity. This is unlike the situation with lions, where the cubs of females tend to be killed if the pride male is changed (Schaller 1972).

The sustainable offtakes under sport hunting appear to exceed the intrinsic growth rate of the population. This is an artifact caused by the decrease in the non-breeding segment of the population. There are in fact no more cubs produced per year than when the population is below the saturation density and growing at its intrinsic growth rate. However, this number of cubs is being produced from fewer total adults in the population and so the growth rate is higher.

The trade hunting offtakes match the intrinsic growth rates of the population exactly. It might be thought that, by the same reasoning as for sport hunting, if adults only are being killed it should be possible to exceed the intrinsic growth rates very slightly. This doesn't occur because of the additional number of cubs dying each year when their mothers are killed.

The maximum control hunting offtakes are substantially lower than either those for trade or sport hunting. Here, too, it might be expected that with all animals being killed in exactly the proportions in which they occur in the population it should be possible to take off an amount equal to the intrinsic growth rate. Again it is the effect of extra cubs dying which prevents this.

Myers (1976) discusses sustained yield harvesting without giving any figures. He states that a "truly random crop might be the most satisfactory outcome from a biological standpoint, since it would spread the pressure as widely as possible." The results above do not support this conclusion. It is better to harvest adult males since this gives the highest sustainable offtake and causes the least damage to the breeding sector.

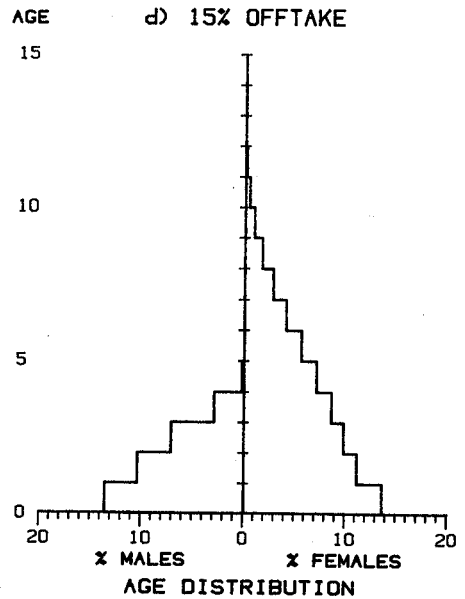
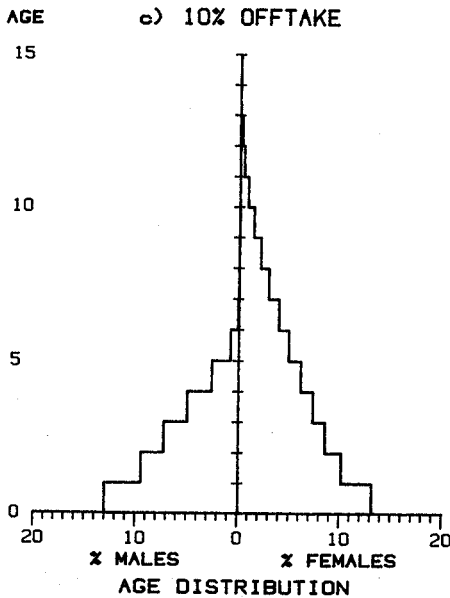
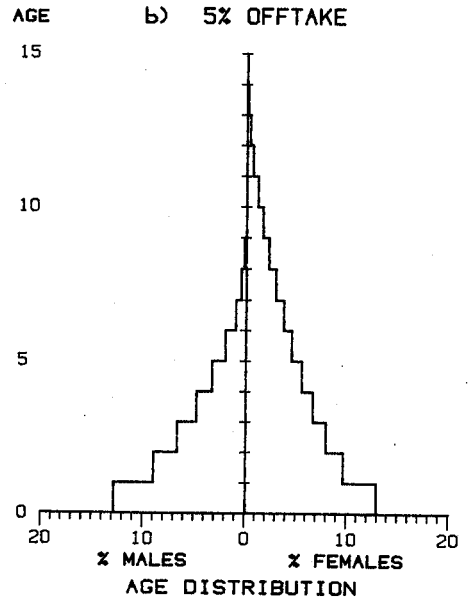
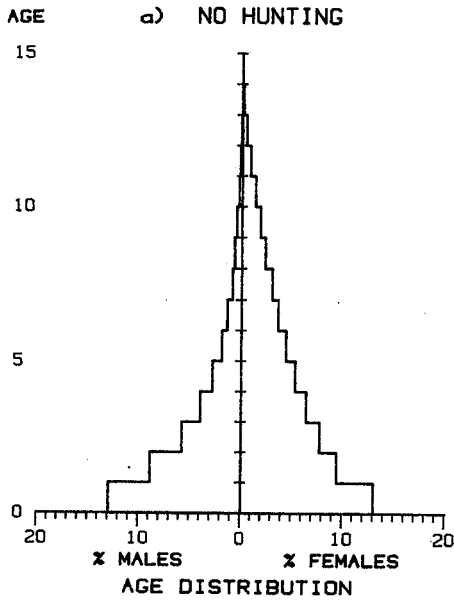
We emphasize that all of the above harvests cause no decrease in the density of leopard populations according to our complete compensation model. Only if they are exceeded does the population crash. There are no intermediate equilibrium levels at various rates of harvesting. However, to say that the population remains exactly the same is not correct. There are significant changes in the population age structure as hunting offtakes are applied.

In Chapter 2 we compared the current estimated offtakes in all countries with a "safe" potential harvest. We now enlarge upon this. In Fig.8 we show the effects of three different sport hunting offtakes on a population at a saturation density of 0.1 leopards/sq.km. In the unharvested case, there are about 7 adult males over 10 years old in a population of 1,000 leopard, and the ratio of adult females to adult males is 2:1. A 5% harvest results in an offtake of 50 leopard per 1000 in the ratio of 3 males:1 female. There are still a few males reaching an age of ten years. When the harvest is increased to 10% no males survive beyond 7 years old and the sex ratio of the offtake alters to 2.33 males per female. At a 15% offtake (the maximum) no males survive beyond 5 years old and the sex ratio of the offtake drops to 1.22 males per female.

We would regard it as desirable under good sport hunting management to ensure that there is at least a chance of producing the odd male trophy over 10 years old, which presumably would be larger than usual. For this reason we would not recommend offtakes of much higher than 5%, although double this harvest would present no threat to the survival of the population. In hunting for trade and control purposes, the model has no bias towards hunting males. In the real world there are usually far more males killed on control than females partly because of dispersal of non-territory holders, and partly because of the greater wariness of females. From the above table it can be seen that an offtake of 5% is fairly safe under any type of hunting except at very low densities.

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Fig. 8: EFFECT OF SPORT HUNTING OFFTAKE  
ON POPULATION AGE STRUCTURE.



### 3.4 ECONOMIC RETURNS

#### 3.4.1 Value of leopards

In a few rare cases certain leopard may have a high value as tourist attractions. Some people travel to Akagera National Park in Rwanda, Serengeti in Tanzania and the Masai Mara in Kenya especially to see leopard. It is difficult to put a value on such leopard, but if we take the case of Londolozi Game Reserve in South Africa which makes a net profit of about US\$250,000 per year and assume that about one fifth of this is due to the guaranteed viewing of a particular female leopard, then this leopard is worth US\$50,000 annually. However, most countries in Africa lose money from tourism when the full costs are taken into account and this would imply negative values for leopard in general.

Apart from a few leopards which are tourist attractions, the highest value arises from sport hunting. We asked safari operators in all countries where leopard are hunted what value they placed on leopard and the figure varied from US\$5,000 to US\$10,000. The higher values come from countries such as Botswana and Zambia where elephant are not available on safari and leopard are one of the main drawcards. The value is not simply the trophy fee which is payable to governments (which is generally about US\$1,000), but rather the gross value to the industry in terms of the hunting days it generates and the foreign exchange earned.

In the analysis which follows we have assumed leopard are worth US\$5,000 each in sport hunting based on their value in Zimbabwe. This has been calculated as the difference between the total cost of a 15 day safari in which the client is entitled to hunt a leopard, and a 10 day plains game safari in which all the other species which were present in the 15 day safari are included except the leopard. Five additional hunting days can be attributed to the leopard and, at a daily rate of about US\$500 per day plus the trophy fee of US\$1000 (when it is resold by the operator to the client with his mark-up on the government price) plus an allowance for additional foreign currency earned on the safari, the total value very easily reaches US\$5,000.

The bulk of Africa's leopard will never achieve this value because they are located in areas where tourism and sport hunting are unlikely to become major industries - particularly those living cheek-by-jowl with rural farmers in heavily settled areas. Governments have the option of making them valueless or realising the current trade prices for leopard skins.

The highest prices we are aware of are those implied in a report from Tom Milliken from Japan (TRAFFIC [Japan] 1984) where some leopard skin coats sold for US\$72,000 in 1980-81. Assuming 6 skins per coat and a 400% mark-up in producing the finished product, this would place a value of US\$3,000 on a single skin. Such prices no longer apply and we assume from the article that the price for an African leopard skin is now nearer US\$500. In Zimbabwe leopard skins are on sale in tourist shops for up to US\$2,500 but not a large number are being sold at this price. Most people involved in the trade put the value of a well-cured leopard skin on a felt backing with a head mount at about US\$1,000. Botswana Game Industries buy raw skins at about US\$100 and sell a well-prepared head-mount skin at about US\$500. Elsewhere in Africa prices are very much lower. In the illegal trade Burundi merchants buy raw skins at about US\$100 each, in Somalia they sell for about US\$100 and in Ethiopia they are worth less than US\$50. The International Fur Trade Federation (IFTF 1987) advise that US\$200 would be a fair price for raw skins in large quantities if the market were to be re-opened. In the analysis which follows we have assumed that governments could sell properly tanned skins at about US\$750 each.

#### 3.4.2 Economic potential

We have calculated the returns which might be possible from exploiting leopard in sub-Saharan Africa using the "safe" potential harvests given in Table 3 which were based on an offtake of 5% of leopard outside protected areas. In order to make the analysis realistic we have gone through the following steps to produce the final totals in Table 4 overleaf.

- a) All countries with leopard populations estimated at less than 1000 animals have been excluded.
- b) It has been assumed that if additional sport hunting were available, the new market would be unlikely to exceed about four times the size of the current offtake (750 animals). At present there is a high demand for leopard on safaris but we suspect that the demand could probably be satisfied with double the present number of leopard available and to double the market again would require some aggressive marketing. On the basis of this we have assumed that a maximum of 3,000 additional leopard could be sold on sport hunting.
- c) We have allocated these leopard to countries in proportion to the size of the potential harvest for the country concerned. We have assumed that those countries with the advantage of an established sport hunting industry would be able to secure their proportion in addition to the animals they are already hunting.

TABLE 4: ESTIMATED POTENTIAL RETURNS FROM LEOPARD EXPLOITATION

COUNTRY	FINAL POPULATION Nos	POTENTIAL HARVEST Nos	SPORT HUNTING Nos	TRADE HUNTING Nos	SPORT HUNTING US\$	LOCAL PAYMENTS US\$	GOVERNMENT SALES US\$	TOTAL RETURNS US\$
ANGOLA .....	62,486	3,056	293	2,763	1,465,000	690,750	1,381,500	3,537,250
BENIN .....	492	24						
BOTSWANA ...	7,729	261	105	156	525,000	39,000	78,000	642,000
BURKINA FASO	1,693	63	6	57	30,000	14,250	28,500	72,750
BURUNDI ....	495	19						
CAMEROUN ...	41,896	1,878	177	851	885,000	212,750	425,500	1,523,250
CAR .....	41,546	1,874	207	834	1,035,000	208,500	417,000	1,660,500
CHAD .....	3,125	155	15	140	75,000	35,000	70,000	180,000
CONGO .....	32,394	1,476	139	669	695,000	167,250	334,500	1,196,750
DJIBOUTI ...	25	1						
EQ. GUINEA .	5,040	235	22	107	110,000	26,750	53,500	190,250
ETHIOPIA ...	9,782	403	63	340	315,000	85,000	170,000	570,000
GABON .....	38,463	1,694	160	767	800,000	191,750	383,500	1,375,250
GAMBIA .....	33	1						
GHANA .....	599	76						
GUINEA .....	1,569	76	7	35	35,000	8,750	17,500	61,250
GUINEA BISSA	341	17						
IVORY COAST.	9,522	371	35	168	175,000	42,000	84,000	301,000
KENYA .....	10,207	259	24	235	120,000	58,750	117,500	296,250
LESOTHO ....	420	20						
LIBERIA ....	503	20						
MALAWI .....	4,530	170	31	139	155,000	34,750	69,500	259,250
MALI .....	3,365	167	16	151	80,000	37,750	75,500	193,250
MALITANIA .	230	11						
MOZAMBIQUE .	37,542	1,779	168	806	840,000	201,500	403,000	1,444,500
NAMIBIA ....	7,745	332	81	251	405,000	62,750	125,500	593,250
NIGER .....	454	21						
NIGERIA ....	9,481	398	38	180	190,000	45,000	90,000	325,000
RWANDA .....	388	11						
SENEGAL ....	781	23						
SIERRA LEONE	280	10						
SOMALIA ....	2,123	79	7	72	35,000	18,000	36,000	89,000
SOUTH AFRICA	23,472	1,050	149	451	745,000	112,750	225,500	1,083,250
SUDAN .....	22,035	853	81	386	405,000	96,500	193,000	694,500
SWAZILAND ..	805	40						
TANZANIA ...	39,343	1,827	332	748	1,660,000	187,000	374,000	2,221,000
TOGO .....	254	10						
UGANDA .....	4,292	147	14	133	70,000	33,250	66,500	169,750
ZAIRE .....	226,192	10,400	982	2,355	4,910,000	588,750	1,177,500	6,676,250
ZAMBIA .....	46,369	2,075	321	877	1,605,000	219,250	438,500	2,262,750
ZIMBABWE ...	16,064	710	267	443	1,335,000	110,750	221,500	1,667,250
TOTALS .	714,105	32,092	3,740	14,114	18,700,000	3,528,500	7,057,000	29,285,500



- d) We have allocated the balance of the potential harvest to trade in leopard skins.
- e) This potential harvest **should** be taken off evenly in the proportions in which leopard occur in the various vegetation types from which the estimates were calculated. Where we have doubts that this could be done, either for logistical reasons or because of the vegetation type, (e.g. tropical rainforest), we have halved the offtake for the trade (Cameroun, Central African Republic, Congo, Gabon, Guinea, Ivory Coast, Mozambique, Nigeria, South Africa, Sudan, Tanzania, Zambia).
- f) In Zaire, in addition to the above, because of the lack of access to remote areas we have reduced the trade harvest to 25%.
- g) In sport hunting leopard are valued at US\$5,000 each.
- h) We have assumed an institutional arrangement whereby governments buy skins from rural farmers who have shot them on control (and perhaps a few deliberately for the trade) at a value of US\$250. The figure that appears in the column **LOCAL PAYMENTS** has been calculated by multiplying trade hunting numbers by US\$250.
- i) We have assumed that governments could resell the skins at US\$750 each, making a net profit to government of US\$500. The figures in the column headed **GOVERNMENT SALES** has been calculated on this basis.
- j) The total value for each country appears in the final column, with overall totals at the foot of the page.

The total potential return is some US\$29 million made up of US\$19 million from sport hunting, and US\$10 million from the trade.

It could be argued that a significant supply of skins would result in a reduced market value. These figures may be inflated, but not excessively. They must be regarded as opportunity costs which are lost to African countries if they adopt certain conservation policies as opposed to others. Those Western countries which are anxious that Africa protect all leopards at all costs should be prepared to pay these opportunity costs.

One leopard taken on safari is worth more than 20 African cattle - to protect which most leopards are being killed. If a way could be found to return this sum to the cattle owner he might have a different approach to conservation of leopard.

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### 3.5 RESEARCH

The foundations of this report are laid on a number of assumptions which need critical testing.

The relationship between densities and rainfall should be examined, particularly in rainforest and particularly in West Africa. The leopard populations predicted by our analysis are far higher than anyone in these countries would be prepared to concede, yet at the same time we have found no conclusive evidence that the populations are at some other level.

The leopard population model developed for this survey needs testing against real populations. The complete compensation aspect of the model is particularly interesting and its validity can only be established by subjecting a closely monitored population of leopard to two or more different levels of harvesting. If densities remain the same the principle can be accepted as proved. There is a further need to verify the thresholds at which sustainable harvests are no longer possible.

The sort of research that is needed to supplement the management of leopard is not the current type of in-depth biological studies being carried out on large carnivores in certain places in Africa. In several places in this report we have also remarked that it is not cost-effective or necessary to attempt to count leopard. In many countries we have visited we have heard government officials state that they cannot contemplate exploiting leopard because they don't know how many they have. Ironically the same problem does not bother the farmer who is doing his best to eradicate leopard.

The research that is required needs to be very much **applied research** and it should relate to active adaptive management. If a starting estimate of the number of leopard in an area is required, it could be simply taken from the density/rainfall regression in the vegetation type concerned. If leopard are to be exploited then offtakes should be low initially and increased as the manager's confidence grows. At all stages the offtakes should be carefully monitored.

Monitoring should involve recording the sex and physical measurements of animals killed, amongst which should be the length and width of the skull which are perhaps the only reliable measure of trophy size. The most valuable parameter for management purposes is the age of the animal. We have shown in section 3.3 that the age pyramid of the population adopts certain shapes under different levels of harvest and, if the age, sex and number of trophies are known, it is possible to estimate the population

size by working backwards from the age structure. From the data, the selectivity of hunters for particular sizes of animals can also be derived, and the results used to improved the harvesting simulation model.

Hunter effort is another index of the abundance of leopard and should be recorded in terms both of success and number of days spent seeking leopard. Akim Mwenya (Chief Game Warden, Zambia National Parks) has carried out such an analysis for all species involved in Zambian hunting, including leopard. If hunter effort rises between one year and the next it may be an indication of reduced numbers.

Sightings of leopards on hunters' baits is another useful record of abundance in an area. Hunters in the Selous Game Reserve told us that so many leopards came to their baits in any one safari that they were able to pick and choose very carefully to obtain the best trophy for a client. By a process of careful recording of individual leopards on baits, densities in any given area could be deduced - data which this report shows is clearly lacking throughout Africa.

The primary research need is to make an hypothesis about the outcome of a particular harvesting offtake, apply the treatment, measure the response and revise the initial hypothesis before applying the next treatment. Alternatively, the next treatment should be applied in such a way that it will answer the questions that previous treatment did not.

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Concluding remarks

In this chapter on leopard management we have discussed policy, institutions, sustainable offtakes, economic returns and research. Of these, we regard questions of policy and the building of institutions as by far the most important. The illegal trade in leopard skins has flourished in the past because of unworkable policies and a lack of any sensible legal arrangements to cater for a wildlife product that will inevitably be available for trade. The solution to this, as seen mainly by persons outside Africa, has been to kill the demand for the product.

There are vastly differing perceptions among the various parties interested in the fate of leopard as to the future of conservation in Africa and the methods which will be used to secure that future. We have found that not only does the northern hemisphere not understand Africa, but even within the continent there is a very limited appreciation by any one country of the problems in another.

In Rwanda we were told very forcefully (Monfort, Vandeweghe, pers.comm) that wildlife cannot compete with agriculture, and that the only grounds for conservation are aesthetic. (Later it was conceded that perhaps wildlife utilisation has a place in the low rainfall parts of Africa). However, they felt that Rwanda should be taken as the future model for Africa where wildlife will survive in national parks only and the remainder of all countries will be devoted to raising crops and domestic livestock.

This view seems to be shared by many people including most of the major development agencies giving aid to Africa. Wildlife management is not thought of as a land use which competes with livestock and agriculture. Rather game is preserved for its aesthetic values in designated areas and if it earns any money it will be through tourism. And yet the terms of trade for agriculture and livestock production have never been worse for Africa than they are at the moment. There is a grain surplus in the northern hemisphere and nobody wants Africa's beef. It is taken as a concession under aid agreements and it will join stock piles in Europe. This is a clear case of aid money being used to promote a failing industry at the expense of a more promising one - wildlife exploitation. One commodity which Africa does possess with which it can compete exclusively in export markets is its wildlife.

Recent work (Clarke et al. 1986) showed that well-managed multi-species indigenous wildlife systems could outcompete domestic livestock in most of the areas which development agencies regard as potential cattle pasture. When wildlife is managed for a combination of sport hunting, game cropping and live animal sales, and secondary industries are based upon this exploitation, the returns may be double those from the livestock industry. These returns are also largely in the form of foreign exchange.

To cut the leopard out of such systems because it is mistakenly thought of as a "special animal" is to disadvantage the wildlife industry in its competition with other forms of land use. Myers (1976 p72) recommended a moratorium on all forms of leopard exploitation until CITES was well established and the appropriate controls on the trade could be introduced. Myers views the situation of one in which external controls are imposed on Africa by a wise external body. Elsewhere, Myers (1980b p4) has said that because of the inability of Africa to manage its wildlife resources, it is essential that the west should not countenance any exploitation of leopard until the conservation scene in Africa improves.

It is precisely this sort of attitude which estranges African governments and does untold damage to those pilot projects where wildlife industries are working. It should be clearly understood that "saving" wildlife in Africa is a race against time. Any sort of moratorium of the sort proposed by Myers is helping to lose that race.

We, too, are fairly unimpressed with the standard of wildlife management we have seen in most African countries. One of us has had the opportunity to compare the situation in 1984/85 with the present situation, and sees little cause for optimism. But we do not see any solution through paternalistic controls imposed by the northern hemisphere. More serious in our view than bad wildlife management is the set of antiquated policies being followed in most countries which they feel will meet with Western approval. Unless there is some original thought coming from African policy makers themselves, we cannot see the present wildlife scene improving. Perhaps wildlife management would improve if all staff in wildlife agencies did not feel that they belonged to second-rate ministries, and were really given original policies to implement which met with the approval of their own public. They might then be highly motivated.

Most strongly of all we feel that rural peasants are not going to take matters of wildlife management seriously until, firstly, they are aware of the values and, secondly, they can legitimately get a personal share in those values. To achieve this requires some new approaches on the part of African governments.

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#### 4. RECOMMENDATIONS TO CITES

##### 4.1 WHICH APPENDIX ?

In this section we present the arguments for and against the retention of the African leopard on Appendix I of the CITES. We assume that if it is not retained on Appendix I it will be reclassified to Appendix II of the Convention. There may be arguments for it to be removed from the CITES appendices altogether, but we do not think the time has come to consider this eventuality.

Article II, paragraph 1 of the Convention in International Trade in Endangered Species of Wild Fauna and Flora states:

Appendix I shall contain all species threatened with extinction which are or may be affected by trade. Trade in specimens of these species must be subject to particularly strict regulation in order not to endanger further their survival and must only be authorised in exceptional circumstances.

The key issue here is whether the species is **currently threatened with extinction**. The text is unambiguous. At a first glance it might be thought that if the species status is likely to be affected by trade there may be grounds for placing it on Appendix I. This is not correct. The species must be threatened with extinction before it qualifies for inclusion on Appendix I. If its status is presently satisfactory but there is a possibility that trade might jeopardise this, then it belongs on Appendix II.

Appendix II includes two categories of species: those which are not necessarily threatened with extinction now, but which might become so if the trade is not regulated, and those which are not threatened at all but nevertheless should be included because of their similarity to certain other species which could be threatened by trade.

Party States to the Convention and observers at the Conference of the parties may present a number of arguments for or against the listing of leopard on Appendix I. The main issue at stake is whether or not the leopard in sub-Saharan Africa is threatened with extinction. If it is not, then we view this as a **necessary and sufficient condition** for the African population of the species to be moved off Appendix I.

Our estimate for the number of leopard in Africa is 700,000 (subject to certain assumptions which have been discussed). The confidence intervals on our analysis suggest that it is unlikely to be less than 600,000 or more than 900,000. The figure lies between Eaton's (1978) "conservative" estimate of about a half-million leopard and his "realistic" estimate of about one million, but an independent technique has been used and we believe it has been more rigorously derived. The estimate indicates an average density of about one leopard in 30 sq.km over Africa as a whole.

When it is considered that the animal is a carnivorous predator at the top of the food chain, this density is very high indeed. **The species is not threatened with extinction.**

The discussion should end here. However, since it undoubtedly won't at the CITES Meeting of the Parties, we will consider a number of secondary arguments on the subject. These can be divided into two groups.

**A: Arguments in favour of retaining the leopard on Appendix I**

1. To protect other "look-alike" species which are threatened.
2. The principle of "positive listing".
3. The existence of locally threatened leopard populations in Africa.
4. The threat of a resumption of the fur trade if removed from Appendix I.

**B: Arguments in favour of removing the leopard from Appendix I**

1. Appendix I should list only endangered species.
2. Appendix I listing is damaging to developing wildlife industries.
3. The Convention is compromised by having "quotas" on Appendix I.
4. The costs to producer countries.
5. The credibility of the Convention.

**A1: The "look-alike" issue**

It can be argued that the African leopard is only one of a group of spotted cats, and that many other species may not enjoy as healthy a conservation status. If trade is affecting the Snow leopard, the Clouded leopard and the jaguar on other continents is this not a good reason to keep the African leopard on Appendix I ? There may be a danger that any legitimate trade in leopard skins might provide the opening whereby skins of these rarer species find their way onto commercial markets. Article II of the convention provides for Appendix II status of common animals which fall into the category of the African leopard in such cases.

We are aware that the "Berne" criteria (Conf. 1.1) provide for the inclusion of species which are not endangered on Appendix I if the majority of species in the genus are endangered. However, we would argue that it would be a misapplication of Conf. 1.1 to insist that the African leopard remain on Appendix I because of the questionable status of certain other leopard species or sub-species. Firstly, recent evidence suggests that many of the Asian and South American *Panthera* are far more numerous than had been suspected at the time of the Washington Convention (1973). Secondly, the African leopard dominates the genus by very large orders of magnitude, and it would be allowing "the tail to wag the dog" to ignore this. Thirdly, whilst the original intentions behind Conf. 1.1 in including complete genera on Appendix I may have been laudable, ten years of operation of the Convention have shown that the system is often highly biased and impractical. The original provisions of Article II of the Convention are better applied in this case.

#### A2: Positive listing

The persons who have ultimately to implement the provisions of CITES are customs officers. Already the Appendices of the Convention are extremely large and it requires expert advice for many customs officers to carry out their task. The principle on which "positive listing" works is that it is simpler for all spotted cat skins to be treated as Appendix I species in which trade is normally prohibited. We are in favour of making it easier for customs officers to implement the Convention. Our concern is that, as a result of it, legitimate wildlife traders are disadvantaged with bureaucratic controls which don't affect illegal traders or the other livestock industries against which wildlife is competing.

#### A3: Threatened leopard populations within Africa

Certain leopard populations in West Africa are reported as being endangered, although we found no convincing evidence to support the supposition. It must be acknowledged that most wildlife in West Africa does not have a secure future, largely because of the pressure of human numbers. The Convention provides for Parties to unilaterally prohibit exploitation and/or trade in an Appendix II species and, indeed, this mechanism is presently used by many countries. It would be a misuse of the Convention to list a species on Appendix I if it were locally endangered in a small part of its range. The best view we heard on this subject came from the Director of Game and Wildlife in Ghana who, whilst far from happy with the status of leopard in his country, saw the problem largely as matter of internal conservation rather than something CITES could address through trade controls.



A4: The threat of the fur trade

The question of whether the fur trade could ever again reach the levels of 1967-1973 is one which bothers CITES Party States. Statements such as "RECOGNISING the overwhelming desire of the Parties that the commercial market for leopard skins should not be reopened;..." (Conf.4.13) are common in the preamble to CITES resolutions on leopard. Before considering whether the threat still exists, perhaps we should examine just how bad the threat was.

We have used a population model to simulate the effects of the exploitation to which leopard populations were subjected from 1950 to the present date (Section 2.1). Our conclusion is that had the impact been spread evenly over the entire continent the peak of the harvest would have had a negligible effect on the African leopard population. As it was, only two regions in Africa could have suffered as a result of this harvest. In North Africa and East Africa had it been possible to sustain the level of harvest on leopard for any length of time there certainly could have been local extinctions. However, our simulation leads to the inescapable conclusion that either the offtake was not as high as people would represent it, or the numbers of leopard were very much higher than thought in the first place. The irrefutable proof of this is that leopard are not extinct, even locally, in the regions concerned. Most African countries were relatively untouched by the exploitation at the height of the fur trade and those populations which were most heavily exploited have recovered since 1975.

Past history does not determine Appendix I status. To be included in Appendix I, a species requires to be currently threatened with extinction. If the trade could threaten it in the future it should be on Appendix II.

We are not sure whether a vast leopard skin trade could ever re-emerge. There is a much more important question to be asked here. Does CITES work or doesn't it? In the case of the leopard skin trade it is difficult to answer that question, because CITES had little to do with the collapse of the fur trade. A far more powerful force, **public opinion**, was responsible. The fur trade was virtually over before the first meeting of the Parties to CITES in Berne in 1976.

Those who fear the emergence of a second boom in the leopard skin trade are more or less stating that they doubt the ability of the Convention to contain it unless the species retains its Appendix I status. But it is not the Appendix I status of leopard which is limiting the fur trade - it is the lack of a market. Most illegal traders with whom we spoke felt that if

there were a market for leopard skins they could satisfy it immediately - CITES or no CITES. We are inclined to believe this when we see the ease with which so-called trade controls are evaded for rhino horn and many other Appendix I species. There is little difficulty in getting illegal leopard skins into Europe as we learnt firsthand. If this is the case then surely neither Appendix I status nor Appendix II status matters.

It is doubtful if the present official ban on commercial shipments of leopard skins being maintained by governments in Western countries is a major factor in leopard conservation. The public itself decides what it finds acceptable. Notwithstanding their Appendix I status, leopard are being killed at a high rate wherever they run counter to human interests in Africa. All that has been achieved is to make their products worthless, which will not reverse the killing process in African rural areas.

The Convention is based on the prior fact of trade and not the ethics of whether there should be trade. The key role of the CITES is to monitor the legitimate trade in Appendix II species and sound the warning bells if the trend in trade starts to threaten a species' survival. By adopting policies which promote illegal trade or inhibit effective monitoring this vital role is compromised.

By the far the most serious implication of this discussion of the fur trade is the workability of the Convention, and the relative effectiveness of trade measures for species on Appendix I and Appendix II. We return to this topic later when discussing the credibility of the Convention.

#### **B1: Use of Appendix I**

Amongst the participants in the CITES forum are different perceptions of the function of Appendix I. Some regard each new species added to Appendix I as a conservation victory. Others see additions to Appendix I as evidence of yet one more conservation failure. It is easier to get species included in Appendix I than it is to get them removed. In the case of leopard, the decision to include the species on Appendix I was taken at the Washington Convention in 1973 by a group of people which did not include representatives of many African countries.

The Convention has become unwieldy with the large number of species listed on Appendix I. If customs officers are to implement the Convention effectively then the list should be reserved for animals that really are on the brink of extinction - and likely to be pushed over the brink by trade. To compare the status of the black rhino, for example, with that of leopard highlights the rather ludicrous state to which Appendix I has been reduced.

The rhino really is threatened (and Appendix I listing has not arrested its decline) while the leopard is a common animal. The Convention can only be weakened by such paradoxes.

We have heard the view expressed that it is most unwise to tamper with the list of species on Appendix I because this will only cause confusion in the minds of the public. One minute the biologists are saying that an animal is endangered and the next they are saying that it is not. This is not a valid excuse for a wrong decision. The public are not idiots and will judge any well-reasoned case on its merits. It is dishonest to cry "Crisis!" when none exists.

#### **B2: The disadvantage to developing wildlife industries**

In the concluding remarks to Chapter 3 we discussed the situation which exists in many parts of Africa where the wildlife industry is competing as a land-use with domestic livestock industries. For its success it relies on sustained exploitation of a wide range of species. It is a disadvantage if any species are not available for exploitation, particularly for artificial reasons.

#### **B3: Compromising the Convention with quotas on Appendix I**

Article II of the Convention states clearly that trade in Appendix I species should only be authorised in exceptional circumstances. Legal trade in leopard skins is occurring at the moment under circumstances which are not exceptional. This arises as a result of quotas which were granted to certain countries at the 4th meeting of the Parties to the Conference, and revised at the 5th meeting in 1985. These quotas have given rise to the uncomfortable situation that certain types of trade are acceptable (such as animals sold to be hunted by sportsmen or single skins bought as souvenirs by tourists) but others are not (such as more than one skin bought by a commercial dealer). The quotas permit the movement of leopard trophies and leopard skins without the very stringent controls specified in Article III. The politics of this were discussed in the introduction to this report and will not be repeated here.

The *de facto* situation has arisen where the Conference of the Parties recognises that there is no sound basis to prevent the export of hunters' trophies and some skins, but rather than reclassify the species to Appendix II, the current situation is a compromise. Unfortunately it is a compromise which acts contrary to the spirit and letter of the Convention and lowers the very special status which Appendix I accords other species. It is a strong argument for placing the leopard on Appendix II.

**B4: Costs to producer countries**

A realistic estimate of the opportunity costs for not exploiting leopard legitimately and rationally in Africa are of the order of US\$30 million per annum (3.4.2). These costs are being borne by Africa, not by the conservation lobby who wish to see the leopard on Appendix I. Even the CITES Management and Scientific Authorities from Africa who vote on the issue at the Meeting of the Parties are not necessarily the disadvantaged parties, for they are not the prime economic risk-takers. The end effects will be felt by legitimate wildlife ranchers and rural people. The advantage is all to the illegal trader.

**B5: Credibility of the Convention**

In A4 above we touched on the topic of whether CITES works or doesn't. Perhaps it is worth reviewing a few key developments which affect the leopard issue.

In the late 1960s and early 1970s a vast trade in leopard skins was taking place out of Africa. There was no CITES at this time. Myers (1976) recommended a moratorium on all exploitation of leopard in Africa. The United States added the leopard to their list of Endangered species in 1972 and at the Washington Convention in 1973 the leopard was included in Appendix I of what was to become the CITES in 1976. The fur trade collapsed in 1973-75 as a result of public opinion. CITES grew in strength and is now well established in 1987. The question has arisen whether the leopard should be moved to Appendix II of CITES. The arguments against this move are based mainly on the perceived effects of the fur trade 15 years ago.

But things have changed. We now have the controls which were lacking 15 years ago, and we have gone through the moratorium recommended by Myers. If CITES works then the controls on trade in Appendix II species should work as well as the controls on Appendix I species. From the tone of the arguments it is clearly apparent that a lot of people don't believe that they do. What is the difference ?

The difference lies in the the provisions of Article III and Article IV of the Convention. Trade in Appendix I specimens requires the approval of the Scientific and Management Authorities in the importing country, notwithstanding any blessing given by the exporting country. For species on Appendix II, only the Scientific and Management Authorities of the exporting country are involved: in the importing country there is no need for customs officers to refer matters to their Scientific and Management Authorities.

So in effect, those who say that Appendix I status is vital for the leopard are saying "We don't trust the Scientific and Management authorities in Africa. We need the extra control given to us under the Convention to be able to reverse any of your decisions if we think fit."

In the introduction, we explained that the main underlying motive of the African countries which sought and obtained quotas was to lift the yoke of the Scientific and Management Authorities outside Africa. We emphasize now that the only possible reason for refusing to place the leopard on Appendix II must be seen as a distrust of African CITES Authorities.

Many people have criticised the official bodies responsible for wildlife management in Africa (e.g. Myers 1980a, Hamilton 1981, Martin 1985 and this report) and much of the criticism is justified. But we would hasten to disabuse anyone of the notion that the problem can be rectified by withholding the right to trade under the Convention. CITES should be founded on mutual trust and diplomatic recognition of all accredited representatives, without which there is no basis for agreement. We share the frustrations of those who are desperately anxious to see an end to abuse of wildlife, but we do not believe that anything constructive will be achieved by playing politics with the CITES Appendices. If the Convention is to work, then decisions should be based on the best technical information.

The technical basis for removing the species from Appendix I can be argued indefinitely without any resolution between parties with entrenched viewpoints. This argument could be greatly reduced if the arguing parties recognised that there is a point where technical matters cease and aesthetic decisions take over (Bell 1983, 1984). There is nothing to be ashamed of in stating that ultimately the idea of exploitation of leopard is repugnant. This argument carries far more weight with us than any of the so-called technical reasons why the leopard should be on Appendix I. However, the decision-maker using this as his final argument should be well aware of the implications, practicalities and costs of his decision. As far as possible, the CITES forum is meant to be totally objective over matters of trade and extinction.

Many countries have expressed the view to us that to leave the leopard on Appendix I with quotas is not a major hardship. It will not prevent them from exporting hunters' trophies or the occasional skin, it has the benefit of "positive listing" as discussed above, and it satisfies those who feel very strongly on emotional grounds that the species is deserving of the highest protection. However, they feel fairly strongly that quotas should be set by themselves and advised to the CITES Secretariat for notification of all parties.

We feel bound to advise that whilst the above approach is realistic, it is not the solution to the problem. There is a principle involved which, if ignored, can only harm CITES. If species which are not endangered continue to be listed on Appendix I, the Convention will be weakened and cease to fulfil its original function.

To summarise this section: the leopard is not threatened with extinction and therefore does not qualify for Appendix I status.

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#### 4.2 NECESSARY CONTROLS

##### Quotas

This section is written on the assumption that the species moves to Appendix II. At present, trade in leopard products is permitted on Appendix I to those countries which have quotas for the purpose. We would point out that quotas are not strictly necessary: provided the Scientific and Management Authorities in both the exporting and importing country approve the transaction, the export can take place (e.g South Africa has no quota for leopard but still exports hunting trophies on this basis).

In the normal course of events, there is no need for any species to be subject to the restrictions of a quota if it is on Appendix II. Conf. 5.21 provides for the transfer of species from Appendix I to Appendix II without the strict criteria of Conf. 1.2 provided quotas are imposed on the species when it assumes Appendix II status. We regard this as a resolution only to be used in rare interim situations: if it were applied in all cases it would result in a large number of Appendix II species not subject to the provisions of Article III of the Convention. It more or less precludes the admission that any species was ever wrongly placed on Appendix I or that a species status may have changed since it was placed on Appendix I.

Quotas were introduced at the last Meeting of the Parties in Buenos Aires in 1985 for the first time for an Appendix II species to control the trade in ivory. Since their introduction many people have claimed all manner of abuses resulting from them, but these criticisms result mainly from the amnesty which had to be declared to allow all existing stocks of ivory to be legally registered - whether they were legally obtained or not. It is difficult to see how the ivory unit at the CITES Secretariat could have functioned without this declaration of ivory by all owners, since the effectiveness of the quota system relies on being able to monitor all new tusks entering the trade.

By far the most important function of the quota system for elephant is to encourage African wildlife departments to reconcile the ivory which leaves their countries with their own stated management policies. The anomaly at the moment in the management of elephant in Africa is that the types of management policy which most countries profess to be following could not lead to the large number of tusks entering the market. If the quota system addresses this question it may have done some good.

By the same token there is merit in retaining the concept of quotas for leopard on Appendix II. Provided these quotas are not an imposition by other countries on African producers, the approach should be encouraged as positive management. Most countries know well in advance each year how many leopard they intend to allow to be shot for sport hunting so that it is not difficult to determine at least this aspect of the required quota.

The remainder of the quota could arise in several different ways depending on the internal policies of the country. If it is Government staff who do the control shooting of leopard, an estimate can be made based on previous experience. If farmers are allowed to carry out their own problem animal control and sell the skins then quotas can be based over a number of years on the demand for tags. If most skins come from confiscation, then again past figures are a guide. However, we do not favour those systems where confiscation is the primary source of skins: it cannot be called "management" of a species.

We strongly urge governments to implement policies such as Botswana's towards problem leopard in rural areas at the time of embarking on any quota system. This eliminates the illegal trade and does not result in undue exploitation.

The quota should not be seen as an exact estimate of the number of leopard which will die in the year concerned. Apart from sport hunting, this is impossible to predict. Rather it should be the maximum number of leopard which the authorities would be regard as being a safe harvest from the population. Above this number there would be concern if more leopard were killed (note that this concern would come from the producer countries themselves, rather than anyone else). There is no obligation to fulfil the number of skins stated in the quota.

Notwithstanding the provisions of Conf. 5.21, we can see no reason for the quotas to be granted by the Meeting of the Parties to CITES. As in the case of elephant, these quotas should be advised to the Secretariat and the Parties duly notified. If a country decides to increase its quota at any stage this too should involve no more than a letter to Secretariat advising them of the new quota.

### Marking Systems

The main function of a tagging system is as a double check on fraudulent export certification. We favour retaining the present system of locking tags for export of leopard skins. These tags should be issued by the CITES Secretariat in response to any country's request for a quota or for an increase in its quota. It is debatable whether quotas are necessary at all if the tags are recognised throughout the world as the authentic seal of approval of the Scientific and Management Authorities in the exporting country.

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### **4.3 VIEWS OF AFRICAN COUNTRIES**

It would be extremely tedious for us to repeat in full the subject matter of the interviews we held with the wildlife authorities in each of the countries we visited on the question of the Appendix I status of leopard and the controls necessary for the trade. Instead we have attempted to summarise them in **Table 5** which covers all possible contingencies. Because several authorities expressed preferences and second choices we have allocated points in the sequence: 3= Most favoured choice, 2=Second preference and 1=Third choice. We have excluded those countries we did not visit.

The results show that there is a preference for retaining the existing system with the leopard on Appendix I with quotas for those States which require them and a system of tags for all exported skins. The second choice is for the species to be on Appendix II with quotas and tags and the third choice is for Appendix II with no quotas but tags being retained. The combined sum of the second and third choices exceeds those in favour of retaining the species on Appendix I. Very few Authorities believe there should be absolutely no exploitation of leopard (Appendix I without quotas) and none believe that no controls are necessary on Appendix II. A few non-CITES members had no opinion, but stated they did not intend to exploit leopard in their countries. Where certain countries favoured the use of quotas for sport-hunting trophies only we have indicated this.

We support those countries who believe that the leopard should be on Appendix II with quotas and tags for the reasons given in the previous section.

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TABLE 5: VIEWS OF INDIVIDUAL COUNTRIES ON THE PREFERRED CITES SYSTEM

#	COUNTRY	App I	App I QUOTA TAGS	App II QUOTA TAGS	App II TAGS	App II	Ap III	NO. APP.	NO OPINION	NOTES
1	ANGOLA .....									
2	BENIN .....		3						1	
3	BOTSWANA ...			2	3	1				
4	BURKINA FASO*									
5	BURUNDI .....			3	2					
6	CAMEROUN ...		3	2						
7	CAR .....		2	3						###
8	CHAD .....									
9	CONGO .....		3							
10	DJIBOUTI ...*									
11	EQ. GUINEA .*									
12	ETHIOPIA ...		1	2	3					
13	GABON .....		2	3	1					
14	GAMBIA .....									
15	GHANA .....		1	3	2					
16	GUINEA .....									
17	GUINEA BISSA*									
18	IVORY COAST.	2	3							
19	KENYA .....		1	2	3					
20	LESOTHO ...*									
21	LIBERIA ...*									
22	MALAWI .....			2	3					
23	MALI .....									
24	MAURITANIA .*									
25	MOZAMBIQUE .*									
26	NAMIBIA ...*									
27	NIGER .....									
28	NIGERIA ...*									
29	RWANDA .....	3	2							
30	SENEGAL ...*									
31	SIERRA LEONE								3	
32	SOMALIA ....		3	2	1					
33	SOUTH AFRICA		3							###
34	SUDAN .....		3	2						
35	SWAZILAND ...*									
36	TANZANIA ...		3							
37	TOGO .....		3	2	1					###
38	UGANDA .....		2	1					3	
39	ZAIRE .....		3							
40	ZAMBIA .....		1	2	3					
41	ZIMBABWE ...		1	3	2					
TOTALS .		5	43	34	24	1			7	

\* - country not visited

### - sport hunting trophies only

APPENDIX 1

A POPULATION MODEL FOR LEOPARD

Caughley (1985) described the "Complete Compensation Model" as one where population size is unaffected by harvesting unless the rate of offtake exceeds some threshold (in a partial compensation model improved fecundity and survival cannot fully compensate for harvesting). As this concept is likely to be controversial, we will discuss its background. Caughley (op.cit.) states that the origins of the model are obscure, but that Leopold (1933) might have been the first to mention it. Slobodkin (1961) reviews several studies of territorial animals and points out the limitations of the sigmoid growth model for animal populations. Wynne-Edwards (1962) gives examples of breeding and recruitment rates increasing when a population is subjected to culling. Watson & Moss (1970) discuss the principle of compensation in mortality and give examples - e.g. Lowe (1969) claimed that culling largely (but not completely) replaced natural mortality in red deer. However, Watson & Moss (op. cit.) conclude that there appears to be no good evidence that mortality factors and/or changes in recruitment rates compensate for each other exactly in the long term. Wynne-Edwards (1970) discusses the feedback from food resources to population levels and points out that differential mortality exists within many populations of territorial animals between territory holders and those animals which are surplus to the social group. This situation applies directly to leopard. Murray (1979) criticises the logistic model for population growth and points out that models which produce a steady-state population can be constructed without resorting to its use. He further points out (p70) that "a steady-state population is a virtual impossibility in food-limited and predator-limited populations. [Only] the space-limited population can maintain a steady-state because territoriality can limit recruitment at some constant value." Murray (op.cit.) discuss compensation but does not consider complete compensation.

Anderson and Burnham (1976) claimed complete compensation in a study of hunting effects on mallard duck, but Caughley (op.cit) throws doubt on their conclusions showing that their results could just as well indicate partial compensation. Perhaps the strongest evidence we can find to support the complete compensation model for a territorial carnivore is given by Gasaway et al.(1983) in the case of wolves (*Canis lupus*). In their study area in Alaska offtakes of approximately 20% per annum limited wolf numbers. They state that Pimlott et al.(1969) and Van Ballenberghe et al.(1975) found that wolf populations would not increase at harvest levels of about 25% per annum. Keith's (1983) review indicates that wolf numbers do not decline unless harvest rates in excess of 30% are applied.

TABLE 5: VIEWS OF INDIVIDUAL COUNTRIES ON THE PREFERRED CITES SYSTEM

#	COUNTRY	App I	App I QUOTA TAGS	App II QUOTA TAGS	App II TAGS	App II	Ap III	NO. APP.	NO OPINION	NOTES
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7	CAR .....		2	3						###
8	CHAD .....									
9	CONGO .....		3							
10	DJIBOUTI ...*									
11	EQ. GUINEA .*									
12	ETHIOPIA ...		1	2	3					
13	GABON .....		2	3	1					
14	GAMBIA .....									
15	GHANA .....		1	3	2					
16	GUINEA .....									
17	GUINEA BISSA*									
18	IVORY COAST.	2	3							
19	KENYA .....		1	2	3					
20	LESOTHO ....*									
21	LIBERIA ....*									
22	MALAWI .....			2	3					
23	MALI .....									
24	MAURITANIA .*									
25	MOZAMBIQUE .*									
26	NAMIBIA ....*									
27	NIGER .....									
28	NIGERIA ....*									
29	RWANDA .....	3	2							
30	SENEGAL ....*									
31	SIERRA LEONE								3	
32	SOMALIA ....		3	2	1					###
33	SOUTH AFRICA		3							
34	SUDAN .....		3	2						
35	SWAZILAND ..*									
36	TANZANIA ...		3							
37	TOGO .....		3	2	1					###
38	UGANDA .....		2	1					3	
39	ZAIRE .....		3							
40	ZAMBIA .....		1	2	3					
41	ZIMBABWE ...		1	3	2					
TOTALS .		5	43	34	24	1			7	

\* - country not visited

### - sport hunting trophies only

In the main report we have produced some evidence which shows the suitability of the complete compensation model for leopard. In this appendix we restrict ourselves to describing the operation of the model.

Most models for a density dependent population have relied on the Lotka-Volterra curve (Caughley 1977), although Murray (1979) has derived alternative models. In this model, we sought a method which did not rely on the prior assumption of any formal mathematical relationship between the density of the population and its survival.

We felt it would be a mistake to assume too much at the outset in defining the relationship between leopard numbers and breeding parameters, as there are few data on the population dynamics of the species in the wild. We made the assumption that, being territorial animals, leopard would reach a maximum density in any given habitat if they were not exploited. Whilst this density might fluctuate in the short term due to changes in prey availability and other factors, we assumed that there would be a mean saturation density for any given area.

#### PRINCIPLE OF OPERATION

The model uses positive and negative feedback to adjust the survival of the population in order to regulate its density at any given level. We are not aware of any density dependent variations in the fecundity of females which might contribute to the regulating process, although Rabinowitz (1986a) has hinted at the possibility for jaguar and the average size of litters born to leopard in zoos appears to be less than in the wild (see Fecundity later in this appendix). From a modelling point of view it does not affect the outcome whether regulation is achieved through increased mortality or reduced fecundity, or a combination of both - the end result is the same.

Regulation is achieved through the use of a classical control system. Since we are not aware that it has been used before for modelling biological populations, we will describe the principles in some detail.

The function controlling the amount of feedback which is applied to regulate the population has the following form:

$$F(E) = K_1.E + K_2.dE/dt + K_3.\int E.dt \quad \dots\dots\dots (A)$$

where E is the error (or difference) between the saturation density and the actual density of the population, t is time, and K<sub>1</sub>-K<sub>3</sub> are constants which determine the nature of the feedback response.

The effect of each of the terms in the relationship is discussed below:

- a) The error ( $K_1.E$ ): This term provides feedback proportional to the error between the desired control level and the actual level. In biological terms it can be thought of as an energy surplus or deficit which will cause the population to increase or decrease.
- b) The derivative of the error ( $K_2.dE/dt$ ): This term is necessary to damp the response of the population to various perturbations. When the population is below saturation density and increasing rapidly towards it, both the error term and the integral of the error are providing positive feedback which would cause the population to overshoot the asymptote. The overshoot can be anticipated by measuring the rate of change of the population and applying the appropriate feedback. In biological terms it can be thought of as the population's own perception of its status: if numbers are increasing rapidly, this could induce homeostatic responses from individuals in the population before the asymptote is reached. Wynne-Edwards (1970 p422), in discussing the need for adaptive feedback, states that "population limiting mechanisms.....are contrived to operate while food is plentiful and while consumers are in normal health and condition."
- c) The integral of the error ( $K_3.E.dt$ ): When the population is at saturation level, both the error and the derivative of the error are zero and there is no parameter to hold the feedback at the required level. The integral term, which is the sum of all past errors, is not zero when the saturation density is reached and provides the holding control. In practice, this term is implicit in our model. Each alteration in survival is "remembered" so that when saturation density is reached, the survival values which pertain are those immediately following the last adjustment caused by the first two terms before they became zero.

In designing a control system, it is the values assigned to the 3 coefficients ( $K_1$ - $K_3$ ) in relation to the time constant of the system that determine the final response. The time constant of the system is given by the intrinsic growth rate of the population and is a measure of the "speed" with which the population can react to any perturbation. The effects of different choices of constants on the manner in which an increasing population approaches the saturation density are shown in Fig.A1-1. An infinite range of responses are possible, but they can generally be classified into 3 groups. The underdamped situation occurs when there is little contribution from the derivative term and results in an overshoot of the control level. In the critically-damped case constants are balanced in

Fig. A1-1.

DENSITY (/eq. km)

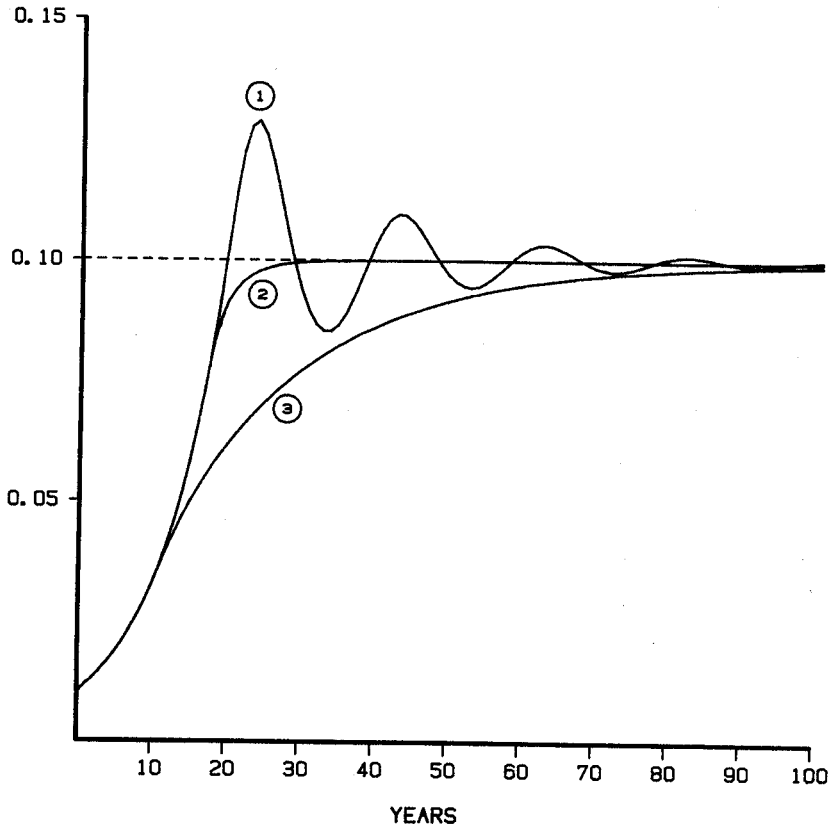


Fig. A1-1: RESPONSES TO CONTROL SYSTEM CONSTANTS

① - UNDERDAMPED	K1=0.1	K2=0.1	K3=1.0
② - CRITICALLY DAMPED	K1=0.3	K2=1.1	K3=1.0
③ - OVERDAMPED	K1=0.1	K2=2.0	K3=1.0

such a way that the population reaches the asymptote in the minimum of time without overshooting. The overdamped case occurs when too little error and too much derivative feedback is permitted. The population takes a long time to reach the desired level and to react to changes thereafter.

We have chosen the constants by trial and error to give a more or less critically damped situation. The constants can be theoretically calculated with the use of Laplace Transforms (standard engineering texts) but we found the iterative process was simpler.

#### MODELLING TECHNIQUE

The model is a modified Leslie Matrix birth-pulse system developed by Martin (1985) for general use on wildlife populations. Instead of using the square matrix of Leslie, numbers of males and females, age specific fecundities and age specific survival values are held in vector arrays. This permits faster array multiplication and the facility to introduce various harvests during each birth-pulse phase. Through a matrix reordering operation we separate male and female births and keep both male and female cohorts in the model which can be subjected to different natural and imposed mortalities. In this application the model runs on an annual cycle and in each cycle the density of the population is measured and the appropriate feedback is applied before the next cycle.

The feedback operates by raising and lowering the age specific survival values. We have set minimum age specific mortalities for both males and females which operate when the population is well below the saturation density, and which are the lower limits to which mortality is allowed to fall. As the population rises towards the saturation density, every age-specific survival value is modified by a multiplier derived from the control formula described in the previous section. When the population is at the saturation density the value of the multiplier becomes unity and survival remains the same from one year to the next. As soon as a harvest is imposed on the population, the control system modifies the survival in a manner dependent on how far from the saturation density the population is displaced. However, mortalities are not allowed at any stage to fall below the minimum values mentioned above.

#### FEATURES OF THE MODEL

The desired saturation density is specified by the user.

The adult sex ratio at saturation density is specifiable in the programme. A control system similar to that described above is used to impose an increased mortality on adult males near the saturation level.

The intrinsic rate of increase of the population has been related to the final saturation density. We have assumed that populations which achieve high saturation densities have higher growth rates than populations which stabilise at lower densities. This is a debatable feature which we will discuss. Cumming (pers.comm.) suggested to us that we should take the possibility into account because the prey biomass is greater in higher rainfall environments (Coe et al. 1976). This should not only lead to higher densities but also higher population growth rates. Western (pers.comm.) suggested that leopards might not attain higher densities in environments such as rain forests because the prey suitability was perhaps not as great as in more arid environments. Western (1983) showed that the mean body size of mammals is greater with increasing production and, if there is a certain optimum prey size for leopard, then the higher rainfall environments might not provide this. V.J. Wilson (pers.comm.), after recent visits to the Ivory Coast rainforest, feels strongly that there is a very large community of prey of suitable size for the leopard in these environments, including many duiker and pygmy antelope species. Mills (pers.comm.) feels there is little data to substantiate the possibility that leopard populations could grow faster in more productive environments.

Part of the problem lies in the fact that, as most leopard populations are at saturation densities, there is no way to measure the intrinsic rate of increase for such a population. We have incorporated the feature into the model simply to be conservative. If it is true, then we will have anticipated it correctly. If not, then little harm will have been done other than to underestimate the potential harvests which might be removed from certain less productive leopard populations.

The model can be subjected to a range of specifiable harvests for sport hunting, trade and control killing, and it can be used to simulate the effects of any sequence of annual harvests. This aspect belongs mainly in Chapters 2 and 3 and will be discussed in another appendix.

#### SPECIFIC VALUES USED IN THE MODEL

##### **1. Age specific fecundities:**

There are few data available for the mean litter size, age at first conception, interval between litters and breeding lifetime of female leopard in the wild. In order to establish fecundities, we have relied on data from the few specific cases in the wild where a female was seen with a young litter and monitored until she produced her next litter.



Since the exact date of birth of cubs is seldom known because they are kept hidden in the wild until they are several weeks old, we have taken the dates between first sightings to establish interbirth intervals. If there is a discrepancy in the size of cubs at the time of the two first sightings we have made an allowance. Frequently cubs may die unrecorded in the period between being born and being first seen by observers. The number of cubs given in the table overleaf is the number which survived this initial period immediately after birth. The mortality given in the table is for those which died in the first year of life after they were first seen.

#### CALCULATION OF FECUNDITY

Leopard no.	1	1	1	1	1	1	2	2	2	2	3	3	4	4	5	5	TOTAL
						*			*		*				*		
Interval	19	16	16	18	15	17	14	14	13	17	9	17	15	16	17	16	249 months
No. of cubs	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	34
Cubs died	0	0	2	0	0	0	2	2	2	1	2	1	1	0	1	0	14

\* - denotes average interbirth interval inserted where no data available

#### References:

Leopard #1: This is the "mother" leopard which has been monitored by John Varty and staff at Londolozi Game Reserve since Jan 1980. She has produced 6 litters to date. An average interbirth interval has been used for the last litter since these cubs are only 3 months old.

Leopard #2: This is the daughter of leopard #1, born in the first litter. She has produced 4 litters, of which all the cubs have died except one from the latest litter. As above, we have assumed an average interbirth interval for the last litter since the cub is only 5 months old at time of writing.

Leopard #3: This animal was born in the Masai-Mara National Park in Jan. 1983 and produced her first litter in June 1985. Both cubs died and she produced a second litter 9 months later. One cub in the second litter survived (Jonathan Scott pers.comm.).

Leopard #4: This is "Chui" who stars in **The Leopard's Tale** (Scott 1986). She was born in July 1978 and had her first litter of 2 cubs in Dec. 1980 of which 1 survived. There appears to be no good data regarding

her second litter in 1982 (Scott mentions a leopard who may have been Chui producing a litter, and we have assumed she did). Her next litter was produced in July 1983 consisting of two cubs both of whom survived their first year. We have taken the period from the first to third litter and subdivided it approximately equally, and to replace the missing information for the middle litter we have substituted the information from the last litter.

Leopard #5: This is the leopard "Kalindi" (Wilson 1981 p164-168) in the Chipangali area of eastern Zambia. She was first observed in Jan. 1962 and was seen with a litter of two month old cubs in Jan. 1963. We have assumed an average interbirth interval preceding this litter, since observations started only ten months before the birth. One of the 3 cubs produced died in the first year of life. In March 1964 she produced a litter of two cubs both of whom were alive in Oct 1964 when observations ceased.

The fecundity derived from the data is 1.64 cubs/year ( $34 \times 12 / 249$ ). This is the average production of cubs (both sexes) per year. To assign age specific fecundities we require the age at first parturition and the breeding lifetime.

We have combined 8 estimates for age at first birth.

1. Phil Berry (pers.comm.) has one example of a known age female in oestrus at 33 months and we have assumed her first litter would have been born at **36 months**.
2. Jonathan Scott (pers.comm.) for the two leopards referred to in the previous section gives ages at first birth of **30 and 36 months**.
3. Le Roux (1984) gives the age at first birth for leopard #2 studied at Londolozi as **41 months**.
4. Varty & Hess (1987) give the age at first birth of another female at Londolozi as **34 months**.
5. Joy Adamson's (1980) leopard came into first oestrus at 21 months and mated at 26 months. We have taken age at first birth to be **30 months**.
6. Haltenorth & Diller (1980) give age at sexual maturity to be 2.5-3 yrs. We have taken this as **33 months** at first birth.
7. Smithers (1983) gives the age at sexual maturity as 2.5-4 yrs. We have taken the midpoint of this range, **39 months**, as the age at first birth.

The average of these values is 34.8 months. Thus in the third year of life, on average, leopards produce for only 1.2 months out of 12. On a proportional basis this gives the fecundity in the third year as 0.164 cubs/year ( $1.64 \times 1.2/12$ ).

Our knowledge of the breeding lifetime of females in the wild is rather vague. Jonathan Scott (pers.comm.) gives a record of a female who is at least 10 years old having recently produced a litter which may not be her last. If the Londolozi "mother" leopard (Leopard #1 above) is taken as three years old at the time of her first litter in 1980, then she is at least 10 years old now with a young litter which may not be her last. Bertram (1978) records 2 female leopard aged 10 and 12 years, one in poor condition. He does not state whether they had bred recently.

Based on this scanty evidence we have allocated reduced fecundities for leopard over 9 years old and assumed that there is no breeding beyond an age of 14 years. Fecundities are the number of offspring of both sexes produced by a single female in one year.

#### AGE-SPECIFIC FECUNDITIES FOR LEOPARD

Age	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14
Fec.	0	0	0.2	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.5	1.3	1.0	0.5

Eaton (1977) gives the mean litter size for 59 litters born in zoos as 1.65, and the average age at last parturition for four females in Woodland Park Zoo as 8.5 years. Both these values are very much lower than results from the wild. In zoos the interval between litters is very much a function of management so no data are available for this parameter. However, if the average interval is taken as 17 months (this study) then this represents a fecundity of 1.16 cubs/year, which is also much lower than values from the wild. Captive leopards at Chipangali Wildlife Sanctuary in Zimbabwe produce either one or two cubs in each litter and have never produced three (V.J. Wilson pers.comm.). This, too, would yield a lower fecundity value than leopards in the wild.

## 2. Longevity:

We can locate no data for longevity of leopards in the wild, other than those given above. Eaton (1977) gives records of maximum values from a number of zoos ranging from 15.5 to 22 years. From his records it appears that males generally live longer than females. Rabinowitz (1986a) gives a record for a jaguar of 23 years in captivity, but of the skulls which he

aged from 17 natural deaths in Belize only 2 were older than 11 years. We have assumed that males live slightly longer than females in the wild and that very few animals survive beyond 15 years.

### 3. Sex ratio of adults at saturation density:

Hamilton (1981) found home range sizes of 30.5 sq.km (average) for males and 14 sq.km for one adult female. This would suggest a sex ratio of about 2 adult female leopards to 1 adult male. Bailey (in Hamilton) found a sex ratio of 1 adult male:1.8 adult females. We have arbitrarily set the sex ratio at 1 adult male:2 adult females at the saturation density.

### 4. Age specific mortalities:

The mortalities which are specified in the model are the minimum mortalities which operate when the population is below the saturation density. These minimum mortalities also vary with the saturation density as discussed earlier to cause reduced intrinsic rates of increase at lower saturation densities. When the population is at the saturation density mortality is increased by the control system. In setting mortalities, we have worked iteratively between the conditions at saturation density and the minimum mortalities.

The data from the section on fecundities suggest a mortality in the first year of life of 41% ( $100 \times 14/34$ ). This may be slightly biased by the very high reproductive performance of leopard #1 who lost only 2 cubs out of 17 produced. Jonathan Scott (pers.comm.) feels that the mortality in general for the first year of life may be as high as 50% and that the mortality for males in their second year of life is considerably higher than that for females. We have raised the first year mortality to 47% for both sexes and assumed that this is the mortality which the model must show when the population is at the saturation density.

Our next step was to set some minimum mortality values for a population which would finally reach a high saturation density. The minimum first year mortality was then adjusted so that at saturation the population showed a first year mortality of 47%. The second year male mortality was set at a higher level than that for females, and the old age mortality was adjusted to produce slightly more males than females. The minimum age specific mortalities for populations at four density levels are given below. At all saturation densities the mortality rises to the same values which, apart from the mortality in the first year, are determined by the feedback process. The higher mortality for males at saturation density is a result of the skewed sex ratio at saturation density (1 male:2 females).

**AGE SPECIFIC MORTALITY AT SATURATION DENSITY**

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 years
Males	47	32	35	31	30	30	30	30	30	31	35	39	46	57	71 %
Females	47	27	19	17	17	17	17	19	20	23	27	36	49	66	91 %

**MINIMUM AGE SPECIFIC MORTALITIES FOR MALES v FINAL SATURATION DENSITY**

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Density															
1/sq.km	38	20	10	5	3	3	3	3	3	5	10	15	25	40	60 %
0.1	41	23	14	9	7	7	7	7	7	9	14	18	28	42	62 %
0.01	43	26	17	13	11	11	11	11	11	13	17	22	31	45	63 %
0.001	45	29	21	16	14	14	14	14	14	16	21	25	34	47	65 %

**MINIMUM AGE SPECIFIC MORTALITIES FOR FEMALES v FINAL SATURATION DENSITY**

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Density															
1/sq.km	38	15	5	3	3	3	3	5	7	10	15	25	40	60	90 %
0.1	41	19	9	7	7	7	7	9	11	14	18	28	42	62	90 %
0.01	43	22	13	11	11	11	11	13	14	17	22	31	45	63	91 %
0.001	45	25	16	14	14	14	14	16	18	21	25	34	47	65	91 %

**5. Intrinsic rates of increase:**

The population parameters defined in the previous sections 1-4 result in the following intrinsic rates of increase during the period when the population is well below saturation density.

Final saturation density (/sq.km)	0.001	0.01	0.1	1.0
Intrinsic growth rate (%)	3.29	7.70	12.21	16.96

It has been remarked upon that this a very wide range, with growth rates at a density of 1/sq.km being four times higher than for a density of 1/1000 sq.km. This was discussed on page 67. We point out that we have not assumed growth rates are four times higher in the high density case (Luxmoore & Broad 1987): rather we have assumed growth rates are four times lower in the low density situation! We also draw attention to the very wide range of densities considered.

**6. Choice of constants for regulation:**

In order that the regulating function (A) can operate effectively over the full range of saturation densities which may be specified in the model, it has been normalised. The integral term is implicit in the modelling process and this appears as unity.

$$F(E) = (K1.E + K2.dE/dt + K3.Ds) / Ds \quad \text{..... (B)}$$

The values of the constants for optimum response are:

$$K1=0.3$$

$$K2=1.1$$

$$K3=1$$

The sex ratio at saturation density is controlled by comparing the actual sex ratio with the desired sex ratio and adjusting male mortality through a similar control process. The control function is:

$$F(R) = 1 - (J1.R + J2.dR/dt)$$

where R is the error in the sex ratio and  $J1 = 0.15$ ,  $J2 = 0.3$

---

## RESULTS

The first use of the model is to produce a population at the specified saturation density. This is achieved by a run-up phase in which the population is started at 1/10th of the final saturation density and allowed to reach its asymptote. Examples of the process for four different saturation densities are shown in Fig. A1-2. The typical age pyramid at the saturation density is given below for a density of 1 leopard in 10 sq.km (the numbers given are for a population of 1,000 leopard in 10,000 sq.km).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Males	130	89	58	40	28	19	14	10	7	5	3	2	1	0	0
Females	130	94	77	64	53	44	36	30	24	18	13	8	4	1	0

Hamilton (1981 p155) gave a factor of 1.7 to determine the size of the total leopard population from the number of breeding adults. From the age pyramid above, if males above 5 years old are taken as adults and females above 3 years old are taken as adults, the factor is 1.77 - which is very close indeed.

The model has then be used to demonstrate the effects of various harvests from the population. The response to several different rates of harvest are shown in Fig. A1-3. The method of harvesting is that given for sport hunting in Chapter 2, where males are taken taken in a higher proportion than females and there is some selectivity for body size. Harvesting is discussed in greater detail in Chapters 2 and 3. The main point to be demonstrated here is that when harvesting commences the population drops initially while the age pyramid adjusts and survival values increase, and then returns to the saturation density. If the harvest rate exceeds a certain threshold the population declines to extinction. It should be noted that the initial dip in the population is entirely the result of applying the full value of the harvest to the population suddenly - in other words the control system is subjected to a step function. If the harvest were applied gradually and increased to the final intended level at a rate slower than the intrinsic growth rate of the population there would be no departure from the saturation density unless the maximum harvest rate were exceeded.

The above characteristics describe the Complete Compensation Model.

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Fig. A1-2.

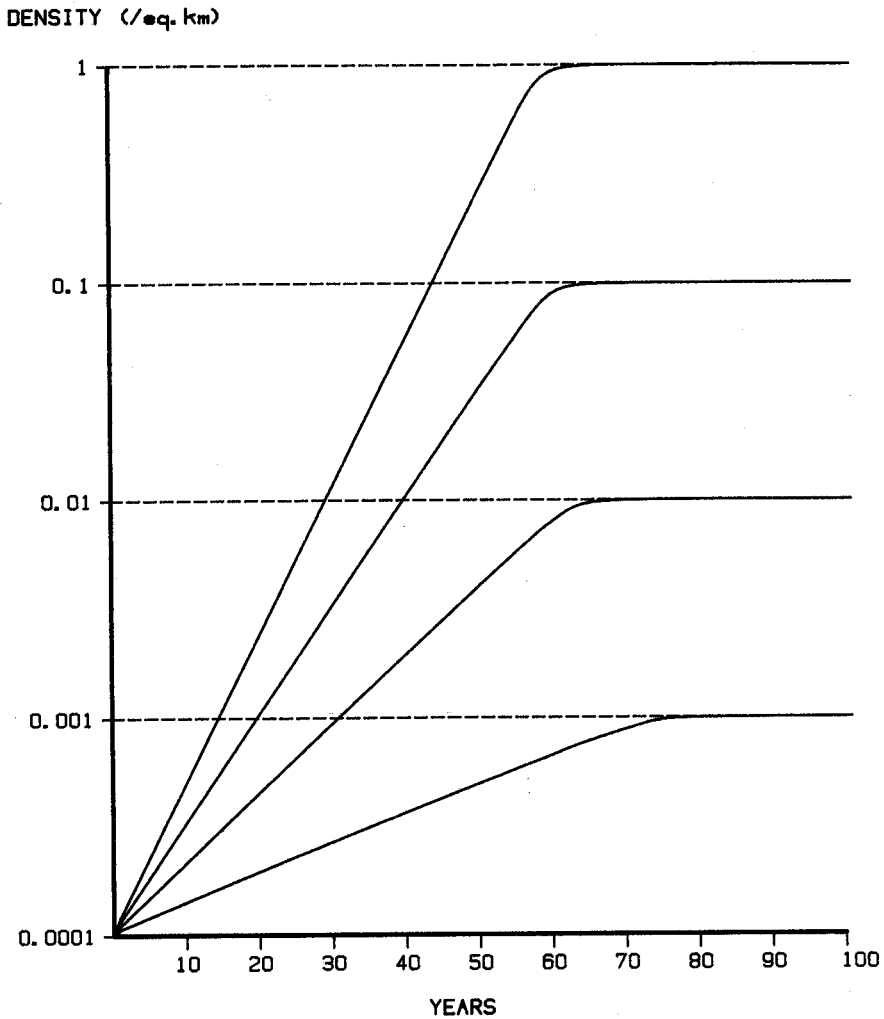


Fig. A1-2: DENSITY DEPENDENT POPULATION REGULATION  
INTRINSIC GROWTH RATES RELATED TO FINAL SATURATION DENSITY



Fig. A1-3.

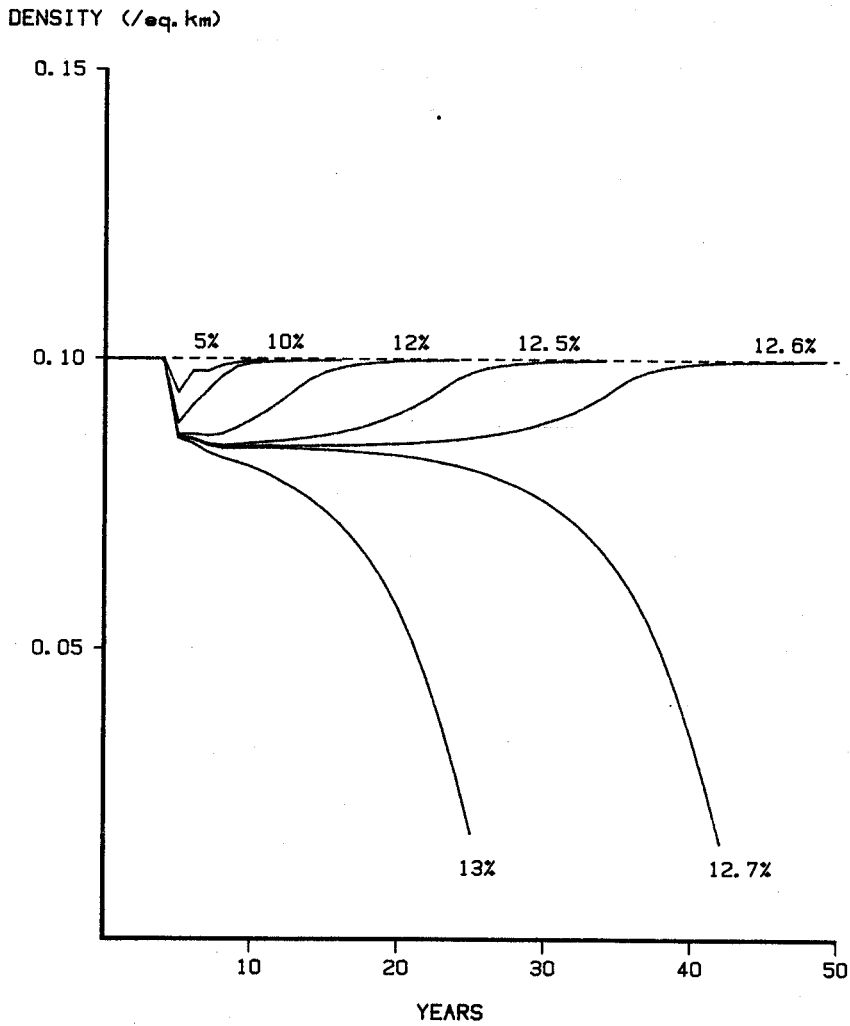


Fig. A1-3: RESPONSES TO VARIOUS HARVEST RATES

## APPENDIX 2

### RELATIONSHIP BETWEEN LEOPARD DENSITIES AND RAINFALL

There are very few detailed studies of leopard densities in Africa. In the course of this consultancy we have obtained a wide range of density estimates for various habitat types from publications and personal communications. Our most difficult task has been to judge which of these estimates are reliable. In choosing 23 data points for the regression of density versus rainfall (Table A2-1) we adopted the following criteria:

- The chosen points are generally conservative. We omitted the results of several studies of leopard (e.g. Hamilton (1976) and Smith (1977)) because it seemed that these areas might be particularly favourable habitats within the broad vegetation categories which we later used to extrapolate leopard numbers for large regions.
- We sought densities which would represent saturation levels for leopard in woodland habitats. Norton and Lawson's (1984) study was omitted because the authors themselves state that the low density of leopard was due to a long history of persecution by farmers.
- We tried as far as possible to use published densities or to derive densities from published home range data. However, several "personal estimates" have been included.

The rainfall data has been derived from a number of sources. Where rainfall data was given in the published work from which the leopard density was obtained, we have used this figure. In other cases we have used the official meteorological records for the country concerned and, where these have not been available, we have interpreted rainfall from the Atlas Afrique (Jeune Afrique 1974).

The points used for the regression are shown in Fig A2-1. Those estimates which were not used in the regression are given in Table A2-2 and plotted on the same graph as the original points (Fig A2-2).

The reason that the "reliable" points of Table A2-2a are not included in the regression becomes readily apparent when Fig A2-2 is inspected. Apart from the first point, the remainder all form a cluster in the upper part of the scatter diagram. We have chosen to interpret this as indicating that the areas are particularly suitable for leopard and cannot be considered as typical of the habitat type universally. This may be the reason that they were chosen as study areas. However, as a general point, we also notice that whenever a serious study on leopard is undertaken in any given area leopard densities tend to be higher than expected at the outset. This would suggest that leopard densities are usually underestimated on a broad scale. Perhaps we have erred in leaving out

these high values, but it gives us some confidence that the extrapolations based on vegetation types and rainfall are unlikely to be overestimates.

The informed guesses (Table A2-2B) do not significantly affect the form of the relationship but simply add to the scatter. The comparative data from leopard (and jaguar) on other continents (Table A2-2c) suggest that the relationship is reasonable.

All the points are discussed individually at the end of this appendix.

**TABLE A2-1: REGRESSION OF LEOPARD DENSITIES v RAINFALL**

Data points used in Fig. A2-1

#	DENSITY /sq.km	RAINFALL mm	AREA	REFERENCE
1	0.01282	220	Kalahari Gemsbok NP	Bothma & Le Riche (1984).
2	0.01563	220	Kalahari Gemsbok NP	Labuschagne in Myers (1976 p39).
3	0.01600	200	Kalahari Gemsbok NP	East (1984 p258)
4	0.02000	400	Central Kalahari	Wilson (1987 pers.comm.)
5	0.05128	530	Hwange National Park	Wilson (1975)
6	0.05000	690	Iwaba Ranch Zimbabwe	Seymour-Smith (1987 pers.comm.)
7	0.05000	823	Nakuru	Kutilek (1974)
8	0.05128	530	Kruger National Park	Pienaar (in Myers 1976)
9	0.05952	803	Serengeti Woodland	Schaller (1972 p283)
10	0.07143	700	Nairobi Nat. Park	Rudnai (1974)
11	0.07692	893	Ngorongoro	East (1984 p258)
12	0.07143	700	Nairobi Nat. Park	East (1984 p258)
13	0.09091	803	Serengeti Woodland	Kyungi (1986)
14	0.10000	760	Selous Game Reserve	Carr-Hartley (1987 pers.comm.)
15	0.10000	832	Miombo forest Zambia	Berry (1987 pers.comm.)
16	0.10000	700	SWRA	National Parks, Zimbabwe.
17	0.10989	915	Lake Manyara NP	East (1984 p258)
18	0.12500	1010	Ruwenzori	Myers (1976 p28)
19	0.15873	1800	Ituri Forest Zaire	IZCN (pers. comm.)
20	0.20000	2000	Tropical rain forest	Wilson (1987 pers.comm.)
21	0.20833	1750	Parc National de Tai	Hoppe (1981)
22	0.33333	2000	Tropical rain forest	Myers (1976 pl4)
23	0.40000	2000	Tropical rain forest	Hamilton (1987 pers.comm.)

The regression of the above points gives -

$$\text{Log (density)} = - 8.3441 + 1.3241.\text{Log (rainfall(cm))}$$

The 95% confidence limits for the regression coefficient are 1.147 to 1.502 and for the constant they are -9.122 to -7.566.

Fig. A2-1.

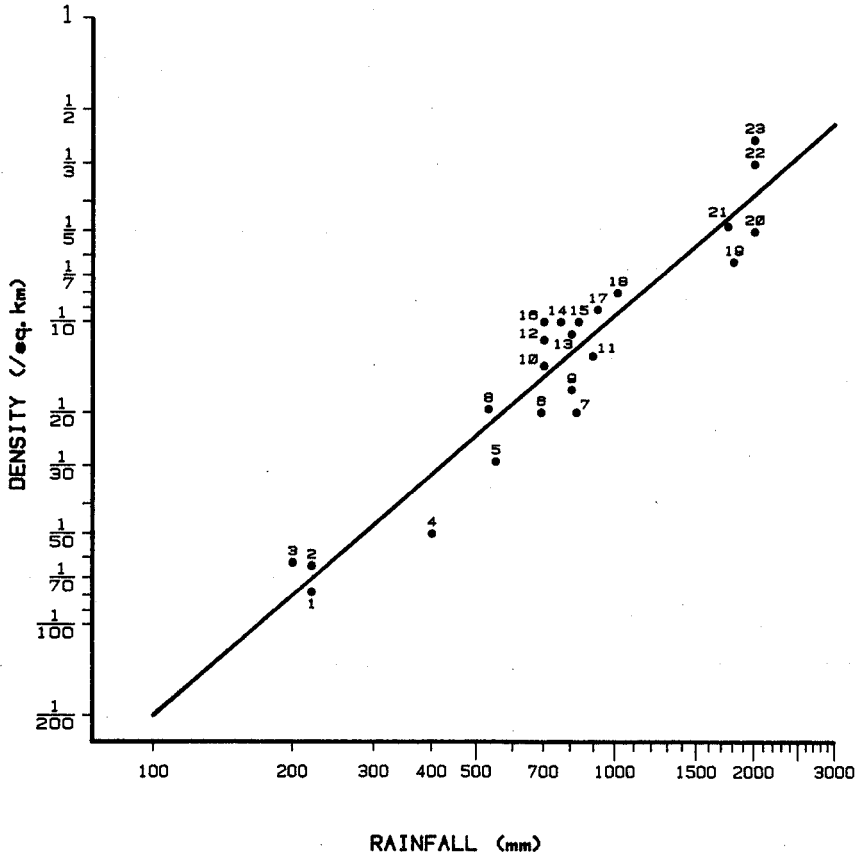


Fig. A2-1: RELATIONSHIP BETWEEN LEOPARD DENSITY AND RAINFALL

Reference numbers apply to points in Table A2-1

TABLE A2-2: OTHER ESTIMATES FOR LEOPARD DENSITIES

#	DENSITY	RAINFALL	AREA	REFERENCE
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a) Reliable density estimates not used in the regression

1	0.00769	600	Cape Fynbos	Norton and Lawson (1984)
2	0.12350	650	Tsavo National Park	Hamilton (1976)
3	0.18180	650	Matetsi Safari Area	Booth (1987)
4	0.20000	580	Matopos Nat. Park	Grobler in Myers (1976 p18)
5	0.22222	800	Luangwa Nat. Park	Berry (1986)
6	0.23600	580	Matopos Nat. Park	Smith (1977)
7	0.23810	530	Londolosi Game Res.	Varty & Hess (1987)
8	0.25000	650	Galana Ranch	Parker (pers.comm.)
9	0.50000	1400	Aberdares NP	Woodley (in Hamilton 1981 p62)

b) Informed guesses

1	0.01000	220	Kalahari Gemsbok NP	Mills (pers.comm.)
2	0.01000	200	North Kenya	Parker (pers.comm.)
3	0.01000	350	Kalahari, Botswana	Becker (pers.comm.)
4	0.02000	350	W. Kalahari Botswana	Engelbrecht (pers.comm.)
5	0.10000	500	Buffalo Range Zimb.	Osborn (pers.comm.)
6	0.22000	650	Matetsi Safari Area	Longhurst (in Myers 1976)
7	0.15380	600	Gwaai River	Booth (pers.comm.)
8	0.04350	750	Miombo wood. Selous	Eaton (1978)
9	0.06060	850	Miombo wood. Zambia	Eaton (1978)
10	0.66700	1200	Southern Ethiopia	Brown & Urban (in Myers 1976)
11	0.22222	500	Othawa Farm, SA	Robson (in Myers 1976)
12	0.01250	800	Niokolo-Koba Senegal	Verschuren (1977)
13	0.25000	1500	Akagera NP Rwanda	Vandeweghe & Monfort (pers.comm.)
14	0.10000	650	Omay CA, Zimbabwe	Grobler (pers.comm.)
15	0.10000	900	Kafue Nat. Park	Mubanga (pers.comm.)
16	0.10000	1000	Nyika NP, Malawi	Mphande (pers.comm.)
17	0.20000	800	Masai Mara NP	Binks (pers.comm.)
18	0.05000	1200	Southern Ethiopia	Roussos (pers.comm.)
19	0.02000	200	Harrar, Ethiopia	Roussos (pers.comm.)
20	0.13333	530	Kruger National Park	Hornocker & Bailey (1974)
21	0.45454	1200	Solio Ranch, Kenya	Hamilton (1981)
22	0.20000	2200	Rainforest, Gabon	Maroga Mbina (pers.comm.)
23	0.02860	1000	Comoe NP Ivory Coast	Sournier (pers.comm.)

c) Leopard (and Jaguar) outside Africa

1	0.38460	2200	Wilpattu, Sri Lanka	Eisenberg & Lockhart (1972)
				Muckenhiirn & Eisenberg (1973)
2	0.32260	2300	Chitawan, Nepal	Seidensticker (1976)
3	0.22000	2500	Cockscomb, Belize	Rabinowitz & Nottingham (1986)
4	0.08095	1150	Pantanal, SW Brazil	Schaller & Crawshaw (1980)

Fig. A2-2.

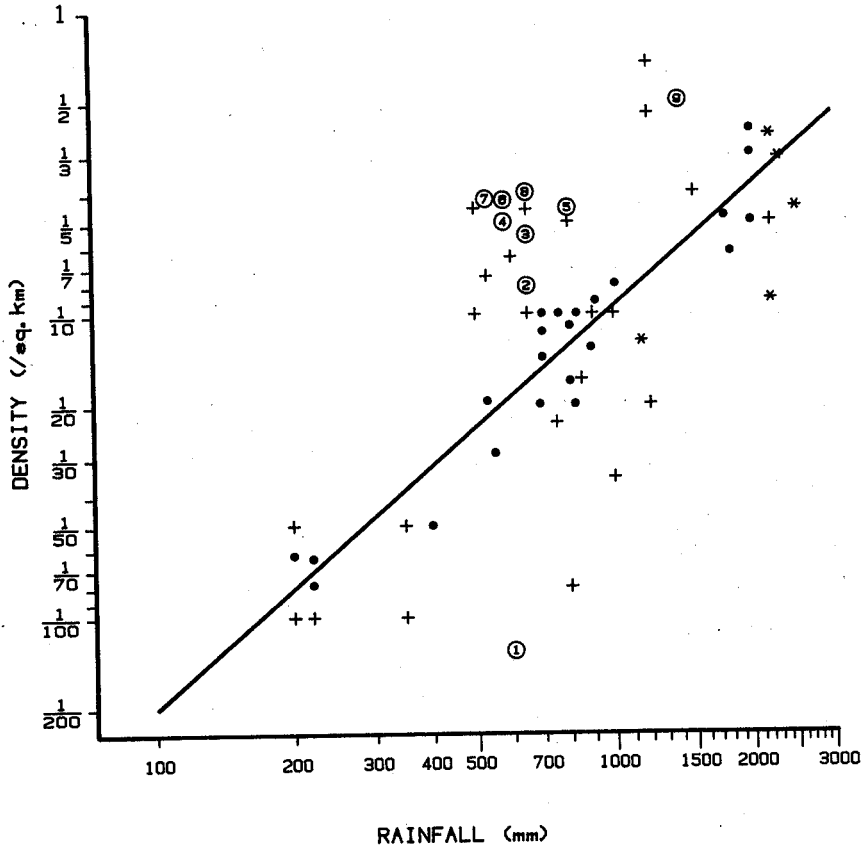


Fig. A2-2: RELATIONSHIP BETWEEN LEOPARD DENSITY AND RAINFALL

- - Original data points from Fig. A2-1 & Table A2-1
- ⊙ - Sound data points not used in regression (Table A2-2a)
- +
- Informed guesses. (Table A2-2b)
- \*
- Data points for leopard outside Africa (Table A2-2c)

### SOURCES OF DATA

Reference numbers from Table A2-1: Points included in the regression.

1. Bothma and Le Riche (1984) found home ranges of approximately 400 sq km for two male leopards. We have assumed that each male home range would contain 2 female leopards. Hamilton (1981) gives a ratio of 1:1.8 and numerous other authors suggest similar ratios. Using a factor of 1.7 given by Hamilton (1981 p115) to relate the number of adult leopards in a given area to sub-adults, cubs and transients, this gives a total of 5.1 leopards in 400 sq.km.
2. Labuschagne (in Myers 1976 p39) estimated 150 leopards in the Kalahari Gemsbok National Park (9591 sq.km).
3. East (1984) gives a biomass density of 0.48 kg/sq.km for leopard in the Kalahari Gemsbok National Park, quoting Myers (1976) and various other authors as his source. It is not clear exactly how he arrived at this final figure, but we have accepted it and converted it to an animal density using a mean body weight of 30 kg for leopard.
4. V.J. Wilson, who has worked in the Kalahari for many years and is member of the Cat Specialist Group, estimates an average density for leopard of 1/50 sq.km in the Central Kalahari.
5. Wilson (1975) gives a total population for Hwange National Park (14500 sq.km) of about 300 leopard based on reports from staff. This estimate has recently been revised to a minimum of about 500 leopard.
6. P. Seymour-Smith has estimated the number of leopard on Iwaba game ranch in the Midlands province of Zimbabwe by regular baiting over a period of 10 years.
7. Kutilek (1974) established leopard densities of 0.05/sq.km in an area of 28.4 sq.km in Lake Nakuru National Park using ground transects.
8. Pienaar (1969) estimated the number of leopard in the Kruger National Park as 650, and later revised this to at least 1000 leopards (pers. comm. in Myers 1976). The area of the park is 19500 sq.km.
9. Schaller (1972) estimated 7 resident adult leopards in 200 sq.km in Serengeti National park in the Seronera area. Using the same technique as in 1. above this gives a density of 1/16.8 sq.km.
10. Rudnai (1974) counted 8 leopard in Nairobi National Park (114 sq.km).
11. East (1984) gives a biomass figure of 2.31 kg/sq.km for leopard in the Ngorongoro conservation area based on Schaller (1972). We have derived a density figure of 1/13 sq.km using a mean body weight of 30kg.

12. East (1984) gives a biomass density of 2.61 kg/sq.km in the Nairobi National Park (no references).
13. Kiyungi (1986) studied leopard in 5 areas in the Serengeti woodlands and found an average density of 1/11 sq.km. Bertram (in Myers 1976 p17) suggests that densities in this area are higher than at Seronera.
14. Roy Carr-Hartley (pers.comm.) estimates approximately 1/10 sq.km for leopard in the Selous Game Reserve based on numbers coming to baits.
15. Phil Berry (pers.comm.) has kept detailed leopard records for more than ten years in the South Luangwa National Park. This figure for Miombo woodland is based on densities relative to the valley flood plain.
16. D.H.M. Cumming, G.C. Craig and R.B. Martin estimate approximately one leopard in 10/sq.km in the Sengwa Wildlife Research Area in Zimbabwe. Cumming (1975) estimated 15-25 leopard in the 370 sq.km SWRA before 1970 but increased prey densities in 1987 justify the present estimate.
17. East (1984) estimates a biomass density of 3.3 kg/sq.km in the Lake Manyara National Park.
18. Myers (1976 p28) estimates densities of 1/8 sq.km in the Ruwenzori National Park in Uganda from staff reports.
19. Staff of the Institut Zairois pour Conservation de la Nature who have worked on the research project in the Ituri Forest with the Harts advise leopard densities of 1/5-1/7.5 sq.km resulting from radio tracking studies. We have taken the midpoint of this range.
20. V.J. Wilson has recently undertaken field trips to rainforests in the Ivory Coast and the Central African Republic. In both areas leopard and signs of leopard were seen, and the estimate of 1/5 sq.km is considered a minimum.
21. Hoppe (1981) calculated home ranges of 12.3 sq.km in the secondary forest of Tai National Park in the Ivory Coast. Assuming this is a female home range and working on a basis of 2 female home ranges to 1 male home range, this gives 3 resident adults in 24.6 sq.km. Using Hamilton's (1981) factor of 1.7 gives a density of 1/4.8 sq.km.
22. Myers (1976 p14) gives leopard densities in rainforest from 1/3 sq.km to as high as 1/1 sq.km. No authorities are given for these estimates. Hamilton (1981 p62) explains how Myers reached the high estimate by misquoting Woodley, and how this has been propagated through the literature (eg Eaton 1978). We have chosen the lower figure.
23. Hamilton (pers.comm.) estimates leopard densities in rainforest at about 1/2.5 sq.km.



Reference numbers from Table A2-2a: Sound data points omitted from the regression.

1. Norton & Lawson (1984) derived home ranges of 388 sq.km and 487 sq.km for a male and female leopard in the Stellenbosch area of the Cape province. The fact that the female's range is larger than the male's is anomalous (a male's home range usually encloses more than one female home range). We have assumed one adult male and one adult female living in the same mean home range of 437 sq.km and, using a factor of 1.7 to account for sub adults, cubs etc. (Hamilton 1981), this gives a density of 1/130 sq.km. We are far from confident about the result and hence have left it out of the regression. It would not appear to represent leopards at a saturation density for the habitat concerned, and the authors state that leopard are heavily hunted in the area.
2. Hamilton (1976) gives a density of 1 leopard in 8.1 sq.km as a minimum estimate for his study area in Tsavo National Park. The estimate has not been included in the regression although there is no reason to doubt its validity. The vegetation type of Tsavo in White's map extends throughout Kenya northwards to Somalia and we felt that it was unlikely such densities would pertain further northwards (indeed, Hamilton (1981) suggests lower densities in northern Kenya). Hamilton further states that the Tsavo study area was centred on the rugged Ngulia range which is probably ideal habitat for leopard.
3. Booth (1987) estimates a density for leopard of 1/5.5 sq.km in the Matetsi Safari Area based on the analysis of hunting records and sightings of leopards on hunters' baits since 1980.
4. Grobler (pers.comm. to Myers 1976) is reported as stating that leopard densities in Matopos are as high as 2/3 sq.km. However, on checking this figure with V.J. Wilson, who worked closely with Grobler during the period he was research officer in Matopos, he felt this was not correct and that both he and Grobler agreed on leopard densities of 1/5 sq.km (which corresponds with 6. below).
5. Phil Berry has been keeping records on leopard in an area of 10 sq.km (5 x 2 km) near Mfuwe Lodge in the Luangwa Valley, Zambia for the past three years. In this area at present are 6 resident leopard (1 adult male, 3 adult females and 2 sub-adults). This would represent a density of 1/1.67 sq.km (Dale Lewis (pers.comm.) has recorded such high densities close to the Luangwa River in the Lupande Game Management Area). However, the home ranges of the animals concerned extend outside the 10 sq.km block and a more realistic area encompassing all ranges may be 27 sq.km giving a density of 1/4.5 sq.km. Close to the Luangwa River the vegetation is favourable riparian habitat with large populations of impala and puku. In White's vegetation map the area is classified as Mopane woodland and these high densities would not be appropriate for this vegetation type on any extensive basis.

6. Smith (1977) estimated leopards at a density of 1/4.5 to 1/5 sq.km in the Matopos National Park in Zimbabwe in a detailed study using spoor, sightings and faecal deposits. Both points for Matopos (4. and 6.) have been omitted from the regression because the area contains numerous granite kopjes with high populations of dassies and is unusually suitable habitat for leopard.
7. John Varty and Alex Hess have been keeping detailed records on leopard in Londolozi Game Reserve adjacent to the Kruger National Park since 1980. From their estimate of a male home range of 2,500 ha containing 2.5 female home ranges, and multiplying the total number of adult residents by 1.7 we derive a density of 1/4.2 sq.km. This corresponds with the highest densities recorded by Pienaar (1969) in the Kruger National Park and for this reason we have omitted the estimate.
8. Ian Parker placed baits over an area of 8 square miles on Galana Ranch and recorded 5 leopard.
9. Woodley (Hamilton 1981 p62) stated that leopard densities might attain 1/2 sq.km in the Treetops salient area of the Aberdares range. To avoid the controversy which attended Myers (1976) and Eaton (1978) we have omitted this point from the regression. Hamilton (1981) implies that it is an unusually high density for leopard and it lies well above the regression line of Fig A2-2.

Reference numbers from Table A2-2b: Informed guesses.

1. Gus Mills studied brown hyaena in the Kalahari Gemsbok Park for several years and is currently studying the carnivores in Kruger National Park. He regards leopard as the most difficult animals of all carnivores to census and advised me that this estimate of 1 leopard in 100 sq.km could be subject to large errors.
2. This estimate from Ian Parker is based on the relative abundance of leopard in a number of parts of Kenya with which he is familiar.
3. Peter Becker (Botswana Game Industries) has experience of all parts of Botswana and the Kalahari in particular.
4. Willy Engelbrecht is a professional hunter with Hunters Africa Ltd. in Botswana. This estimate is based on definite records of 4 leopard in 200 sq.km in the Jackie's Pan area of the Kalahari.
5. John Osborne is manager of the game section of Buffalo Range in the south-east lowveld of Zimbabwe and a professional hunter with Buffalo Range Safaris Ltd..

6. This estimate for Matetsi Safari Area in Zimbabwe is attributed to Longhurst (Myers 1976) who is unknown to current members of staff.
7. Booth reports an estimate of 1 leopard in 6.5 sq.km from Steffen in the Gwaai River area of Zimbabwe.
8. Eaton (1978) took Myers' (1976 p28) guess of 2,000 leopard in the Selous Game Reserve (35,000 sq.km) and Ruaha National Park (11,500 sq.km) to obtain a density of 1/23 sq.km.
9. Eaton (1978) took Myers' (1976 p32) guess of 10,000-20,000 leopards in protected areas in Zambia (225,000 sq.km). to obtain densities of 1/11 to 1/22 sq.km in Miombo woodland. Both this and the preceding figure have no sound foundation and perhaps we are guilty of perpetuating doubtful data by considering them.
10. Brown and Urban (1970, in Myers 1976 p57) estimated as many as 2 leopard in 3 sq.km in the forests of southern Ethiopia.
11. Myers (1976) estimated 1 leopard in 4-5 sq.km on Othawa Farm near Kruger National Park based on a personal communication by Robson that 3-4 territorial male leopard occupied an area of 32 sq.km. We do not agree with the method of calculation.
12. Verschuren (1977) took Dupuy's estimate of 100 leopard in Niokolo-Koba National Park (8,000 sq.km) to arrive at a density of 1/80 sq.km. However, he remarks that this may be an underestimate.
13. Dr J. Vandeweghe and Dr A. Monfort (Office Rwandais du Tourisme et des Parcs Nationaux) estimated a density of 1 leopard in 4 sq.km in Akagera National park, Rwanda.
14. Steve Grobler of Paul Grobler Safaris Ltd. estimates a leopard density of 1/10 sq.km in the Omay Communal Land, Zimbabwe, based on known numbers of leopards coming to baits.
15. George Mubanga (Senior Research Officer) estimates a density of 1/10 sq.km in the Kafue National Park, Zambia.
16. John Mphande (Senior Parks & Wildlife Officer) estimates 1/10 sq.km for the Nyika Plateau in Malawi.
17. Alan Binks has conducted numerous tours through the Masai Mara area and estimates leopard densities at 1/5 sq.km.
18. A.N. Roussos (Ethiopian Rift Valley Safaris) is the major hunting safari operator in Ethiopia. His estimate of 1 leopard in 20 sq.km in the southern forests of Ethiopia is based on leopard calls and spoor.

19. Roussos estimates that leopard in the Harrar desert region are as common as 1/50 sq.km. They are plainly visible during the day and there is no need for baits to hunt them.
20. Hornocker & Bailey (1974) report leopards at a density of 1/7.5 sq.km in the Kruger National park.
21. Hamilton (1981) reports leopard densities as high as 1/2.2 sq.km on Solio Ranch east of the Aberdares in Kenya. However he regards this as an unusual estimate resulting from the exceptionally suitable habitat for leopard on the property.
22. Joseph Maroga-Mbina (Chef du Service de l'Amenagement de la Faune) and Henri Max Boudiala (Chef de Service de Chasse) of the Gabon wildlife department estimate densities in the primary rainforest in Gabon of 1/5 sq.km. They estimate slightly lower densities in secondary forest.
23. D. Sournier (IUCN Regional representative, West Africa) estimates one leopard in 35 sq.km in the Comoe National Park in Ivory Coast.

Reference numbers from Table A2-2c:      Comparative densities from other continents.

1. Eisenberg & Lockhart (1972) give the home ranges of adult males as 9-10 sq.km and adult females as 8-10 sq.km in Wilpattu National Park, Sri Lanka. Assuming from the home range data that 1 adult of each sex shares an area of 9 sq.km, and using a factor of 1.7 to allow for the number of juveniles, sub-adults and transients (Hamilton 1981) this gives a density of 1/2.6 sq.km. Muckenhirn & Eisenberg (1973) obtain a similar result. It is worth noting that the pattern of Sri Lanka home ranges is not identical to those found in Africa. Males and females share small exclusive home ranges which do overlap with adjacent leopard pairs. In Africa male home ranges appear to be exclusive, but female home ranges overlap considerably with each other and a single male home range may include several female ranges.
2. Seidensticker (1976) found home ranges of 8 sq.km for female leopard in the Royal Chitawan National Park, Nepal. Using a similar calculation to the above, but assuming that male home ranges are twice as large as female, this gives a density estimate of 1/3.1 sq.km.
3. Rabinowitz & Nottingham (1986) give male jaguar home ranges as 28-40 sq.km and female home ranges as 10 sq.km. Taking the average male home range as 34 sq.km and assuming 3.4 females live within it, and using a factor of 1.7 to account for the remainder of the population, this gives 7.5 jaguars in 34 sq.km, or a density of 1/4.5 sq.km. Rabinowitz (pers. comm.) felt that densities might be as high as 1/3 sq.km but were unlikely to reach 1/2 sq.km.

4. Schaller and Crawshaw (1980) give a density estimate of 1 jaguar in 25 sq.km on two small ranches in the Pantanal district of Brazil. In the same article the estimate is revised to 1/12.5 sq.km on one ranch and 1/22.5 sq.km on the other. If the above technique based on home range size is used, it gives a density of 1/12.4 sq.km which is virtually identical to the higher density estimate.

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#### Footnotes

1. It is possible in the preceding list that some authors have used others' data for densities which gives rise to duplications.
2. Cumming (pers.comm.) has correctly pointed out since the completion of this appendix that Bartlett's Best Fit method of regression might have been more appropriate in this application since the rainfall values are also estimates.
3. Cumming has also drawn our attention to the fact that the regression may be inaccurate at high rainfall values in West African lowland forests. Productivity may be lower than expected because of high temperatures on relatively poor leached soils.
4. Bell (pers.comm.) has queried a number of the data points used and has strong feelings about the use of such regressions which do not take into account soil fertility (Bell 1982). We, in turn, argue that with such limited data there is little point in attempting to refine the relationship to a multiple linear regression. It is not correct to state that soil fertility effects are totally ignored because they have not been separated out as a variable: this simply means that the regression will have a wider scatter because soil effects are implicit in the relationship.

#### APPENDIX 4

##### ESTIMATES OF LEOPARD NUMBERS IN INDIVIDUAL COUNTRIES

On the following 13 pages of tables are estimates of leopard numbers in each vegetation type in each country. The tables are based on Mackinnon & Mackinnon's (1986 Section 5) breakdown of areas of the original vegetation types within each country, unmodified proportions of vegetation types, and protected areas.

The steps involved in our analysis are as follows:

- a) In each country we have listed the vegetation types present and the original areas of each vegetation type according to Mackinnon & Mackinnon (op.cit.).
- b) The percentage of the original vegetation type still remaining has been tabulated and used to calculate an area of unmodified habitat. The balance of the area is modified habitat.
- c) A mean rainfall value has been assigned to each vegetation type in each country. Sources for rainfall data are given in Appendix 2.

It was not possible to specify a single rainfall value for a given vegetation type which could be used throughout its occurrence. We frequently found that for the same vegetation type in different countries the rainfall varied considerably. Even within a single country, the rainfall often varied over the same vegetation type and, when this occurred, we allocated a mean value for the type which was generally closest to the lower end of the rainfall range. An example of this is type 42 (Somali-Masai ~~Acacia-Commiphora~~ deciduous bushland and thicket) which extends from Somalia and Ethiopia through Kenya into Tanzania. In the Somalia end of the range rainfall is as low as 100mm whilst in parts of Kenya it is as high as 1100mm. The mean value we have used for type 42 in Kenya is 300mm.

- d) A density for leopard in the unmodified portion of each vegetation type has been computed from the regression given in Appendix 2.
- e) The density in the unmodified area has been reduced where necessary by the habitat factor given in Appendix 3.
- f) The density in the modified portion of the same habitat has been assumed to be one-tenth that of the density in the unmodified part.

We realise that this is arbitrary but see no way of improving the situation. Leopard definitely occur in modified habitats throughout Africa except perhaps in the most densely settled parts of West Africa (see below). Under this assumption the contribution to the overall total from leopards outside the unmodified areas is only 8.5%, so that this is unlikely to be a large source of positive error.

- g) In certain countries in West Africa where the density of humans exceeds 25/sq.km, the density in the modified areas has been reduced to 1/100 of the density in the corresponding unmodified areas in all vegetation types. This correction has not been applied in east and central Africa except in certain specific vegetation types where human densities are known to be very high. In general in east and central Africa leopard still exist in fair numbers in the modified areas. Hamilton (1987 pl2) points out that leopard still persist in extensively cultivated districts in western Kenya with more than 150 persons/sq.km, with the largest livestock populations in the country, and with little natural habitat and prey.
- h) The number of leopards in the unmodified and modified areas have been computed using the above densities in each original vegetation type.
- i) These numbers have been summed to give the total number of leopard in the original vegetation type.

The following abbreviations and notes apply to the tables.

**Area** - The total area given for each country is the sum of the areas of each vegetation type in the country. Occasionally this leads to small discrepancies with the official areas of each country. These discrepancies arise because of the exclusion of inland water bodies, and the exclusion of pure desert areas from the northern sub-Saharan countries.

**Population** - Human population numbers for the year 1985 have been taken from FAO (1986) and multiplied by 1.0609 to allow for population increase since 1985.

**Density/sq.km** - This is human population density calculated from country area and population.

**VT** - White's (1983) vegetation types.

**OR.AREA** - Original extent of the vegetation type within the country (sq.km)

**RZ** - The percentage of the area of the original vegetation type remaining in an unmodified condition.

**RNFL** - The estimated mean rainfall (mm) for the vegetation type in the country concerned.

**LD1** - Leopard density for the unmodified portion of the vegetation type based on a) the density/rainfall regression, and (b) the correction factor from Appendix 3, if any.

**LD2** - Leopard density for the balance of the original area based on 1/10 of LD1. Where there is an \* next to the code LD1 this indicates that densities have been taken at 1/100th of LD1.

**LN1** - The number of leopards in the unmodified part of the vegetation type:  $LN1 = .01 \times R \times OR.AREA \times LD1$

**LN2** - The number of leopards in the balance of the original area.  
 $LN2 = .01 \times (100 - R) \times OR.AREA \times LD1/10$  (or  $LD1/100$ )

**TOTAL** - This is the sum of LN1 & LN2.

**NP** - This is the area within the vegetation type which has been set aside as National Parks or non-hunting protected areas. In a few places in Mackinnon & Mackinnon's (op.cit.) tables we found that the remaining proportion of the original vegetation type was smaller than the designated protected areas in that vegetation type. In such cases we took the smaller of the two areas.

**PH** - This is the potential harvest from the population based on a 5% offtake from the leopard population outside the protected areas.

**NT** - This column contains occasional notes relating to individual lines of the calculation. An \* in this column indicates that the value of LD2 for that line only has been taken as 1/100th of LD1.

The tables for individual countries follow.



## ANGOLA

Area 1246700 Population (millions) 9.287 Density/sq.km 7.45

VT	OR.AREA	R%	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	157,600	50	1,100	0.120	0.001	9,458	95	9,552	0	478	*
14	51,700	60	1,300	0.150	0.015	4,645	310	4,954	0	248	
15	1,100	80	900	0.092	0.009	81	2	83	0	4	
19A	1,900	80	750	0.072	0.007	110	3	113	1,500	0	
2	3,700	50	1,700	0.214	0.021	395	40	435	0	22	
21	64,100	79	1,500	0.181	0.018	9,164	244	9,408	600	465	
22A	131,800	50	700	0.049	0.005	3,261	326	3,587	900	177	
25	375,600	55	1,000	0.106	0.011	21,854	1,788	23,642	7,000	1,145	
28	68,300	60	500	0.042	0.004	1,732	115	1,847	1,000	90	
29C	66,100	45	350	0.026	0.003	784	96	880	10,960	30	
36	16,900	30	300	0.021	0.002	109	25	134	0	7	
47	155,900	90	900	0.046	0.005	6,455	72	6,527	0	326	
51	44,000	80	150	0.009	0.001	302	8	310	4,000	14	
6	2,600	50	1,300	0.150	0.015	195	19	214	0	11	
60	95,100	72	1,000	0.011	0.001	724	28	753	0	38	
64	2,400	80	700	0.013	0.001	25	1	26	0	1	
74	5,700	100	50	0.002	0.000	11	0	11	450	1	
77	2,200	50	900	0.009	0.001	10	1	11	0	1	

TOT. 1,246,700 59,315 3,171 62,486 26,410 3,056

## BENIN

Area 115800 Population (millions) 4.297 Density/sq.km 37.1

VT	OR.AREA	R%	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	16,000	20	1,200	0.135	0.001	431	17	448	0	22	
2	800	20	1,700	0.214	0.002	34	1	36	0	2	
27	74,500	40	1,200	0.135	0.001	4,013	60	4,074	0	204	
29A	22,300	60	850	0.021	0.000	285	2	287	8,435	5	
30	2,200	40	800	0.079	0.001	69	1	70	0	4	

TOT. 115,800 4,833 82 4,915 8,435 237

## BOTSWANA

Area 585400 Population (millions) 1.174 Density/sq.km 2.0

VT	OR.AREA	R%	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
22A	11,500	50	500	0.032	0.003	182	18	200	3,000	5	
28	97,700	50	450	0.037	0.004	1,795	180	1,975	7,000	86	
29C	600	50	500	0.042	0.004	13	1	14	0	1	
29D	1,600	50	550	0.048	0.005	38	4	42	0	2	
35A	184,600	31	500	0.042	0.004	2,418	538	2,956	18,390	109	
44	218,100	40	300	0.021	0.002	1,874	281	2,155	55,632	48	
56	22,800	60	200	0.013	0.001	172	11	183	13,400	1	
75	25,900	90	450	0.007	0.001	171	2	173	2,370	8	
76	10,500	90	400	0.003	0.000	30	0	30	1,140	1	
PAN	12,100	100	400	0.000	0.000	0	0	0	2,000	0	

TOT. 585,400 6,694 1,036 7,729 102,932 261

## BURKINA FASO

Area 273800

Population (millions)

7.365

Density/sq.km

26.9

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
27	40,500	20	1,100	0.120	0.001	972	39	1,011	2,863	33	
29A	203,400	20	600	0.013	0.000	547	22	569	6,596	24	
30	4,300	20	800	0.079	0.001	68	3	70	0	4	
43	25,600	30	300	0.005	0.000	41	1	42	0	2	
TOT.	273,800					1,628	64	1,693	9,459	63	

## BURUNDI

Area 25700

Population (millions)

5.009

Density/sq.km

195

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
19A	10,000	10	1,500	0.181	0.002	181	16	197	379	6	
25	2,800	5	1,000	0.106	0.001	15	3	18	0	1	
4	600	5	2,000	0.265	0.003	8	2	9	2	0	
45	12,300	20	1,000	0.106	0.001	260	10	271	486	11	
TOT.	25,700					464	31	495	867	19	

## CAMEROUN

Area 469400

Population (millions)

10.47

Density/sq.km

22.3

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	126,900	32	1,500	0.181	0.018	7,349	1,562	8,911	8,476	369	
19A	16,300	40	2,100	0.283	0.028	1,842	276	2,119	100	105	
1A	115,900	50	2,000	0.265	0.026	15,349	1,535	16,884	6,937	752	
2	78,600	50	1,600	0.197	0.020	7,747	775	8,521	1,200	414	
27	38,500	30	1,000	0.106	0.011	1,222	285	1,507	5,250	48	
29A	34,800	30	700	0.016	0.002	172	40	212	2,800	8	
3	17,800	60	2,000	0.265	0.026	2,829	189	3,017	0	151	
33	4,900	20	850	0.043	0.004	42	17	59	0	3	
43	500	20	300	0.005	0.001	1	0	1	0	0	
62	2,400	20	300	0.004	0.000	2	1	3	0	0	
63	10,600	30	600	0.011	0.001	34	8	42	900	2	
75	800	20	300	0.004	0.000	1	0	1	0	0	
77	8,100	60	3,500	0.056	0.006	270	18	288	600	13	
8	13,300	50	1,500	0.045	0.005	301	30	331	1,430	13	
TOT.	469,400					37,160	4,736	41,896	27,693	1,878	

## CENTRAL AFRICAN REPUBLIC

Area 623000      Population (millions)      2.733      Density/sq.km      4.39

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	295,300	40	1,400	0.165	0.017	19,510	2,927	22,437	0	1,122	
1A	2,000	50	1,600	0.197	0.020	197	20	217	0	11	
2	26,200	49	1,600	0.197	0.020	2,531	263	2,794	2,000	120	
27	272,700	50	1,000	0.106	0.011	14,425	1,442	15,867	33,340	617	
29A	1,000	70	1,600	0.049	0.005	34	1	36	650	0	
TOT.	623,000					36,867	4,679	41,546	42,690	1,874	

## CHAD

Area 72080      Population (millions)      5.324      Density/sq.km      7.39

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
27	44,600	20	1,000	0.106	0.011	944	377	1,321	0	66	
29A	247,800	20	700	0.016	0.002	817	327	1,144	1,140	56	
43	134,600	30	300	0.005	0.001	217	51	267	0	13	
54A	217,600	30	150	0.002	0.000	140	33	173	0	9	
62	17,400	20	300	0.004	0.000	15	6	21	0	1	
63	52,200	20	700	0.013	0.001	138	55	193	0	10	
75	6,600	10	300	0.004	0.000	3	3	5	0	0	
TOT.	720,800					2,273	851	3,125	1,140	155	

## CONGO

Area 342000      Population (millions)      1.846      Density/sq.km      5.4

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	90,400	40	1,600	0.197	0.002	7,128	107	7,235	8,627	277	*
1A	69,300	60	1,900	0.247	0.025	10,290	686	10,976	2,848	514	
2	76,800	60	1,800	0.230	0.023	10,616	708	11,324	2,056	543	
8	105,500	50	1,600	0.049	0.005	2,599	260	2,859	0	143	
TOT.	342,000					30,634	1,761	32,394	13,531	1,476	

## DJIBOUTI

Area 21800      Population (millions)      0.386      Density/sq.km      17.7

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
54B	20,000	50	50	0.002	0.000	20	2	22	30	1	
68B	1,500	80	50	0.002	0.000	2	0	2	0	0	
77	300	30	50	0.000	0.000	0	0	0	0	0	
TOT.	21,800					22	2	25	30	1	

# EQUATORIAL GUINEA

Area 26000 Population (millions) 0.416 Density/sq.km 16.0

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
1A	100	50	2,000	0.265	0.026	13	1	15	0	1	
3	25,600	50	2,500	0.356	0.036	4,556	456	5,011	950	234	
77	300	40	3,200	0.099	0.010	12	2	14	0	1	
TOT.	26,000					4,581	459	5,040	950	235	

# ETHIOPIA

Area 1101000 Population (millions) 46.21 Density/sq.km 42.0

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
17	12,700	20	1,200	0.013	0.001	34	14	48	1,000	2	
19A	213,400	10	900	0.092	0.001	1,964	177	2,140	3,325	92	*
29B	127,900	10	900	0.092	0.009	1,177	1,059	2,236	6,650	81	
35B	9,300	30	1,000	0.106	0.011	295	69	364	500	16	
38	82,500	20	650	0.060	0.001	987	39	1,026	5,600	32	*
42	449,600	40	250	0.017	0.002	3,035	455	3,490	15,415	162	1
43	38,900	30	300	0.005	0.001	63	15	77	3,300	3	
45	700	30	700	0.066	0.007	14	3	17	0	1	
54A	3,000	50	150	0.002	0.000	3	0	4	0	0	
54B	138,700	50	50	0.002	0.000	129	13	142	14,700	6	
61	2,100	5	850	0.009	0.001	1	2	3	0	0	
62	800	20	400	0.006	0.001	1	0	1	0	0	
64	700	50	400	0.006	0.001	2	0	2	0	0	
65	23,200	70	1,200	0.013	0.001	219	9	228	2,600	10	2
68B	2,300	70	50	0.002	0.000	3	0	3	0	0	
71	5,200	70	150	0.000	0.000	0	0	0	0	0	3
TOT.	1,101,000					7,926	1,856	9,782	53,990	403	

# NOTES:

- 1 Rainfall in this zone varies from 150 to 600 east to west.
- 2 Leopards reported to be rare above the timberline (Rousos).
- 3 Leopards reported to be absent from Danakil Depression - IUCN.

# GABON

Area 267000 Population (millions) 1.221 Density/sq.km 4.57

VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	52,800	50	1,600	0.197	0.002	5,204	52	5,256	8,980	174	*
1A	158,100	70	1,750	0.222	0.022	24,563	1,053	25,616	12,400	1,143	
2	30,800	70	1,800	0.230	0.023	4,967	213	5,180	0	259	
3	11,600	70	1,800	0.230	0.023	1,871	80	1,951	0	98	
77	2,300	50	2,500	0.036	0.004	41	4	45	0	2	
8	11,400	50	2,000	0.066	0.007	377	38	415	1,000	17	
TOT.	267,000					37,023	1,440	38,463	22,380	1,694	

# GAMBIA

Area 11300		Population (millions)			0.682	Density/sq.km		60.4			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	2,400	5	900	0.092	0.001	11	2	13	100	0	
29A	7,200	10	800	0.020	0.000	14	1	15	0	1	
77	1,700	30	900	0.009	0.000	5	0	5	0	0	
TOT.	11,300					30	3	33	100	1	

# GHANA

Area 230000		Population (millions)			14.42	Density/sq.km		62.7			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	53,100	20	1,200	0.135	0.001	1,430	57	1,487	6,250	32	
12	5,200	20	1,250	0.142	0.001	148	6	154	274	6	
15	6,000	20	700	0.066	0.001	79	3	82	0	4	
1A	18,300	10	1,700	0.214	0.002	391	35	426	0	21	
2	60,300	10	400	0.165	0.002	996	90	1,086	692	49	
27	67,000	30	1,100	0.120	0.001	2,412	56	2,469	4,921	94	
29A	10,700	30	900	0.023	0.000	74	2	76	0	4	
30	7,300	30	900	0.092	0.001	202	5	206	0	10	
77	2,100	30	700	0.007	0.000	4	0	4	0	0	
TOT.	230,000					5,736	254	5,990	12,137	220	

# GUINEA

Area 245887		Population (millions)			6.445	Density/sq.km		26.2			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	156,100	30	1,800	0.230	0.002	10,789	252	11,041	2,000	529	
12	2,100	30	1,600	0.197	0.002	124	3	127	0	6	
13	4,100	30	1,600	0.197	0.002	242	6	248	0	12	
19A	1,200	60	2,000	0.265	0.003	191	1	192	70	9	
27	52,500	30	1,100	0.120	0.001	1,890	44	1,934	0	97	
29A	7,600	20	900	0.023	0.000	35	1	36	0	2	
3	19,300	40	2,000	0.265	0.003	2,045	31	2,076	0	104	
77	3,000	40	2,100	0.028	0.000	34	1	34	1,000	0	1
TOT.	245,900					15,350	338	15,689	3,070	759	

# GUINEA BISSAU

Area 36100		Population (millions)			0.943	Density/sq.km		26.1			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	25,600	20	1,100	0.120	0.001	615	25	639	0	32	
77	10,500	30	1,200	0.013	0.000	42	1	43	0	2	
TOT.	36,100					657	26	682	0	34	

IVORY COAST  
Area 318000

		Population (millions)		10.41		Density/sq.km		32.7			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	93,600	20	1,200	0.135	0.001	2,521	101	2,622	3,520	107	
19A	300	60	2,000	0.265	0.003	48	0	48	50	2	
1A	44,900	10	1,800	0.230	0.002	1,034	93	1,128	1,300	41	
2	61,500	10	1,450	0.173	0.002	1,064	96	1,160	1,743	43	
27	88,600	40	1,000	0.106	0.001	3,749	56	3,805	9,500	140	
3	24,500	10	1,900	0.247	0.002	606	55	661	0	33	
77	1,600	40	2,000	0.026	0.000	17	0	17	20	1	
8	3,000	40	2,000	0.066	0.001	79	1	81	190	3	
TOT.	318000					9,119	402	9,522	16,323	371	

KENYA

Area 569500

		Population (millions)		21.85		Density/sq.km		38.4			
VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
11A	11,500	10	1,200	0.135	0.013	155	139	294	0	15	
16A	28,400	10	1,000	0.106	0.011	300	270	571	0	29	
16B	4,600	48	1,250	0.142	0.014	314	34	348	168	16	
19A	28,900	50	1,000	0.106	0.011	1,529	153	1,682	1,972	74	
2	2,900	10	1,300	0.150	0.015	43	39	83	97	3	
42	327,300	60	300	0.021	0.002	4,219	281	4,500	22,272	201	1
45	69,800	37	800	0.079	0.008	2,033	346	2,379	3,502	105	
54B	89,200	60	100	0.005	0.001	268	18	286	1,570	14	
64	1,800	50	300	0.004	0.000	4	0	4	0	0	
65	1,800	100	2,000	0.026	0.003	48	0	48	688	1	
76	200	95	300	0.002	0.000	0	0	0	190	0	
77	3,100	30	1,000	0.011	0.001	10	2	12	0	1	
TOT.	569,500					8,924	1,284	10,207	30,459	459	

NOTE: 1 This habitat type covers the rainfall range 150-600mm.

LESOTHO

Area 30400

		Population (millions)		1.612		Density/sq.km		53.0			
VT	OR.AREA	RZ	RNFL	LD1	LD2	LN1	LN2	TOTAL	NP	PH	NT
20	19,100	10	1,200	0.135	0.001	257	23	280	0	14	
58	4,700	30	700	0.007	0.000	9	0	10	0	0	
66	6,600	100	1,600	0.020	0.000	130	0	130	68	6	
TOT.	30,400					397	23	420	68	21	

## LIBERIA

Area 111400      Population (millions)      2.324      Density/sq.km      20.9

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	16,800	10	2,800	0.414	0.004	695	63	757	500	28	*
19A	100	80	2,000	0.265	0.026	21	1	22	70	0	
1A	31,300	20	2,200	0.301	0.003	1,881	75	1,956	1,300	78	*
3	61,800	10	2,400	0.337	0.003	2,084	188	2,271	1,360	91	*
77	1,200	30	2,800	0.041	0.004	15	3	18	50	1	
8	200	20	2,700	0.099	0.010	4	2	6	40	0	
TOT.	111,400					4,700	331	5,031	3,320	198	

## MALAWI

Area 94100      Population (millions)      7.367      Density/sq.km      78.3

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16B	100	50	900	0.092	0.009	5	0	5	0	0	
19A	10,500	60	1,200	0.135	0.013	848	57	905	3,352	23	
25	53,200	40	1,000	0.106	0.011	2,251	338	2,589	4,710	105	
26	6,300	50	750	0.072	0.007	228	23	250	264	12	
28	1,500	70	500	0.042	0.004	44	2	46	960	0	
29C	19,600	40	800	0.079	0.008	617	93	710	1,619	29	
65	100	100	1,100	0.012	0.001	1	0	1	0	0	
75	2,800	40	900	0.018	0.002	21	3	24	0	1	
TOT.	94,100					4,015	515	4,530	10,905	170	

## MALI

Area 754100      Population (millions)      8.574      Density/sq.km      11.4

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
27	78,600	30	1,000	0.106	0.001	2,495	58	2,553	0	128	*
29A	265,600	20	500	0.011	0.000	561	22	584	0	29	*
43	145,200	20	200	0.003	0.000	91	36	128	0	6	
54A	222,300	20	100	0.001	0.000	56	22	78	17,500	3	
64	42,400	24	150	0.002	0.000	17	6	23	0	1	
TOT.	754,100					3,220	145	3,365	17,500	167	

## MAURITANIA

Area 388600      Population (millions)      2.003      Density/sq.km      5.15

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
29A	600	10	500	0.011	0.001	1	1	1	0	0	
43	175,000	20	200	0.003	0.000	110	44	154	0	8	
54A	213,000	20	100	0.001	0.000	53	21	75	0	4	
TOT.	388,600					164	66	230	0	11	

MOZAMBIQUE  
Area 783200

Area 783200		Population (millions)			14.81	Density/sq.km		18.9			
VT	OR.AREA	R%	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16	6,800	50	1,200	0.135	0.013	458	46	504	250		24
16A	229,700	50	1,250	0.142	0.014	16,327	1,633	17,959	1,150		890
16B	2,300	50	1,200	0.135	0.013	155	15	170	0		9
16C	17,100	50	850	0.085	0.009	729	73	802	720		37
19A	1,200	80	1,100	0.120	0.012	115	3	118	0		6
25	92,500	40	1,200	0.135	0.013	4,983	747	5,730	500		283
26	212,100	40	800	0.079	0.008	6,679	1,002	7,681	16,150		320
28	110,600	30	400	0.031	0.003	1,043	243	1,287	11,500		46
39C	68,200	50	650	0.060	0.006	2,039	204	2,243	0		112
29D	14,700	55	600	0.054	0.005	435	36	470	0		24
29E	10,500	50	800	0.079	0.008	413	41	455	0		23
75	1,900	90	900	0.018	0.002	31	0	32	0		2
76	8,700	80	800	0.008	0.001	55	1	56	0		3
77	6,900	40	1,000	0.011	0.001	29	4	34	80		2
TOT.	783,200					33,493	4,049	37,542	30,350		1,779

NAMIBIA

Area 823200

Area 823200		Population (millions)			1.644	Density/sq.km		2.0			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
22A	53,500	50	600	0.040	0.004	1,079	108	1,187	5,300		49
28	92,900	50	500	0.042	0.004	1,963	196	2,159	19,000		68
35A	106,900	50	450	0.037	0.004	1,964	196	-2,161	0		108
35C	19,600	60	300	0.021	0.002	253	17	269	0		13
36	39,300	30	250	0.017	0.002	199	46	245	0		12
44	87,800	40	300	0.021	0.002	754	113	868	405		43
51	177,700	40	50	0.002	0.000	142	21	164	24,260		6
56	92,600	40	200	0.013	0.001	465	70	535	350		27
64	600	80	800	0.016	0.002	8	0	8	0		0
74	145,700	100	25	0.001	0.000	117	0	117	16,911		5
75	2,500	90	500	0.008	0.001	19	0	19	0		1
76	4,100	90	450	0.004	0.000	14	0	14	2,270		0
TOT.	823,200					6,976	769	7,745	68,496		332

NIGER

Area 556000

NIGER		Population (millions)				6.487		Density/sq.km		11.7	
Area 556000											
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
29A	113,900	20	500	0.011	0.000	241	10	250	0	13	*
43	222,100	20	150	0.002	0.000	95	38	133	0	7	
54A	218,100	30	75	0.001	0.000	56	13	69	40,760	2	
75	1,900	20	150	0.002	0.000	1	0	1	0	0	
TOT.	556,000					393	61	454	40,760	21	



# NIGERIA

Area 919800		Population (millions)			101.0	Density/sq.km		110			
VT	OR.AREA	R%	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	253,700	20	1,200	0.135	0.001	6,833	273	7,107	0	355	
12	23,100	20	1,400	0.165	0.002	763	31	794	1,900	24	
19A	3,700	50	2,000	0.265	0.003	490	5	495	0	25	
1A	60,300	10	2,400	0.337	0.003	2,033	183	2,216	4,620	33	
2	37,000	10	1,600	0.197	0.002	729	66	795	1,715	23	
27	147,500	30	900	0.092	0.001	4,072	95	4,167	6,441	179	
29A	286,500	30	700	0.016	0.000	1,418	33	1,451	2,060	71	
30	23,100	30	800	0.079	0.001	546	13	558	2,240	19	
32	13,000	30	800	0.039	0.000	154	4	157	0	8	
33	1,700	30	850	0.043	0.000	22	1	22	0	1	
43	24,900	20	300	0.005	0.000	27	1	28	4,980	0	#
75	2,100	20	300	0.004	0.000	2	0	2	0	0	
77	24,400	50	3,500	0.056	0.001	678	7	685	85	34	
8	18,800	30	2,400	0.084	0.001	475	11	487	0	24	
TOT.	919,800					18,241	721	18,963	24,041	796	

# RWANDA

Area 25100		Population (millions)			6.439	Density/sq.km		257			
VT	OR.AREA	R%	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
19A	8,400	10	1,600	0.197	0.002	166	15	180	0	9	
45	15,700	10	1,000	0.106	0.001	166	15	181	1,570	1	#
65	1,000	100	2,000	0.026	0.000	26	0	26	130	1	
TOT.	25,100					358	30	388	1,700	11	

# SENEGAL

Area 196200		Population (millions)			6.836	Density/sq.km		34.8			
VT	OR.AREA	R%	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	27,000	10	1,200	0.135	0.001	364	33	396	700	15	
29A	112,500	20	600	0.013	0.000	303	12	315	13,837	6	
43	56,000	20	300	0.005	0.000	60	2	63	5,496	2	
77	700	60	1,400	0.017	0.000	7	0	7	80	0	
TOT.	196,200					733	47	781	20,113	23	

SIERRA LEONE  
Area 71600

		Population (millions)				Density/sq.km		53.3			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	55,600	10	2,400	0.337	0.003	1,875	169	2,044	1,000	85	
19A	800	60	2,400	0.337	0.003	162	1	163	200	5	
3	5,500	20	2,600	0.375	0.004	412	16	429	779	7	
77	6,800	50	2,700	0.039	0.000	134	1	135	360	6	
8	3,000	10	2,700	0.099	0.001	30	3	32	200	1	
TOT.	71,700					2,613	190	2,803	2,539	104	

SOMALIA  
Area 637700

		Population (millions)				Density/sq.km		7.74			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16A	18,200	30	600	0.054	0.005	294	69	362	3,400	9	
19A	1,200	80	150	0.009	0.001	8	0	8	280	0	
38	8,600	40	100	0.005	0.001	17	3	20	1,100	1	
42	427,100	20	200	0.013	0.001	1,073	429	1,502	25,450	59	1
54B	173,400	60	50	0.002	0.000	208	14	222	15,800	10	
67	6,000	100	25	0.001	0.000	5	0	5	0	0	
68B	1,400	80	25	0.000	0.000	0	0	0	0	0	
77	1,800	30	600	0.005	0.001	3	1	4	370	0	
TOT.	637,700					1,608	515	2,123	46,400	79	

NOTE: 1 The percentage remaining has been reduced from 60% to 20%.

SOUTH AFRICA  
Area 1236500

		Population (millions)				Density/sq.km		27.8			
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16C	51,600	50	1,000	0.106	0.011	2,729	273	3,002	1,797	141	
19A	77,400	50	1,200	0.135	0.013	5,212	521	5,733	3,246	265	
20	21,100	40	1,200	0.135	0.013	1,137	171	1,307	0	65	
24	27,400	60	1,100	0.120	0.012	1,973	132	2,105	129	104	
28	25,000	70	500	0.042	0.004	739	32	771	8,558	20	
29D	127,900	60	500	0.042	0.004	3,242	216	3,459	7,597	157	
29E	18,300	40	700	0.066	0.007	483	72	555	6,216	7	
34	20,600	50	700	0.033	0.003	340	34	374	133	18	
35A	5,300	40	400	0.031	0.003	67	10	77	0	4	
39	28,000	50	900	0.092	0.009	1,288	129	1,417	247	70	
44	137,800	39	300	0.021	0.002	1,155	181	1,335	257	66	
48	7,400	20	950	0.099	0.010	146	59	205	0	10	
50	76,600	40	500	0.042	0.004	1,295	194	1,489	12,364	48	
51	105,500	50	100	0.005	0.001	265	26	291	2,727	14	
52	48,600	60	150	0.002	0.000	63	4	67	0	3	
53	138,800	30	200	0.003	0.000	31	31	161	0	8	
56	58,300	40	200	0.013	0.001	293	44	337	9,591	11	
57A	12,900	40	200	0.006	0.001	32	5	37	162	2	
57B	99,800	30	500	0.011	0.001	316	74	390	891	19	
58	135,800	30	700	0.007	0.001	269	63	331	251	16	
66	2,700	40	1,200	0.013	0.001	15	2	17	347	1	
74	8,800	100	25	0.001	0.000	7	0	7	0	0	
77	900	50	1,000	0.011	0.001	5	0	5	0	0	
TOT.	1,236,500					21,201	2,272	23,472	54,513	1,052	

SUDAN

Area 1783000 Population (millions) 22.86 Density/sq.km 12.8

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	22,800	9	1,400	0.165	0.017	339	343	682	770	28	
19A	4,200	40	300	0.021	0.002	36	5	42f	1,000	1	
19B	1,700	80	400	0.031	0.003	43	1	44	1,360	0	
27	267,700	30	1,000	0.106	0.011	8,496	1,982	10,478	18,270	427	
29A	195,400	20	700	0.016	0.002	645	258	902	0	45	
29B	97,200	30	900	0.092	0.009	2,683	626	3,309	4,400	145	
35B	80,100	30	800	0.079	0.008	1,892	441	2,333	24,030	22	
38	700	50	250	0.017	0.002	6	1	6	0	0	
42	26,400	50	500	0.042	0.004	558	56	614	4,600	21	
43	214,400	20	300	0.021	0.002	921	368	1,290	0	64	
54A	461,500	40	150	0.002	0.000	317	48	364	0	18	
54B	700	50	100	0.005	0.001	2	0	2	0	0	
61	147,700	30	850	0.009	0.001	378	88	466	12,500	18	
62	190,900	20	800	0.016	0.002	601	240	842	5,700	38	
63	15,500	20	700	0.013	0.001	41	16	57	0	3	
64	56,100	59	850	0.017	0.002	565	39	604	9,500	22	
TOT.	1,783,000					17,522	4,514	22,035	82,130	853	

SWAZILAND

Area 17400 Population (millions) 0.689 Density/sq.km 39.6

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
19A	2,200	60	1,200	0.135	0.013	178	12	190	180	8	
24	1,600	60	1,100	0.120	0.012	115	8	123	0	6	
29E	13,600	40	800	0.079	0.008	428	64	493	0	25	
TOT.	17,400					721	84	805	180	39	

TANZANIA

Area 886200 Population (millions) 23.87 Density/sq.km 26.9

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	12,700	20	800	0.079	0.008	200	80	280	457	12	
16A	97,700	24	1,200	0.135	0.013	3,158	1,000	4,158	1,700	196	
16B	600	50	1,200	0.135	0.013	40	4	44	0	2	
17	7,600	90	850	0.009	0.001	58	1	59	250	3	
19A	50,300	80	1,000	0.106	0.011	4,257	106	4,363	6,507	184	
25	116,900	38	900	0.092	0.009	4,087	667	4,754	1,235	232	
26	297,500	79	750	0.072	0.007	16,988	452	17,439	5,530	852	
29C	6,300	50	800	0.079	0.008	248	25	273	0	14	
35A	10,100	40	800	0.079	0.008	318	48	366	800	15	
40	6,800	50	1,000	0.106	0.011	360	36	396	0	20	
42	213,000	49	600	0.054	0.005	5,614	584	6,198	22,813	249	
45	18,700	36	800	0.079	0.008	530	94	624	0	31	
54B	1,000	80	300	0.021	0.002	17	0	18	0	1	
59	17,700	60	800	0.008	0.001	84	6	89	3,820	3	
64	9,800	80	850	0.017	0.002	134	3	137	0	7	
65	1,200	100	1,300	0.015	0.001	18	0	18	400	1	
76	12,200	80	650	0.006	0.001	58	1	60	0	3	
77	5,300	40	1,200	0.013	0.001	29	4	33	0	2	
8	800	20	1,300	0.150	0.015	24	10	34	0	2	
TOT.	886,200					36,222	3,121	39,343	43,512	1,827	

TOGO		Population (millions)		3.141		Density/sq.km		56.1			
Area 56000											
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	12,800	20	1,200	0.135	0.001	345	14	359	350	16	
2	5,200	10	1,500	0.181	0.002	94	8	103	0	5	
27	32,900	40	1,300	0.150	0.001	1,970	30	2,000	3,716	72	
29A	5,100	60	950	0.025	0.000	76	1	76	90	4	
TOT.	56,000					2,485	52	2,537	4,156	97	

UGANDA		Population (millions)		16.42		Density/sq.km		84.8			
Area 193700											
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	88,400	10	1,300	0.150	0.001	1,324	119	1,443	3,279	48	*
19A	6,600	50	1,100	0.120	0.012	396	40	436	144	21	
2	7,300	58	1,600	0.197	0.002	835	6	841	1,852	24	*
27	2,300	30	1,000	0.106	0.011	73	17	90	289	3	
29A	52,100	30	800	0.020	0.002	308	72	379	2,873	16	
42	16,200	40	600	0.054	0.005	349	52	401	2,056	15	
45	19,700	20	1,000	0.106	0.001	417	17	433	2,571	8	*
65	1,000	100	2,000	0.265	0.026	265	0	265	0	13	
8	100	20	1,300	0.150	0.015	3	1	4	0	0	
TOT.	193,700					3,968	324	4,292	13,064	147	

ZAIRE		Population (millions)		31.76		Density/sq.km		13.6			
Area 2335900											
VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
11A	395,400	31	1,500	0.181	0.002	22,182	494	22,676	13,420	1,012	*
14	4,700	40	1,500	0.181	0.018	340	51	391	0	20	
15	2,100	20	900	0.092	0.009	39	15	54	0	3	
19A	54,100	80	2,000	0.265	0.026	11,464	287	11,750	8,500	475	
1A	617,200	50	2,000	0.265	0.026	81,740	8,174	89,914	33,560	4,051	
2	339,300	46	1,900	0.247	0.002	38,627	453	39,080	2,730	1,920	*
21	32,000	30	1,200	0.135	0.013	1,293	302	1,595	0	80	
25	365,000	48	1,000	0.106	0.011	18,535	2,008	20,542	14,500	950	
29A	2,700	10	1,200	0.034	0.003	9	8	17	0	1	
31	70,200	28	1,250	0.071	0.007	1,397	359	1,756	550	86	
37	12,900	30	1,000	0.053	0.005	205	48	252	550	11	
4	22,200	80	2,200	0.301	0.030	5,337	133	5,470	4,330	208	
40	400	20	800	0.079	0.008	6	3	9	0	0	
45	7,100	60	1,200	0.135	0.013	574	38	612	3,800	5	
60	57,300	80	1,100	0.012	0.001	550	14	564	3,670	26	
65	600	100	2,200	0.030	0.003	18	0	18	0	1	
75	4,300	50	1,000	0.021	0.002	45	5	50	0	3	
77	2,500	50	900	0.009	0.001	12	1	13	0	1	
8	148,800	30	1,600	0.049	0.005	2,200	513	2,713	4,500	125	
9	197,100	50	2,000	0.265	0.026	26,103	2,610	28,714	1,000	1,422	
TOT.	2,335,900					210,676	15,516	226,192	91,110	10,400	

## ZAMBIA

Area 752600      Population (millions)      7.072      Density/sq.km      9.40

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16B	300	50	1,000	0.106	0.011	16	2	17	0	1	
19A	300	80	1,000	0.106	0.011	25	1	26	0	1	
21	20,100	20	1,300	0.150	0.015	602	241	843	540	38	
22A	16,100	50	700	0.049	0.005	398	40	438	3,600	13	
25	372,700	80	1,000	0.106	0.011	31,543	789	32,331	27,350	1,472	
26	134,700	50	800	0.079	0.008	5,302	530	5,833	11,014	248	
28	37,600	100	600	0.054	0.005	2,022	0	2,022	9,142	77	
29C	24,300	70	800	0.079	0.008	1,339	57	1,397	300	69	
40	5,000	60	1,000	0.106	0.011	317	21	339	500	14	
6	33,700	40	1,100	0.120	0.012	1,618	243	1,861	1,404	85	
60	28,300	90	900	0.009	0.001	234	3	237	5,700	9	
64	64,100	80	700	0.013	0.001	677	17	693	4,260	32	
75	12,900	90	1,200	0.027	0.003	313	3	316	0	16	
76	2,500	80	800	0.008	0.001	16	0	16	400	1	
TOT.	752,600					44,423	1,946	46,369	64,210	2,075	

## ZIMBABWE

Area 390200      Population (millions)      9.312      Density/sq.km      23.9

VT	OR.AREA	RZ	RNFL	LD1	LD2*	LN1	LN2	TOTAL	NP	PH	NT
16	1,200	50	1,250	0.142	0.014	85	9	94	150	4	
19A	6,500	80	1,100	0.120	0.012	624	16	640	485	29	
22A	34,500	60	500	0.032	0.003	656	44	700	12,083	16	
26	170,600	40	750	0.072	0.007	4,932	740	5,672	2,688	274	
28	110,600	45	400	0.100	0.010	4,977	608	5,585	9,147	234	1
29C	66,800	45	600	0.100	0.010	3,006	367	3,373	2,932	154	2
TOT.	390,200					14,281	1,783	16,064	27,485	710	3

NOTES: 1 Density increased to 0.1/sq.km based on Booth (1987).  
2 Density increased to 0.1/sq.km based on Smith (1977).

## APPENDIX 5

### CONSISTENCY WITH FAO DATA

The purpose of this analysis is to check the consistency of our analysis in Appendix 4 using independently derived estimates of rainfall and forest cover in each country.

FAO (1986) gives overall land use tables for each country in Africa with remaining areas of "Forest & Woodland". We have summed these for each country and assigned a mean rainfall for the country as a whole from Parker (1984). From this rainfall figure we have predicted an average leopard density for the country and computed a total number of leopard. This analysis appears in Table A5-1.

For eleven countries, the results are almost identical. These are Angola, Benin, Cameroun, Chad, Equatorial Guinea, Nigeria, Somalia, Sudan, Tanzania, Togo and Zimbabwe.

The results for the following thirteen countries all lie within the 95% confidence intervals derived in section 1.2.4. The figures in brackets indicate whether the FAO estimates are higher (H) or lower (L). Central African Republic(H), Congo(H), Gabon(H), Guinea(H), Ivory Coast(H), Malawi(H), Mali(L), Namibia(L), Niger(L), Rwanda(H), Uganda(H), Zaire(H) and Zambia(L). The estimate for Ethiopia is only just outside the confidence limits (approximately double our estimate). Most of the estimates using the FAO data are higher than those from Appendix 4.

Certain results can be ignored. Those for Botswana, Kenya, Mozambique and South Africa are clearly the result of FAO including very large parts of the area of each country as "Permanent Pasture" rather than "Woodland" in the land use classes. It is clear that FAO land use planners view Africa as an area to be developed for domestic livestock. Another factor leading to the low predictions for Botswana and South Africa from the FAO data is the absence of any significant areas of "Forest": Karroo and Kalahari shrubland are excluded on this basis. The populations for Burundi, Lesotho and Swaziland derived from the FAO data differ from ours but estimates from both sources of data are low.

This leaves a group of countries for which the results using the FAO data are so much higher than ours that they cannot be ignored. These are all West African countries. Gambia, Ghana, Guinea Bissau, Liberia, Senegal and Sierra Leone are in the rainforest group, and Mauritania and Burkina Faso are in the drier part of West Africa. The result for the latter two can be explained by the inclusion by FAO of a large amount of the Sahel as "Woodland" rather than "Permanent Pasture".

In the main text (section 1.2.6) we discuss the large discrepancy between our predicted values and the local estimates for leopard numbers in West African lowland rainforest areas. The predictions obtained using FAO estimates of remaining forest cover are even higher than ours.

By and large, the comparison of our predictions with a crude estimates based on undifferentiated forest cover and overall mean rainfall for entire countries suggests that there are no glaring inconsistencies in the technique. The orders of magnitude for the populations are much the same.

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TABLE A5-1: ESTIMATES USING FAO LAND CLASS DATA

#	COUNTRY	RAINFALL mm	FOREST sq. km	LEOPARD DENSITY	PREDICTED POPULATION	TABLE 1 RESULT
1	ANGOLA .....	1,088	534,000	0.1183	63,167	62,486
2	BENIN .....	1,153	37,700	0.1277	4,816	4,915
3	BOTSWANA .....	435	9,620	0.0351	338	7,729
4	BURKINA FASO .....	879	100,000	0.0892	8,918	1,693
5	BURUNDI .....	1,196	640	0.1341	86	495
6	CAMEROUN .....	1,572	252,000	0.1926	48,526	41,896
7	CENTRAL AFRICAN REPUBLIC .....	1,436	358,600	0.1708	61,256	41,546
8	CHAD .....	335	132,100	0.0249	3,284	3,125
9	CONGO .....	1,643	213,200	0.2042	43,527	32,394
10	DJIBOUTI .....				0	25
11	EQUATORIAL GUINEA .....	2,582	12,950	0.3715	4,810	5,040
12	ETHIOPIA .....	697	297,000	0.0656	19,482	9,782
13	GABON .....	1,871	200,000	0.2425	48,499	38,463
14	GAMBIA .....	1,138	1,920	0.1255	241	33
15	GHANA .....	1,326	84,900	0.1537	13,050	5,990
16	GUINEA .....	1,911	102,600	0.2494	25,587	15,689
17	GUINEA BISSAU .....	1,180	10,700	0.1317	1,409	682
18	IVORY COAST .....	1,434	78,800	0.1705	13,436	9,522
19	KENYA .....	528	37,400	0.0454	1,698	10,207
20	LESOTHO .....	786	20,000	0.0769	1,538	420
21	LIBERIA .....	2,731	37,600	0.4001	15,044	5,031
22	MALAWI .....	1,057	46,300	0.1138	5,271	4,530
23	MALI .....	391	86,400	0.0305	2,636	3,365
24	MAURITANIA .....	251	150,000	0.0170	2,545	230
25	MOZAMBIQUE .....	968	152,100	0.1013	15,413	37,542
26	NAMIBIA .....	292	184,200	0.0207	3,818	7,745
27	NIGER .....	182	26,600	0.0111	295	454
28	NIGERIA .....	1,300	152,000	0.1497	22,760	18,963
29	RWANDA .....	1,103	5,080	0.1205	612	388
30	SENEGAL .....	855	59,420	0.0860	5,109	781
31	SIERRA LEONE .....	2,937	20,900	0.4406	9,208	2,803
32	SOMALIA .....	270	89,500	0.0187	1,672	2,123
33	SOUTH AFRICA .....	477	41,500	0.0397	1,647	23,472
34	SUDAN .....	453	477,000	0.0371	17,685	22,035
35	SWAZILAND .....	796	1,000	0.0782	78	805
36	TANZANIA .....	905	427,850	0.0927	39,659	39,343
37	TOGO .....	1,228	15,000	0.1389	2,083	2,537
38	UGANDA .....	1,109	58,600	0.1213	7,109	4,292
39	ZAIRE .....	1,613	1,762,900	0.1992	351,239	226,192
40	ZAMBIA .....	1,018	294,900	0.1083	31,943	46,369
41	ZIMBABWE .....	677	238,100	0.0631	15,028	16,064
TOTALS .....					914,521	757,196



## APPENDIX 7

### SIMULATION OF PAST LEOPARD HARVESTS

We have used the population model described in Appendix 1 to simulate the effects of past harvests on the estimated populations (Table 1, main report). The period we have considered is from 1950 to the present date.

The data on exports of leopard skins and killing of leopard are too poor to permit the construction of individual scenarios for each country. The best we have been able to do is to divide Africa into 5 regions and make estimates of the number of leopard which might have been killed in each year in these regions. A large amount of deduction and guesswork has gone into making up these estimates and, if anything we have tried to err on the high side. For example, Myers (1976 p65) thought that the total number of leopard being killed in 1968 & 1969 might have been as high as 50,000; we have worked on 61,000. He states that it is generally accepted that for every skin entering the trade another is rejected as useless: we have accepted this principle although there is no proof for it. For every female killed we have assumed that the cubs die also, and we have made substantial allowances for leopards being killed to protect of livestock and dying as result of inefficient hunting.

Our sources for the harvest profiles shown in the following figures are as follows: Myers (1971, 1974,1976), Hamilton (1981), Paradiso (1972), Esterhuisen & Norton (1985), Funialli & Simonetta (1966), Traffic Bulletins (1978,1980b,1981), Traffic [Japan] (1984), HM Customs and Excise Wildlife Seizures (1979), US Fish & Wildlife Service (1986), Munich Merkur (1979), Burundi customs statistics, CITES trade statistics, data from Traffic files in Germany, Italy and Belgium, and data from numerous traders in Africa who prefer not be named. None of the sources need feel responsible for the final estimates in the following tables. We note, as a matter of interest, that there is virtually no reconciliation between any of the export and import figures in any particular year. The CITES data appears to reflect the least amount of exports of any source - not that this is important: the fur trade had virtually ceased by the time of CITES inception.

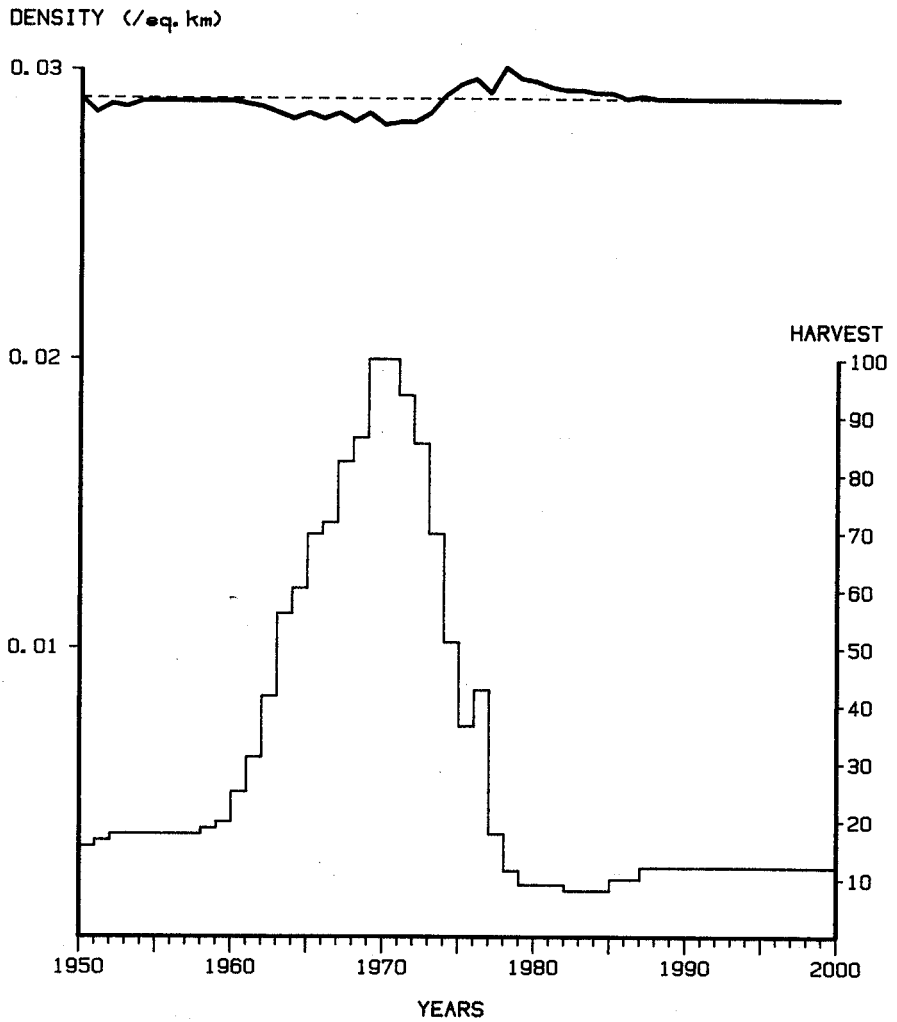
In the diagrams which follow, the regions which are specified are:

AFRICA: includes all countries.  
CENTRAL AFRICA: Zaire, Congo, Gabon, Equatorial Guinea, Burundi, Rwanda.  
SOUTHERN AFRICA: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe.  
WESTERN AFRICA: Benin, Burkina Faso, Cameroun, CAR, Chad, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo.  
EASTERN AFRICA: Kenya, Tanzania, Uganda.  
NORTHERN AFRICA: Djibouti, Ethiopia, Somalia, Sudan.

We have derived approximate population values from the 95% confidence intervals for each region which have been used in some cases in the simulations (bold print). Densities in each region are based on the population estimate used and the total area of the region.

----- POPULATION ESTIMATES -----					
	Lower Confidence Limit	Central Estimate	Upper Confidence Limit	MEAN DENSITY	Figure Number
AFRICA	<b>598000</b>	714105	854000	0.029	A7-1
CENTRAL	<b>200000</b>	302972	500000	0.066	A7-2
SOUTH	<b>145000</b>	207169	331000	0.024	A7-3
WEST	93000	<b>116164</b>	163000	0.019	A7-4
EAST	32000	<b>53842</b>	<b>92000</b>	0.033	A7-5, A7-7
NORTH	20000	33965	<b>58000</b>	0.016	A7-6
NORTH (Rev.)			<b>100000</b>	0.028	A7-8

Fig. A7-1.



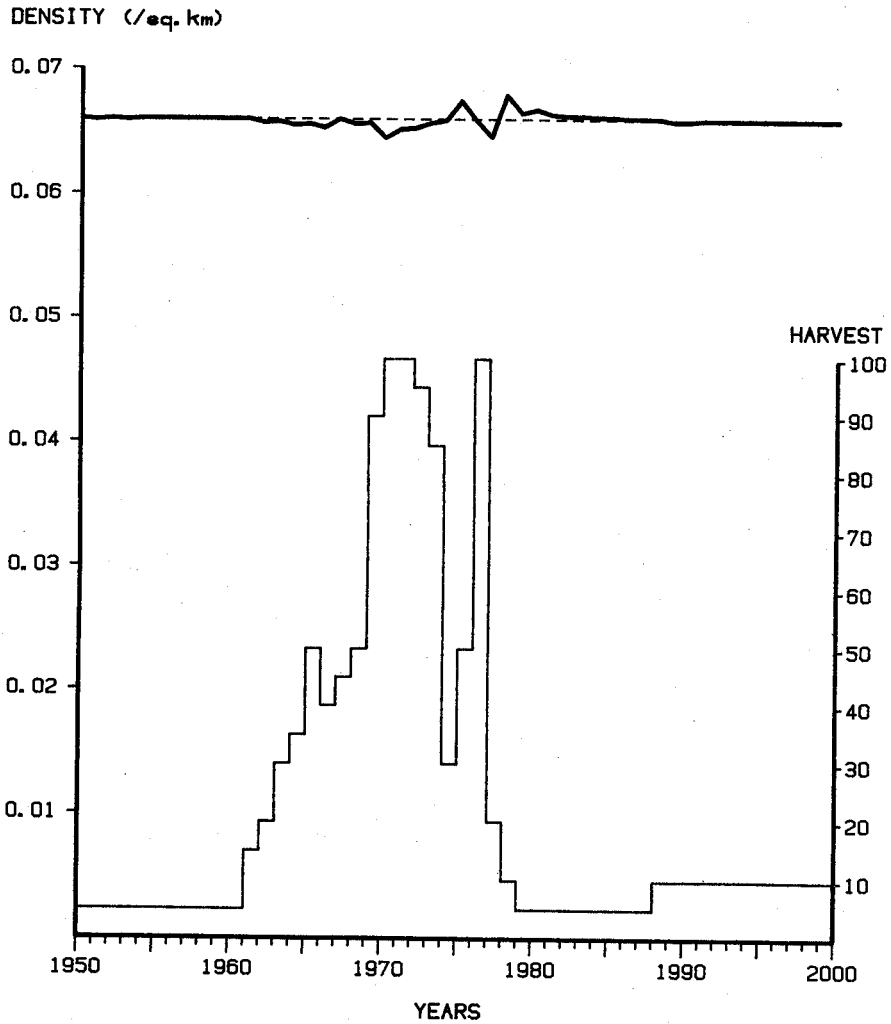
HARVEST: 100 = 61 000 leopard

AREA: 20 272 000 sq. km

POPULATION: 598 000 leopard (LCI estimate)

Fig. A7-1: SUB-SAHARAN AFRICA - RESPONSE TO HARVEST

Fig. A7-2.



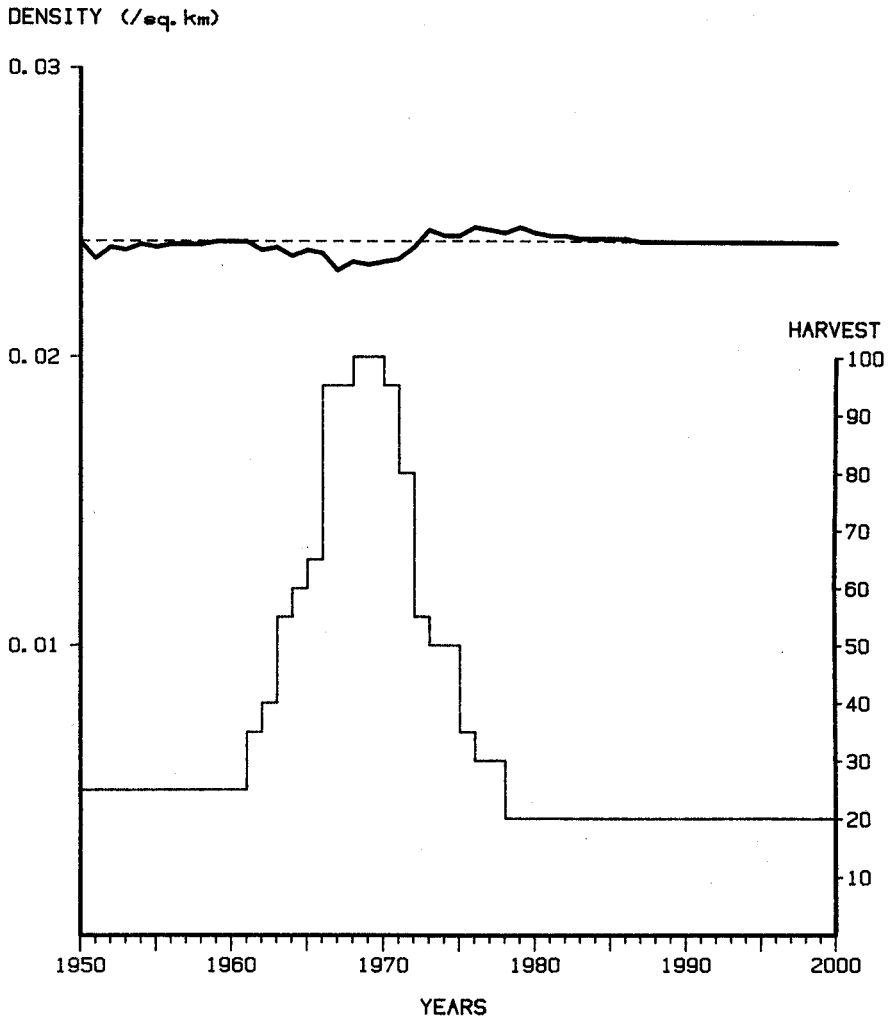
HARVEST: 100 = 8 000 leopard

AREA: 3 022 000 sq. km

POPULATION: 200 000 leopard (LCI estimate)

Fig. A7-2: CENTRAL AFRICA - RESPONSE TO HARVEST

Fig. A7-3.



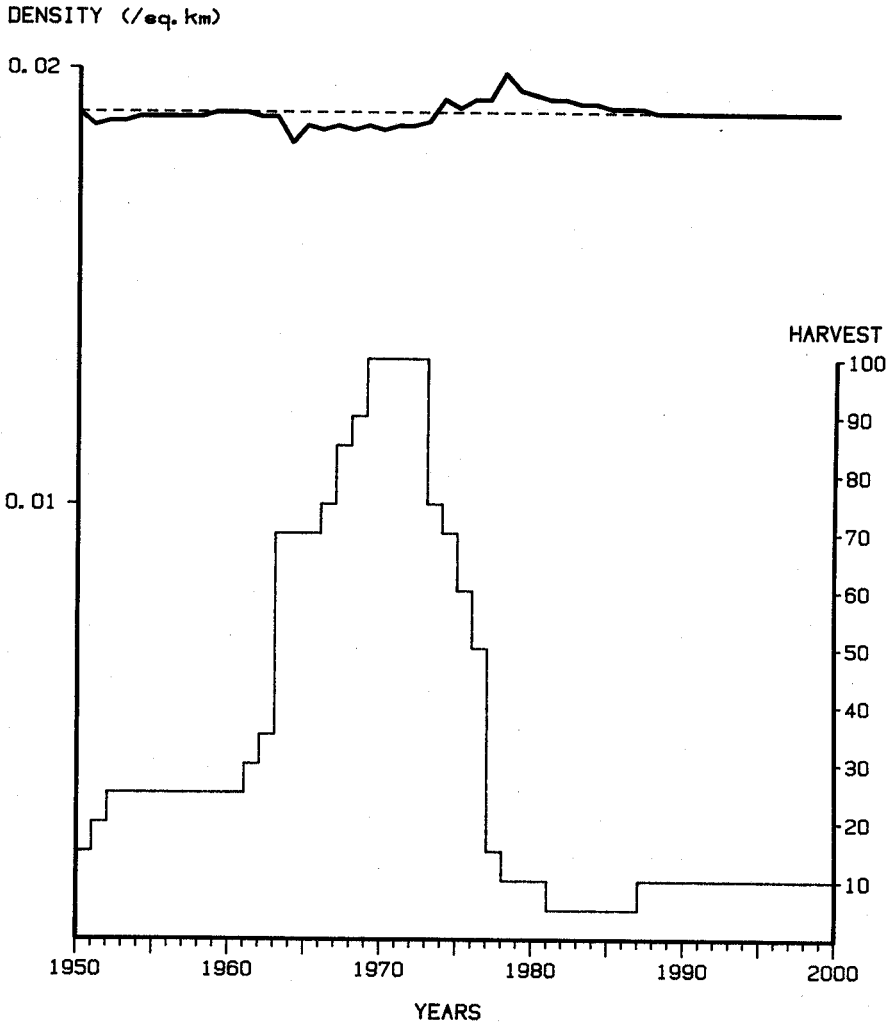
HARVEST: 100 = 13 500 leopard

AREA: 5 959 000 sq. km

POPULATION: 145 000 leopard (LCI estimate)

Fig. A7-3: SOUTHERN AFRICA - RESPONSE TO HARVEST

Fig. A7-4.



HARVEST: 100 = 10 000 leopard

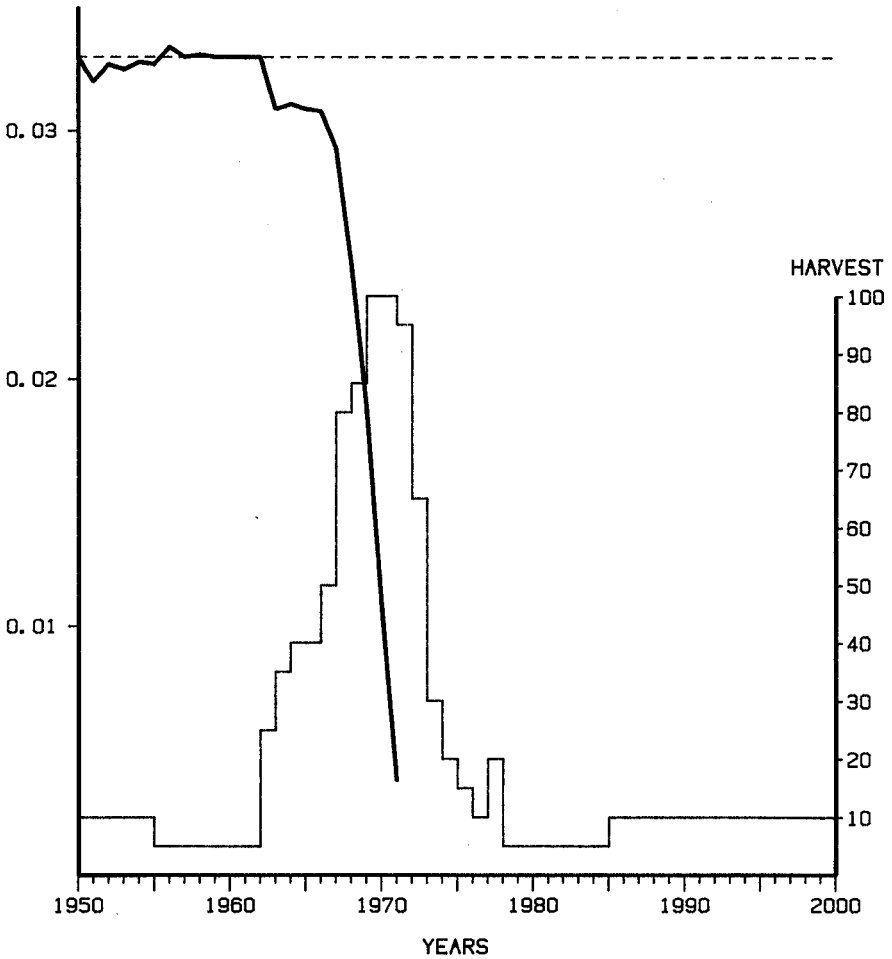
AREA: 6 097 000 sq. km

POPULATION: 116 164 leopard (central estimate)

Fig. A7-4: WESTERN AFRICA - RESPONSE TO HARVEST

Fig. A7-5.

DENSITY (/eq. km)



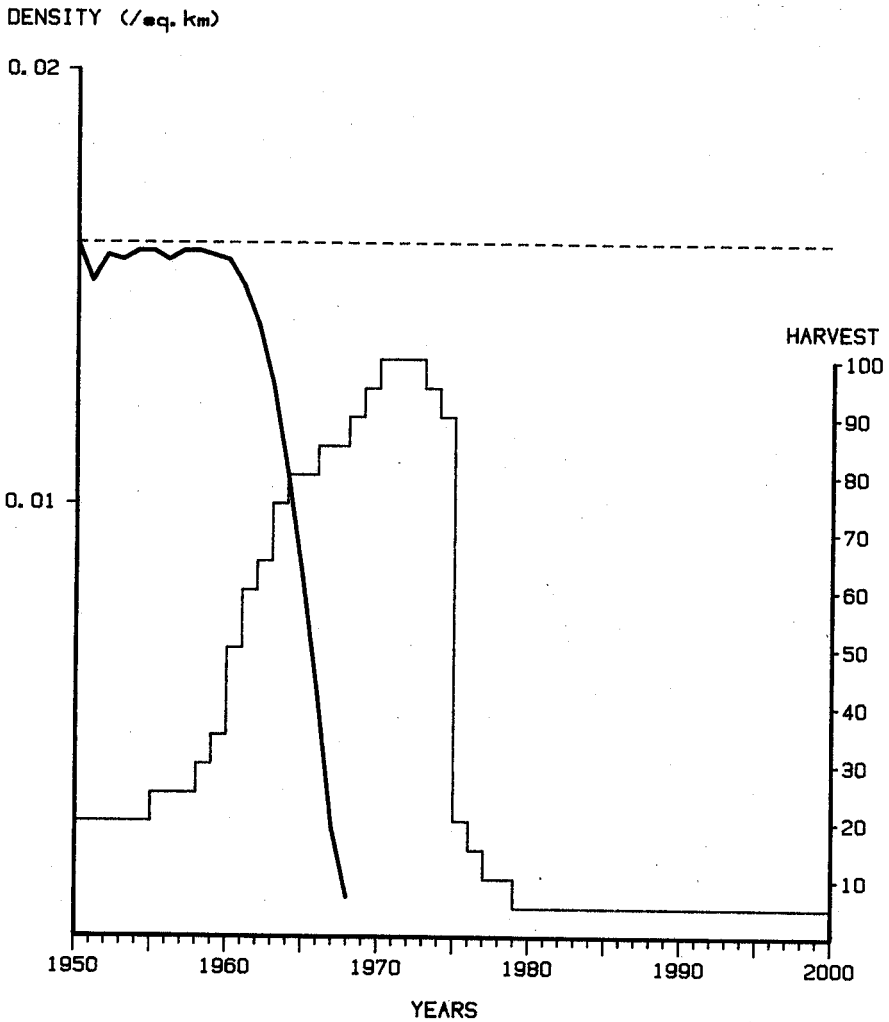
HARVEST: 100 = 15 000 leopard

AREA: 1 650 000 eq. km

POPULATION: 53 842 leopard (central estimate)

Fig. A7-5: EASTERN AFRICA - RESPONSE TO HARVEST

Fig. A7-6.

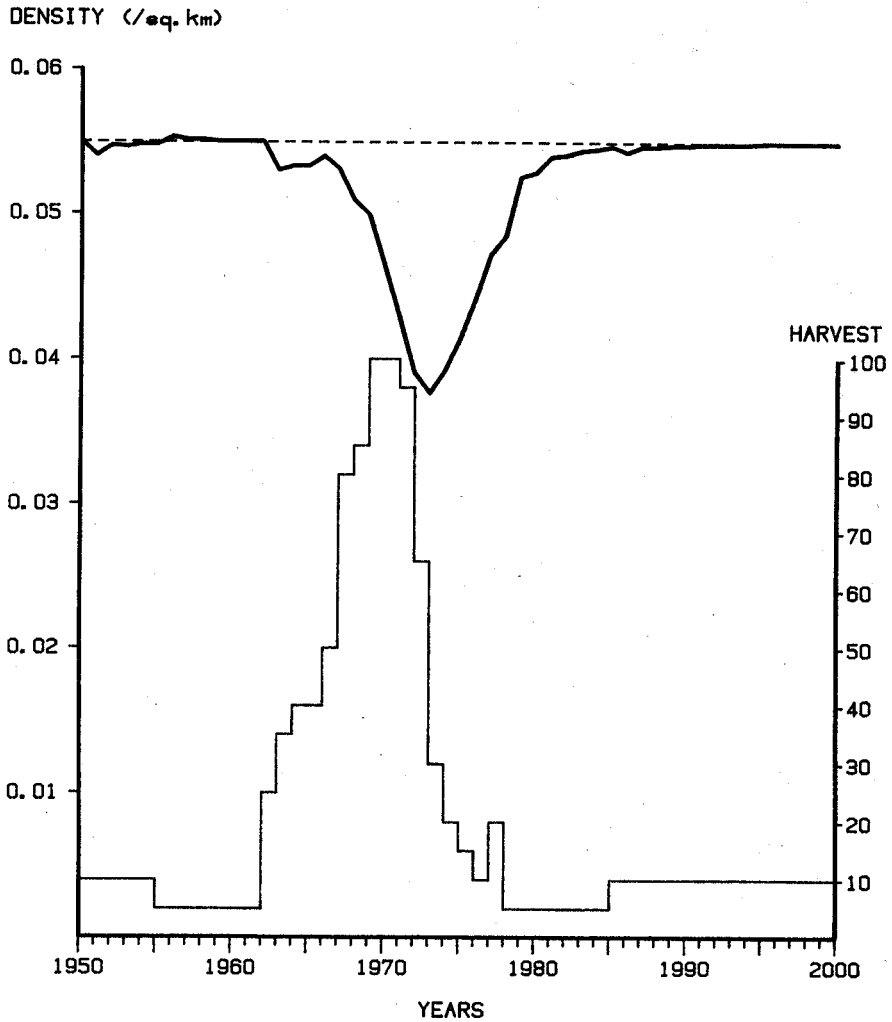


HARVEST: 100 = 14 500 leopard  
 AREA: 3 544 000 sq. km  
 POPULATION: 58 000 leopard (UCI estimate)

Fig. A7-6: NORTHERN AFRICA - RESPONSE TO HARVEST



Fig. A7-7.



HARVEST: 100 = 15 000 leopard

AREA: 1 650 000 sq. km

POPULATION: 92 000 leopard (UCI estimate)

Fig. A7-7: EASTERN AFRICA - REVISED RESPONSE TO HARVEST

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