Introduction

From 1981 to 1989, the elephant population of Africa fell from 1.3 million to 650 thousand (Barbier et al., 1990, Table 1.1). Eastern and central African countries allowed poachers to slaughter elephants for their ivory. Southern African countries controlled poaching and maintained their populations. Although conservationists questioned the population estimates (Cumming, 1989), many people feared that African elephants would soon disappear from the earth (Beddington, et al., 1989).

Two campaigns were begun to save the elephants. One was political lobbying to ban international trade in ivory. The other was a strategy to create common property rights and give local communities an incentive to conserve elephants.

The campaign to ban trade was launched with the “Urgent Memorandum” by the African Wildlife Foundation (AWF). Sent to AWF members, it warned of the rapid decline in elephant numbers and asked for tax deductible donations (Bonner, 1993, p. 53). In response, the World Wide Fund for Nature (WWF) convened a private meeting in Zambia to discuss their elephant conservation policy (Bonner, 1993, p. 89; Martin, 1998). Scientists within WWF were not invited to the meeting.

First to propose a ban were the Humane Society of the United States (Thomson, 1992). They wished to upgrade African elephants from Appendix II to Appendix I of the Convention on
International Trade in Endangered Species of Flora and Fauna (CITES), declaring elephants an endangered species. Not to be outdone, Friends of Animals organised a public relations campaign to convince WWF to support the ban (Bonner, 1993, p. 112). An individual within WWF drafted a proposal to CITES for which the Environmental Investigative Agency took credit (Bonner, 1993, p. 127; Sugg and Kreuter, 1994, p. 31; Martin, 1998).

Only governments are parties to CITES, but Tanzania in eastern Africa was persuaded to submit the proposal (Bonner, 1993, p. 128). Neighbouring Kenya quickly installed Richard Leakey as head of its wildlife department and became leader of the “ban” wagon (Bonner, 1993, p. 130). The most famous spectacle of the campaign soon followed. Kenya built a pyre of $US3 million worth of ivory and burned it in front of the cameras (Bonner, 1993, p. 149). What seemed like a waste was actually good public relations as Leakey then raised donations of $US143 million (Satchell, 1993).

Intellectual support for the ban on ivory trade came from the Ivory Trade Review Group (ITRG, 1989), a group which excluded opponents of the trade ban (Martin, 1998). Economists within the ITRG argued that even optimally managed elephant populations may be driven to extinction (Barbier et al., 1990, pp. 11-14). On the one hand, elephants products are valuable, elephants are easy to harvest and the proceeds of the harvest can be invested in the economy at the social discount rate. On the other hand, elephants reproduce and grow slowly. The rate of return to dead elephants may exceed the rate of return to living elephants and it may be optimal to shoot the elephants and invest the proceeds.

The economists did not support a complete ban, however, because this would have deprived African countries of the funds needed to protect wildlife. Instead, they proposed a temporary ban, giving time to implement a “truly effective package of regulation”. (Barbier et
al., 1990, p. 138). The economists were overruled (Martin, 1998) and, in October 1989, African elephants were listed in Appendix I of CITES.

The second campaign to save the elephants began in January 1989, when the people of Nyaminyami, a village in north western Zimbabwe, were granted authority to manage wildlife in their district (Bonner, 1993, p. 253). This was the first trial of the Communal Area Management Programme for Indigenous Resources (CAMPFIRE). CAMPFIRE was the brainchild of Rowan Martin (1986), with help from Marshall Murphree at the Centre for Applied Social Sciences at the University of Zimbabwe, WWF in Harare and from Zimbabwe Trust. The principle is simple. Local communities with property rights over wildlife, in particular elephants, will have the incentive to sustain the populations.

Many people in Africa aren’t interested in sustaining elephants. Bonner (1990, p. 222) cites an article from a newspaper in Kenya which may explain this attitude:

“A woman, who was eight months pregnant, was gored to death by elephants in Wundanyi District on Friday morning… Ms Henrita Mkankjala Mwamburi (40) was trying to scare the elephants which had invaded her maize plantation… One of the elephants charged at Ms Mwamburi and hurled her about 10 metres away. Her stomach burst open and the unborn child was thrown out. Both died on the spot.”

In the early 1990s, an average of 27 people were killed every year by elephants in Kenya (Dublin, Milliken and Barnes, p. 25, undated). Most were farmers protecting their crops. For this reason, farmers are suspected of encouraging poachers. If local communities are to sustain elephant populations, farmers must be compensated for any crop damage and not try to protect their crops. Further, elephants must be worth more alive than dead.

Who is right? Are the economists of the ITRG correct in concluding that even optimally managed elephant populations are in danger of extinction? Are the proponents of CAMPFIRE
correct in thinking that local communities with property rights over elephants will manage them sustainably?

The economists based their conclusions on a biomass model which assumes all elephants are the same. They argued from theory rather than from empirical results. In this paper I report results from a biomass model which predicts that elephant populations should be maintained at about one third the carrying capacity of the habitat. However, a biomass model is inadequate for elephants which have a complex life cycle and become more valuable as they grow older. Letting young elephants grow into older and more valuable elephants provides an additional rate of return to living elephants which cannot be included in a biomass model. In this paper I also report results from an age structured model to track individual elephants through their life cycle. This model predicts that elephant populations should be sustained just below the carrying capacity of the habitat.

**Bioeconomic Models**

The biomass and age structured models are documented in Hertzler and Gomera (1998). Both models include the benefits and costs of multiple uses for elephants. The models differ, however, in their description of the population dynamics. The biomass model describes the dynamics of elephant populations by a single equation for the change in stocks. The age structured model describes the dynamics by 61 equations, one equation for each age of elephants. This allows recruitment, natural mortality and trophy hunting to be specified for elephants at different stages in their life cycle.

Ideally, the population dynamics would be estimated statistically. Data for elephant stocks, the quantities culled and hunted and the effort expended in culling and hunting are available for Zimbabwe. Unfortunately, the data show a very rapid and unpredictable increase in
elephant stocks beginning in 1989, probably due to immigration from other countries. Attempts at statistical estimation gave unrealistically high rates of recruitment. Instead, the population dynamics were calibrated from published literature to give biologically reasonable predictions, as shown in Figures 1 and 2.

Figure 1: Actual and Predicted Stocks for the Biomass Model.

Figure 2: Actual and Predicted Stocks for the Age Structured Model.
Recruitment, mortality and environmental interaction parameters were chosen to predict elephant stocks during the 1980s. The intrinsic recruitment rate is set at 36%. In the biomass model, the natural mortality rate was set at 3.2% and in the age structured model, natural mortality rates decline from 8% for new born elephants to 2.62% for elephants 5 years old and older. Environmental interaction parameters reduce recruitment and increase natural mortality. These were adjusted to set the carrying capacity of the habitat at 66,172 elephants, the minimum viable population at 3,000 elephants and the maximum sustainable yield at 863 elephants per year. In the age structured model, elephants reach sexual maturity at 10 years of age, females have their first calf at 12 years of age after a 22 month gestation, elephants reach trophy size at 41 years of age, females reach menopause at 56 years of age and all elephants have a lifespan of 60 years. In Figure 2, the lowest line represents the number of new born elephants less than 1 year old. The next line up represents all elephants less than two years old. Continuing this process, the top line represents all elephants less than 60 years old which is the total stock of elephants. The distances between lines represent the elephants in each age group. There are many elephants in the younger age groups and, as not all of them survive, fewer elephants in older age groups.

### Results

Some countries, Kenya is one example, have failed to enforce the state’s rights to the elephants. Even with elephants listed in Appendix I of CITES there will be open access. In Zimbabwe, local communities have property rights to elephants through the CAMPFIRE program. These property rights are not perfect (Muir and Bojö, 1994; IIED, 1994) but at least open access is eliminated. To approximate the different situations in Kenya and Zimbabwe, we solve the biomass and age structured models for both open access and optimal management.
**Biomass Model**

With open access, farmers and poachers ignore the user costs of depleting elephants from the wild. Figure 3 shows the stocks of elephants, culling and hunting over time as predicted by the biomass model.

![Figure 3: Biomass Model with Open Access.](image)

Because the biomass model cannot predict how many trophy animals are in the population, hunting is restricted to be less than or equal to 350 elephants per year. The model predicts that massive culling will drive the stock of elephants from 63,780 to below the minimum viable population of 3,000 elephants by year 5. The elephants are “mined” generating a net present value of $US69 million. This describes the situation in Kenya which had approximately 65,000 elephants in 1981 and only 16,000 elephants in 1989 (Barbier et al., 1990, Table 1.1).

Many parameters in the model are imprecise. The baseline parameters can be varied to gauge the sensitivity of the open access solution. Table 1 shows the year when stocks are driven below the minimum viable population and the net present value (NPV) for selected scenarios.
Kenya was a key supporter for listing elephants in Appendix I of CITES. Suppose, however, that elephants had not been listed and the price for culling was higher. Elephants are still exterminated but the wealth generated by elephants increases by $US35 million to $US104 million.

Kenya also banned trophy hunting of elephants, although this ban may soon be reversed (Baskin, 1994). Banning of trophy hunting is modelled by setting the price of hunting to zero. The ban cannot save the elephants. It simply reduces wealth of the country by another $US35 million. Kenya was reported to receive $US143 million in donations (Satchell, 1993). Perhaps, this explains its support for the listing of elephants in Appendix I of CITES and its ban on hunting which together reduced the country’s wealth by only $US70 million.

If elephants were not pests to agriculture, the price for damage to agriculture would be zero but it would make little difference. Elephants would still be driven to extinction and the wealth of the country would only be $US1 million larger.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Minimum Viable Population (year)</th>
<th>NPV ($US million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Access</td>
<td>5</td>
<td>69</td>
</tr>
<tr>
<td>No Appendix I</td>
<td>2</td>
<td>104</td>
</tr>
<tr>
<td>No trophy hunting</td>
<td>3</td>
<td>34</td>
</tr>
<tr>
<td>No damage to agriculture</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td>Amenity value</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>Higher cost of culling</td>
<td>8</td>
<td>78</td>
</tr>
</tbody>
</table>
Since the economy of Kenya depends upon tourism, elephants might be credited for their contribution to the tourist industry. To model this, a price for amenity and existence value was included. This value is unknown and chosen somewhat arbitrarily at $US200 per elephant. With this value, results for the age structured model to follow show that elephants will be optimally managed near the carrying capacity of the habitat, even in the worst case scenario. In the biomass model with open access, this amenity and existence value contributes $US21 million to the economy of Kenya before the elephants are driven to extinction.

Efforts to enforce the state’s rights to elephants would increase the costs to poachers of shooting elephants. This could be modelled by more than doubling the price of effort for culling. Elephants are exterminated in 8 years instead of 5 and wealth increases by $US9 million. Enforcement is not free, however. It could easily cost the government $US9 million to enforce its property rights (Sugg and Kreuter, 1994, pp. 42-43) and the wealth of the country would be unchanged.

If property rights work perfectly, local communities will consider the full user costs of elephants in the wild. Elephants will be optimally managed. The biomass model predicts that stocks will be dramatically culled but still be sustained above the minimum viable population, as shown in Figure 4.
Eventually the stocks approach a steady state of 18,207 elephants with culling of 159 elephants and hunting of 350 elephants per year. The net present value of optimally managed elephants is $US184 million which is $US115 million higher than with open access.

Demand and supply in the steady state are shown in Figure 5. The steady state supply curve increases until quantities of culling and hunting reach the maximum sustainable yield of 863 elephants per year. Then the supply curve bends backward, increasing further as quantities decrease.
In the steady state, optimal culling and hunting total 509 elephants per year. At a culling of 159 elephants per year, the price of a culled elephant is $US1,246 and the marginal effort cost of culling is only $US97. The difference between the price and the marginal effort cost is the marginal user cost of $US1,149 per elephant, which is the value of an elephant in the wild. Thus, the marginal effort cost contributes 8% and the marginal user cost contributes 92% of the final sale price of a culled elephant.

The baseline parameters are varied to gauge the sensitivity of the optimal management solution. Table 2 shows the stocks of elephants in the steady state and the net present value (NPV) for the baseline parameters and several scenarios.
According to the biomass model, if elephants had not been listed in Appendix I of CITES, a viable population would still be sustained and Zimbabwe would be about $US51 million wealthier. By agreement with other southern African countries, this added wealth would have been used for wildlife management (SACIM, 1994).

Animal rights groups argue that elephants should not be treated as a resource but be preserved without exploitation. In addition to a ban on trade in ivory, they would prefer an international ban on the importation of trophy animals. This would set the price of hunting to zero. Unfortunately, elephants still have value for hides and meat and are pests to agriculture. With no trophy hunting, elephant stocks would be reduced to a steady state of 3,013 elephants after 40 years. An international ban on the import of trophies would jeopardise the survival of elephants and reduce the wealth of Zimbabwe by $US141 million.

The model assumes a fixed carrying capacity of the habitat with competition between elephants and humans modelled as damage to agriculture. If elephants did not damage agriculture, there would be little change in optimal management. The damage reduces the wealth of Zimbabwe by only $US5 million and is a minor factor in explaining the decline in elephant populations.
This result must be qualified, however. In the past, a major reason for the decline in elephant populations has been the reduction in habitat from the increase in agriculture (WWF, 1997). On the other hand, elephants increase their own habitat and the habitat of other grazing animals by changing woodlands into grasslands. In a more complete model with a variable carrying capacity, it may be optimal to establish more agriculture and reduce the habitat for elephants, or it may be optimal to increase the habitat for elephants because they are more profitable than livestock (Jansen, Bond and Child, 1992).

In Zimbabwe, revenues from tourism are distributed to local communities (Muir and Bojö; 1994, IIED, 1994) who make the life or death decisions for elephants. If elephants have an amenity and existence value of $US200 per elephant, stocks will be sustained just below the carrying capacity of the habitat, providing the money actually reaches the local communities. This would increase the wealth of the Zimbabwe by about $US219 million.

Zimbabwe must also enforce property rights to elephants by discouraging poachers. Enforcement costs might be added to the price of culling. The higher price has a negligible effect on optimal management and reduces wealth by only $US2 million because elephants are still extremely cheap to manage.

The maximum sustainable yield (MSY) is determined by the environmental interaction parameters in the model. Because the parameters could not be estimated, a conservative estimate of 863 elephants per year is used. Increasing the MSY to 1,487 elephants per year, while holding the carrying capacity of the habitat and the minimum viable population constant, increased the steady state stock by 6,337 elephants and the wealth of Zimbabwe by $US10 million but does not change the basic conclusions from the model.
The social rate of discount is set to 5% in the baseline which may be low for developing countries. Doubling the discount rate to 10% reduces the steady state stock of elephants by 4,044 elephants, but does not drive them toward extinction. The net present value is significantly reduced but is not comparable with other net present values in Table 2 because the future is discounted much more. Suppose the discount rate is 10% and there was no listing of elephants in Appendix I. The stocks of elephants would slowly be reduced to around the minimum viable population by year 50. With a discount rate of 10% and no listing, adding an amenity and existence value of $US200 would help sustain the stock of elephants well above the minimum viable population.

Age Structured Model

The open access solutions from the biomass model are consistent with decisions in a country such as Kenya where elephant stocks plummeted from 65,000 to 16,000 between 1981 and 1989 (Barbier et al., p. 2). However, the optimal management solutions are not consistent with decisions in a country such as Zimbabwe where stocks have been sustained above 60,000 elephants, near the carrying capacity of the habitat. Solutions to the age structured model may be consistent because the additional rate of return to letting young animals grow older and more valuable will increase the optimal stocks of elephants.

Figure 6 shows the open access solution for the age structured model. For ease of presentation, the age groups for elephants are aggregated into juveniles from 0 to 9 years, middle aged from 10 to 39 years and old aged from 40 to 60 years. Juveniles have not yet reached sexual maturity. Middle aged and many of the old aged elephants are fertile. Only old aged elephants are hunted as trophy animals.
As with open access in the biomass model, massive culling drives the stocks below the minimum viable population in 4 years. Unlike in the biomass model, however, hunting is not restricted to 350 elephants but is chosen from the old aged stocks, allowing more hunting in early years and giving a higher net present value (NPV) of $US106 million.

Table 3 shows the same scenarios for the age structured model as for the biomass model in Table 1.

The wealth generated by elephants in a country such as Kenya with open access and a ban on hunting is predicted to be almost the same by the two models. Curiously, if elephants had not
been listed in Appendix I, the wealth of the country would be less. Listing in Appendix I reduces
the incentive for poaching and allows more hunting which is more profitable. The best strategy
for a country such as Kenya would be to allow hunting, but lobby for the ban on international
trade by listing elephants in Appendix I. Unfortunately, the elephants are exterminated,
regardless, because there are no property rights.

Figure 7 shows that it is optimal for a country with established property rights, such as
Zimbabwe, to conserve its elephants near the carrying capacity of the habitat.

![Figure 7: Age Structured Model with Optimal Management.](image)

The old aged elephants are hunted but there is no culling. Rather, juvenile and middle aged
elephants are left to grow into old age. In the steady state, 494 elephants are hunted per year and
stocks are 59,826 elephants. Optimal management generates a net present value of $US201
million.

Table 4 contains the steady state stocks and net present values (NPV) for the same
scenarios as in Table 2 for the biomass model. The age structured model predicts that a ban on
hunting would exterminate the elephants in 16 years. For most other scenarios, the model predicts that stocks should be sustained just below the carrying capacity.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Steady State Stocks (head)</th>
<th>NPV ($US million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Management</td>
<td>59,826</td>
<td>201</td>
</tr>
<tr>
<td>No Appendix I</td>
<td>42,437</td>
<td>201</td>
</tr>
<tr>
<td>No trophy hunting</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td>No damage to agriculture</td>
<td>59,840</td>
<td>212</td>
</tr>
<tr>
<td>Amenity value</td>
<td>60,083</td>
<td>449</td>
</tr>
<tr>
<td>Higher cost of culling</td>
<td>59,824</td>
<td>201</td>
</tr>
<tr>
<td>Higher surplus yield</td>
<td>61,946</td>
<td>208</td>
</tr>
<tr>
<td>Higher discount rate</td>
<td>59,204</td>
<td>140</td>
</tr>
<tr>
<td>and No Appendix I</td>
<td>0</td>
<td>165</td>
</tr>
<tr>
<td>and Amenity value</td>
<td>59,110</td>
<td>270</td>
</tr>
</tbody>
</table>

A major argument against listing elephants in Appendix I was that countries which managed elephants wisely would be unduly penalised by the ban on trade. The age structured model suggests that a ban on trade has had negligible effect on the wealth of Zimbabwe because trophy hunting is more profitable than culling for ivory, even without a ban. This result does not consider the stockpile of ivory collected from past culls, problem animal control and natural deaths. In June of 1997, the parties to CITES approved limited export of ivory under strict quotas from Zimbabwe, Botswana and Namibia to Japan (CITES, 1997). Limited trade may allow these countries to sell their stockpiles and gain the funds needed for wildlife management (SACIM, 1994).

These results change, however, if the social discount rate is higher than 5%. First suppose the rate is 10%. With a ban on trade in ivory, elephant stocks are sustained near the carrying capacity. With free trade in ivory, stocks are culled below the minimum viable population in 16 years. Next suppose the rate is 15%. Although not shown in the table, even with a ban on trade, stocks are culled below the minimum viable population in 11 years.
Therefore listing elephants in Appendix I is ineffective at both lower and higher discount rates. The ban on international trade has played a role in saving elephants only if the social discount rate of Zimbabwe is around 10%.

This result must also be qualified, however. If the amenity and existence value is $US200 per elephant, elephants are sustained near the carrying capacity even with a social discount rate of 10% and free trade in ivory. For the 59,110 elephants in the steady state, $US200 per elephant is $US11,822.00 per year. This is less than half the estimate of Brown and Henry (cited in Barbier et al., p. 18, 1990) for the contribution of elephants to tourism in Kenya. Tourism is only one aspect of amenity and existence values and $US200 is surely a very low estimate.

**Concluding Remarks**

Are African elephants an endangered species? No. Did the listing of African elephants in Appendix I of CITES, which banned international trade in ivory, help save the elephants? No.

The true campaign to save elephants began in the village of Nyaminyami in north western Zimbabwe. Villagers were granted authority to manage wildlife in their district as part of the CAMPFIRE program (Bonner, 1993, p. 253). With property rights, local communities collect a significant portion of the marginal user costs, which are the values of elephants in the wild, conserve their elephants and generate wealth for the country. So long as farmers are compensated for any crop damage and don’t risk their lives to protect their livelihood, the damage to agriculture caused by elephants is relatively small. The value of elephants for trophy hunting exceeds their value for ivory. Therefore, it is not optimal to cull elephants. Instead, elephant populations should be sustained just below the carrying capacity of the habitat so that as
many as possible can be hunted for trophies. Adding their contribution to tourism ensures the future of African elephants, even in the worst case scenario.

The campaign to list African elephants in Appendix I of CITES and ban international trade in ivory was a noisy distraction. The slaughter of elephants in eastern and central African countries (Barbier et al., 1990) was caused by corruption in governments like that of Kenya (Kenya Wildlife Service, 1990, as cited in Bonner, 1993, p. 134). Corruption led to open access in which the marginal user costs of elephants in the wild were zero. Poachers slaughtered elephants for their ivory and destroyed wealth. Even if a ban on trade makes ivory worthless, the hide and meat give revenue in excess of the very low costs of harvest and elephants will still be slaughtered.

On the other hand, the ban on trade has not severely penalised the southern African countries because it is not optimal for them to harvest elephants for their ivory. The ban has only prevented them from selling stockpiles of ivory which accumulated in the 1980s before the CAMPFIRE program, with small additions from the control of problem animals and natural deaths. The approval by the 10th conference of parties to CITES for Zimbabwe, Botswana and Namibia to sell limited quantities under strict quotas to Japan (CITES, 1997) will provide funds which the countries have agreed to use for wildlife management (SACIM, 1994).

During the campaign to ban international trade in ivory, concerned people around the world contributed to animal rights and environmental groups. Their contributions were wasted. Instead of working to ban ivory trade, animal rights and environmental groups should have been working with African countries to establish programs like CAMPFIRE. Instead of spending on lobbying and salaries, they should have paid local communities an existence value for each elephant preserved.
Animal rights groups, particularly in the United States and the United Kingdom, also campaigned against trophy hunting. The irony is that banning trophy hunting is the quickest way to drive elephants to extinction.

Using theoretical results from a biomass model, economists of the Ivory Trade Review Group (ITRG) argued against the textbook conclusion that optimally managed populations are sustained at high stocks. They pointed out that ivory and hides are very valuable and elephants are inexpensive to shoot. Investing in the economy of an African country has a return on investment equal to the social discount rate of, say, 10%. Surplus yield from elephants is only about 5%. Therefore it may be optimal to shoot the elephants and invest the proceeds in the economy (Barbier et al., 1990, pp. 11-14).

However, the question must be answered empirically. We quantified and solved a biomass model which predicts that elephants should be maintained at about one-third the carrying capacity of the habitat and well above the minimum viable population. Moreover, elephants are not biomass. They have a complex life cycle in which reproduction and mortality are age specific and the value of an individual elephant grows as it ages. Biomass models do not include the rate of return from letting young animals grow into older and more valuable trophy animals. We also constructed, quantified and solved an age structured model which predicts that elephant populations should be sustained just below the carrying capacity of the habitat. Younger elephants should be left to grow into trophy animals.

Finally, we end with another question. What does the rate of return to letting young animals grow into older more valuable animals mean for fisheries and wildlife management in general? Many management strategies are based on biomass models which do not include this
rate of return. Therefore, even “optimally managed” stocks are being over exploited—but by how much?

References


