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CHAPTER 20

DEVELOPING A FRAMEWORK FOR ASSESSING THE SUSTAINABILITY OF BUSHMEAT HUNTING

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The hunting of animals in tropical forests for food ("bushmeat hunting") has emerged as a major conservation issue over the last few years, with concerns about the "bushmeat crisis" focusing on the forests of West/Central Africa.[1] Eating wildlife is not new, and reasons for our current preoccupation with this issue are complex.[2] However it is undeniable that bushmeat species are being severely overexploited in many areas, and that vulnerable species are threatened with extinction.[3,4] In other places, however, the situation seems relatively stable, with vulnerable species already extirpated, and the remaining resilient species apparently supplying markets on a relatively sustainable basis.[5] In order to prioritise conservation action effectively, we need to assess the relative sustainability of bushmeat hunting in different areas. We can also use sustainability assessments as the foundation for examining options for intervention to conserve species endangered by over-exploitation.

Bushmeat is a high-profile example of the issues facing conservation more widely. It involves balancing the imperatives of improving the livelihoods of desperately poor people and conservation of endangered species.[6] It also highlights the issues of controlling profitable commercial trade, and of battling against weak or non-existent governance.[7] Because bushmeat hunting is relatively non-selective, vulnerable species are killed along with resilient ones, and species-specific conservation actions are less straightforward to implement. Finally, the widespread and diffuse nature of the problem makes monitoring and intervention difficult to target. The closest analogue to bushmeat is artisanal reef-based fishing, but the separation of the resource from human habitation, the visibility of users and the limitation in landing sites makes fishing easier to monitor and control than bushmeat hunting. Hence bushmeat is a useful, if extreme, model for examining approaches to assessing sustainability, and more importantly, implementing effective and scientifically sound management. If conservation action for bushmeat species is successful, a significant step forward will have been taken for the conservation of natural resources more generally.

In this chapter, I will discuss the kinds of data that are required for a full assessment of the sustainability of bushmeat hunting, and compare these requirements to the data that are usually available. I will then address some of the issues that arise out of the weaknesses in the available data, and particularly the difficulty of inferring lack of sustainability from market data alone. There are already some methods in use for assessing the sustainability of bushmeat hunting. Simple indices of the ratio of extraction to production are the most widespread of these. I will examine the potential of these indices to provide a robust estimate of sustainability under realistic field conditions, and identify the key components that are needed in a valid sustainability index. New frameworks for assessing sustainability include Bayesian networks and simulation modelling. Finally I consider the prospects for conserving bushmeat species and identify priority situations for conservation intervention.

DATA REQUIREMENTS

Like most bio-economic systems, bushmeat hunting is complex, multi-scale, dynamic and heterogeneous (Fig. 1). At the smallest scale, sustainability ultimately depends on the behaviour of individual hunters and their prey. This in turn is affected by the hunter's household economy, determining his investment in different activites. Whether someone chooses to hunt or farm depends on the relative profitability of each activity, which is influenced by consumer demand for the goods produced and costs of inputs. A consumer's choice between foodstuffs depends on the interaction between preferences, affordability and availability. The incentives felt by individual consumers and producers are products of the wider economy within which they are embedded.

[Fig. 1 near here]

On the biological side, prey availability is determined by the distribution and abundance of individuals (which may be influenced by avoidance of disturbance caused by hunting). A key determinant of prey distribution is habitat distribution, which is determined both locally by the hunting/farming tradeoff (more farming often means more habitat conversion) and regionally by government decisions on land clearance and logging rights. Finally, the behaviour of individuals and institutions is influenced by the regulatory regime and the effectiveness with which it is implemented and enforced on the local and regional scales.

The individual hunter

The idea of hunters as optimal foragers, maximising some fitness proxy such as profit per hunt, was explored by Alvard.[8] Hunters in his study villages in Amazonia did not act as "ecologically noble savages", conserving resources, but as rational utility-maximisers. This chimes with the predictions of both behavioural ecology and economics.[9] The interactions between individual hunters and their prey can be complex, and vary with the gear type used. Rowcliffe *et al*.[10] extended standard foraging theory to consider the difference between snare hunting, when the gear is assumed static and the animals mobile, and gun hunting, when the gear is assumed mobile and the prey static. The encounter rate of prey and the approach distance needed to trigger the gear vary substantially between these two extremes.

A number of empirical studies have followed hunters and obtained useful data on their behaviour and movement patterns.[11] However there has been virtually no work done on the rules of thumb which hunters use to determine when to change their hunting behaviour. For example, how low must catches be, and for how long, before they decide to act, and what steps do they take to increase catches: add more snares, move snares locally, or leave the area completely? These decision rules are critical to prediction of the level of depletion reached in hunted areas, but are not well understood.

The individual hunter is embedded in a household with various productive activities. Barrett & Arcese[12] used an economic model to suggest that agricultural productivity is a critical determinant of poaching rates in the Serengeti, while Damania *et al.*[13] looked at the decision to invest in bushmeat hunting. Damania *et al.*'s model showed that improved agricultural productivity does not necessarily reduce hunting rates, because the consequent improvement in income leads to greater demand for meat by the household and also gives hunters the ability to replace less efficient, cheaper technology, such as snares, with guns. Given that guns target vulnerable species such as primates as well as the more resilient species, improvements in agricultural incomes can exacerbate conservation problems.

In order to model the offtake of meat by individual hunters, a range of data on the livelihoods available to actual and potential hunting households is required, as well as specific information about behaviour while out hunting. Needless to say, very little of this kind of information is collected, and virtually never as part of an integrated project that also collects information on prey densities and consumer behaviour.

The market

Once an animal is caught by the hunter, there is a long way to go before it reaches the market, where most data are collected. Along the way, individual animals drop out of the commodity chain (Fig. 2). The animals reaching the end-market are a highly biassed selection of those killed, chiefly because low value individuals killed by non-professional hunters are generally eaten or bartered in the local villages, and only higher-valued animals are worth transporting to market. If law enforcement is effective, protected species are also likely not to appear in the end market.

[Fig. 2, near here]

The main determinant of whether it is worth selling bushmeat in the market is the price it fetches compared to the costs of sale. Transport costs are often a large proportion of total hunter costs,[14] and these depend on factors in the wider economy such as the price of petrol. Bushmeat prices are determined by consumer demand. Often bushmeat is sold in open markets, where it is competing with many other foodstuffs; hence the price and availability of other meats is an important determinant of bushmeat demand. Brashares *et al.* [15] have shown that poaching rates in Ghanaian National Parks increase in years with poor fishing yields, and that the effect is stronger the nearer the Park is to the coast. Consumer choice is a complex process, and the few published studies of bushmeat consumption suggest that consumer preferences, consumption and availability are all strongly inter-related. Often the person's nationality or tribal origin and wealth class also play a role.[16] East *et al.*[17] show that urban consumers in Equatorial Guinea have a strong preference for fresh fish and bushmeat, but that they mostly consume much less preferred frozen fish and livestock (Fig. 3). This is because frozen produce is much cheaper; preferences are followed more closely by wealthier consumers. This is particularly significant because Equatorial Guinea is currently experiencing an oil boom that is increasing both the urban population and the average income of cities such as Bata; this is likely to enable people to satisfy their preferences more easily. Hence it seems likely that demand for bushmeat in Bata will rise in the near future, increasing pressure on wildlife populations.

[Fig. 3, near here]

The effects of income, substitute goods and price on demand are captured in elasticities. Elasticities measure the percentage by which the quantity of a good demanded changes with a 1% change in the explantory variable. As yet there is only one published study of elasticities of demand for bushmeat, by Wilkie & Godoy,[18] and this is for Amerindian households in South America rather than for an African site. The lack of understanding of the effects of income and prices on consumer demand is a major impediment to policy-making, because the commercial bushmeat trade is founded on consumer demand. Many policies proposed for controlling the commercial bushmeat trade rely on altering prices or incomes, and the effects of these changes on demand and offtake rates are not necessarily obvious.[13]

Biological data

Good data on the abundance of forest mammals are very difficult to obtain, often relying on indirect methods such as dung counts, which are notoriously unreliable.[19] However, much effort has been put into obtaining estimates of population densities of hunted species, often comparing protected and exploited areas.[20] There is usually signficant variation between sites, partly explained by differences in factors such as vegetation and soil type, but also linked to hunting. As populations get lower and hence less observable due to hunting, either more effort must be put into surveys or the variation around estimates of population size will be higher. For example, Peres[21] estimated the biomass of large-bodied species at 18 forest sites in Amazonia as 663 ± 50 kg/km^2 in unhunted areas, and 232 ± 85 kg/km^2 in heavily hunted sites.

The biology of many hunted forest species is very poorly known; without long-term studies, data on reproductive rates and mortality schedules can be difficult to obtain. Hence the assumptions used in sustainability analyses for many commonly traded species are based on allometric relationships between measurable variables such as mean body mass and the variables of interest, such as intrinsic rate of increase, group size or carrying capacity.[22] These relationships are adequate for crude estimation in the absence of other data, but often have substantial variation around them. This also contributes to the uncertainty surrounding any estimates of the productivity of exploited populations.

Bio-economic interactions

The interactions between biological and economic processes occur at all scales. At the small scale, changes in habitat type from forest to farm-bush as villagers expand agriculture (and back as agriculture declines) lead to changes in local species composition. At the larger scale, bushmeat hunting and logging are often linked and devastating in their synergistic effects on wildlife and habitats.[23] One key side-effect of logging is improvements in roads and infrastructure, which can promote overexploitation by opening up access to markets,[24] although there are also examples where access to markets reduces hunting by allowing people to purchase domestic meat and encouraging them to concentrate on farming.[25]

In Sulawesi, road improvements in the early 1990s led to a dramatic increase in wild pig hunting as traders could drive further into the forest and still return to market with saleable produce.[26] This led to increased travel times for a case study dealer as nearby forests were depleted of pigs (Fig 4). However, habitat conversion was also occurring along the road, reducing the amount of primary forest available to the endemic babirusa wild pig (*Babyrousa babyrussa*, Fig. 5). The babirusa is one of two species of endemic wild pigs traded together in North Sulawesi; the other, the Sulawesi Wild Pig (*Sus celebensis*) is able to persist in secondary forest, and hence is probably less affected by habitat loss. The Sulawesi Wild Pig is also more substantially more resilient to hunting than the babirusa, such that the combination of hunting and habitat loss impacts far more severely on one species than the other. This example illustrates the complexity of bioeconomic interactions affecting hunting sustainability.

[Figs. 4 & 5, near here]

Although there is a general realisation that there are wider influences on hunting sustainability and that they have synergistic effects, these dynamic interactions are difficult to take into account in sustainability assessments, and so are often ignored.

THE EFFECT OF DATA DEFICIENCIES

Because population estimates are so uncertain, and ridden with unquantifiable biases, it is extremely difficult to estimate the sustainable level of production from a given area. The detailed surveys that would allow us to quantify sustainable offtakes to an adequate degree of accuracy are few and far between in tropical forests worldwide. Examples such as Peres,[21] in which multiple sites are examined, such that the effects of hunting can be separated from other factors, are very rare. Abundance data alone cannot be used for sustainability assessments because abundance is only one component of productivity; data on species life histories, population growth rates and catchabilities are also needed. This is not to say that a crude estimate of productivity cannot be obtained based on abundance, allometric relationships and inferences from offtake data, but this cannot form a robust basis for managed hunting.

Market data are easier to obtain than biological data, and in theory could provide signals of lack of sustainability. For example, a decline in the number of animals on sale or an increase in their price might indicate depletion of the wildlife stock. In a multi-species system, it would be expected that larger, slower-growing species would disappear from the market first, a phenomenon observed in fisheries.[27] Finally, as observed in North Sulawesi, an increase in the distance animals travel to the market might be a strong signal of depletion.[28] However, a more thorough examination of market data shows how misleading such trends can be.

An example of problems with market data

To illustrate these points, Crookes *et al*.[29] examined trends in a dataset, collected by the Ghanaian Wildlife Department in Atwemonom market, Kumasi, Ghana. The dataset comprised 36,099 animals, observed on 2,446 market days from 1987 to 2002. This is a mature market, in which 7 relatively common and resilient species make up 95% of the open season trade; vulnerable species are hunted, and do appear occasionally in the market,[30] but are not in this dataset at levels that permit statistical examination of trends.

The data show no evidence for a decline in the number or biomass of traded species, nor in the proportion of slower-growing species. However, there was a sharp increase in price from 1999 to 2002 (Fig. 6a), together with a significant increase in the proportion of the trade that came from more distant sources. This increase was almost entirely fuelled by an increase in the proportion of grasscutters (*Thryonomys swinderianus*) on sale (Fig 6b). Most market datasets do not include data on the location where animals were killed or the method of killing. However, this information is extremely useful, and is included in the Atwemonom dataset. The proportion of individuals killed by cutlass rather than gun increased for all species at the time of the price increase (Fig. 7). Cutlass-killed animals are often trapped first, and this gear combination represents cheap technology that might be used by new entrants and non-professional hunters, compared to the professionals who tend to use expensive but more efficient gear such as guns.

[Figs. 6 & 7 near here]

The trends in this dataset can be interpreted in very different ways. They are compatible with an explanation based on unsustainable use, or with hunting becoming more profitable due to extraneous circumstances:

> ***Explanation 1.*** Unsustainable use. Consumer demand for bushmeat started to grow rapidly in the late 1990s, due to some extrinsic factor such as urban population increase, taste changes or scarcity of alternative foodstuffs. Bushmeat hunters are struggling to keep up with demand, hence prices are rising but quantities supplied are relatively constant. In order to maintain supply, traders are having to recruit hunters from further and further afield. Wildlife depletion in the forests makes gun hunting less viable economically, so hunters are using cheaper technology, trapping near their fields. Grasscutters are the most valuable animal that is routinely trapped, and so are now sold more than other species.

Explanation 2. A profitable profession. Increasing consumer demand is leading to rising prices. The higher prices are tempting people to sell in the market, including hunters from distant locations who did not previously sell to Kumasi due to prohibitive transport costs. New entrants to hunting start cheaply with trapping, expecting to invest in a gun if their trade continues to be profitable. Similarly, non-professional hunters who previously only trapped around their fields for subsistence are tempted now to sell their produce (particularly the more valuable grasscutters).

Under explanation 1, the expectation is that prices will continue to rise unless extrinsic factors change, and that local offtakes will decline as produce is transported increasingly far to the market. Under explanation 2, the impact on sustainability depends on whether effort is increasing due to new entrants, or whether people are simply choosing to sell more of their catch. However with time, hunting is likely to become less sustainable as profits encourage people to invest in more efficient technologies.

This example illustrates how difficult it is to make inferences about trends in market data without supporting information on changes in species' abundance or on hunter behaviour. In particular, the dynamics of hunter effort, including movement of individuals into and out of the profession, is important but rarely considered in the literature. Market data represents an amalgamation of influences, including wildlife stock depletion and external factors, and hence should be treated with caution unless accompanied by supporting data.

APPROACHES TO THE PROBLEM

Given that high-quality data for sustainability assessments of bushmeat hunting will never be available from more than a handful of sites, how best can we approach the problem, using data that are realistically obtainable? One response to the poor coverage of bushmeat data is the Bushmeat Crisis Task Force's Information Management and Analysis Project,[31] which aims to collect spatially referenced information on the intensity and location of bushmeat hunting and markets. If widely used, this could go a long way towards building a more integrated view of the dynamics of the bushmeat trade. On the more local level, superficially the most attractive way forward is to try to find a robust index of sustainability, based on the limited data that can feasibly be obtained.

Sustainability indices

Detailed analyses of the sustainability of bushmeat hunting are virtually non-existent. Generally, sustainability assessments for local areas involve obtaining estimates of animal abundance and comparing them to offtake data from hunters.[32] There is a lot of effort and scientific rigour involved in getting these data. By contrast, and despite being the point of the exercise, the sustainability analysis is usually extremely crude. The almost universal method for calculating sustainability in bushmeat studies is Robinson & Redford's[33] index:

$$P = 0.6\ K\ (R_{max} - 1)\ F$$

where P = production (animals/km^2/year), K = carrying capacity (animals/km^2), R_{max} = arithmetic intrinsic rate of population increase (animals/year), F = natural mortality correction factor.

Milner-Gulland & Akcakaya[34] showed that if this index were used as a basis for management, it would rapidly send the population to extinction. This is because it does not take uncertainty and bias or current abundance into account. However it has been widely applied in bushmeat research because it is simple and does not require large quantities of data. One similarly simple sustainability index that does perform well is the National Marine Fisheries Service's index of the sustainability of cetacean bycatch:[35]

$$P = 0.5\ N\ (R_{max} - 1)\ F$$

where the notation is as above with the exception of: F = correction factor for bias & uncertainty between 0 and 1, N = a minimum estimate of abundance (animals/km^2).

This takes uncertainty and bias into account partly through F and partly because N is a minimum estimate, while the use of N in place of K ensures current abundance is included in the analysis. Given the robustness of this index, and the fact that in general, simple harvesting strategies are more robust than complex ones,[36] this suggests that the use of sustainability indices may be worth exploring further. However it is also clear that simple indices based on flawed models can be extremely misleading.

Another type of index that has been proposed for bushmeat is prey profiles.[10] This builds on the idea that in a multi-species system, the prey composition should change as species are depleted. Reductions in the proportions of vulnerable species in the offtake could act as a warning signal of depletion. Prey profiles are as yet untested in the field, but could potentially be useful if applied at the village scale to situations in which effort and technology remained constant over time and market dynamics were not relevant. This is likely to be a relatively limited subset of bushmeat hunting situations.

Bayesian network approaches

One way of including a realistic representation of uncertainty into a simple model is use Bayesian Belief Networks (BBNs). BBNs provide an intuitive analytical framework for combining various types of information of differing degrees of certainty, so that all the available information can be used. The system is represented in an "influence diagram", which is a network of influences between variables (such as the population of a bushmeat species, the number taken by hunters, the number sold on in a market, and so on), each of which has a probability distribution attached to it. This probability distribution can be derived from actual survey data, expert opinion or from the literature. Several user-friendly packages exist allowing a model to be constructed rapidly and straightforwardly.[37]

Figure 8 is a simple example of an influence diagram for assessing the sustainability of bushmeat hunting. It shows that indicators of the sustainability of use can be obtained, but more importantly that they are accompanied by a realistic visualisation of their uncertainty. As new information is obtained for a particular variable, its probability distribution can be updated. This updating affects all the other variables in the network, both in the direction of causality and against it. For example, if several individuals of a particular species appear in a market, this observation updates probability distributions throughout the network, ultimately affecting the probability distribution for the population size of the species prior to the offtake. Policy interventions can easily be modelled within this framework. For example, one could predict the effects of a ban on market sales of a particularly vulnerable species on all other species in the market, because changes in the marketability of the banned species would propagate through the network to affect the dynamics of all other species.

[Fig. 8, near here]

One powerful use of BBNs is in identifying data needs. By examining the sensitivity of results to improvements in knowledge about each variable, the model shows where reducing uncertainty is most critical. For example, the model may show that the proportion of offtake which goes to commercial markets as compared to subsistence use and wastage is a variable with a high degree of uncertainty which is also critical to the sustainability of offtake. This facility allows researchers and managers to target resources most effectively.

There is a growing interest in the potential of BBNs for conservation. Recently, a BBN model was developed for assessing the impacts of land use changes on bull trout populations in the USA.[38] Another recent application of BBNs is to modelling uncertainties in fish stock assessment and the impact of seal culling on fish stocks.[39] Marcot *et al.*[40] have used BBNs for evaluating population viability under different land management alternatives, while Wisdom *et al.*[41] used BBNs in conservation planning for the greater sage-grouse. However, these are isolated cases, and BBNs are still not widely used in conservation planning. They could make an important impact, if only as a way of improving the transparency of conservationists' assumptions about uncertainty and causal linkages between variables in the system, and improving the effectiveness with which data of various types and qualities are used. Although complex to develop, the final interface could be straightforward enough for non-modellers to use, which is the main attraction of sustainability indices such as Robinson & Redford's.

BBNs do have drawbacks, and are not the only modelling tool that could be used to represent uncertainty. The attractive graphical representation soon becomes unwieldy under more realistic conditions, particularly when a dynamic network is required, as it would be for bushmeat. It is also important to realise that the BBN's representation of uncertainty is built on point estimates, rather than distributions. A Bayesian model, in the normal sense of the word, provides a better representation of uncertainty based on probability distributions, with the loss of some of the strengths of BBNs, such as backwards updating. Bayesian models are already widely used in fisheries management,[42] but the relative lack of quantitative analysis in bushmeat research and management, and the lack of capacity for policy implementation mean that they are not likely to be used for bushmeat in the foreseeable future.

Using virtual worlds

As computing power becomes less of a limitation, simulation modelling has become a much more powerful tool in understanding the dynamics of complex systems. The advantage of this is that policy interventions can be tested by simulation rather than in the real world. As the real world is effectively one realisation of a stochastic simulation, predictive power should be improved by running simulation models repeatedly. A particularly powerful feature of the simulation approach is the ability to model the observation process itself. Thus the effect of observation uncertainty can be included as well as the process uncertainty inherent in the system[43] (e.g. climate-driven population fluctuations). Model uncertainty can be addressed by running the simulation under a range of possible assumptions about system structure, and using a model selection procedure such as Akaike's Information Criterion.[44]

There is an increasing ecological literature using simulation modelling to address observation uncertainty.[45] One of the early applications to natural resource management was the Revised Management Procedure developed by the scientific committee of the International Whaling Commission[46] (Fig 9). This is an example of the broader "operating model" approach to fisheries management[47], in which management plans are developed on the basis of flawed observational data, but the performance of the system can be monitored using variables based on actual values of the system such as true population size. Fisheries models of this type tend not to include individual human behaviour, but instead concentrate on the options for a single management authority; this is not realistic for most bushmeat hunting, in which the management authority has little control over individual behaviour.

[Fig. 9, near here]

Within bushmeat research, the simulation modelling approach has yet to catch on. Bousquet *et al*.[48] use a individual-based model of individual hunters and duikers (*Cephalophus monticola*) to show how individual agents act when hunting a common property resource, but do not address observational uncertainty. Some of the drawbacks of the simulation approach include the need for computer programming expertise, and the problem that complex models can lose heuristic power. Simple models are far more enlightening than complex ones so long as the simplifying assumptions are valid. Although limited in some ways, simulation modelling is potentially a very useful tool in bushmeat research, particularly in testing frameworks for managing uncertainty.

PROSPECTS FOR BUSHMEAT

Bushmeat hunting is complex ecologically, socially and economically. Conservationists will not be able to obtain data for full sustainability assessments in any but a handful of locations. Under these circumstances, action still has to be taken to safeguard vulnerable species and to ensure that wildlife is not extirpated over wide swathes of tropical forest. Fa *et al.*[3] estimate that bushmeat hunting is currently about 2.8 times the sustainable level in the Congo Basin as a whole; despite the broadbrush nature of this estimate, it is clear that the wildlife resource in this area is not able to sustain current offtake levels. However, there is heterogeneity in offtake rates, and some way to capture this is required, in order to prioritise interventions.

The key to moving forward in this situation is to acknowledge that sustainability assessments for bushmeat are plagued with uncertainty, and ensure that this uncertainty is realistically represented in assessments. We need to strengthen our understanding of the socio-economic context of bushmeat hunting, so that we can be sure that our interventions are having the desired effect on people's decision-making.[49] And crucially, effective protected areas are required in order to ensure the persistence of unhunted ecological communities.

Bushmeat hunting in Africa can be crudely divided into three scenarios: mature markets, frontier bonanzas and declining source-sinks. In some areas it seems that hunting has continued for decades to supply mature bushmeat markets. The animals are coming from the farm-bush matrix rather than from forested areas, and are all resilient, fast-growing species. The vulnerable species are already extirpated. Cowlishaw *et al.*[5] describe such a scenario for Takoradi market in Ghana. These areas are likely to be of low priority for conservation intervention, but research is still required on the potential of these areas to produce a sustainable bushmeat supply, and on the livelihood importance of bushmeat to people living there.[50] There is also no clear understanding of the extent or importance of these areas as a component of overall bushmeat supply.

The frontier bonanza scenario is the one of most conservation concern. Here, primary forest is being opened up for logging or other commercial or development activities. Wildlife communities are rapidly extirpated as immigrants move into the area, and intervention is required to safeguard both hunted animals and often also the livelihoods of vulnerable people already living in the area.[23,24] This is where pressure on governments or multinationals and urgent action to protect habitat are crucial.

Perhaps the most widespread and difficult form of bushmeat hunting is the declining source-sink system. In this scenario a build-up of hunting effort is reducing wildlife populations over a wide area, but with spatial variation caused by differences in habitat, travel costs or other factors. The causes for this build-up are complex and interacting, as discussed above. Here the problem is at its most intractable, and imaginative interventions such as no-take zones, community-based management and alternative livelihoods are most often tried. It is to this scenario that the suggestions for future management approaches made in this chapter are most likely to be relevant. Sustainable bushmeat hunting in these areas is only going to be achieved, if at all, when it is addressed in the context of the wider economy, and with a full understanding of the inherent uncertainties.

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[50] For an excellent example of the kind of research that is required, see de Merode, E., Homewood, K., Cowlishaw, G. 2004 The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. Biological Conservation 118, 573-581.

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Figure 1. A schematic representation of bushmeat as a bioeconomic system, Ecological sustainability depends on the balance between offtake and productivity. The increasingly large-scale economic and biological influences are shown, together with arrows representing possible interactions between the biological and economic components. These interactions are fundamental to bioeconomic systems, and include the effects of macroeconomic policy on habitat availability for hunted species.

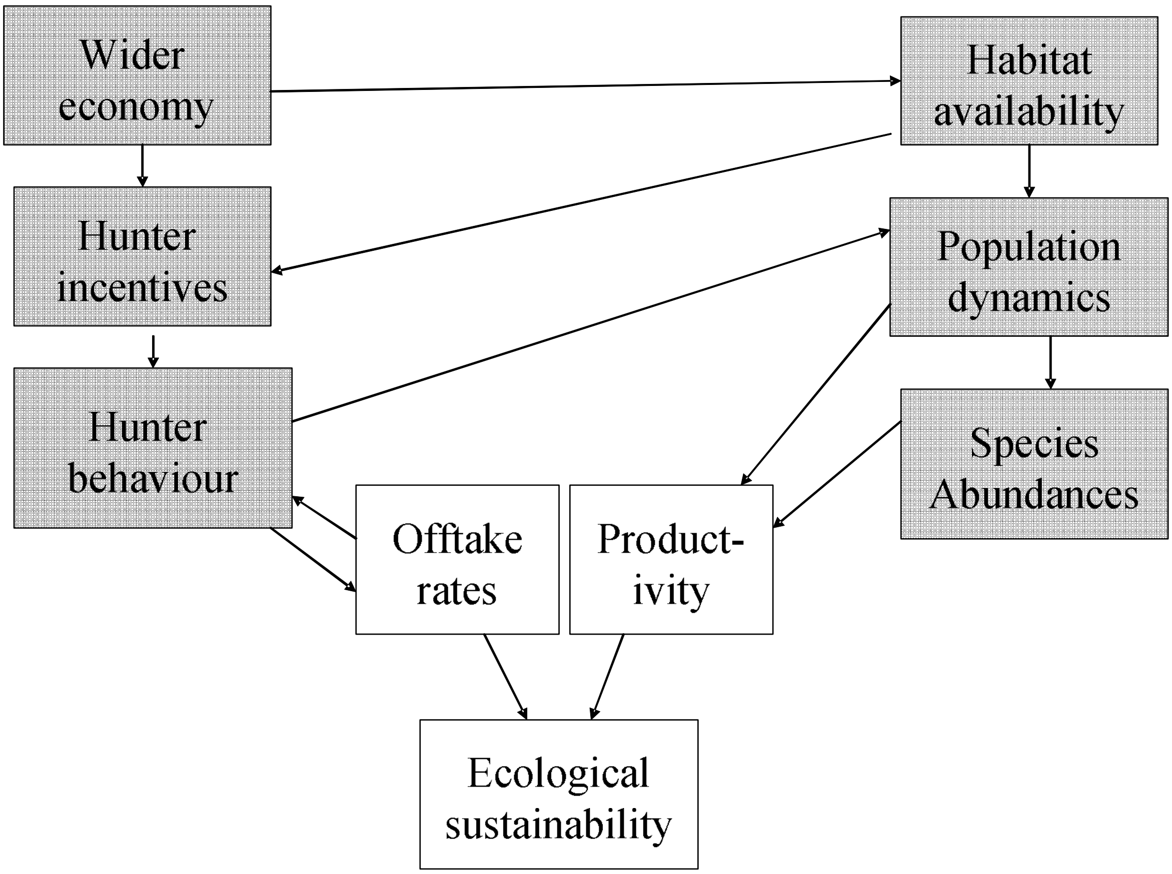

Figure 2. A stylised commodity chain, showing the journey of a carcass from being trapped in the forest to being observed in the end market. The actual structure of the commodity chain will vary from place to place, but this gives an idea of some of the main ways in which meat is disposed of. Different species will be more or less likely to reach the end of the chain, depending on their value and protected status.

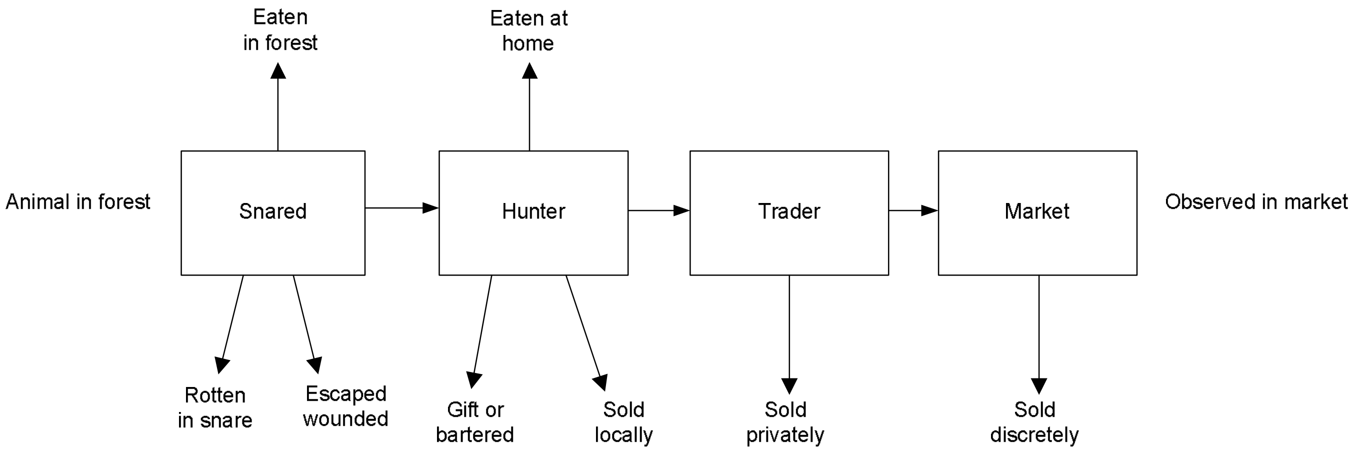

Figure 3. Consumption and preference scores for urban consumers in Bata, Equatorial Guinea.[17] Data are taken from a survey of 100 randomly selected households, in which individual meats were ranked 1-3 in order of frequency of consumption and preference. Scores are the normalised sums, for all meats in a category, of the number of people ranking an item 1st-3rd, multiplied by 3 for 1st place, 2 for 2nd place or 1 for 3rd place.

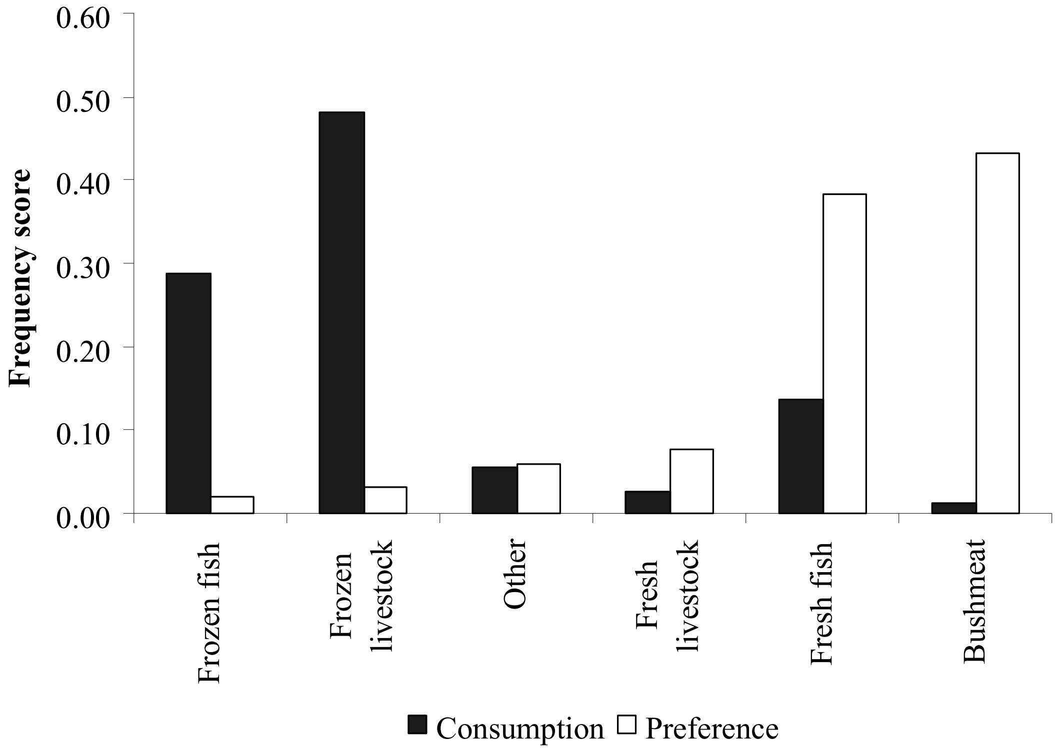

Figure 4. Travel times for a case study wild pig dealer in North Sulawesi, 1988-1997. The travel times are for single journeys, weighted by the number of pigs purchased in each location along the way.[28]

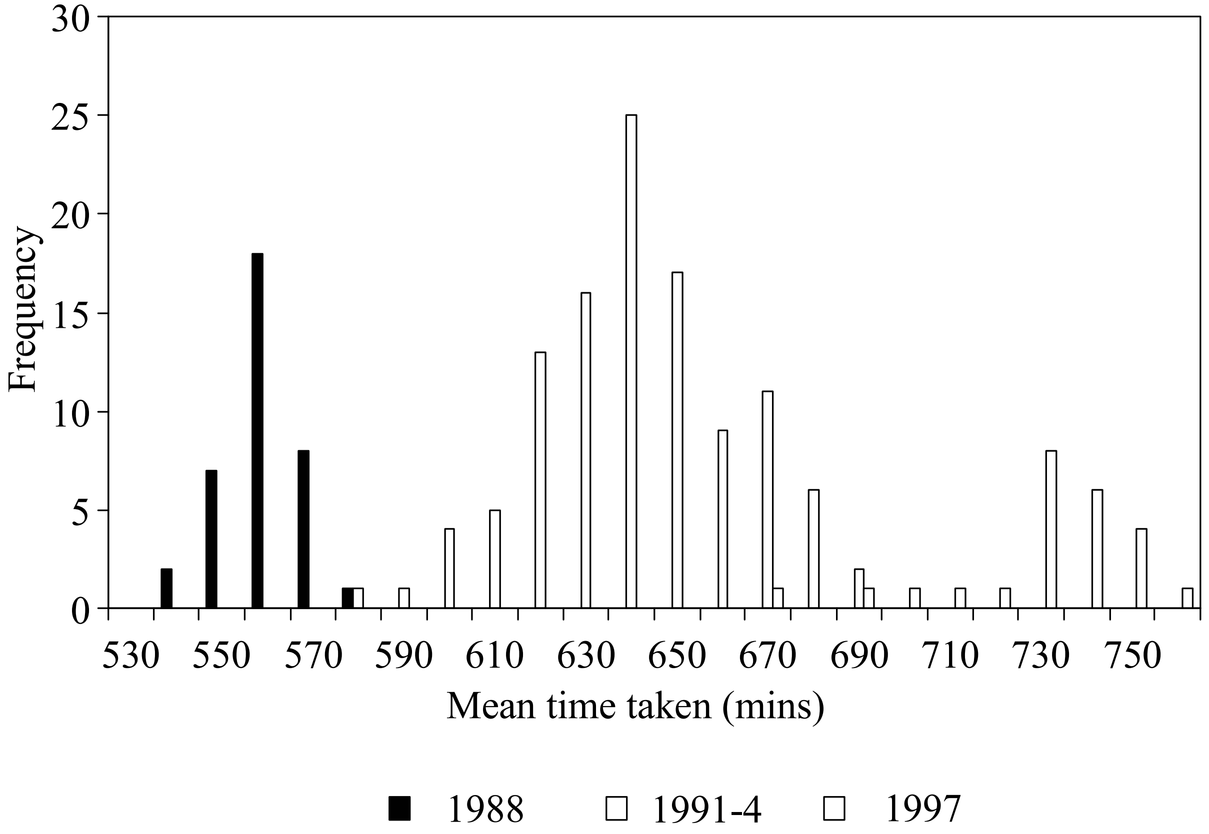

Figure 5. Vegetation of Gorontalo region, North Sulawesi, in 1998. Classifications are taken from a ground-truthed AVHRR image, and divided into primary and secondary forest or mixed agriculture. The major road along which pig dealers travel is shown. This is the region from which the majority of the wild pigs for sale were being hunted at the time. The image shows substantial forest conversion emanating from roads and rivers.[51]

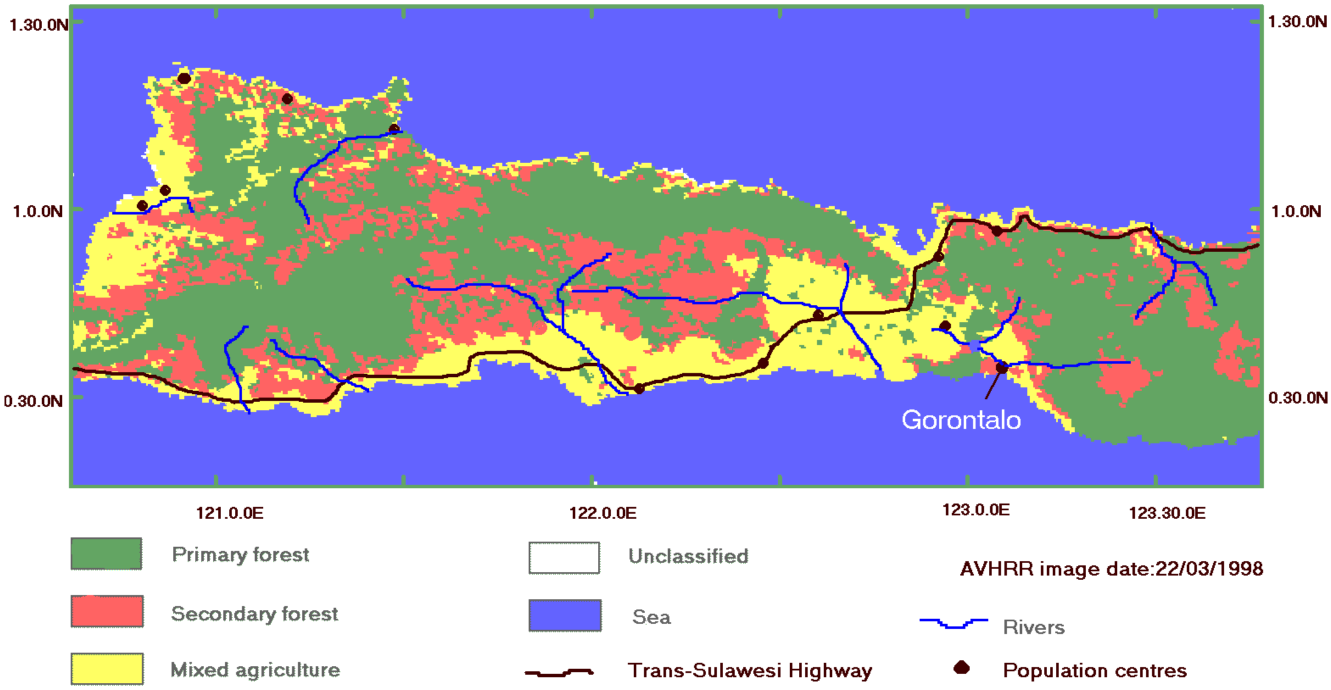

Figure 6. a) Normalised real price of the seven most commonly traded bushmeat species at Atwemonom market, Kumasi, Ghana, based on a dataset collected by the Ghanaian Wildlife Department. b) Changes in the proportion of the Wildlife Department dataset represented by the 7 species over the same time period, using data from the open season when all these species were legally traded.[29]

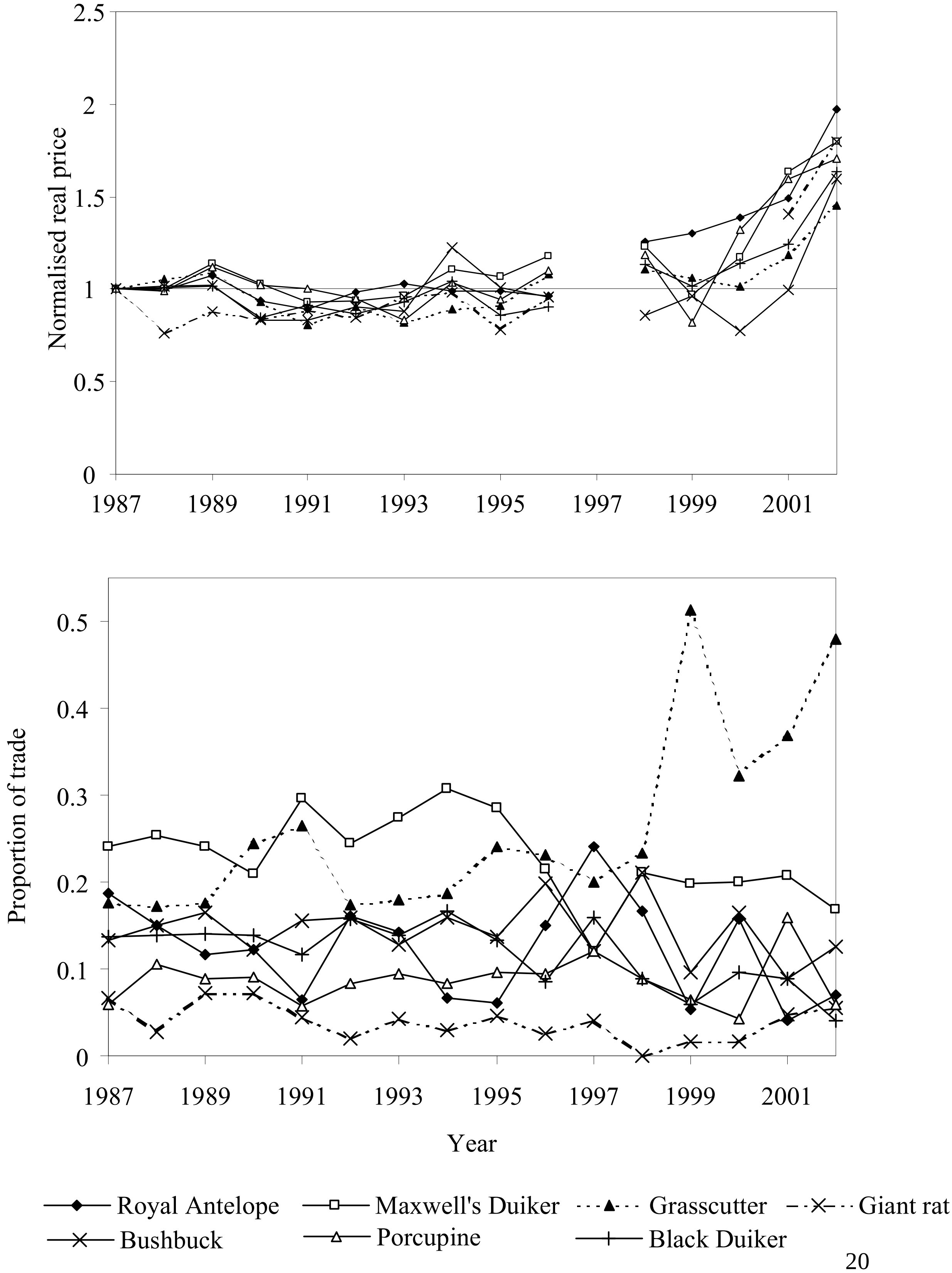

Figure 7. The proportion of animals in the Atwemonom dataset that were killed by guns, cutlasses or directly in traps over the period 1987-2002.[29]

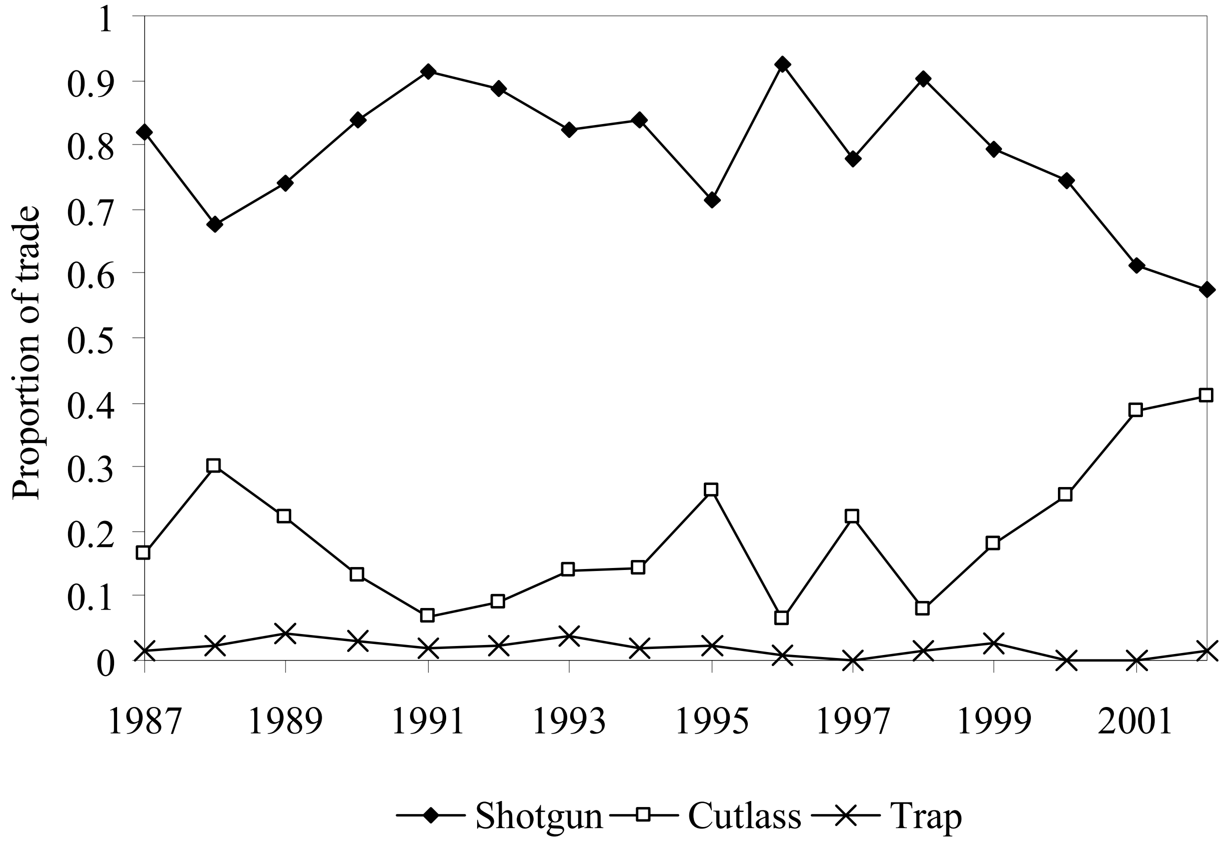

Figure 8. An example of a simple Bayesian Belief Network. The influence diagram shows how variables relate to each other, and for each variable a probability distribution of values is given. Note that this example is simplified for demonstration purposes, showing one location, one point in time, and one species. Two measures of sustainability are included in this example: i) Is the population size below a threshold level of 10% of carrying capacity? The probability of being below the threshold (dashed line) is shown by the white column. ii) The change in catch per unit effort (from previous time periods). A declining Catch per Unit Effort (CPUE) is an unreliable indicator of unsustainable use, which would not be used in practice, but is shown here for demonstration purposes. The probability of a declining CPUE is the sum of the white columns in the probability distribution.

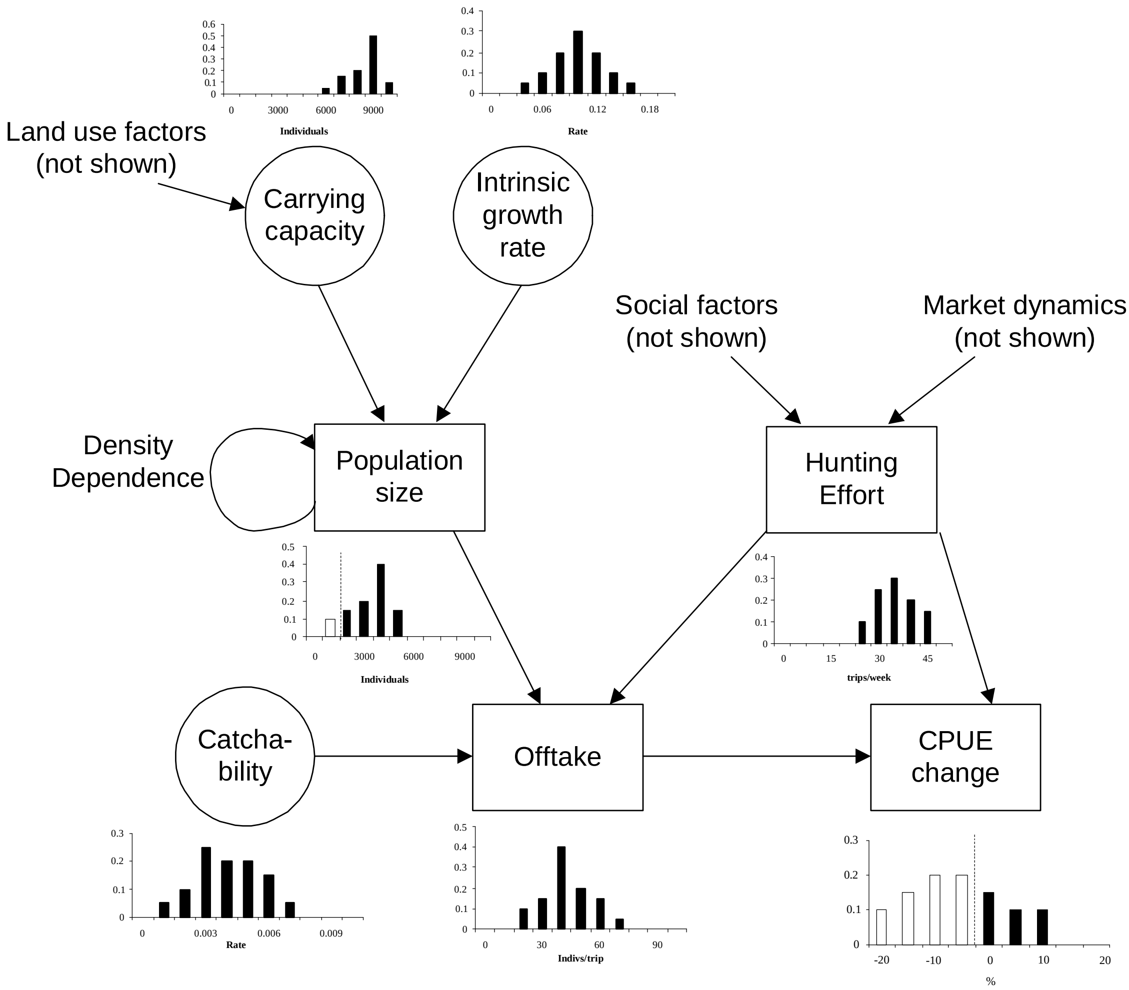

Figure 9. The conceptual basis of the International Whaling Commission's revised management procedure, showing the relationship between the true system dynamics and the management plan operating through data. The performance of management rules can be assessed in the simulation using the performance indicators, which represent the true status of stocks and catches.[46,52]