The Environmentalist **18**, 109–118 (1998)

Protected areas, agricultural pests and economic damage: conflicts with elephants and pests in Yunnan, China

CLEM TISDELL* AND XIANG ZHU

The University of Queensland, Brisbane, 4072, Australia

Summary

Protected areas are often the source of agricultural pests and Xishuangbanna State Nature Reserve in Yunnan is no exception. The main pest associated with the reserve is the Asian elephant *Elephas maximus* which causes damage outside the reserve to agriculture and also within the reserve. These elephants are an important attraction for tourists visiting Xishuangbanna. Xishuangbanna prefecture contains the only remaining wild elephants in China. The present direct economic value of tourism within the reserve is much less than the loss resulting from the economic damage caused by the elephants and other species protected by it. Whether the net economic value of protecting this species in Xishuangbanna is positive depends on other factors or future tourism prospects. Methods of controlling pests from the reserve are discussed, as is the scheme for compensating agriculturalists for the damage caused by these pests. The problem of achieving an equitable solution to the pest problem is given considerable attention. The economics of reconciling the conflicting interests of those who either regard a species as a pest or as an asset are considered.

Introduction

It is currently popular to emphasize the benefits of protected areas and the conservation of species. While this is reasonable, sight should not be lost of the fact that protected areas can be a source of negative spill-overs to nearby farmers. Protected areas may, for example, increase fire risks to nearby farms or be a source of agricultural pests such as 'weeds' and animal agricultural pests such as elephants and wild pigs (Tisdell, 1982). When animal species are protected in a nature reserve and cause agricultural damage on nearby farms, the economic loss incurred results in farmers' grievances towards the nature reserve if the farmers receive inadequate compensation for such damage. Their dissatisfaction is further heightened if the animal species involved are completely protected both inside and outside the nature reserve, as in Xishuangbanna prefecture in China.

*Dr Clem Tisdell is Professor of Economics at the University of Queensland, Brisbane, Australia; Xiang Zhu is Associate Professor at the World Bank Loan Project Centre, Ministry of Forestry, Beijing, PRC. Correspondence should be addressed to Professor Clem Tisdell.

Xishuangbanna prefecture is located in the far south of Yunnan and is bordered by Laos and Myanmar (Burma). It has been classified as an area of megadiversity (Myers, 1988; Mittermaier and Werner, 1990) and, consequently, the nature conservation in this prefecture is of worldwide interest. Xishuangbanna contains the last remnants of China's population of Asian elephants, *Elephas maximus*, as well as a very high degree of botanic diversity. Tourism is a rapidly developing and important industry in this prefecture and the Chinese authorities would like to reap economic benefits from the further development of nature-based tourism in the area.

There are two important nature reserves in the prefecture: Xishuangbanna State Nature Reserve and Nangunhe Nature Reserve. In 1989, Sukumar (1989, pp. 18, and 30) indicated that probably 100–230 elephants existed in these reserves. In 1994, the number of elephants in Xishuangbanna was to be estimated approximately 150–250 and it was shown that the population had increased in recent years. Nevertheless, this elephant population is very low and the distribution of elephants is seriously reduced in comparison to that of China in historic times when the range of *E. maximus* extended to the Yantze (Chang) River.

While the nature reserves in Xishuangbanna help conserve nature species with some positive economic values, several of these species cause damage to the crops of local farmers. Consequently, this is a source of social conflict and, as evidenced below, the agricultural damage caused by elephants is the most severe. On the other hand, elephants are one of the most important tourist attractions for the Xishuangbanna nature reserves. This social conflict cannot be ignored from a conservation viewpoint because, as Sukumar (1989) observed, 'any grandiose plan for conservation without adequate provision for human interests is bound to fail'(p. 202).

This paper considers the animal pests emanating from the nature reserves in Xishuangbanna in terms of their total economic value. In practice, this means concentrating on the Asian elephant. However, the conservation and appropriate management of endemic vertebrate species requires social conflicts to be resolved and, therefore, policymakers, in seeking practical solutions to conservation issues, must go well beyond the total economic evaluation of such species.

The case material used here was collected in Xishuangbanna, but the problems observed are placed in a general context since they are not peculiar to this case. First, the total economic evaluation of an agricultural pest species such as *E. maximus* is discussed along with the broad issues involved in conflict resolution and management of the species. It is observed that, while much attention has been given to the economic evaluation of the African elephant *Loxodonta africana*, (see, for example, Barbier *et al*., 1990), much less economic attention has been given to the Asian elephant, *E. maximus*. While both species have some common economic values and cause similar damage, there are differences, as highlighted below.

The status of animal pests from Xishuangbanna State Nature Reserve, in particular the elephant, is outlined. The control and management of vertebrate pests from the reserve is then considered, including the measures which local farmers take to protect their property against these pests. Even when populations of wild animals are managed optimally from a social viewpoint, farmers are still liable to incur economic damage from such animals. The question then arises as to whether farmers should be compensated and, if so, how. Considerable attention is given to compensation and social security schemes in relation to protected animal 'pests'. The scope for local farmers to gain economic benefits from the conservation of such animals is discussed and the compensation scheme currently operating in Xishuangbanna prefecture is critically analysed.

Total economic evaluation of the species, conflict resolution and control

Protected animals are often agricultural pests and this creates difficulties for their conservation and economic evaluation since some may regard them as assets. Sometimes the same individual may even see the same species as a pest in some contexts and as an asset in others. For example, elephants may be regarded as pests by farmers and villagers in areas near nature reserves if they roam onto their farms and cause damage. Nevertheless, these farmers and villagers may consider elephants positively if they remain in the nature reserve or do very little agricultural damage. On the other hand, tourists and those valuing the existence of such animals regard the populations of such animals as a positive asset. Given this conflict, how is a species to be valued from an economic viewpoint?

In cost–benefit analysis, economists have traditionally determined the social benefits resulting from variations in the availability of resources by using the Kaldor–Hicks principle. This principle, which is sometimes called the potential Paretian improvement principle, implies that social benefits are to be determined by adding the benefits or losses experienced by individuals or groups from the variation in the availability of a resource. This means that the effects of this variation on income distribution are ignored. For example, suppose that the resource is the level of population, P, of a species and let $R(P)$ represent the total value placed on it by those who see the species as an asset (determining this value is by no means straight forward despite the existence of methods such as contingent valuation) and let $L(P)$ specify the economic loss suffered by those who see the species as a pest. Applying the Kaldor–Hicks principle, the social economic benefit from the population of the species can be expressed as

$$V(P) = R(P) - L(P) \qquad (1)$$

As a rule the population of a species can be varied by human intervention at a cost. The level of population of a species may be reduced below its 'natural' level at a cost or can even be increased by expenditure designed to improve the habitat or other conditions experienced by the species. If $\overline{P}$ represents the natural level of population of a species, the cost of varying its population may be of the form $C(P,\overline{P})$. Hence, extending the above view of economic welfare, the social net benefit from the availability of the species is

$$B(P) = R(P) - L(P) - C(P,\overline{P}) \qquad (2)$$

and the socially optimal level of population of the species is the one which maximizes this expression.

Note that this model incorporates similar assumptions to those of the pest control model of Headley (1972) as discussed in Tisdell (1991, Chapter. 9). It is a simple model because it does

not take account of the dynamics of management of a species. The calculus of variations and dynamic programming may be applied to model dynamics as has been done by Conrad and Clark (1987) and Clark (1990), but at the expense of much greater complexity.

According to the Kaldor-Hicks principle, a change is a social improvement if those gaining from the change could compensate the losers and be better off than prior to the change. Usually the application of the principle results in some degree of compromise between the parties with conflicting interests. For example, if some individuals regard the species as an asset and others see it as a pest, the socially optimal level of population of the species, based on the maximization of Equation 2, will normally result in a smaller population of the species than is optimal for those viewing the species positively and a higher level of population of the species than is desirable from the point of view of those who regard the species negatively (Tisdell and Zhu, 1995, Appendix). In this socially 'ideal' situation, conflict will continue to exist between the parties and will need to be 'managed' by regulators. As part of such management, compensation schemes for economic damage by a species may be introduced, as has been done in Xishuangbanna.

The whole question of the social value to place on the population of a species is an extremely complex one but it is now more widely appreciated that economic values must include not only direct but indirect values. The notion of total economic value, consisting of direct and indirect use and non-use values, has, for instance, been popularized by Pearce *et al.* (1989) and has been applied to valuation of the African elephant (Barbier *et al.*, 1990, pp. 17–21) in a general way.

Barbier *et al.* (1990, p. 18) suggested that the greatest direct economic use values of the African elephant are for tourism, ivory, meat and hides. In terms of export earnings, tourism may be the most important economic benefit from the African elephant. In terms of its natural ecological functions, the African elephant also has indirect use value because it has 'the ability to diversify savanna and forest ecosystems, and as seed dispensers, reduce bushlands, expand grasslands and reduce the incidence of the tsetse fly' (Barbier *et al.*, 1990, p. 19). This may improve the conditions for grazers and other species. The Asian elephant may perform similar functions. Furthermore, the African elephant was considered to have significant non-use values, such as existence, bequest and option values.

In comparison, the Asian elephant also has significant tourism value but no studies of the type undertaken by Brown and Henry (1989) for the non-consumptive value of elephants for tourism purposes in Kenya appear to have been undertaken in Asia. In this respect, however, it should be noted that in some parts of Asia, such as Xishuangbanna, it is difficult to see elephants because of their low densities and because they are confined, as a rule, to tropical rainforests or similar vegetation thereby reducing their visibility in comparison to the savannah areas of Africa. This may therefore provide the animals with a smaller economic tourism potential than in Africa. Furthermore, the eating of elephant meat is no longer practised in most of Asia and the Asian elephant is less valuable than the African elephant for ivory. This is because female Asian elephants do not have tusks and a proportion of Asian males are also without tusks. Consequently, the direct value of the Asian elephant could be lower than the African elephant, particularly in areas such as Xishuangbanna. On the other hand, the Asian elephant can be domesticated and is still used in some countries such as Myanmar for logging. However, their domestic use is declining.

The fact that the Asian elephant can be domesticated makes it a tourist attraction since it can be used for transporting tourists safely, for instance within national parks. Furthermore, elephant 'schools' such as the one north of Lampang in Thailand draw many visitors. In addition, the non-use value of the Asian elephant is probably very high given the standing of the elephant in Asian history, culture, religion and folklore. Unfortunately, no hard and fast estimates of these values are available.

The status of animal pests from Xishuangbanna State Nature Reserve

Xishuangbanna State Nature Reserve in Yunnan consists of five separate subreserves and, like many other nature reserves, is a source of agricultural pest. The main agricultural pest is the Asian elephant, *E. maximus*, which is thought to be responsible for approximately 90% of the agricultural economic damage caused by pests roaming from the reserve. The other animal pests include monkeys, e.g. rhesus monkeys *Macaca mulatta*, bears, gaur *Bos gaurus*, spotted or Sambar deer *Cervus unicolor* and wild pigs *Sus scrofa*, but on the whole these are not considered to be serious agricultural pests.

On average, it was estimated (October 1994) that pests straying from Xishuangbanna State Nature Reserve cause ¥1 million in agricultural damage and that the agricultural damage in the whole of Xishuangbanna prefecture from wild animals is approximately ¥2 million annually (personal communication from Cao Meng Liang, Director, Bureau for the Protection of Xishuangbanna State Nature Reserve). (In October 1994 it was approximately the case that ¥8.3 = US$1.00.)

In Xishuangbanna, elephants eat crops such as rice, corn and bananas (Fig. 1). Many damage the embankments of paddy fields and break fences. Even within the reserve they may cause some damage. For example, walking tracks may be damaged and undermined by the movement of

Fig. 1. Banana trees in Zhong Tian Ba village. Such trees are a favourite food of marauding elephants.

elephants. This has already happened along one of the important newly constructed walking tracks at the San-Ca-He site in the Mengyang subreserve. Substantial portions of the track are constructed of concrete bricks and are located along a route frequently used by elephants. In the wet season in particular, elephants slide off the track and sometimes travel down the embankment on which it is built, thereby undermining the track (Fig. 2). Trees are pushed across the track by elephants so adding to the maintenance costs. This is a source of concern for the management of the subreserve because it has scant funds of its own for maintenance.

In large densities, elephants seriously damage forest vegetation in order to satisfy their food requirements. They also use trees and shrubs as scratching posts and knock them down 'to let off steam' or test their strength. It may be observed, however, that Asian elephants, when disturbing rainforest, may normally be performing an important ecological function as noted earlier in relation to the African elephant.

Fig. 2. Damage at the side of a walking path at San-Ca-He caused by elephants sliding down the embankment. Eventually the path is likely to be undermined.

The elephant populations in the subreserves of Xishuangbanna State Nature Reserve are unevenly distributed. The main concentration is in Shangyong and Mengla subreserves in the far south of the prefecture. The elephant population moves between these subreserves, the first of which (Shangyong) is on the Laotian border. Elephants often cross the Lancang (Mekong) River and so move between Laos and Xishuangbanna prefecture. The managers of the subreserves report that, mainly due to the heavy hunting pressure on elephants in Laos, there has been a net migration of elephants to the Chinese side of the border. In general, the population of elephants in the reserve is increasing and, on average, the numbers in the whole reserve are estimated to be 150–200 head.

There are probably approximately 50 elephants in Mengyang subreserve but only three to four in the smallest subreserve, Menglun, which is in fact a fragmented subreserve.

Due to economic development, the elephant population in Mengyang subreserve has become isolated from the population further to the south. and further migration of the elephants is impeded. It has been suggested that land corridors be established between the subreserves to assist the migration of the elephants and to ensure genetic mixing of the populations. Plans have been drawn up for the creation of such corridors but these are very tentative and in fact may never be established because the cost of land acquisition is likely to be very high. Furthermore, the corridors would add to the pest problem for agriculture from the reserve. In addition, the corridor proposed at present is dissected by at least one major road and this adds to the problems of establishing the corridor.

There are several reasons for the major decline in populations of wild elephants in China in historic times. These include past open access to the species (Hardin, 1968; Repetto and Gillis, 1988; Clark, 1990; Tisdell, 1991) and, particular, the conversion of land from natural vegetation cover to other uses such as agriculture (Hardin, 1960; Swanson, 1994, pp. 10–11). Sukumar (1989, pp. 32–38) listed several specific factors that have resulted in the decline of elephant populations throughout Asia.

(i) Exploitation of the habitats of elephants by humans, e.g. competition from humans for plant resources, changes in vegetation cover such as the establishment of forest plantations often of monocultures and logging.

(ii) Land and vegetation degradation caused by shortened cycles in shifting agriculture.

(iii) The spread of permanent agriculture.

(iv) The construction of hydroelectric and irrigation dams which displace elephants and deprive them of valuable food resources located in the valleys.

(v) The legal and illegal capture of elephants.

(vi) The hunting of elephants for ivory, meat and hides and for pest control purposes.

Most of these adverse factors have operated in Xishuangbanna in recent times. For example, some of the areas in Xishuangbanna frequented by elephants were converted to rubber plantations. Xishuangbanna also contains a number of tribal minorities who still practise shifting agriculture. Due to population pressures, the cycles of shifting cultivation have been reduced in length thus reducing the area of forested land at any one time and the extent to which disturbed forest communities are able to recover after cultivation. This has reduced the available food resources for elephants and increased their vulnerability to hunting. Furthermore, the area brought under agricultural cultivation has been extended, sometimes illegally, e.g. previously into the Xishuangbanna State Nature Reserve. While no major dams have been built in Xishuangbanna, a major dam to be located on the Lancang (Mekong) River for the purpose of electricity generation and irrigation has been contemplated for location in the Mengyang subreserve of Xishuangbanna State Nature Reserve. In the past, the Asian elephants in Xishuangbanna were heavily poached. As a result, a high proportion of the elephants present are without tusks or have very small tusks due to selection.

Economic development in Xishuangbanna can be expected to place increasing pressure on the elephants when they are outside the reserves, even though the hunting of elephants is illegal. From the viewpoint of China as a whole, maintaining the existence of the Asian elephant population in China may have a reasonably high value. However, this indirect value has not been measured. Nor has the value of the elephants in attracting tourists to Xishuangbanna or to the reserve been measured. The local tourist industry uses wild elephants for promotional purposes and wooden carved elephants are produced and sold in Xishuangbanna. A multisided relief of elephants decorates the centrepiece of a main road intersection in Jinghong, the capital of Xishuangbanna prefecture. On the other hand, the chances of tourists seeing wild elephants in Xishuangbanna are relatively low and the majority of Chinese tourists to Xishuangbanna never venture into the reserve or look for elephants there.

At San-Ca-He, there is an elephant-viewing treetop lookout which can be reached by an approximately 30 min walk from the entrance to the site. It overlooks a favourite watering and bathing area of wild elephants (Fig. 3). However, the elephants do not always frequent it. To increase the chance of seeing elephants, it is possible to stay the night there in the treetop 'hotel'.

Fig. 3. Treetop hotel at San-Ca-He for viewing elephants. It is near a favourite bathing spot of the elephants. Salt is sometimes distributed nearby to entice elephants to visit the area (photograph courtesy of J. Wen).

In October 1994, there was only one domesticated elephant at the San-Ca-He site. This fed locally in the subreserve and was mainly used by

Fig. 4. Domestic elephant at San-Ca-He, (Oct. 1994) with one of the authors mounted on it.

tourists for rides and photographing (Fig. 4). It was brought from Myanmar. This is in fact the only elephant that most visitors to this site or the reserve see. The possibility of having an extra domestic elephant was discussed with the managers of the subreserve. This would help to compensate visitors for not seeing wild elephants or other animals. Wild animals are not easily seen in tropical forests such as those in Xishuangbanna State Nature Reserve, in contrast to the situation on the plains or open woodland in Africa. This reduces the appeal of tropical forests to many ecotourists.

The management of the subreserve felt that the main difficulty in increasing the number of domesticated elephants at San-Ca-He would be that the domesticated elephants would feed locally and damage the vegetation of the subreserve and supplementary feeding might be costly.

The possibility that visitors to San-Ca-He could be encouraged to buy corn and sugar cane to feed to the elephants was discussed. This is done, for example, in Thailand at the elephant training school to the north of Lampang where such activities are popular with visiting tourists. A similar practice occurs at the Lone Pine Koala Sanctuary in Brisbane, Asustralia, where visitors can buy pellets to feed kangaroos. However, those managing San-Ca-He said that they had tried a scheme whereby visitors could buy concentrated food to feed to the domesticated elephant but that the Chinese were not inclined to make such purchases and so this approach was discontinued. Domesticated elephants have to be protected from wild elephants. At night the domesticated elephant at San-Ca-He is housed in a building with thick steel pipes as side walls to protect it from wild elephants. Extra costs could be involved in adding to such enclosures.

To have a definite quantitative measure of the total economic value of the wild elephants in Xishuangbanna would be useful for management purposes. The direct use for tourism is low, since only a small proportion of visitors to Xishuangbanna actually visit the reserves inhabited by elephants and look for elephants. Furthermore, the chances of seeing elephants in the rainforest are very low. In fact only approximately ¥30 000 is collected annually in the fees from visitors to Xishuangbanna State Nature Reserve. Driml and Common (1995), discussed the issues involved in general terms. It is impossible at this stage to say to what extent visits to the reserves are motivated by the possibility of seeing a wild Asian elephant.

On the other hand, the indirect and economic non-use values of the elephant in Xishuangbanna may be high. The Asian elephant probably performs an important role in maintaining the botanic diversity in the reserve and the elephant is a publicized tourist feature in the major towns such as Jinghong where tourists to Xishuangbanna spend much of their time. The local elephant carving industry, involved in production for the tourist market, probably owes its continuing existence to the presence of elephants in the locality (Fig. 5). It seems that some tourists visit an area because of an image factor and elephants add to the natural image of Xishuangbanna. It might also be observed that there are other species that are rarely seen, such as the tiger, but visitors still go to nature reserves and national parks such as the Sundabarns in India and Bangladesh on the chance that they may see them. They add 'character' to the tourist destination and, therefore, draw tourists to the neighbourhood.

Using the terminology of Barbier *et al*. (1990), the non-use value of the Asian elephant in Xishuangbanna from the Chinese perspective is likely to be relatively high because it is the only remaining population in China. Even if not all Chinese place an economic value on conserving the Asian elephant in China and even if the value placed on this by individual Chinese people is relatively low, China's population of 1.2 billion can be expected to result in a substantial total sum for the elephant's continuing existence. For example, if 400 million Chinese were willing to pay the equivalent of 1 cent per year to retain the Asian elephant in China, this would amount to $4 million annually. Option and bequest values would add to the total economic non-use value of the elephant in Xishuangbanna.

Against the total benefits of the Asian elephant one has to offset its economic damage plus the expenditure involved in deterring the elephant from doing such damage plus the other costs associated with the management of the elephant. The economic damage involved appears to be ¥0.9–1.8 million annually for the whole of Xishuangbanna according to the director of the Xishuangbanna State Nature Reserve. The other costs probably amount to no more than ¥0.2 million annually. Consequently, from the indirect

Fig. 5. Carving wooden elephants on the footpath in Jinghong, the capital of Xishuangbanna prefecture. These carvings are for sale to tourists.

evidence, the total net economic value of the Asian elephant population in Xishuangbanna is highly positive. Nevertheless, there must be some doubt as to whether the populations of elephants in Xishuangbanna are viable in the long-run given the fragmentation of Xishuangbanna State Nature Reserve and the available areas for the elephants (Sukumar, 1989, p. 206).

Controlling vertebrate pests from protected areas

The animals under consideration may be regarded as mixed goods–assets from the point of view of the protected area and the general public, but pests from the standpoint of agriculturalists. Because of their mobility, they can also be regarded as transboundary resources (Clark, 1990, pp. 158–68). Sometimes, it is economic to implement management strategies to control such species taking into account the economic damage which they cause to agriculturalists.

The agricultural damage caused by vertebrate pests straying from protected areas can be controlled in three different ways.

(i) Enforced enclosure of the animals in the nature reserve.
(ii) Exclusion of the animals from agricultural land or from agricultural areas likely to be damaged (e.g. by appropriate fencing).
(iii) Reduction of their populations (possibly selectively) by human action.

Each of these options can be costly.

The subreserves of Xishuangbanna State Nature Reserve appear to be mainly unfenced and the wild animals are not enclosed. To build fences or barriers to enclose the elephants effectively would be very difficult and costly. It would also interfere with the movement of the elephants between the subreserves and, therefore, would reduce genetic mixing.

Some villagers in Xishuangbanna have erected short lengths of electric fence at points where elephants are likely to enter farmed land and cause damage. These single-strand fences are set relatively high on wooden posts and the electrified wire is held by porcelain insulators. The power is supplied by a battery unit recharged by solar energy (Fig. 6). These units have been supplied by the WWF (Worldwide Fund for Nature) Europe and are maintained by the Bureau for the Protection of Xishuangbanna State Nature Reserve. Such a unit, for example, is located at Zhong Tian Ba village which adjoins Mengyang subreserve. The fence is several metres in length and is stretched across a slight gully which extends from this subreserve. At the time of inspection, corn (maize) was growing in this area. With only slight difficulty, an 'intelligent' elephant could have walked around the fence since it formed a barrier rather than an enclosure for the crops.

Fig. 6. Single-strand electrified fence in an old maize field near Zhong Tian Ba across a path previously used by elephants. The battery is charged by a solar panel which can be seen in the foreground.

The villagers reported that initially the electric fences are a relatively effective deterrent to the elephants. However, in time, some elephants learn how to disable the electric fences. They pull out the wooden posts holding the electrified wire, thereby knocking the fence to the ground and then walk over it. The opinion of the villagers was that the fence was of some value to exclude elephants but was not completely effective. Zhong Tian Ba had suffered loss of rice to elephants. When the elephants began raiding the rice fields and the electric fence was not fully effective, the villagers stayed up at night to guard the fields, camp there and light fires to frighten the elephants away (Figs 7 and 8). Most villagers appear to want more electric fencing.

Electric fencing is in fact widely used in many countries as a barrier to prevent movement by elephants. Thouless and Sakwa (1995) stated that 'in the past a variety of barriers were constructed to exclude elephants from farming areas, but electrified fences are now considered to be the best solution to the problem' (p.99). While electric fences appear to vary in their effectiveness, this appears not to be closely related to their design, construction and voltage, but may depend on the previous experience of elephants with such fences and the nature of the elephant population involved. Thouless and Sakwa (1995) suggested that fences should be regarded as signals for 'no-go' areas rather than real barriers to elephants. The shooting of rogue elephants which make it a habit to break through electric fences may be required. This would be a more suitable approach than randomly reducing the population of elephants. Electric fences appear to be more effective for the control of the Asian elephant than the African elephant. Thouless and Sakwa (1995, p. 105) indicated that this may be because many Asian elephants are tuskless and African elephants make considerable use of their tusks for breaking electric fences.

Fig. 7. Leaders in the village of Zhong Tian Ba discuss, with the authors, the problems which they encounter with wildlife from the nearby Mengyang subreserve.

Fig. 8. Ripening rice crop in the valley near Zhong Tian Ba with Mengyang subreserve visible in the background. Rice has been eaten by elephants in the past and the villagers stay up and light fires to frighten them away when necessary.

As for the strategy of reducing animal populations as a pest control measure, this policy is not favoured in Xishuangbanna State Nature Reserve. There is, for example, no culling programme for elephants as was the case in the Kruger National Park in South Africa. The elephant populations in Xishuangbanna are still considered to be relatively low and the conservation of their population is the main goal. Extensive culls of large mammals may be an unnecessary and costly strategy for the control of damage to agricultural crops. Sometimes it is sufficient to remove 'rogue' animals or to reduce the male population of the species for control purposes. Sukumar (1989) pointed out that 'adult male elephants are far more prone than a member of a female-based family herd to raid agricultural crops and kill people' (p-93).

Whatever control policies are adopted to manage vertebrate pests protected by nature reserves, these should ideally be devised and implemented with cooperation between the managers of the nature reserves and local land holders. The management problem should be approached in an integrated manner. This is not to say that the control of 'pest' species is always desirable or economic and this leaves open the question of payment of compensation to agriculturalists suffering damage from wildlife movements from protected areas.

In fact, four broad strategies exist to deal with the protected wildlife pest problem: (i) no control and no compensation to land-holders damaged by the wildlife, (ii) control but no compensation, (iii) no control but compensation and (iv) control and compensation. In the case of Xishuangbanna State Nature Reserve there is no control of the wildlife populations but some compensation is paid to agriculturists who suffer damage from such wildlife.

Compensation paid to agriculturalists for damage caused by wildlife

The compensation paid by the Bureau for the Protection of Xishuangbanna State Nature Reserve to villagers for the damage caused by animals straying from Xishuangbanna State Nature Reserve amounts to approximately ¥100 000 per year. This compensation comes from a fund provided annually from government sources, the exact amount being determined each year. However, it seems to be relatively stationary at ¥100 000. The budgeted amount is allocated to villagers in proportion to the amount of pest damage estimated by the bureau for each claim. This proportion is found by dividing the total compensation fund by the total agreed damage. Currently, this is approximately 10% of the estimated economic damage.

When damage from animal pests from the reserve occurs in a village, in order to make a claim, the village must report this damage to the management of the relevant local subreserve who send their own assessors to assess the damage. In the past, the damage could be certified by any local government officer but this was found to be un-

reliable. At the end of the year, all allowed claims are added up and the available compensation funds distributed for all claims in proportion to the total compensation fund available. Most of the compensation paid is for the damage caused by elephants.

The difficulties observed for this compensation scheme are as follows.

(i) The proportionate compensation is low.
(ii) The proportionate compensation for damage is the same whether the farmer loses his/her whole crop or just a small fraction of it.
(iii) There is a long delay before any compensation is paid.
(iv) Transaction costs are involved – the villagers must report and confirm the damage and it must be assessed by subreserve staff.

The proportionate compensation is presumably low because, given the low incomes in China, little surplus is available to fund income security schemes. In essence, the scheme involves co-insurance but the proportionate burden carried by villagers is very high at 90% This is not to suggest that it would be desirable to pay 100% compensation even if it were feasible. To do so (or to compensate to a high degree) would increase moral hazards. For example, villagers may take little or no action to prevent marauding animals from destroying their crops.

The question has also been raised of whether the proportionate payment of compensation in relation to the value of the estimated damage is equitable. For example, a farmer who loses the whole of his/her crop would end up with 10% of its value after compensation whereas, for example, one who loses 20% would end up with 82% of its value after compensation. If the farmers had the same income and the same amount of cropped land this would seem inequitable. This could in principle be allowed for by paying compensation on a sliding scale with the proportionate compensation rising in proportion to the percentage of damage sustained by the farmer in relation to his/her income. This, however, still leaves open the question of whether poorer farmers should receive greater proportionate compensation for the same percentage of damage sustained. In relative utility terms, the proportionate loss of the poorer farmers is higher.

It would be of considerable assistance to those affected by pest damage if the period for processing claims and paying compensation was reduced. The possibility of doing this needs to be explored. Care should also be taken to reduce transaction costs to the lowest practical level.

If the protection of animals located in the reserve becomes more effective and their population increases (this is currently an objective), the extent of agricultural damage caused is likely to increase. Furthermore, as agricultural yields and the intensification of agriculture in Xishuangbanna increases, the extent of pest damage is also liable to increase. This is bound to have implications for future relationships between the reserve and local farming communities.

Concluding comments

Nearly all nature reserves are a source of pests for neighbouring agricultural properties and this has to be taken into account in establishing and managing nature reserves. The problem of achieving optimal levels of populations of species in nature reserves is complicated by many factors. For example, the species may be an agricultural pest but regarded as an asset by non-agricultural members of the community. Furthermore, varying the level of population of a species or reducing its propensity to cause agricultural damage is often only possible at an economic cost. Thus, several economic problems arise in managing populations of wild species. Some of these issues have been illustrated for Xishuangbanna prefecture, Yunnan. Apart from optimal management questions, economics also have relevance to schemes designed to compensate villagers for damage caused by protected wild animals. Again this has been illustrated for Xishuangbanna prefecture.

An issue that has not been discussed is who should pay into the pool of funds available for compensation. Economists often argue that beneficiaries should pay. If the general community benefits, then this provides some rationale for the government to contribute to the compensation fund. Possibly most of China's population sees some value in conserving the elephants in Xishuangbanna and in protecting the biodiversity there. Hence, it seems not unreasonable for the Chinese Government to contribute. Even the international community may benefit, so some contribution from it too would also be justified. As yet there is no formal scheme for this contribution. The only international contribution so far has been the voluntary one of the WWF in providing facilities for electric fencing to exclude the elephants from farming property. If tourists or the tourism industry benefit from the preservation of a pest species as in Xishuangbanna then possibly they should also contribute some funds to the compensation fund.

The 'equitable' solution depends on how it is believed rights should be assigned. If farmers have a right to protect themselves against pests and are prevented by some laws from doing this, compensation to farmers seems justified. On the other hand, if it is believed that wild animals have a right to life and ought to be conserved, no compensation might be paid to farmers for damage.

In the latter circumstance, if farmers bear the full cost of agricultural damage, they may still find it worthwhile to set up a cooperative insurance fund, as suggested by Sukumar (1989, p. 218). If

pest damage is not predictable and involves a random element, such a fund could be used for compensation. However, farmers would need to be divided into classes to determine the appropriate insurance premiums. It would also be possible, in principle, to establish a compensation fund financed partially by the insurance contributions of farmers and by contributions from the government and other parties benefiting from the conservation of the pest species. Ethically, such an approach would be based upon the idea that property rights do not belong exclusively to any single party having an economic interest in the populations of a particular species. *De facto* shared rights in the environment and in natural resources have in fact become commonplace. The solutions to problems involving such joint rights often involve compromise and cannot always be precisely specified in advance. This case provides an example of a limitation to the 'property rights' solution to environmental problems (advocated for example by Coase (1960)) which traditionally involves the allocation of exclusive property rights to a single person or entity.

Acknowledgements

Some financial support for this research was provided from the Australian Centre for International Agricultural Research (ACIAR), Project No. 40, Economic Impact and Rural Adjustments to Nature Conservation (Biodiversity) Programmes: A Case Study of Xishuangbanna Dai Autonomous Prefecture, Yunnan, China. Much of the data was collected during a visit to Xishungbanna prefecture. The authors wish to thank all those who assisted them with their enquiries, in particular the director of the Xishuangbanna State Nature Reserve. This paper does not necessarily represent the views of the Ministry of Forestry, ACIAR and those interviewed.

References

Barbier, E.B., Burgess, J.C., Swanson, T.M. and Pearce, D.W. (1990). *Elephants, Economics and Ivory*. London: Earthscan.

Brown, G. and Henry, W. (1989) *The Economic Value of Elephants*. London: London Environmental Economics Centre.

Clark, C.W. (1990) *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, 3rd edn. New York: John Wiley.

Coase, R. (1960) The problem of social cost. *J. Law Econ.* **3**, 1–44.

Conrad, J.N. and Clark, C.W. (1987). *Natural Resource Economics: Notes and Problems*. Cambridge: Cambridge University Press.

Driml, S. and Common, M. (1995) Economic and financial benefits of tourism in major protected areas. *Aust. J. Environ. Manage.* **2**(1), 19–29.

Hardin, G. (1960) The competitive exclusion principle. *Science* **141**, 1291–7.

Hardin, G. (1968) The tragedy of the commons. *Science* **162**, 1243–7.

Headley, J.C. (1972) Defining the economic threshold. In *Pest Control Strategies for the Future*, (Agricultural Board, Division of Biology and Agriculture, National Research Council, eds) pp.100–8. Washington, DC: National Academy of Sciences.

Mittermaier, R.A. and Werner, T.B. (1990) World of plants and animals in megadiversity countries. *Tropicus* **4**(1), 1, 4–5.

Myers, N. (1988) Threatened biota: hotspots in tropical forests. *The Environmentalist* **8**(8), 1–20.

Pearce, D.W., Markandya, A. and Barbier, E.B. (1989) *Blueprint for a Green Economy*. London: Earthscan.

Repetto, R. and Gillis, M. (1988) *Public Policies and the Misuse of Forest Resources*. Cambridge: Cambridge University Press

Sukumar, R. (1989) *The Asian Elephant: Ecology and Management*. Cambridge: Cambridge University Press.

Swanson, T.M. (1994) *The International Regulation of Extinction*. New York: New York University Press.

Thouless, C.R. and Sakwa, J. (1995) Shocking elephants: fences and crop raiders in the Laikipia District, Kenya. *Biol Conservat* **72**, 92–107.

Tisdell, C.A. (1982) *Wild Pigs: Environmental Pest or Economic Resource?* Sydney: Pergamon.

Tisdell, C.A. (1991) *Economics of Environmental Conservation*. Amsterdam: Elsevier.

Tisdell, C.A. and Zhu, X. (1995) *Protected Areas, Agricultural Pests and Economic Damages*. Brisbane: Department of Economics, The University of Queensland.