Managing Elephant Depredation in Agricultural and Forestry Projects

John Seidensticker
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John Seidensticker is a wildlife ecologist for the National Zoological Park of the Smithsonian Institution in Washington, D.C. and a consultant to the World Bank.

The cover illustration shows that elephant herds are usually composed of related females and their calves. Bulls join these herds temporarily when a cow is in estrus. In African elephants (bottom) both sexes have tusks. Only male Asian elephants (top) have tusks, and in some populations almost all males are tuskless. Grass is an important food for both species. Drawing by Judy Gradwohl.
ABSTRACT

Agricultural and forestry projects established in traditional habitats of African and Asian elephants (Loxodonta africana and Elephas maximus, respectively) obligate elephants living there to modify their movements and behavior. Damage resulting in major financial losses has occurred when elephants live in or enter and feed in project areas. In this paper, procedures sensitive to elephants' conservation status (Asians are endangered, Africans are threatened) are described to plan for and manage elephants in and adjacent to project areas; these procedures are to be used in conjunction with overall project design and operations.

A pre-project design assessment, conducted with local wildlife authorities, can predict the response of elephants to a proposed project and provide the basis for building measures into the project to avoid major conflicts. Final project design should include features that prevent elephants from entering production areas and ensure local elephant access to critical resources or provide these through habitat enrichment. Emphasis in the project design should be placed on passive elephant-management features. These can include minor modification in infrastructure to either facilitate or block elephant movements, and the creation of buffer zones to effectively separate production areas and forest refuges. Careful scheduling of project activities is required to ensure that groups of elephants are not isolated or "pocketed" in production areas. Such elephants can be very dangerous and destructive.

A successful elephant management program requires a strong local institutional support base. Technical and financial assistance measures which may be required by local wildlife management authorities are outlined.
ABSTRAIT

Les projets agricoles et forestiers entrepris dans des régions qui constituent l'habitat naturel des éléphants d'Afrique et d'Asie (*Loxodonta africana* et *Elephas maximus*) obligent ces animaux à modifier leurs déplacements et leurs comportements. Il arrive que des éléphants vivant dans des zones de projet, y pénétrant ou s'y nourrissant, causent des dégâts qui entraînent d'importantes pertes financières. Ce document décrit des procédures tenant compte de la situation des éléphants (ceux d'Asie sont en danger et ceux d'Afrique, menacés) et visant à mettre en œuvre une politique concrète à l'égard des éléphants qui vivent dans des zones de projet ou à proximité. Ces procédures doivent être appliquées en harmonie avec la conception du projet et son exécution.

Une étude préalable, effectuée en collaboration avec les autorités locales responsables de la faune sauvage, peut prévoir la réaction des éléphants à un projet envisagé et assortir celui-ci de mesures susceptibles d'éviter des problèmes majeurs. Sous sa forme finale, le projet devrait être conçu de telle façon que les éléphants ne puissent pas pénétrer dans les zones productives, qu'ils aient accès à des ressources vitales pour eux ou qu'on les leur assure en améliorant leur habitat. Au stade de la conception du projet, il conviendrait de mettre l'accent sur des mesures passives de gestion des éléphants, consistant, par exemple, à modifier légèrement l'infrastructure ou bien à faciliter ou empêcher leurs déplacements, et à créer des zones-tampons destinées à bien séparer les
zones productives des refuges forestiers. Il importe de programmer soigneusement les activités d'un projet pour faire en sorte que des groupes d'éléphants ne se trouvent pas isolés ou "bloqués" dans des zones productives, car dans ce cas, ils peuvent devenir très dangereux et causer des dégâts considérables.

Pour réussir, un programme de gestion des troupeaux d'éléphants doit s'appuyer sur des structures institutionnelles solides. Les différentes formes d'assistance technique et financière dont peuvent avoir besoin les autorités locales responsables de la faune sauvage sont indiquées dans ce document.

**EXTRACTO**

Los proyectos agrícolas y de silvicultura emplazados en los habitat tradicionales de los elefantes africanos y asiáticos (*Loxodonta africana* y *Elephas maximus*, respectivamente) obligan a estos animales a modificar sus desplazamientos y comportamiento. Los estragos causados cuando los elefantes habitan en zonas de proyectos o las invaden para alimentarse redundan en fuertes pérdidas financieras. En el presente estudio se describen procedimientos para prever y controlar el comportamiento de los elefantes, tanto en las zonas de los proyectos como en las adyacentes, que tienen en cuenta los fines de protección de la especie (los elefantes asiáticos están amenazados de extinción y los africanos en peligro de llegar a estarlo). Estos procedimientos deben seguirse en el diseño general y en las operaciones de los proyectos.
Una evaluación previa del diseño del proyecto, realizada con la colaboración de las autoridades locales responsables de la fauna silvestre, permite pronosticar el comportamiento de los elefantes en relación con un proyecto propuesto y proporciona la base para incorporar a éste medidas que eviten conflictos graves. El diseño definitivo del proyecto deberá incluir instalaciones para impedir la entrada de los elefantes a las zonas de producción y, al mismo tiempo, asegurarles acceso a los recursos necesarios para su supervivencia o proporcionándoles mediante un mejoramiento del habitat. En el diseño del proyecto se deberá hacer hincapié en la inclusión de medidas pasivas para el control de los elefantes; éstas pueden ser modificaciones de menor importancia en la infraestructura, para facilitar o bien entorpecer el tránsito de los elefantes, y la creación de zonas que separen eficazmente las áreas de producción de las que constituyen refugios forestales. Es preciso programar cuidadosamente las actividades de los proyectos para asegurarse de que no queden grupos de elefantes aislados o "arrinconados" en las zonas de producción. En esas condiciones, los elefantes pueden ser muy peligrosos y destructores.

Un buen programa de control y protección de los elefantes exige una sólida base de apoyo institucional local. En el documento también se esbozan las medidas de asistencia técnica y financiera que podrían necesitar las autoridades locales a cargo de la fauna silvestre.
PREFACE

This technical paper is based on a seminar presented at the World Bank on January 24, 1983, which was jointly sponsored by the Agriculture Department and the Projects Policy Department, Office of Environmental Affairs.

The Seminar was an outgrowth of awareness of elephant depredation in the Jahore Land Settlement Project in Malaysia. Upon recognizing this as an issue demanding attention, the Agriculture Department requested the Office of Environmental Affairs to furnish information regarding similar problems created by elephants in other Bank agriculture projects. This request resulted in a selected list of 13 Bank projects where elephants were a major consideration. The author, Dr. John Seidensticker, Wildlife Ecologist, National Zoological Park, Smithsonian Institution, based this paper on his experiences with elephants and wildlife management in Sri Lanka, Indonesia, Nepal, and Bangladesh.
ACKNOWLEDGMENTS

This paper draws heavily upon the extensive research and writing of Dr. John Eisenberg, Ordway Professor of Ecosystem Conservation, University of Florida. Drs. R. Goodland, R. Rudran, S. Lumpkin, A.J.T. Johnsingh, J.C. Daniel, J. McNeely and Ms. J. Tralka have helped in crystalizing ideas and procedures presented here. The World Bank and the National Zoological Park, Smithsonian Institution, supported the preparation of this report.
1.0 INTRODUCTION

The World Bank and other international development agencies have invested billions of dollars in hydroelectric, agricultural, forestry and other projects in developing countries where excellent elephant habitat occurs. The main World Bank assisted projects are listed in the Annex. Recently there has been increasing concern for the welfare and survival of the world's estimated 23,000-41,000 Asian (Elephas maximus) and 1.3 million African elephants (Loxodonta africana). Authorities have designated these species as "endangered" and "threatened", and have listed them in the Red Data Books of the International Union for the Conservation of Nature and Natural Resources, and on the United States List of Endangered Species(53).

Continual loss of elephant habitat (e.g., conversion of forests to agriculture) is a major conservation problem, which is further compounded by the elephants. They enter and eat the rich patches of food which constitute the plantations of sugar cane, rice, teak, rubber and oil palm, established in their traditional foraging areas, usually in disregard of the best efforts to keep them out. This behavior has resulted in millions of dollars in damage and in project cost overruns, thus causing concern to economists and project designers(4,51). The losses have to be stopped for the benefit of elephant conservation, for the affected projects as well as for the investors. Management measures implemented have to be sensitive to the elephants' status as threatened species.

Elephants have been raiding crops for thousands of years, but case studies of such problems are not readily available to the economic planners or wildlife managers who need them. The efficacy of the preventive and mitigatory measures frequently proposed need review in the light of what has been learned in the last two decades about the behavioral ecology of
elephants. This paper is a step towards improved planning and management in order to reconcile development priorities with the increasingly urgent need for effective conservation measures.

1.1 About Elephants

The elephant Order Proboscidea has a long and spectacular evolutionary history from its beginnings in Africa during the Eocene(14). The two surviving species of this evolution are placed in different genera. *Elephas maximus* is usually separated into 3 subspecies: *E. m. maximus* of Sri Lanka, *E. m. indicus* of the Indian Subcontinent and Southeast Asia including Borneo and *E. m. sumatranus* from Sumatra. The "bush" elephants of East and South Africa are usually placed in *Loxodonta africana africana* and the West African "forest" elephants, in *L. a. cyclotis*(18,46).

African elephants are slightly larger than Asian elephants. Adult males weigh up to 6000 kg; females up to 3200 kg. African elephants have a concave shape to their back, large ears, relatively smooth skin, and a trunk with 2 "fingers" at the tip; Asian elephants have a distinctive convex shaped back, smaller ears, skin that appears wrinkled and a trunk with one "finger". There are differences between the two species distinguished by the number of ribs and vertebrae, and in the morphology of the cheek teeth. Male and female African elephants have tusks; female Asians, and a large percentage of males in some populations, do not have tusks. Lacking tusks, both males and females may have an alternate type of modified incisor, or tushes, that are barely visible beyond the lip(18,27,46).

From a management perspective, an important difference between the two species is their ability to tolerate the sun and utilize open habitats. Heat dissipation is a problem for both species. Asian elephants need access to shade during much of each day(15,18,27,33), while African
elephants are much less restricted, except when young with calves. This
difference alone suggests that project design features which could
disourage Asian elephants may not succeed with African elephants.
Therefore, measures taken to manage elephants need to consider species as
well as site characteristics.

Elephants are never the numerically dominant ungulate in their
habitat, but they are frequently ecological dominants in terms of biomass
and the cycling of plant material. The habitats occupied vary, but usually
are ecotones between forest and grasslands and areas with moderate tree
cover grading into savanna. The sites are always in association with
permanent water which is well dispersed in the vegetational mosaic. Asian
elephants do not extend into desertic areas. They do occur in dense rain
forest only if there is sufficient interspersion of water and grass.
Secondary or disturbed forests contain more suitable food plants. In
suitable South Asian habitats, crude density of elephants can range from
0.1 to 1/km²(14,16). Habitats described as suitable for Asian elephants
also support the densest African elephant populations, with the exception
noted that African elephants appear to have a greater tolerance for drier
conditions(7,13,14,16).

Asian and African elephant literature contain both useful and
confusing information on elephant husbandry and management(18,27,46).
Resolving elephant-development conflicts requires data from which reliable
predictions can be made about the response of elephants to changes in the
patterns and processes in their habitat brought about by a particular
project. This is customarily termed a facultative or behavioral response
to environmental change, as opposed to a numerical response or change in
population numbers.
An important distinction should be made here between crude and ecological density, because density estimates(7,15,16,33) are frequently employed by wildlife managers. Crude density estimates take the average density of a species over the entire sample space. Ecological density is the crude density estimate corrected for habitat differences within a non-homogenous habitat(16). Through some habitat modifications, the ecological density of elephants in a specific area might shift (a behavioral response), but the overall or crude density of elephants in the region might not (a numerical response).

The long-term problem of stabilizing elephant numbers in relation to available resources requires knowledge of the genetic and quantitative dynamics of populations and of the long-term coactions of these herbivores with their food plants(28,29,32,37,43,49). These issues which have generated extensive elephant management literature(9), are important in the management of elephant refuges, but contribute little to solving the problem of separating elephants and development projects.

Long-term studies of elephant behavioral ecology have been carried out or are in progress in Manayara, Tanzania; in Amboseli, Kenya; in Addo, South Africa; and in the dry zone national parks of Sri Lanka (6,15,22,33,55). These are monsoon areas with strong wet and dry seasons. There are few detailed behavioral and ecological data for elephants living in wet, high tropical forest areas of Africa or Asia. This lack of information is significant, because of the large number of projects located in this vegetation type (Annex), and because of the differences in movement patterns and densities of elephants already noted(40).

Elephants are the largest grazing-browsing herbivores(14) that improve the predictability of their food supply by maximizing the area over
which they forage(42). They push over trees or break them off to expand their foraging space. Their large size and efficient locomotion provide for energetically cheap long-distance cruising, with herd movement constrained only by the youngest members. The trunk enables them to feed on coarse forage ranging from short grasses to branches four meters and more above the ground.

Asian elephants may spend 70% to 90% of their time foraging, with two major bouts per 24-hour day. An adult consumes 150kg of vegetation (wet weight) per day with an average intake rate of about 7kg/hr. African elephants consume up to 220kg/day(13,14,15,23,27,33,38). While elephants may at one time or another eat, or at least sample, a wide variety of the plant species in their foraging areas, they have food preferences and needs. Grass, for example, is always a major dietary component. During a cycle, the rate of feeding varies with the food patch and increases markedly as the animal approaches an optimum feeding site; once there, feeding is at a maximum rate. Drinking sites appear to be traditional(15,33). Bouts of drinking and bathing by elephants are clustered in the morning and evening(13,15,33,55), and both species drink once a day or more often if water is available.

Studies of elephant sociality show that females live in small, cohesive groups of close relatives (mother-daughter and siblings) and their offspring. At puberty, young females remain with the group while males leave or are expelled. The age of puberty varies with nutrition during development. These cow herds, termed clans by Eisenberg(12,14), divide into smaller units during the daily cycle and reassemble when drinking and moving from one area to another. The subgroups frequently differ in sex and age composition. Females with their immediate offspring constitute the
family units, and tend to move in company with their small calves. There can be cohesive movement between females and half-grown young and between males 6 or 7 years old. It is within the cow herd that the calf matures and learns the template of its environment. The cow herd serves as the repository of traditional knowledge, which includes routes to water-holes, to mineral sources, and to seasonal foraging areas(12,13,14,15,33).

Adult males live alone or occasionally in company with 1 to 3 satellite males with weak social bonds. Adults are capable of breeding at any time of year, but when they reach an adequate nutritional plane they enter a condition known as musth which is analogous to rut in bovids and cervids. When in musth, males are extremely aggressive and dangerous, and this condition probably allows them to dominate in contests with cows and other males(14). In the dry zone of Sri Lanka, males use restricted areas that may be frequented by a number of cow groups. More than one male at a time may be in attendance with an estrous female in a cow herd(15,22,33). Under the strong wet-dry seasonal regime of East Africa, bulls switch to a strategy where they travel long distances in search of estrous females from one that is associated with intensive feeding in restricted areas. During the dry and early wet season, bulls maximize food intake; a fat bull has a better chance of rutting longer and still retaining sufficient energy stores to survive the long dry season(3).

To visualize the impact a project may have on elephant movements, it is useful to examine how land-tenure and movement patterns reflect elephant adaptations to different environments. The environmental patterns can be characterized by first, seasonal flux in resources; second, predictability in the timing and amount that will become available during the flux; and third, resource distribution. These parameters are depicted in
Figure 1. There can be strong, intermediate, or little seasonal flux and the resource base may be predictable or unpredictable. A useful rating of the spatial distribution of food in the environment can be obtained by plotting the richness of a patch against the density of simultaneously available patches(14).

In the dry zone, monsoon forests of Sri Lanka, elephants forage in areas where there is a high density of simultaneously available patches. These are usually of rather poor quality(23,37,55), in a moderate or low fluctuating environment that is moderately unpredictable. Cow herds display movements based on three time scales(34): 1) daily movements associated with feeding, and moving to and from water; 2) seasonal movements between dry season and wet season home ranges; and 3) medium-term movements between sectors of the seasonal home range (Figure 1). For a cow herd, home ranges of 25 km² and 60 km² have been determined for wet and dry seasons, respectively. Ranges for adult males vary from 10 km² to 17 km² (24).

This contrasts with elephant movements in Kenya's huge Tsavo National Park, which is semi-arid savanna with "notoriously irregular rainfall". Elephants show high fidelity to their relatively small, localized, dry-season areas which are near permanent water sources. Food in these areas, however, becomes severely depleted by the end of the dry season. Sensing rain from considerable distances, the first and subsequent rain storms trigger long-distance elephant movements, up to 50 km, to eat new grass growing where rain has fallen. This is schematically depicted in Figure 1. Outward movements from dry season ranges are unpredictable; return movements can be more accurately predicted. Aggregations of 1000 elephants and more can form in response to the first rains of the season which come predictably to restricted areas(31).
Regional rainfall patterns determine the flux, predictability, patch size and occurrence of elephant food resources. The elephant's large body size allows energy efficient, long-distance movements. Consequently, elephant feeding ranges can vary strikingly in pattern and size from one region to the next(14).

In Tsavo National Park, Kenya, elephant clans spend the dry season near permanent water sources, the rivers. During the wet season, showers are irregular in time and space, and elephant groups move great distances to take advantage of the new grass. Home ranges from some clans exceed 1000 km²(31).

In Sri Lanka's Gal Oya National Park, some cow clans display movement patterns based on three time scales: i) daily movements associated with feeding and to and from water; ii) seasonal movements between wet and dry season home ranges; and iii) medium-term movements between sections of a seasonal home range. Total home ranges are less than 100 km² in size(34).

In the Rokan-Barumun region in the Central Sumatran lowlands (Indonesia), big rivers block the north-south movements of elephants. Elephant groups rapidly cross large expanses of high rainforest to feed in dispersed patches of secondary forest and at ladangs (shifting cultivation) when crops are suitable as food. Elephants' home ranges are probably 100's of km² in size in this vegetation type but they have never been adequately measured (Seidensticker and Suyone, unpublished observations).

Patch richness/simultaneous availability of food patches: D=dry season, W=wet season; numbers indicate locations 1-3 above. Relationships indicated are hypothetical (14).
Movements of elephants in rain forests resemble similar movements during the dry season in Sri Lanka, with the exception that they move over areas five times as large. However, elephants have no seasonally distinct ranges. Instead, they move widely to find food patches that are sufficiently rich to support them, but which become available asynchronously (40).

The dispersion in time and space of food and water (15, 31, 33, 58), and in some areas mineral licks (45, 56, 57), clearly determines the ways elephants use particular areas. Home ranges vary widely in size, with patterns of movement that embrace areas of prime foraging habitat. By altering these resource dispersion patterns, a project obliges elephants to modify their behavior accordingly.

2.0 PROJECT DESIGN

A review of elephant-development project conflicts shows that project infrastructure and production areas usually affect elephants in predictable ways. The following questions should be addressed during project preparation:

1. Are elephants present in the project area? If so, is their presence seasonal or continuous?
2. How large an area necessary to elephants, will be influenced by the project, including their access to essential habitats?
3. Will the project remove a significant portion of the elephant habitat in a region? If so, how much?
4. How many elephants are involved in total, and more specifically, which clans and subgroups will be affected?
5. Will the project isolate clans or subgroups from more continuous habitat areas during construction? Following project completion, will there be access to continuous tracts of suitable elephant habitat? The "pocketed herd" problem occurs where clans or subgroups become isolated, and frequently the only resources available to the herd are in project production areas.

6. Will the project block seasonal movements between feeding areas and other critical resources such as water sources and mineral deposits?

7. Will the project alter the distribution, abundance and predictability of food and other critical resources?

Information at this level of detail is essential to prepare the workable elephant management plan needed for each project. Much can be anticipated during project design, but some details, such as the response of individual clans and sub-groups, will only become clear with monitoring during project construction and operation.

In the last decade, conservation and wildlife agencies, in many of the countries where elephants are found, have obtained detailed information on the status and trend of many of their large mammal populations. This information can be consulted by planners away from the site (Table 1) to determine if elephants are likely to be a matter of concern.

If elephants are present, an initial overview of their response patterns to that particular environment can be made based on the features outlined. Maps, aerial photos and LANDSAT images can be used to make overlays which characterize predictability and seasonality of rainfall, regional landforms, the vegetational mosaic and the distribution of temporary and permanent water sources. This process can be accomplished in consultation with local wildlife management authorities familiar with the
TABLE 1

**Recent Reports on the Local Distribution of Elephants**

<table>
<thead>
<tr>
<th>Area</th>
<th>Date</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa, most countries</td>
<td>1979</td>
<td>Douglas-Hamilton (11)</td>
</tr>
<tr>
<td>Asia, general</td>
<td>1978</td>
<td>Olivier (41)</td>
</tr>
<tr>
<td>Indian Subcontinent</td>
<td>1980</td>
<td>Asian Elephant Specialist Group (1)</td>
</tr>
<tr>
<td>India, Karnataka</td>
<td>1980</td>
<td>Nair and Gadgil (38)</td>
</tr>
<tr>
<td>India, Uttar Pradesh</td>
<td>1980</td>
<td>Singh (48)</td>
</tr>
<tr>
<td>India, Nilgiri Hills</td>
<td>1983</td>
<td>Davidar and Davidar (10)</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>1980</td>
<td>TAMS (51), McKay (33)</td>
</tr>
<tr>
<td>Bangladesh, Cox's Bazar</td>
<td>1983</td>
<td>Khan, Khan &amp; Rashid (26)</td>
</tr>
<tr>
<td>Thailand</td>
<td>1982</td>
<td>Bain and Humphrey (2)</td>
</tr>
<tr>
<td>Indonesia, North Sumatra</td>
<td>1978</td>
<td>Van Strien (54)</td>
</tr>
</tbody>
</table>

**Note:** Some reports are available from the Office of Environmental Affairs.
site. Using these overlays, an initial assessment can be made of how various project designs will affect the patterns and processes that influence elephants. This approach should provide approximate answers to the questions posed above.

Site specific measures of elephant numbers and their response patterns to local environmental conditions are then required to check the accuracy of the predictions of the first level analysis. This requires specialized knowledge. Elephant field research has not stabilized into a single accepted method or procedure. In most studies, methods have been an art-of-the-possible. To assess numbers and seasonal movement patterns, light aircraft have been used extensively in the African savannas, but in the more closed forest habitats of Asia, aerial counting is of little use. Rough estimates of elephants coming to water sources and crossing rivers and roads are widely used in forests. Movements, habitat use and numbers have been estimated using systematic counts of dung piles. Radio tracking procedures and trailing groups and individuals also provide valuable insights into their movements in response to other elephants and the distribution of environmental resources. These methods, the parameters measured, and selected references are listed in Table 2.

As this more detailed information is developed, the first level overlays should be refined to ensure the basic assumptions are correct and adequately predictive. With this information, measures can be designed into the project with reasonable assurance that major conflicts can be anticipated, avoided or mitigated.

2.1 Historical Traditions in Elephant Management

Traditions of elephant management emerged very differently in Africa and Asia. In Africa, the taming of elephants has been very
TABLE 2

Methods Used to Investigate Elephant Behavior and Ecology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) <strong>African habitats:</strong></td>
<td></td>
</tr>
<tr>
<td>Aerial counts</td>
<td>Norton-Griffiths (39)</td>
</tr>
<tr>
<td>Measuring the distribution of animals in relation to their environment</td>
<td>Western and Grimsdell (59)</td>
</tr>
<tr>
<td>Ground counts</td>
<td>Eltringham (17)</td>
</tr>
<tr>
<td>Establishing density and habitat use by dropping counts (dung piles)</td>
<td>Wing and Buss (60); Jackmann and Bell (24); Coe (6)</td>
</tr>
<tr>
<td>Assessing age-structure</td>
<td>Croze (8)</td>
</tr>
<tr>
<td>Establishing movement patterns with radio telemetry</td>
<td>Leutholt (31)</td>
</tr>
<tr>
<td>b) <strong>Asian habitats:</strong></td>
<td></td>
</tr>
<tr>
<td>Establishing population and habitat status and trend using interview methods</td>
<td>Seidensticker (45)</td>
</tr>
<tr>
<td>Establishing densities in closed habitats</td>
<td>Nair and Gadgil (38)</td>
</tr>
<tr>
<td>Assessing age-structure</td>
<td>Singh (47)</td>
</tr>
<tr>
<td>Establishing movement patterns with radio telemetry</td>
<td>McKay (33); Eisenberg and Lockhart (15)</td>
</tr>
<tr>
<td>Investigating migration path</td>
<td>McKay (33); Eisenberg, and Lockhart (15); Ishwaran (22)</td>
</tr>
<tr>
<td>Investigating elephant-plant relations</td>
<td>Olivier (40)</td>
</tr>
<tr>
<td></td>
<td>Davidar and Davidar (10)</td>
</tr>
<tr>
<td></td>
<td>McKay (33); Eisenberg and Lockhart (15)</td>
</tr>
<tr>
<td></td>
<td>Mueller-Dombois (37)</td>
</tr>
<tr>
<td></td>
<td>Ishwaran (23)</td>
</tr>
</tbody>
</table>
limited. Instead, the ivory has been viewed as a source of wealth, resulting in the culling of elephant populations. Although culling, even in protected natural areas, has been judged by some to be excessive, and therefore controversial, it has been a frequent management tool(20).

The elephant in Asia embodies great metaphysical import, and among domestic animals it is unique. Traditionally for 3000 years, Asian elephants have been driven to other areas or captured and trained (13,30,35) for use in work, ceremony and war. Captive breeding has always been limited, and animals to be tamed are usually obtained from wild populations. Throughout Asia, elephants enjoy strict legal protection. Only the rare problem animal is ever killed, and then only if other means fail.

With this history of elephant management, local authorities often have considerable experience that can be applied to project problems in their area. A judicious blend of recent technology and traditional methods is called for in elephant conservation management.

2.2 Elephants in Project Design

Projects should be designed to keep elephants out of production areas using passive features wherever possible. Portions of a project area including catchments and banks of reservoirs, as shown in Figure 2, can sometimes be used to accommodate displaced elephants. Some features in a project may serve to stabilize environmental conditions for elephants in the region. However, some active management measures are usually needed as well, and can be undertaken in collaboration with local wildlife management authorities. The features and requirements of specific projects will dictate the training, technical and financial needs of the local authorities in order to carry out the task.
The water level relative to the floodplain and the slope of banks in reservoirs will determine the capacity of a catchment area to support elephants. These can be adjusted in favor of feeding areas for elephants making them important conservation areas. Such areas can help to alleviate elephant problems in production areas.

Source: (13).
If there is an "elephant problem" confronting project planners, engineers and wildlife managers will usually need to consider and resolve the following issues:

1). How are Elephants to be moved if they occur in production areas, or are cut off from areas of continuous habitat?

2). What features in the project infrastructure can be adjusted, or what other actions can be taken to keep elephants out of production areas?

3). How, where, and under what conditions should project infrastructure be modified to accommodate elephant movements?

4). What mitigatory measures will ensure that elephant needs are met, if substantial habitat areas or critical resources are eliminated by the project? Can elephants be accommodated in parts of the project area such as catchments and banks of reservoirs (Fig. 2)?

5). Who will monitor elephant responses to project activities, and how will new findings be addressed during project implementation? Who will carry out elephant management activities?

Elephants usually cross at traditional sites which are points rather than areas. Asian elephants can traverse rather wide bodies of water(25) and rivers which flow at considerable velocity. African elephants swim, but the effectiveness of the barriers created by different water bodies needs to be established(27).

Where infrastructure modifications should be made, and what modifications are required depend on site-specific information obtained during the pre-project assessment. Accommodations in the infrastructures need not be extensive, just adequate. Specifications for canal crossings can be obtained from zoos experienced in constructing exhibits with access to elephant bathing areas, or from projects which have constructed
successful intersections. In the construction of a new crossing, the
problem most likely to be encountered is how to get elephants to use it,
even though it may be physically traversable. Therefore, the task is to
turn an unfamiliar situation into one with which elephants are
comfortable. This suggests a sequence where crossings are established in
the canals or other project infrastructure at traditional sites. Elephants
are then allowed to become familiar with them under benign conditions,
i.e., before canals are activated and water levels rise. Domestic
elephants may be used to "season" an intersection by establishing clearly
that other elephants have gone before.

With this emphasis on the difficulties of providing access for
elephants, it should be clear that canals and other project structures can
be used as barriers to keep elephants out of production areas. It should
also be recognized, that depending on canal type, elephants are capable of
making their own crossings. If these are undesirable, barriers can be made
by sharply sloping the banks, and hardening them with concrete or other
substances where necessary.

Elephants respond to edges, the transition zone between forests
and grasslands, in a positive way. (See Figure 3.) The degree of
interspersion of edges and the density and richness of habitat food patches
are important determinants of habitat suitability, and thus density
(7,15,16,33). Consider then what the immediate juxtapositioning of forest
and crops or young tree plantations means to elephants. This newly created
"edge", together with year round provisioning of water through canals, can
turn what has been a seasonal or marginal environment into an attractive
one, much to the dismay of new settlers and project managers. Elephants
respond to the area by entering and eating; and they tend to spend time in
A major objective in elephant management is to turn "edges" that engender a positive response where it is not wanted into "edges" which do not attract elephants.

a) Placing crops or production areas adjacent to tracks of forest invites trouble. Elephants switch into a refuging foraging pattern, spending the day in the forest and making nightly movements into the adjacent agricultural areas to feed. "Pocketed" herds occur when groups of elephants are isolated in patches of forest and can obtain their food only from surrounding crops.

b) Trenches and fences, even electrified fences, require major maintenance to keep them functional. This maintenance usually cannot be met in the long-term, or even after the first rains erode banks. Elephants respond to barriers of this kind by trying to get through; where an elephant is determined it usually succeeds. Therefore, a more useful approach is to make these "edges" unsuitable as habitat.

c) Wide buffer zones which do not offer suitable food or cover can effectively separate production areas and forest refuges. The refuge areas must provide adequate food and other critical resources to support the number of elephants living there. It is frequently possible to take advantage of watershed protection areas and banks of reservoirs to provide these resources, stabilize the environment and reduce elephant foraging ranges.
proportion to the amount of food provided by the newly established crops. Attempts by men to curtail the nightly elephant raids by manning stations at the margin of fields, even with fires, usually fail, and some men have been killed. Steepsided ditches, or fences with electrification usually are ineffective in repelling elephants(4,5,36,6). Ivory tusks do not conduct electricity. Elephants may push over a tree on the fence or simply shove the fence. They will fill ditches with earth using their feet and head. Erosion accelerated by elephants in the wet tropics or during the wet season can severely damage ditch systems(4). Alternatively, elephants may simply walk around the obstruction (e.g., fence or ditch). The point is that barriers usually employed to keep elephants away from attractive food crops generally do not succeed. Of course, effective barriers can be made. The use of high power energisers and elaborately designed, sited and constructed fences seem to work in certain cases in Asia and Africa. However, many other types of barriers are more expensive than the measures already proposed, and require constant maintenance at a level not often available in a project.

In these situations, project designers can shift emphasis away from features which are essentially walls intended to challenge elephants, to boundaries which have zero appeal (Fig. 3). This means switching from negative design features attempting to thwart and punish elephants at boundaries (e.g. electric fences), to establishing buffer zones that have little utility or attraction as elephant habitat, that will effectively separate elephants from production areas. This approach can be further enforced through the provision of water sources and other habitat enrichment features, such as establishing foraging areas away from project production units.
Buffer zones can be created also by establishing broad expanses of grassland adjacent to production areas that are heavily over-grazed by domestic livestock, and lack any kind of suitable cover. Such zones have been used in Sri Lanka to separate some national park boundaries from agricultural areas. Wide expanses of *Imperata* grasslands may serve the same function in the wet tropics. Care should be taken to ensure that burning to maintain these areas does not occur at a time when the new growth will encourage elephants to visit them. Buffer width must also be calculated through surveys of where elephants will and will not cross open areas.

The problem of "pocketed" herds is created when elephants, living in development areas, are cut off from adjacent forest tracts, or when a clan or subgroup moves into a project area that was formerly used for foraging. In either case, they establish permanent residence in isolated patches of habitat from which they emerge to forage at night. Uninitiated observers are surprised at the number of "pocketed" elephants that live in close proximity to people. These elephants can be extremely dangerous and should be treated accordingly.

Early in the project, steps should be taken to provide suitable habitat corridors through which these "pocketed" herds can be moved to larger adjacent habitat blocks. Wildlife authorities in Sri Lanka, India and Indonesia have considerable experience in moving elephants under such conditions, and these authorities can be consulted for details. The process of transferring elephants can involve 50 or 100 men working full time for months. The important planning considerations are that these elephants have a prearranged place to go, a way to get there, and no easy route by which to return. This calls for careful scheduling of project
activities. There are cases of elephants returning more than 50 km after considerable efforts have been made to move them. If habitat corridors cannot be accomplished, Asian elephants from "pocketed" herds can be captured and brought into the local domestic population for ceremony or work. Also, they can be tamed for export or for zoos. This requires marshalling local expertise in areas where traditions still exist, or engaging specialists where they do not. As it costs a great deal to feed and support an elephant, local authorities will have to use their judgement as to what their economy can support. Accepting additional elephants might be encouraged through tax incentives, thereby giving an advantage to those who use work elephants instead of motorized equipment.

It is often suggested that zoos should be able to absorb displaced elephants. But the absorptive capacity of zoos is low, perhaps 50 for all of North America, partly because elephants live so long. There is an increasing trend towards establishing viable captive breeding programs with wide cooperation between zoos. However, the numbers of elephants that can be absorbed into these programs is small in comparison to the numbers that are displaced by development.

Most risky for both elephants and people are operations where elephants are "darted" (i.e., immobilized through chemical restraint), and transferred to more suitable sites(19). Because this method involves danger, it is not generally recommended unless other methods have been judged to be impracticable.

In short, passive features in project designs to manage elephants are always to be encouraged over overt management actions whenever that is possible. A successful elephant management program requires a strong local institutional support base. How this can be achieved and the issues
involved in creating reserves to hold displaced elephants are considered below.

3.0 PROJECT IMPLEMENTATION

3.1 Managing Wildlife Refuges for Elephants

This paper indicates how elephants may respond to development activities, and outlines methods for keeping them out of production areas. Clearly, if elephants are to be moved from production areas there must be some place to put them. Depending on the environment and the number of elephants involved, adjacent natural habitats may require active management to accommodate displaced herds. Wildlife habitat in national parks and equivalent reserves can be managed under the United Nations definition (21), but habitat management options may be limited by national regulations. In these cases, elephant management areas can be designated as wildlife refuges.

It may be possible to take advantage of portions of project areas to enhance elephant habitat. Shores of reservoirs and catchment areas have been utilized as elephant habitats in Sri Lanka, the Western Ghats of south India and in other areas. The water level and slope of the shore (Fig. 2) and the draw-down characteristics of the reservoirs must be appropriate for the production of grass as food. The establishment of small water holes, or the use of permanent water that may become available as part of irrigation projects can be utilized to stabilize the habitats and enhance elephant carrying capacity.

The cutting of high forests is not to be encouraged to provide richer food patches for elephants. Under most conditions, there will be
adequate areas of secondary forests that can be manipulated to increase their utility as prime elephant foraging areas. What manipulations are of most value can be determined by identifying the food plants for which the elephants show a preference, and applying appropriate silvicultural techniques to encourage those species.

Attention should be given to the availability of mineral licks. It was noted in the first section that elephant distribution can be controlled by the distribution of licks(45,56,57). The provision of appropriate minerals at judicious locations and times can be used to draw elephants away from the project-refuge interface at critical periods in the crop cycle. The provision of minerals also may reduce the range that elephants need to cover in a year.

All of this comes under the general rubric of "habitat enrichment", a subject for which there is no general theory or generally accepted practice in the wildlife management profession although "habitat management" is widely encouraged. The long-term concerns for the dynamics of elephants and their vegetation, genetic management of populations, and a decision to cull or not are, under most circumstances, the responsibility of the local wildlife management authority. The dynamics of elephant populations are not well understood(9,20,28,29,32). But a clearer theoretical and practical understanding of the responses by elephants can be obtained by carefully monitoring what happens during significant environmental perturbations, such as those created during and after the establishment of a project.

3.2 Supporting Local Wildlife Management Authorities

Most local wildlife management and conservation authorities do not have the finances and manpower to provide the level of service required
when a major development project disrupts what has been a large area of wildlife habitat. Many development projects create major shifts in the ecological fabric of the region. A strong and well-equipped wildlife management agency can greatly assist in reducing conflicts, avoiding harm to workers, and reducing damage to project investments, while managing the country's wildlife resources.

The local wildlife management agency can be supported in three ways, by
1). providing technical and financial assistance during project preparation, so that a wildlife management plan, and plans for wildlife refuges can be included in overall project design;
2). providing technical and financial assistance for appropriate short courses and seminars at local universities for department staff; (The long-term wildlife monitoring program can be supported as a joint venture between the wildlife authority and the local university.)
3). providing equipment for habitat improvement, buffer zone maintenance and construction costs for the facilities required in wildlife refuges.

An example of how this approach can be planned is provided in the USAID supported wildlife management activities in the Accelerated Mahaweli Development Program in Sri Lanka(51,52).

SUMMARY

If there were a single, easy way to keep elephants and development projects separate, it would be applied on a routine basis. There is no one way, but effective measures can be recommended depending on project type and site. Elephants are usually treated as an externality in project
planning, and any economic advantage of keeping elephants out of production areas is not systematically included as part of project cost analyses. As more experience is gained, and ex-post audit data become available, the expanding body of evidence suggests that it is more cost-effective to manage elephants in and adjacent to project areas from the beginning of the project. This requires careful pre-project planning, project designs which will prevent elephants from entering production areas, and provisions to ensure local elephants' access to critical resource areas, or to provide these through habitat enrichment and other measures. Experience has shown that progress in reducing elephant depredations can be achieved in many projects through careful planning and manpower assistance to local wildlife management authorities.
ANNEX. BANK-ASSISTED PROJECTS WITH ELEPHANT IMPLICATIONS

1. **IVORY COAST: Rubber III (1978)** Total Project Cost: $19.8M; LN-1633; effective October 1979. Following extensive damage to young rubber plantations (10% of the estate), the operating agency (SAPH) recruited a permanent team of trackers to follow the elephants in the Bettie region and operate a system of explosive elephant scarers to keep the herd away from the plantation.

2. **IVORY COAST: Rubber IV (1983)** Total Project cost: $84.8M; LN-2323; effective November 15, 1983. Electric fences are proposed to protect project "without resorting to killing" elephants and buffalo.

3. **KENYA: Bura Irrigation Settlement (1977)** Total Project Cost: $178.0M; LN-1449 and CR-722; effective June 27, 1978. Adjacent area estimated to contain 6,000-11,000 elephants (4-7/km²). Access is maintained to riverine forest, which is declared a reserve. Irrigation canal crossings also are provided for. Animal watering points are provided every 5-6 kms. Cotton (main crop) is not very attractive, but off-season maize and young trees in forest plantations, of which Prosopis is main species, (4,000 ha fuel wood) are attractive. Total project is undergoing review and will be redesigned.


5. **RWANDA: Bugesera (1977)** Total Project Cost: $25.3M; CR-668; effective November 23, 1977. Elephant relocation is away from agricultural areas and is handled by helicopter to Akagera National Park (not Bank-assisted).

6. **TANZANIA: Kidatu Hydroelectric Project (1961-1977)** Total Project Cost: $50M and $109M; LN-715 and LN-1306; effective March 31, 1971 and March 1, 1977, respectively. (Stages I and II). This project included an ecological study of large herbivores, including elephants at the Mtera reservoir site. It was found that the Mtera reservoir threatened to cut off the elephants' access to traditional watering areas. As a result, the Bank recommended that the Ruaha National Park's boundaries be extended so that elephants and other wildlife could retain undisturbed access to these watering sites. This recommendation was adopted.

8. BURMA: Forestry I (1974) Total Project Cost: $42.5M; CR-493; effective February 27, 1975. Project could further deplete the national stock in the public sector, of about 2,634 trained working elephants (down from 10,000 in 1942). Training of elephants needs 18 years and 3 people (oozies) per elephant. Wild elephant capture (150-200 pa) causes major mortality. This averages 12% in the "Keddah" system, and 14% in the "Mela-shikar" system. Project needs an elephant domestication component.


10. SRI LANKA: Mahaweli Ganga III (1982) Total Project Cost: $201.8M; CR-1166; effective date February 8, 1982. Seasonal forest habitat currently occupied and used by elephants is to be converted mainly into irrigated rice. Sanctuaries, buffer zones, corridors and elephant relocation was discussed. Credit Covenant No. 3.10: The Government has formulated an Environmental Action Plan and it has been adopted by the Mahaweli Authority.

11. INDONESIA: Transmigration III (1983) Total Project Cost: $187.3M; Board Presentation March 1983; not yet signed. South Sumatra near but unrelated to bank project: 100 elephants (of Indonesia's 350 Sumatran sub-species of elephant) were driven/relocated (Dec'82) from Air Sugihan to Lebang Hitam costing Rp 100 million (ca $150,000) in non-project funds. They damaged a settlement and other infrastructure while attempting to return to their former habitat.

12. MALAYSIA: Johore Land Settlement (1974) Total Project Cost: $92.7M; LN-967; effective May 16, 1974. Of the total 94% cost overrun in the project, about 36% was attributed to physical changes (e.g., elephant damage) on 33,000 ha of young oil palms, plus the need for extensive electric fences and moats. Damage partly was due to the lack of sanctuaries which were called for during the design phase of the project (see OED report, December 13, 1982).

13. THAILAND: Nam Choan Hydro (Appraised 1982) Total Project Cost: $532 million of which the prepared Bank loan is $170.0M; not yet signed. The proposed reservoir (ca: 3 km wide) may interfere with elephant migration, and will bisect protected wildlife reserves of about 4000 km². Seasonal woodland occurs on top; evergreen forests fill the valleys. A possible drawdown of 5-15 m will occur at the dam; but the reservoir will be shallow at its tail. Reservoir filling is estimated at 3 years. If migration is from alternate wet seasonal sides of the reservoir, the dam may reduce herd. Field surveys have still to be conducted to confirm the size of the elephant population and their migratory patterns.
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