"The Ecological Impacts of Tourism in the Masai Mara National Reserve, Kenya."

By

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B. Ed. (Science), University of Nairobi, 1984.

A thesis submitted in partial fulfilment of the requirement for a Master of Science in Biology of Conservation in the Department of Zoology, Faculty of Science - University of Nairobi.

1991

DECLARATION

This is my original work and has not been presented for a degree in any other University or Institution.

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DATE 8/1/92.

This thesis has been submitted for examination with my approval as the University Supervisor.

DR. M. TSINGALIA

DATE 13/1/92

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DEDICATION

This work is dedicated to my late nephew Gerald Gichohi Muthanga who taught me the meaning of courage and strength, both which he demonstrated during the period of his illness. And to my niece Linda Ciru Kairo for her `unconditional' Love.

ACKNOWLEDGEMENTS

The project carried out in the Mara Reserve was indeed a great challenge to me. Its completion was, however, made possible by a great number of people.

I would like to express my gratitude to all those who helped me, in one way or another, towards the completion of this project.

Firstly, my gratitude go to Dr. Wesley Henry, who devoted considerable effort and time to have me acquainted with the Mara reserve and the people in this area. Without his guidance, the beginning of the project in Mara would have been extremely difficult.

For creative criticism and technical advice towards the writting of this thesis, many thanks go to Dr.H. Tsingalia; Dr.L. Malaret; Dr.W. Karanja; Dr.E. Vanden Berghe all of the University of Nairobi, Dr.C. Gakahu and Dr.D. Western from W.C.I and Dr.H. Wesley from New York Zoological Society.

In the same vein I thank Professor.R. Mwangi, Chairman - Department of Zoology and his faculty staff for their assistance and support during the time I have been a graduate student at the Department.

While at the Mara I received much valued support and information, but more importantly friendship from many people, who made Mara a second home for me. To the staff of all lodges and camps at the Mara especially to Mr.J. Kones, Manager of Keekorok lodge and his staff, to Sarova, Serena, Kichwa tembo and Governors, I convey many thanks for many kind things.

I realize that nothing much would have been accomplished without the support and friendship of the wardens and the County Council staff at the Mara. Many thanks to Mr.S. Makallah, Mr.O. Tamuu, Mr.M. Koikai and Mr.S. Sindiyo.

Finally, I am greatly indebted to W.C.I and U.S.A.I.D which provided finacial support for this project.

Last but not least, sincere thanks and gratitude to my family for their moral support and encouragement.

THE ECOLOGICAL IMPACTS OF TOURISM ON MASAI MARA NATIONAL RESERVE

ABSTRACT

The Overall objective of this study was to address the impact of tourist vehicles on the grassland of the Masai Mara.

Effects of vehicle passes, speeds and turning radii on vegetation cover were monitored in off-track driving simulation plots.

In order to determine seasonal differences, the experiments were conducted both in wet and dry seasons. The degree of physical disturbances to vegetation cover and soil substrate were more apparent in the wet season than in the dry season. In terms of visual perception track development in the wet season greatly reduced the scenic beauty of the area concerned.

Overall, an increase in the above variables resulted in an increase in vegetation cover loss. Most damage , to vegetation cover was caused by sheer stress at the turning radii loops. Soil compaction also increased with increased number of vehicle passes.

Further information to supplement the findings of the simulation plots was provided by existing tracks in the study area. These tracks were sampled with the object of observing whether there were any plant species associated with tracks. Three plant grass species, Eragrostis tenuifolia, Chloris virgata and Digitaria velutina were found to be associated with

tracks. Themeda triandra, which is a dominant grass in the Mara, was absent on all heavily used tracks that were sampled. This grass species was, however, present on tracks subjected to light vehicle use. This clearly indicates that vehiclar disturbance is responsible for the 'gradual' removal of perennials (e.g. Themeda triandra), most of which are important pasture grasses. Perennials are then replaced by annuals (e.g. Eragrostis tenuifolia and Digitaria velutina) which are of less nutrient quality. Indirectly, this means a decrease in biomass available for herbivore uptake.

The assessment of recovery along the simulation plots, established that the ability to recover diminished with increased level of vehicle use. Level of vehicle use also seemed to influence recovery of the grass species. Themeda triandra recovered fairly fast in plots that had fewer vehicular passes. In plots with higher vehicular passes, vegetation (Themeda triandra in particular) recovery was very poor. This seems to suggest that dominant grass species do not perform well in heavily disturbed areas of the park.

CHAPTER 1

1.1 INTRODUCTION

The growth of tourism in Kenya is without doubt one of the leading sector of the economy. Over the past 20 years this industry has greatly expanded, both in Kenya and in other parts of the world (Budowski 1976). Globally the growth of tourism has been phenomenal, increasing from 25 million people in 1945, to some 280 million in 1980 (Larre and Gajraj 1986). Today it is estimated that more than 1,500 million people travel away from their places of residence yearly (World Tourism Organisation 1989).

A number of developed and developing nations have recognised the economic advantage of this industry and have invested heavily in it. For instance, tourist facilities such as accommodation and communication systems have greatly been expanded. Such improved tourist facilities have attracted an increasing number of visitors to countries concerned (Abrahams 1980; McNulty 1985).

One of the most obvious and immediate benefit of tourism is that it creates employment. Employment in sectors such as hotels, lodges, tour companies and national parks, allows citizens of the countries concerned to participate in cash economy. This in turn raises their standards of living of these people. Tourism further stimulates economic growth in the construction industry, agricultural sector, food processing and handicraft industries.

Tourism also plays a major role in the preservation of cultural heritage. Festivities held in summer in Venice, Arivignon, Leningrad as well as in other parts of the world would not survive without the moral and financial support of the thousands of tourists who attend (Haulot 1976). Monuments in Britain, Japan, Greece, America, Egypt and Kenya are probably still standing today because of the tourism industry (Haulot 1976, 1985). Another important role of tourism is the promotion of international understanding. The inevitable interaction between the visitor and the local resident population brings about better understanding of the different human societies.

Tourism plays a vital role in the Worlds economy. In 1989 for instance, it generated some U.S.$ 2000 billion world-wide (World Tourism Organisation 1989). In 1986 it accounted for 25 to 35% of the world trade, and for some 12% of the gross national product (G.N.P) of the world (Larre & Gajraj 1986).

The industry is also an appreciable source of foreign earnings for developed nations and developing nations. In 1977, for instance, tourism generated US $ 53 billion annually for both developed and developing countries, making it the world's second largest industry (Abrahams 1980). In Africa the industry has experienced a rapid growth. Earnings from tourism in 1987 totalled 3.3 billion dollars (Manfred 1988).

1:2 Development of Tourism in Kenya

Tourism in Kenya is presently the most important single foreign exchange earner (Sunguh 1990; Kenya Wildlife Service pers.comm). Development of tourism began in East Africa at the end of 19th century. Initially visitors to Kenya, Uganda and Tanzania, were attracted by the trade prospects and big game hunting expeditions (Tichy 1979; Sindiyo and Pertet 1984). White settlers in East Africa were also involved in the big game hunting expeditions (Henry 1980). Until the 1940's the connection between tourism and wildlife was based on consumptive hunting rather than on game viewing as it is today. The Colonial Government in the 1940's emphasised on consumptive use of wildlife (Western 1973; Western and Henry 1979; Henry 1980) together with the elimination of wildlife wherever it had adverse effects on agriculture. For, instance a rinderpest outbreak in the early 1940 s forced the government to pay anybody killing wildlife a fee of £ 3 sterling. This fee was paid on surrendering to the government one hide recovered from a dead wild animal. Killing of game was encouraged because wildlife was believed to provide a reservoir from which the disease was passed to cattle owned by the white farmers (Anthony 1990).

The policy, of exterminating game had far reaching consequences for it resulted in the decline of wildlife population in Kenya (Western 1973 and 1975; Henry 1980; Sindiyo and Pertet 1984).

The second world war also contributed greatly to the decline of wildlife. Game was killed to obtain meat for the soldiers and prisoners of war (Henry 1980). The decline gave way to a growing recognition on the need for wildlife preservation.

The 1940's saw the government establish national parks and reserves in different parts of the country. Tasvo National park was the first to be established in 1946. This was followed by Nairobi National Park in 1948 (Mbithi and Burkens 1980). Presently there are a total of 38 National Parks and Reserve in Kenya (Williams 1988, Kenya Wildlife Services pers.comm.).

Soon after independence, the number of overseas visitors began to increase tremendously (Mitchell 1967). Several factors such as better salaries (Abrahams 1980), paid leave (Liddle 1975a; Haulot 1985), falling international airfares, the introduction of inclusive tour fares on scheduled flights of International Air Travel Association (A.I.T.A.) carriers (Mitchell 1967), the introduction of charter flights and package tours (Henry 1980, Sindiyo and Pertet 1984), the rapid expansion of tourist facilities encouraged by the government and a conducive political climate, have been advanced to explain the increase.

In the last three decades, the numbers of visitors to Kenya has risen nearly twenty-fold from 35,000 in 1960 to 676,900 in 1988 (Mitchell 1969; Hamilton 1987; Sunguh 1990). The number of visitors to Kenya has been growing at an average rate of 5.7% per year (Hamilton 1987) . Three distinct periods of growth are however apparent (Fig.1). These include the late 1960's, 1976 and the mid-1980's (Hamilton 1987).

The foreign exchange earned has consequently increased substantially. In 1968, for instance, Kenya earned 17.3 million Kenya Shillings which rose to 7 billion in 1989 (Mitchell 1969; Sunguh 1990; Kenya Wildlife Services per.comm.). Two reasons can account for the surge in the number of visitors to Kenya. First Kenya offers a variety of tourist amenities which attract visitors. The coastal area, with its warm climate, offers a wide choice of recreational activities such as boating, wind surfing, swimming, fishing competitions and snorkelling.

Secondly, National parks and reserves , which have been set aside with a view to conserving wildlife, are also a major attraction. Wildlife, however, is the principal attraction in Kenya and much of the income generated from tourism can be credited to wildlife (Samuel 1983; Eltringham 1984).

Although the economic consequences of tourism are generally recognised as beneficial to Kenya. several authors have expressed concern over tourist pressure on Kenya's parks (Western 1978; Henry 1980; Eltringham 1984; Sindiyo and Pertet 1984, Njoka 1984; Leakey 1989). Olindo (1972) summarised the effect of tourism as: "Tourism is a mixed blessing for while it brings foreign exchange into the country, visitor pressure

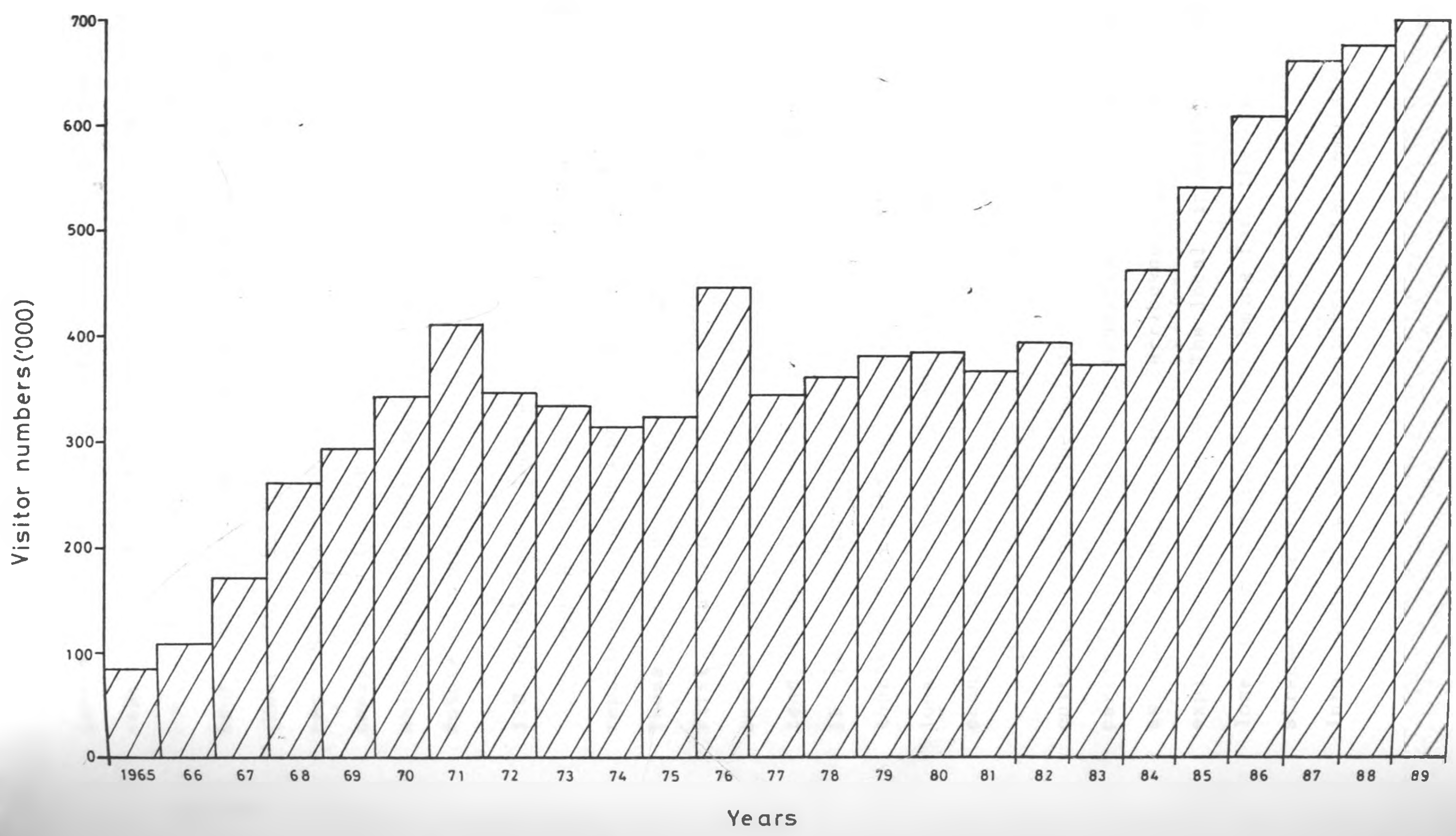
FIG 1: The number of International Visitors to Kenya between 1965-1989.

Sources: a Masai Mara National Reserve Management plan June 1983.

b Kenya Times Feb,24, 1990 quoting George Smith.

c Central Bureau of Statistics.

d European Development fund of European Economic Community (Mara-Serengeti Ecosystem) October 1988.



Visitor numbers('000)
0
100
200
300
400
500
600
700
1965
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
Years

increase and definite problems emerge, the most far-reaching being visitor impact on the ecosystem".

Problems arising from tourism are not unique to Kenya, but have been experienced in many other countries (Henry 1980, Eltringham 1984) . The influx of tourists has had far-reaching environmental and social consequences (Babich 1964; Budowski 1976, Western 1978) which raise concern about its adverse effects and the future of tourism.

1:3 Problems of Tourism

Problems associated with tourism have been reported in various parts of the world (Western 1978). These problems can be divided into two categories. The first category is that of the indirect effects, encompassing the impact on the local population. These tend to be more subtle and therefore often ignored. It is now widely accepted that the arrival of tourists from different cultures can be detrimental to local populations, through changing their cultural and economic values.

There is a general belief that tourism brings about cultural erosion. The cultures of the host countries, particularly those with traditional festivals, such as the Seychelles and Carribeans, are commercially exploited and devalued. The local inhabitants often lose their dignity by performing for the benefit of strangers (Mitchell 1967) . Local residents who come into contact with the visitors, often emulate their life-styles. The change is usually in conflict with the indigenous life-styles. The rise of drug abuse, delinquency, vandalism, crime and prostitution have all been associated with tourism (Haulot 1976, Larre & Gajraj 1986).

In addition the designation of wildlands, national parks and reserves has also resulted in conflicts between the needs of the local inhabitants, the State and the wildlife. Local people are deprived of the use of resources vital to their well-being. In Benin, for example, people traditionally obtained much of their meat from hunting. Hunting was greatly curtailed when the Pendjani National Park was created (Sayer 1981). A similar situation exists in Kenya. The Masai, for instance, used areas like Amboseli and Masai Mara as grazing grounds for their livestock until they were established as protected areas.

Conflicts arise because the interests of various parties concerned vary. On one hand, the parks are expected to provide the aesthetic, ecological and long-term economic goals for the government. On the other hand, the local inhabitants are deprived of resources. They perceive protected areas as a threat to their economic progress and socio-cultural well-being (Sayer 1981). This paradox surrounds the relationship between protected areas and tourism in many developing countries (Hurni and Ashine 1986).

The second category is that of direct effects.

Direct problems comprise the impacts on the environment. Tourist activities in the mountain areas of the Alps, Himalayas and Natal Drakensberg, have caused irreparable damage. Throughout the Alps habitat destruction has been caused by the construction of highways, mountain trains and Ski-slopes (Willard and Marr 1970; Schloeth 1977; Beck 1980; Garland 1985). In the Himalayas, for instance, tourist-related activities, like hotel construction has led to the indiscriminate felling of trees, overgrazing, steep slope terracing and poaching of animals (Singh and Kaur 1986). Tourist activities in National parks, in U.S.A., Japan and England, have caused considerable impact. Such impacts include the formation of tracks, development of campsites, trampling (Parsons 1976; Frissel 1978; Parsons and Macleod 1980), and burning of garbage which has led to areas being deprived of understory vegetation (Dale and Weaver 1974; Stewart 1979; James and Smith 1979). Changes in plant species composition (Liddle 1975a; Hammit 1982), soil erosion, soil compaction and soil desiccation (Lutzt 1945; Dale and Weaver 1974; Foint 1981), are further problems resulting from campsite construction and trampling. Eutrophication has also been reported in many water bodies situated in the parks (Parsons 1976).

Tropical reefs and beaches attracting visitors from the temperate regions are being subjected to great stress due to intensive visitor use (Salm 1985; Salm 1985). Trampling of sand dunes, vegetation depletion by hikers and off-road driving have been reported in the coastal areas of Belgium and France (Pearce and Kirk 1986). Fragile coral reefs, are also under considerable stress. Boat moorings, anchors and chains thrown to the reef smash the corals, scuba-divers (tourists) trample and break the coral branches, others break off corals and collect shells which are later sold to the tourists (Salm 1986; pers.obs.). Extensive damage of corals can lead to species loss and may affect the entire ecosystem (Industry and Environment 1986).

Tourist effects on the corals has also been reported in the Reunion, Mauritius, Comoros and Seychelles in the West Indian Ocean, Sri-Lanka, Malaysia, Thailand in the North-east (Salm 1985), and the Pacific Islands, Mediterranean and the Australian coasts (Kenchington 1989), and along the East African Coast (Sindiyo and Pertet 1984).

The spontaneous development of tourism has resulted in rapid and unplanned construction of hotels, lodges and associated infrastructure (Singh and Kaur 1986). Alongside lodge construction is the problem of garbage disposal (Kenchington 1989). This attracts carrion eaters such as hyenas (Crocuta crocuta), vultures (Gyps rueppelli), marabou storks (Leptoptilos crumeniferous), baboons (Papio cynocephalus and vervet monkeys (Cercopithicus aethiopes (Parsons and Macleod; Sindiyo & Pertet 1984; Lindsay 1986).

Garbage disposal poses problems to the park management since the animals can be an obvious threat to the park personnel and the tourists. The bear-tourist conflict in the Yellowstone National Parks in the U.S.A., is an example of these problems.

In Mwega Lodge in the Queen Elizabeth National Park in Uganda, marabou storks attracted to garbage took to roosting on Euphorbia dawei trees on the slope in front of the lodge, killing the trees and reducing the attractiveness of the scenery as a result. Severe soil erosion also occurred (Eltringham 1984). Garbage disposal problem has also been noted in Amboseli and Tsavo National Parks, and the Masai Mara National Reserve (Swara 1978; Sindiyo & Pertet). Recently an elephant was found dead in the Amboseli National Park as a result of bottles and glasses ingested from the pits (The Standard, 12.9.1989).

Over the past decade the increased number of visitors to the National Parks and Reserve areas has inevitably led to more vehicle congestion in these areas. Some of Kenyan parks and reserves were reported to display signs of overcrowding as early as 1972 (Thresher 1972; Njoka 1984). Amboseli National Reserve, Masai Mara National Park, Nairobi National, Nakuru National Park and Samburu National Reserve have being singled out (Western 1975; Henry 1980; Henry and Western 1980; Eltringham 1984).

In most National Parks and Reserves, off-road driving has resulted in development of multiple tracks criss-crossing the land. This has resulted in degradation of the habitat greatly reducing the aesthetic value of these areas (Piennar 1968).

Congestion and consequent destruction of Kenyan parks and reserves appears to result from uneven distribution of visitors (Gakahu pers. comm.). Of the popular parks and reserve areas listed above in Kenya, Masai Mara National Reserve, has attracted most tourist (Hamilton 1987 and 1988; Western pers. comm.).

1:4 LITERATURE REVIEW

Various investigators have carried out studies with a view to elucidating the impacts of recreational activities of tourists on the environment. Most of these investigations have been lopsided with emphasis on the North and South America and Europe (Western 1978). These studies have mainly, concentrated on the direct effects of trampling and vehicle treading on the vegetation, soil compaction and the flora ,species composition .

Results of these studies have shown that trampling has a direct mechanical effects on the vegetation and indirectly on the soil. Direct mechanical damage results in the reduction in average plant height and stunted growth (Bates 1935 & 1938; Liddle 1975a & b; Roderkerk 1976; Jim 1987a). Moderate treading, however, stimulats primary productivity (Bates 1938; Bayfield 1973; Liddle 1973), while increased treading results in reduction of biomass, particularly of dominant grasses.

The ultimate consequence of heavy use is usually the expansion of bare ground and soil erosion (Jim 1987b). While increased amount of trampling has been shown to decrease species diversity. Liddle (1975a), pointed out that diversity may decrease or increase depending on the actual intensity of treading. There is, however, a general consensus that increased treading leads to change in the vegetation communities involved (Bates 1935; Chapple et al 1971; Liddle 1975b). There is a general consensus that species diversity decreases with increased levels of treading (Chappel et al 1971; Jim 1987a & b).

In the disturbed habitats fast growing species were predominant while slow growing species were rare or completely absent (Grime and Hunt 1975). These studies have also shown that the level of disturbance influences the type of species that regenerate. Liddle (1975a & b) found that at moderate levels of trampling, the proportion of dicotyledonous species increased at the expense of the monocotyledonous ones. Bate´s (1935) also noted that resistant plant species regenerated better and faster in areas subjected to heavy trampling.

When vegetation on the tracks and adjacent areas was sampled it was found that species on the paths, were shallow rooted, had underground runners and were drought resistant (Bates 1935; Burden and Randerson 1972). More so theses species were annuals while perennials dominated the less disturbed sites (Parmeshwar 1933;

Pianka 1970). Investigations also showed that various plant parts were affected. Six passages of a tractor reduced average leaf length of Dactvlis glomerata from 9.1cm to 5.8cm and the number of new tillers from 7.3 to 1.1 per plant (O'Connor 1956), while Liddle (1975a) observed a 57% reduction in leaflets of Trifolum ripens which was growing on a track with 400 vehicle runs.

Effects of treading in both wet and dry season have also been investigated. For instance it has been shown that regardless of the intensity of disturbances, plant communities are less tolerant when the ground is wet than when it is dry (Edmond 1962). Plant recovery in disturbed areas has also produced interesting results. Lambert (1972) noted that lightly disturbed areas had more than 100% increase in number of new plants while highly disturbed areas had very few new plants. Shantz (1917), working in Eastern Colorado, U.S.A., estimated that 50 years were required for vegetation to return to its original state following disturbance. Bell and Bliss (1973) on the other hand estimated a thousand years as the required time for full recovery of vegetation in disturbed sites.

Soil compaction as a result of trampling has been recorded by many researchers (Bates 1935; Lutzt 1945; Dale & Weaver 1974; Liddle 1975a; Cole 1987; Jim 1987a). These researchers found that, with increased level of trampling or vehicle runs, compaction increased and then levelled off (Liddle 1975; Cole 1987). This was then accompanied by a reduction in water infiltration rate and leaching (Jim 1987a & b). Soil bulk density along the paths and tracks was higher than in the adjacent undisturbed sites (Lapage 1962). Diffusion of nutrients dissolved in water has also been shown to decrease with increased soil compaction (Lapage 1962). The effects of increased soil compaction on plant growth were shown collectively by reduced plant height, stunted growth and an increase of invader species (Arndt and Rose 1966; Grime and Hunt 1975; Jim 1987a).

Experimental work on the effects of treading, whether by human trampling or vehicle treading, has not been investigated at length. Cole (1987) looked at the effect of vehicle tracks on vegetation using a simulated approach, including the impact of vehicles on vegetation cover, percentage of species lost, regeneration, soil compaction and soil mineral exposure.

He found that recovery rate was rapid in plots that had fewer passes and very slow or no recovery at all in the plots which had 150 vehicle passes or more. In a similar study, Warren and Brown (1974) looked at the effect of vehicles on the Arctic tundra. They further looked at seasonal differences between the winter and summer seasons and found that not only did increased vehicle passes cause more damage to vegetation but also caused increased soil compaction. They observed that plant species were more resistant to vehicle passages in the dry than in the wet season. Further vehicle impact studies on vegetation in the U.S.A. have shown that below ground biomass is also often greatly affected, which is reflected in the reduction of root mass (Western pers. comm.).

Vehicle impact studies in Kenya are few. Western (1978) looked at vehicle impact on vegetation in Amboseli National Park. He found that increased vehicle speed, runs, weight and turning radii significantly increased visual effects on vegetation damage . The actual reduction of vegetation in Amboseli National Park was estimated to be 0.6% per annum. Onyenyusi (1980) working in the Masai Mara found that increased number of vehicle runs resulted in reduction of vegetation cover. He noted that damage to vegetation cover was higher at the turning radii loops than on the parallel strips (wheel tracks). Onyenyusi (1980) also reported that recovery of grass species affected by experimental vehicle runs was rapid.

Tourism is an extremely sensitive industry and its success depends on ensuring visitor satisfaction. Habitat destruction, presence of multiple tracks and vehicle congestion around the wildlife might reduce the tourist satisfaction. This could force many tourists to search for more natural and less congested areas, to the detriment of Kenya's tourist industry. The premise that the present visitor use of Mara is prejudicial to the conservation of Mara as a natural ecosystem is now a matter of priority. It is important to know specifically how visitor use is affecting wildlife and the Mara Reserve as a whole. The findings of this study have implications for the visitors, Kenya's economy and management in Kenyan parks and indeed in other East African Parks.

1:5 OBJECTIVES

The overall objective of the study was to assess the impact of vehicles on vegetation and its regeneration.

The study had the following specific objectives:

To quantify the impact of off-road driving on:-

(i) the vegetation cover of Masai Mara with emphasis on grasses,

(ii) plant species composition,

(iii) soil compaction, and

(iv) recovery rate of vegetation cover.

1:6 The Natural History of the Masai Mara National Reserve

The Masai Mara National Reserve was gazetted in 1961 and has been administered by the Narok County Council since its establishment. The Mara reserve is a famous and popular tourist resort due to the high diversity of wildlife and scenery. The vegetation zones which vary from open grasslands, riverine forests, dense natural forests, islands of bushes and trees, rocky hills (Taiti 1973; Burney 1980; Hamilton 1987) support the greatest large mammal diversity and biomass in Kenya. The animal biomass is particularly high, from July to December, during the annual Serengeti-Mara wildebeest migration.

All these factors have made Mara the most popular wildlife viewing area in Kenya. Development of tourist facilities in the reserve has been rapid in response to the increasing number of visitors. Among the first lodges to be established was Keekerok Lodge which was built in 1963 (Makallah pers. comm; Kones pers. comm; Hamilton 1987). This was the only lodge erected to cater for tourists at the time. Today, there are 3 lodges and 9 permanent camps in the Mara with bed capacity of 1127 (Table 1).

Improvement and expansion of accommodation facilities has contributed to the Mara receiving the highest number of visitors than any other wildlife area in East Africa (Western pers. comm.). The number of visitor days stands at an estimate of 250,000 annually (Western 1988). Over the last decade the number of visitors have increased by 9% annually. In 1987 for instance the reserve absorbed 18% of all the visitors to the national parks or reserves in Kenya and generated 8% of gross tourist revenues (Hamilton 1988). Figures from Narok County Council show that the Mara generated KShs.445 million in 1987 alone. This was mainly from accommodation tariffs, entry fees, game drives, ballooning, camping, and air and road transport.

Table 1: Growth in accommodation facilities in the Mara, (1965-1989).

YEAR	Camps	No, of lodges	No,of Beds
1963	0	1	48
1975	1	2	264
1980	8	2	548
1985	8	2	838
1987	9	3	1,075
1989	10	4	1,127

Revenues generated in 1988 were probably higher but the figures were not available from the County Council at the time of the study. Figure 2 shows an increase in the number of visitors in the Mara from 1978 to 1989.

One of the consequences of increased accommodation facilities in the Mara is habitat loss, since the lodges take up wildlife habitat. Increased number of visitors has also meant more vehicles in the reserve. In 1987 for instance a total of 23,766 vehicles entered the Mara, while a total of 23,466 were recorded in 1989 (Narok County Council, N.C.C. 1989). Given that the Mara is only 1,510 km^2 this has without doubt created alot of congestion.

One of the problems with the Mara is the lack of a strict policy that limits off-road driving. As a result, vehicles drive off established roads in search wildlife. This has resulted in the development of multiple tracks which has destroyed vegetation cover and reduce the amenity value of the reserve (Plate 1). As Ricunit (1984) stated "off-road driving is the rule in the reserve". As such, drivers do not follow the regulations and move freely in the reserve as long as it is accessible. The presence of few developed roads or tracks in the reserve which are in poor condition further contributes to increased off-track driving.

Awareness of the problems of visitors in the Mara has been voiced by a number of sources and attempts have been made to curb the tourist pressures in this area. In 1983 the then Wildlife Conservation and Management

FIG 2: Masai Mara National Reserve-Visitor Numbers 1978- 1989.

Sources: (i) Narok County Council Masai Mara Reports 1989-1990.

(ii) European Development fund of the European Economic Community. (Mara-Serêngeti Ecosystem) October 1989.

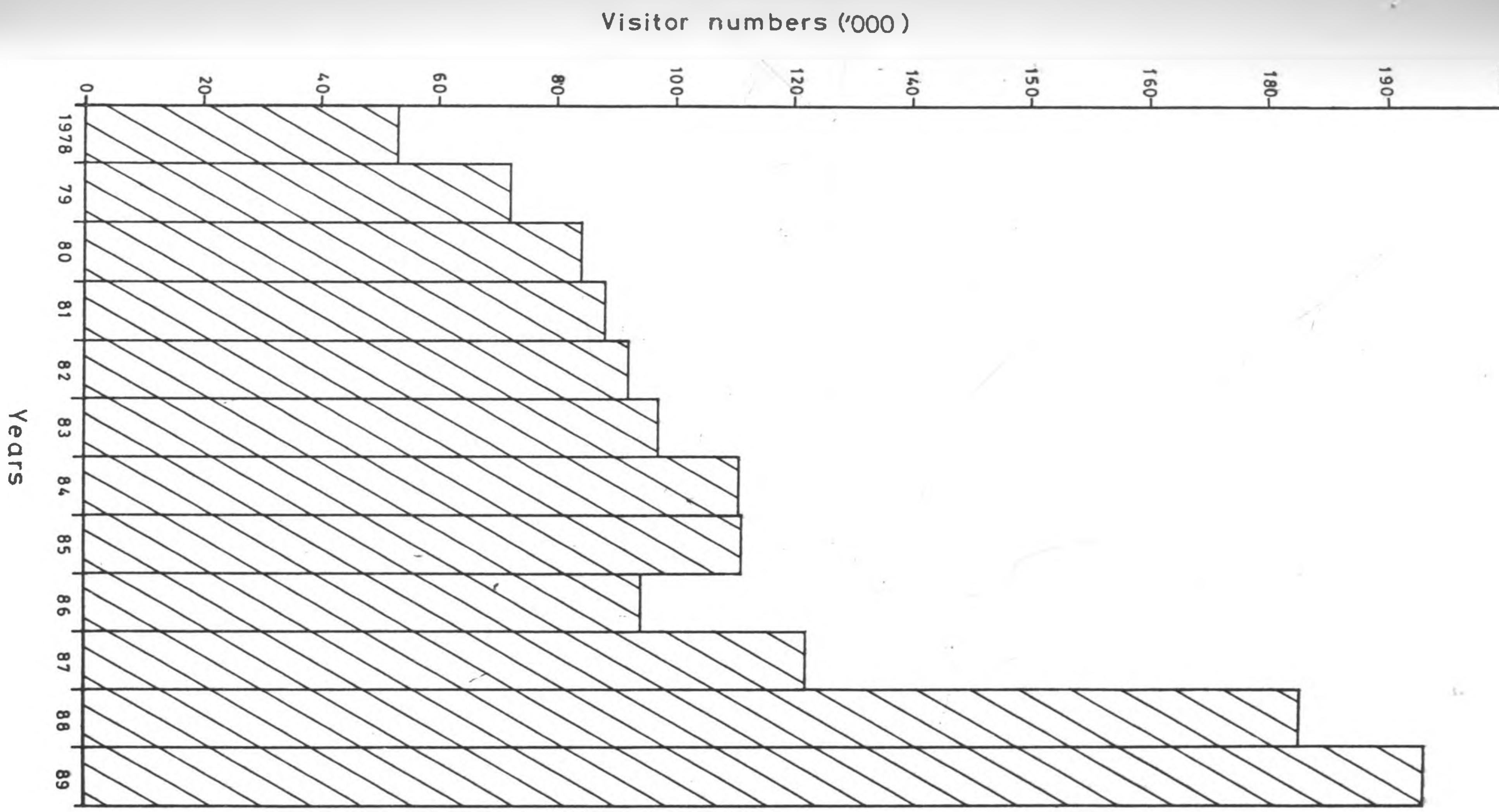
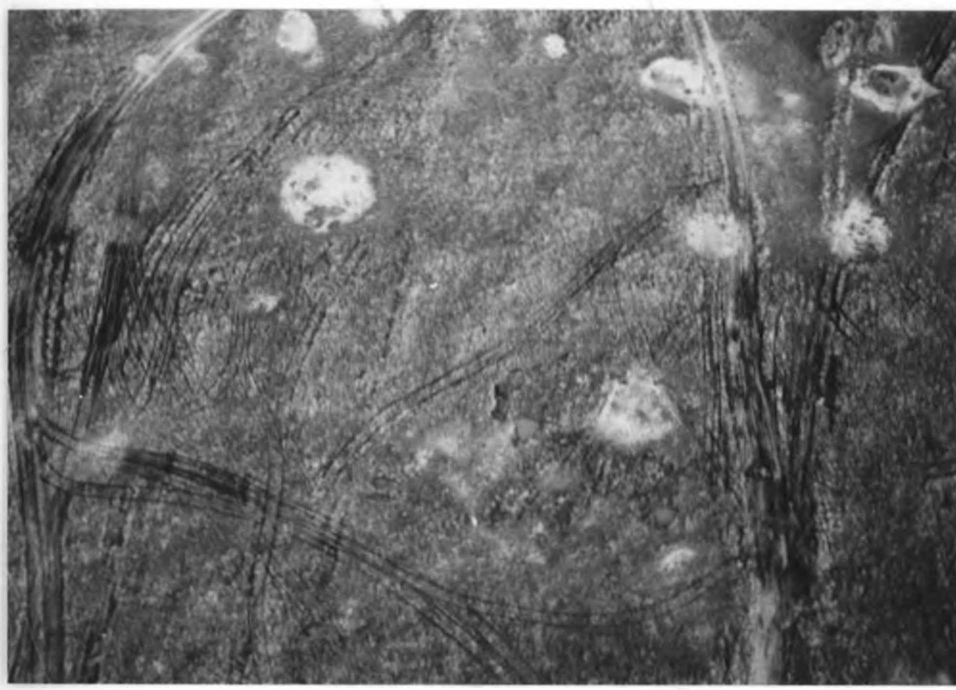

Visitor numbers ('000)
0
20
40
60
80
100
120
140
150
160
180
190
200
Years
1978
79
80
81
82
83
84
85
86
87
88
89

Plate 1 : An aerial view of a section of the Masai Ma
Reserve. Note the multiple tracks criss-cross
the area.



Department (W.C.M.D), carried out studies which covered the aspect of tourist behaviour and off-road driving. One key recommendation from the study was development of viewing tracks, together with improvement and maintenance of the roads as a means of reducing off-road driving. A total of 500kms of viewing tracks were to be developed. To date only 33km have been constructed (Mburugu 1982). In 1987, the Minister for Tourism and Wildlife was forced to halt further lodge development until the congestion problem was evaluated and management plans drawn up. This has recently been reiterated by the Director of Kenya Wildlife Services, (formerly W.C.M.D.). Unfortunately this has not been adhered to since the expansion of old lodges and construction of new ones was observed in the course of this study.

One attempt to reduce habitat degradation by the Senior Warden has been the zoning off part of the Reserve from tourist use in order to permit recovery of the Reserve from the great number of tracks created. Though these measures have been taken, they have not proved to be effective in reducing habitat destruction. It is out of this concern that this study was born. The overall objective of this study was to provide an assessment of the relationship between intensity of use and amount of impact, and also to evaluate tourist pressure in the Mara. This information will hopefully be used to formulate policy and development plans to reduce the amount of negative impact by tourism activities.

CHAPTER TWO

2:1 STUDY AREA

2.1.1. The Masai Mara National Reserve

2.1.2: Location

The Masai Mara National Reserve is situated in the southern part of Narok District. It is the northern most portion of the Serengeti-Mara ecosystem, which covers an area of 40,350 sq.km of which Mara comprises 1,510 sq.km (Burney 1980; Sarunny pers. comm.). The park lies between 1 and 2 degrees South latitude and 35 and 36 degrees East longitude (Button and Tieszen 1983).

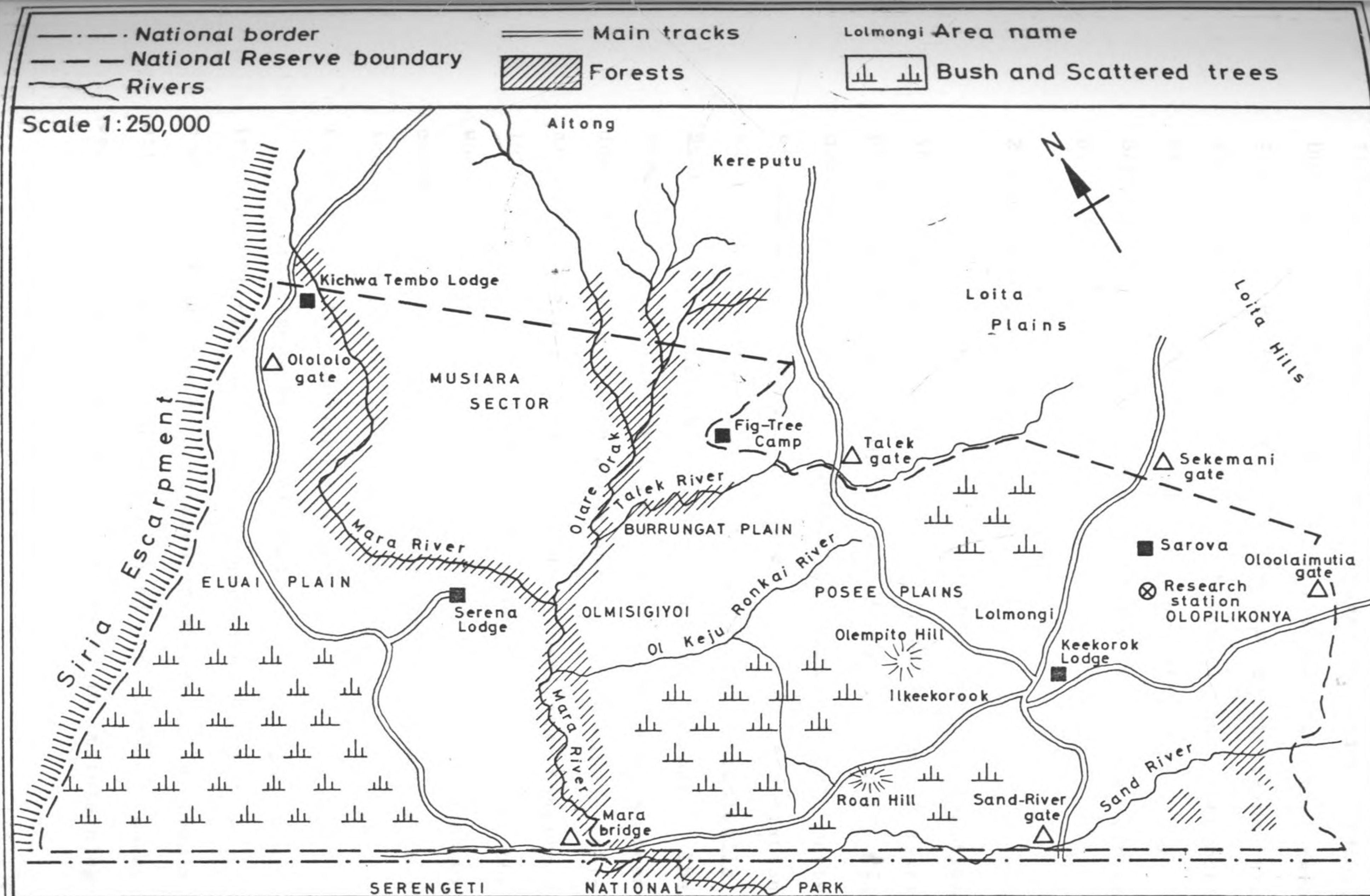
2.1.3: Topography

The Mara consists mainly of undulating and flat plains at 1,600 meters elevation surrounded by hills and an escarpment which averages 2,290 meters above sea level. To the north the Mara Reserve is bordered by the Loita plains, to the west by the Siria escarpment and to the east the Loita hills. The reserve is drained by the Mara River which flows into Lake Victoria. This river has three important tributaries. Talek River to the north, Sand River to the south and Ol Keju Ronkai River which drains the central part of the reserve (Fig. 1988-1989, 3). Soils are of volcanic origin and range from brown sandy loam soils to heavy black cotton soils.

2.1.4: Climate

The Mara generally experiences high rainfall. Mean annual rainfall during the study period was 93.51mm in

FIG 3: A Relief Map of the Masai Mara National Reserve.


National border
National Reserve boundary
Rivers
Main tracks
Forests
Lolmongi Area name
Bush and Scattered trees
Scale 1:250,000
Aitong
Kereputu
N
Kichwa Tembo Lodge
Loita
Plains
Loita Hills
Ololologate
MUSIARA
SECTOR
Fig-Tree Camp
Talek gate
Sekemani gate
Olare Orak
Talek River
Siria Escarpment
Mara River
BURRUNGAT PLAIN
Sarova
Oloolaimutia gate
ELUAI PLAIN
Ol Keju Ronkai River
POSEE PLAINS
Research station
OLOPILIKONYA
Serena Lodge
OLMISIGIYOI
Lolmongi
Olempito Hill
Keekorok Lodge
Ilkeekorook
Mara River
Sand River
Roan Hill
Sand-River gate
Mara bridge
SERENGETI NATIONAL PARK

1988 and 85.83mm in 1989 (Mara Research Station 1989). During the months of March , April and May the Mara receives the long rains, while the short rains are experienced in the months of November and December extending to January. The months of June, July , September and October are usually dry, with very little or no precipitation (Fig 4).

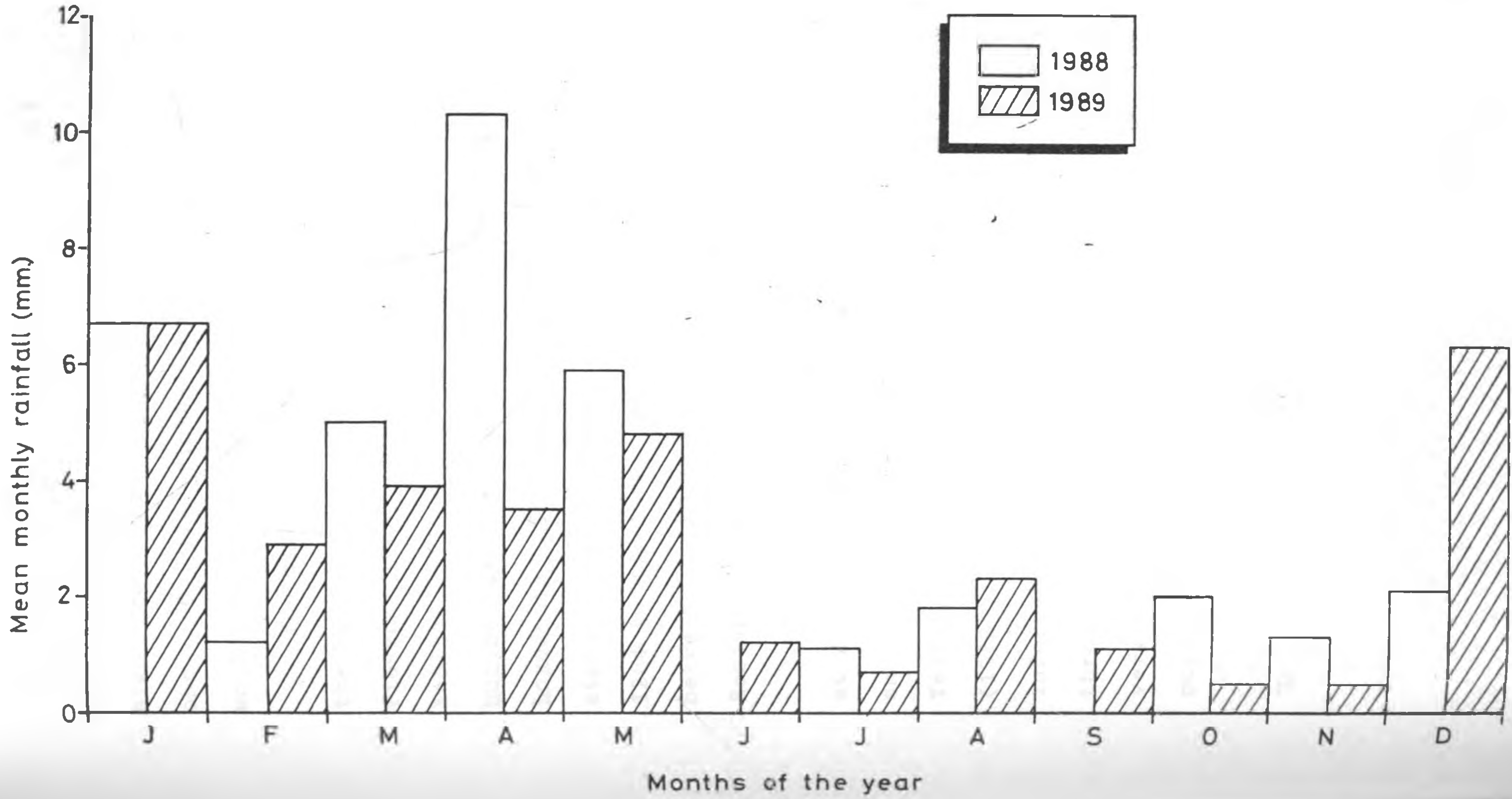
2.1.5: Fauna and Flora

Taiti (1973) identified fourteen plant communities in the Mara. The reserve for most parts consists primarily of open or lightly wooded grasslands which are dominated by the grass Themeda triandra. In most parts of the reserve Themeda triandra occurs in association with other grasses such as Sporobolus pyramidalis. Bothriochloa insculpta and Chloris guyana. The vegetation of the Mara reserve has not always been dominated by the open grasslands. In the 1930s this area had a great diversity of woody habitats (Hamilton 1987). In the late 1950s there was a decrease in the woody habitats. Deliberate destruction of woodlands by colonial administration to reduce tsetse fly habitat and increased numbers of herbivores contributed to the reduction of the woodland habitat.

The grasslands have continued to prevail since there is very little woodland regeneration (Dublin pers. comm.) taking place. Increased numbers of elephants within the reserve has continued to reduce woody vegetation. These factors have assisted in maintaining

FIG 4: Mean Monthly rainfall (mm) during the study period (1988-1989)

Sources: Mara Research Station.


Mean monthly rainfall (mm)
0
2
4
6
8
10
12
1988
1989
J
F
M
A
M
J
J
A
S
O
N
D
Months of the year

the reserve as an open grassland area (Dublin 1984; Hamilton 1988). The high rainfall, permanent water and high grass productivity allow the Mara to support one of the richest assemblages of wildlife in the world (Hamilton 1987).

The diversity, density and biomass of herbivores in the Mara is generally high throughout the year (Button & Tieszen 1983). The most common species of wildlife include wildebeest (Connochaetes taurinus), zebra (Equus burchelli), buffalo (Syncerus caffer), elephant Loxodonta africana. The number of elephants during the study period varied between 990 in May 1988 and 1284 in May 1989, while the number of buffaloes varied between 9,639 in May 1989 and 10,258 in May 1990 (Mara Research Station 1989).

Number of rhinos (Diceros bicornis) were estimated at 27 (Mara Research Station 1989). Detailed information on the herbivores of the Mara has been documented by Talbot and Talbot (1965); Sinclair and Norton griffiths (1979); Button and Tieszen (1983). Apart from information on the lion whose numbers are generally high throughout the year (Sarunny pers. comm.), there is very little information available on the carnivore population.

2:2 LOCATION OF STUDY SITES

In order to examine sections of the reserve which were subjected to the most tourist off-road driving, existing secondary tracks created by vehicles were counted in November 1988. Counts were made using a slow moving vehicle. The tracks encountered along several road transects were counted. The results of this count enabled the location of the sampling zones (Table 2).

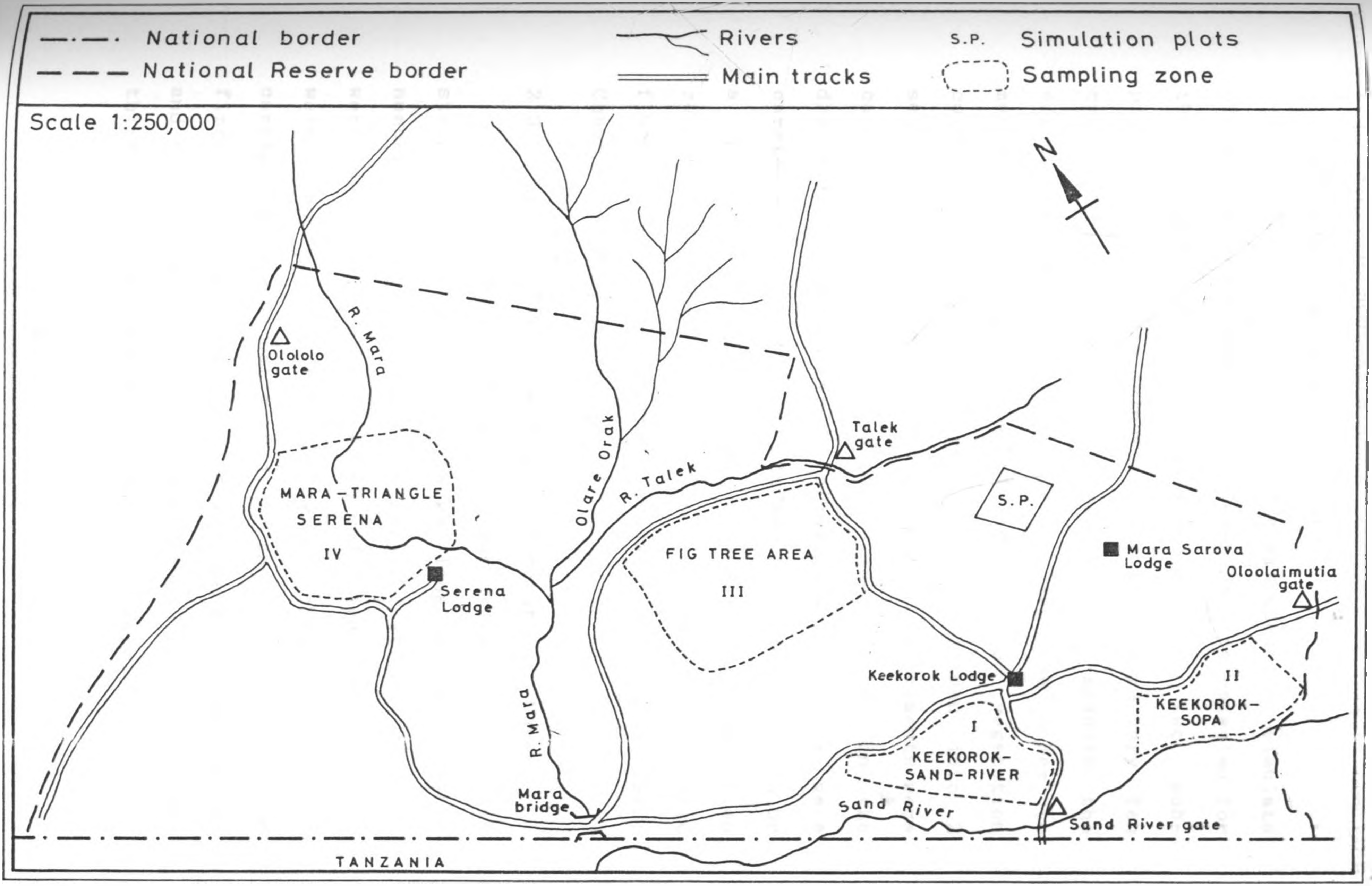
The Sarova-Sekenani region was selected for the simulation experiment plots. This area was suitable since no other tracks existed and this suggested low vehicle use. Presence of tracks would have interfered with the simulation procedure and increased experimental error. In order to ensure that no vehicles gained access to this sampling zone, thus interfering with the experimental exercise, the study sites were zoned off.

The other sampling zones were located in the Mara Triangle-Serena zone, the Fig Tree-Talek area, Keekorok-Sand river and the Keekorok-Sopa area (Fig. 1988, 5). These zones had a high concentration of existing secondary tracks. The tracks were suitable for assessing the long-term effects of vehicle use on the composition of the grassland.

Table 2: Secondary tracks in the Mara

Area of road Transects	Total No. of off- tracks along the transects	Distance of the road transects (km)	Density/km of off-tracks along the transects
Fig Tree-Keekorok	53	33.15	1.6
Sarova-Fig Tree	74	18.9	3.9
Intrapids-Keekorok	32	27	1.2
Mara Bridge-Keekorok	56	28.2	2.0
Keekorok-Sekenani	144	15	9.6
Keekorok-Sopa	132	23	5.7
Keekorok-Mara Bridge	125	28	4.5
Keekorok-Sand River	35	8	4.4
Serena-Kichwa Tembo	72	21.4	3.4
Sopa-Sekenani	4	13	0.3
Sarova-Sekenani	1	10	0.1

FIG 5: Map of Masai Mara showing the location of th Sampling Zones. In the Sampling Zones (I-IV), existing tracks were sampled for Species composition. S.P. shows the location of th simulation experiment sub plots.


National border
National Reserve border
Rivers
Main tracks
S.P. Simulation plots
Sampling zone
Scale 1:250,000
N
R. Mara
Ololololo gate
MARA-TRIANGLE
SERENA
IV
Serena Lodge
Olare Orak
R. Talek
Talek gate
FIG TREE AREA
III
S.P.
Mara Sarova Lodge
Oloolaimutia gate
Keekorok Lodge
II
KEEKOROK-SOPA
I
KEEKOROK-SAND-RIVER
Mara bridge
Sand River
Sand River gate
TANZANIA

2:3 Materials and Methods

Off-road Simulation Procedure:

A four wheel drive vehicle was used to simulate off-road driving. The Sarova-Sekenani zone selected for the simulation procedure was divided into two sub-plots. This zone was selected since there were very few tracks in it. One sub-plot was used to measure the effect of variable vehicle runs, and the other to measure the effect of vehicle speeds, on vegetation cover. Each sub-plot was further divided into 2 sections. In one section the simulation experiments were carried out in the wet season and in the other, in the dry season. Measurements of vegetation cover were carried out since previous studies had shown cover to be a sensitive indicator of changes in vegetation resulting from changes in management, biotic fluctuations or disturbances (Goodall 1952; Thomas 1960; Chapman and More 1986) .

2:3:1 Effect of Vehicle Runs on Vegetation Cover

In Sub-plot 1 the vehicle was driven in parallel strips (vehicle runs in a straight line) for a repeated number of times. In the first parallel strip, 30 runs were made and in the second and third strips, there were 60 and 90 runs respectively. These experiments were carried out in the wet season. In the dry season, in the first parallel strip, 30 runs were made to start with, and then 60, 90, 120, 150 runs followed in the second, third, fourth and fifth strips respectively.

In the wet season no further runs were made after the 90 run category, similarly in the dry no further runs were made after 150 runs. The two limits were found sufficient to record experimental results as further increase in runs resulted in much serious degradation of the vegetation cover. At these numbers of runs, most of the vegetation cover had been destroyed and bare patches were apparent.

At the end of each parallel strip, loops were made as the experimental vehicle turned for another run. The length of all the parallel strip was 300 meters. The speed for each category of runs was held constant at 20 km/h.

2:3:2 Effect of Vehicle Speed on Vegetation Cover

The simulation procedure used in the second sub-plot was similar to that used in sub-plot one. In this case the speed was varied, while the number of runs for all the speed categories was held constant at 30. During the preliminary survey, I accompanied tourist on four game drives with a view of obtaining a range of speeds used by drivers when off-track driving. The speeds varied from 15 Km/h to 40 Km/h. This was used as a base for selecting varying speeds for simulation experiments. In the first parallel strip the speed used to make the runs was 10km/h and in strips 2,3,4 and 5, the speeds were 20km/h, 30km/h, 40km/h and 50km/h respectively. This procedure was carried out for both the wet and the dry season simulation experiments with the exception of the 10 km/h strip which was not repeated in the wet season. This was to avoid getting stuck in the mud. Similarly, at the end of each strip, loops were made as the experimental vehicle turned for another run. Percentage cover of live vegetation remaining after the various runs and speeds, was measured using the Pin-Frame method (Greig-Smith 1957). This method has the advantage, among others, of repeatability and thereby facilitating monitoring change in vegetation.

For each vehicle run variable, the pin-frame was dropped in the wheel-tracks (parallel strips) and along the turning radii loops to assess vegetation cover damage. For a control the measurements of cover were made by dropping the pin-frame within the ruts created. Determination of live vegetation cover was made by dropping the pin-frame at 4 meter intervals along the wheel tracks for the experimental procedure and in-between the tracks for the control measurements. The total number of times the pin touched or hit grass stems, blades or flowers was recorded.

To determine sample size, the standard error (Zar 1974) of the mean values of live vegetation cover was calculated for varying number of pins, for example for 10 pins, 20 pins and so on. The standard error values were then plotted against the number of pins. The standard error curve levelled at 70 pins, and by 100 pins it had reached an asymptote (Gleason 1942). As a result a 100 pins (10 frames), was found to be a suitable sample size for the various simulation experiments.

Two samples were obtained for each simulation procedure and for the controls. For example along the 30 run parallel strips, 200 pins were used to measure live percentage cover (100 pins for each sample), similarly 200 pins were used in the associated turning radii loops (100 pins for each sample). The simulation procedure has been used by Western (1978) and Onyenyusi (1980, 1986).

Values of percentage cover loss were calculated for all parallel strips and associated radii using the formula below (Cole 1987)*:

$$d = \frac{b-c}{b} \times 100$$

d= loss of standing crop(%)

b= mean vegetation cover of undisturbed area(%)

c= mean cover on vehicle tracks after simulation procedure(%)

For the purpose of statistical analysis, the percentage values were transformed, using the arcsine transformation technique. Values used in the analysis, are the arcsine values.

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* Cole s formula was used since he applied percentage cover values otherwise not used in the formula adopted by both Western and Onyenyusi in similar studies.

2:3:3 Effect of Vehicle Runs on Soil Condition

A soil penetrometer was used to determine the impact of vehicles on soil condition. This is a rod with a pointer which measures the force needed to push the rod into the soil to a standard depth usually marked on the penetrometer. The penetrometer essentially measures penetration resistance. This method has been used in other studies by Anderson <u>et al</u> (1980). After each set of vehicle runs 20 soil penetrometer readings were taken. The penetrometer was placed in the parallel strips and along the turning-radii loops and compaction measurements were recorded. This procedure was carried out in both the wet and dry season, in order to determine seasonal differences and variation.

2:3:4 Vegetation Recovery of Simulation Experiment Sub-plots

After the simulation experiments were carried out the sub-plots were left to recover for a period of three months. The wet season sections were sampled for vegetation recovery in May 1989 and the dry season in November 1989. In these months, the pin-frame was placed along the parallel strips (wheel tracks) and along the turning radii loops and recovery measurements of vegetation cover were obtained. This procedure was repeated for all the speed and run categories. Special attention was paid to the recovery of four species which were common grasses in the Mara Reserve. These were

Themeda triandra, *Sporobolus pyramidalis*, *Cynodon dactylon* and *Eragrostis tenuifolia*. For each species the percentage cover after regeneration was recorded. The amount of vegetation cover that regenerated in the simulation experiment was obtained using the following procedure:

To calculate the relative amount of recovery (RAR) the following formula was used (Cole 1987):

$$RAR = \frac{a - b}{\text{control (initial cover)}} \times 100$$

a = surviving cover, after three months of recovery

b = cover remaining immediately after the simulation experiments.

2:3:5 Ecological Impact

In order to project the overall ecological impact of vehicles on the Mara Reserve, the results of the simulation experiments were used in a formula adopted by Western (1978) in the Amboseli National Park. Also included in the formula was the average distance driven off-road (in km) and this was obtained from the four game drives during which I accompanied the tourists.

The total damage resulting from off-road driving was estimated from the formula:

$$d = \frac{V(r.2t)L}{p}$$

d = Percentage loss in vegetation cover.

V = Total number of vehicles that entered the park according to entries collected from all the gates of the Mara Reserve.

r = Average distance driven off-road (in km), by tour drivers.

t = Tyre width (cm).

p = Area of park (km^2).

L = Percentage loss of vegetation cover per vehicle passage.

2:3:6 Vehicle Impact on Species Composition

Long term effects of vehicles on the Mara were assessed using selected zones. The objective was to determine the distribution and composition of grass species in relation to levels of vehicle use along existing tracks in the Mara. Heavily used habitats were targeted and existing tracks were initially counted (Table 2). The assumption was that areas exposed to heavy vehicle use would have a higher number of tracks. The zones selected for sampling were the Mara Triangle-Serena, Fig Tree-Talek, Keekorok-Sand River and Keekorok-Sopa area (Fig.5). The sampling design used was important in detecting whether the plant species (i) changed with increasing distance from the track and (ii) which type of species were associated with tracks. In the four zones, three categories of tracks were identified on the basis of the level of use as reflected by vegetation cover, and these were high, intermediate and low level use tracks. The vegetation cover on tracks was measured in the preliminary survey in all the sampling zones (Table 3). The assumption was that the higher the level of vehicle use, the lower the percentage cover.

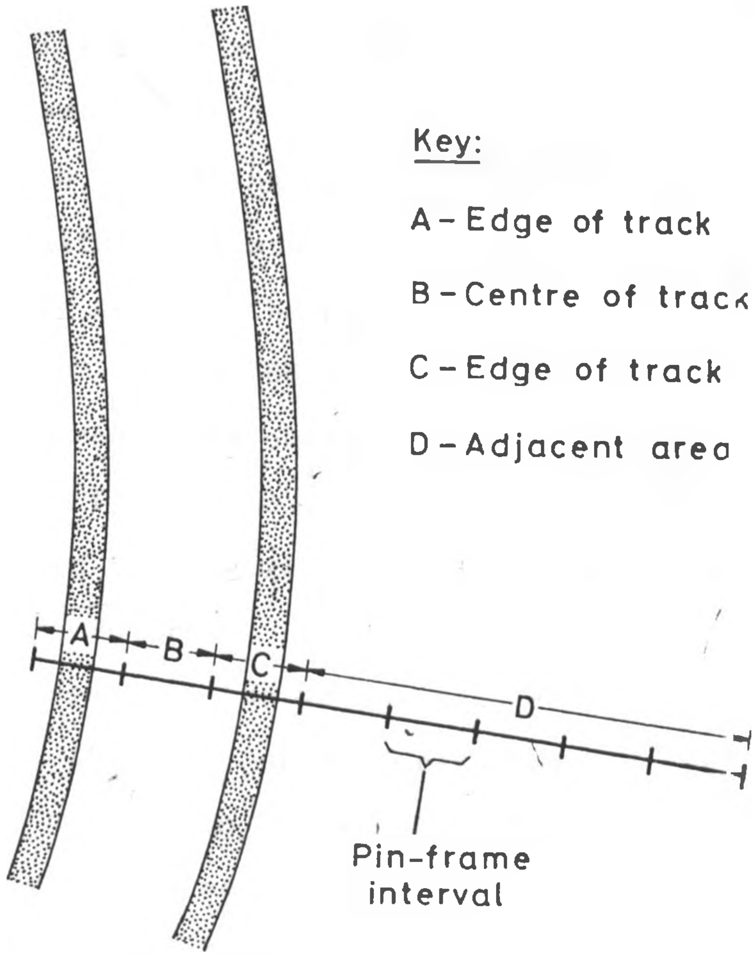
In each of the four zones, a total of six tracks (2 tracks of each category) was sampled for species composition. A total of twenty four samples were obtained from the four zones.

The number of species was plotted against the number of pins, and the resultant curve started levelling off at 60 pins at a distance of 6.6 meters and by 80 pins at a distance of 8.8 meters the curve had levelled off. Thus 8.8 meters was selected as the maximum distance from the track for sampling since no new species were recorded beyond this point. For each sample taken on the track, the pin-frame was placed at a randomly selected point along the edge of the track (Fig. 6, A) and then placed systematically across the track (Fig.6, B). Subsequent samples were then taken along the edge (Fig.6, C) and at an increasing distance from the same track (Fig.6, D) to a distance of 8.8 meters (Fig. 6). The pin-frame values were used to calculate species diversity values for the three categories of tracks (high, intermediate and low), and species diversity along the track and adjacent areas in all the four sampling zones. The Shannon - Weaver Index (Zar 1974), was used to calculate the species diversity indices.

Table 3: Percentage cover along three categories of tracks.

KEEKOROK - SAND RIVER ZONE	Track	Adjacent area
Low use	43.07	56.93
Intermediate use	29.85	70.12
High use	22.5	77.50
FIG - TREE - TALEK ZONE		
Low use	37.44	62.56
Intermediate use	29.51	70.49
High use	19.07	80.93
MARA - TRIANGLE-SERENA ZONE		
Low use	36.19	63.81
Intermediate use	27.5	72.46
High use	19.71	80.29
KEEKOROK - SOPA		
Low use	45.09	59.91
Intermediate use	39.89	60.11
High use	29.11	70.89

FIG 6: Sampling design used along existing tracks in Mara.



Key:
A - Edge of track
B - Centre of track
C - Edge of track
D - Adjacent area
A
B
C
D
Pin-frame
interval

CHAPTER THREE

RESULTS

3:1 Effect of Vehicle Runs on Vegetation Cover

The percentage vegetation cover was plotted* against the number of runs, for the wet season (Fig.7) and dry season (Fig.8). An increase in the number of vehicle runs resulted in an increase in vegetation cover loss both on the parallel strips (wheel tracks) and the turning radii loops, in both seasons.

In the wet season the percentage cover loss per run decreased with increasing vehicle runs (30 - 90 runs) at both the parallel strips and turning radii loops (Table 4). In the dry season, the percentage cover loss per run increased from 30 to 60 runs on the parallel strips. A general decrease was observed as the number of runs were increased from 60 to 150 on the parallel strips and the associated turning radii loops . The results also reveal that 90 runs had the greatest impact on vegetation cover in the wet season (Fig. 7). While, 150 runs in the dry season resulted in removal of most of the vegetation cover (Fig. 8). During the wet season, 90 runs caused a cover loss of 99.3$\pm$ 3.0% and 99.9 $\pm$ 1.9% along the parallel strips and associated turning radii respectively (Table 4) while 150 runs in the dry season caused a cover loss

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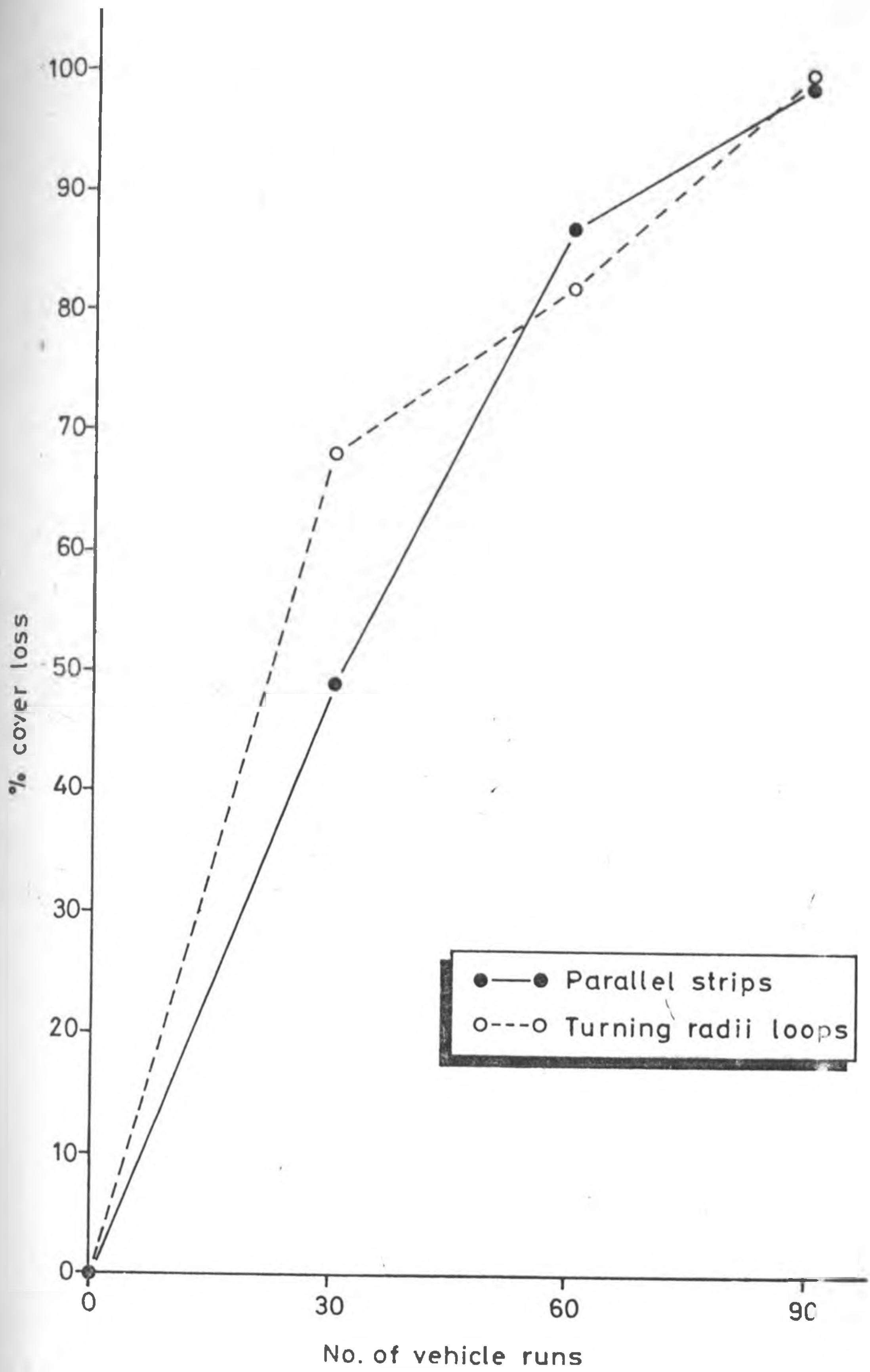
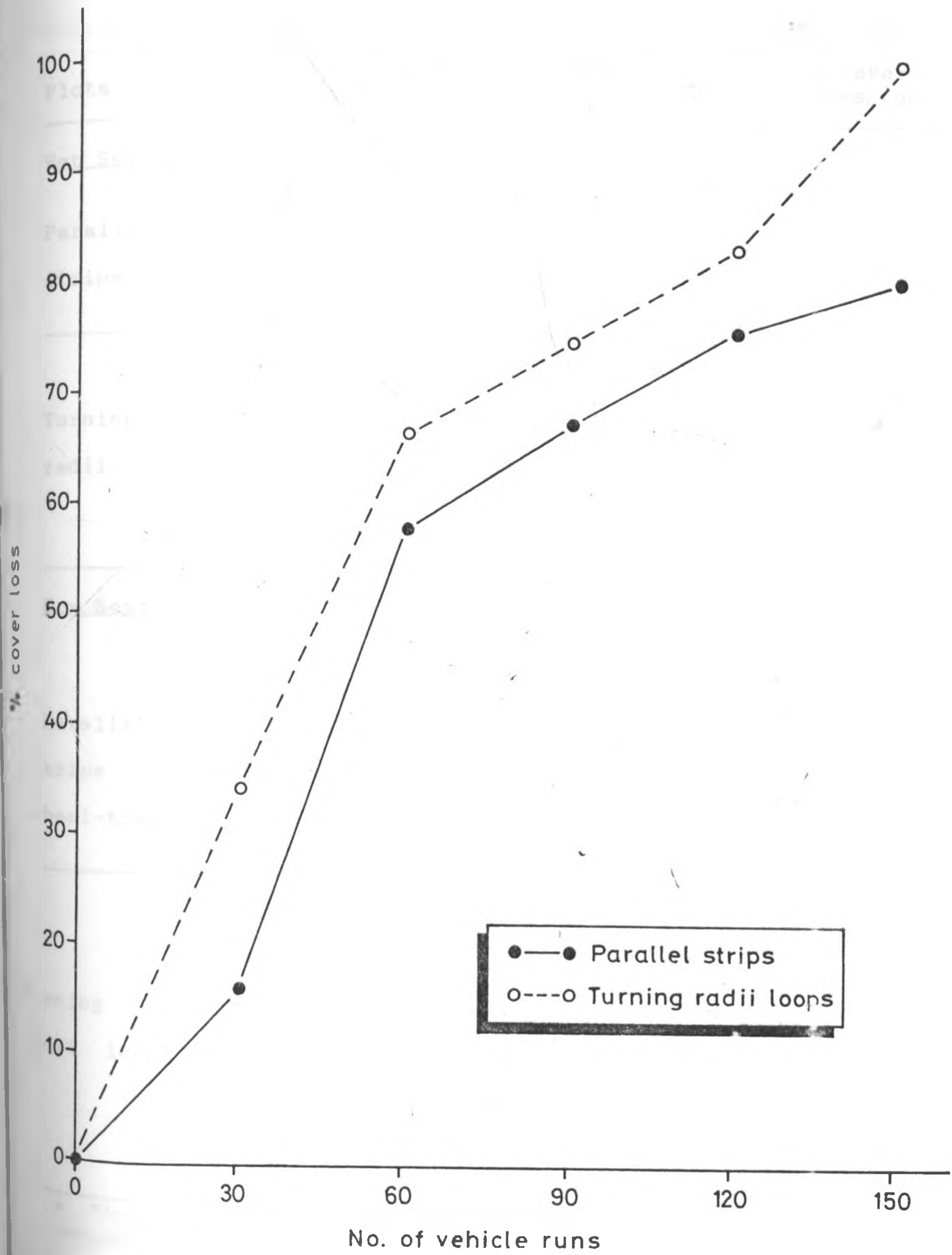
* The standard error bars have being omitted, because there were overlaps of the bars at certain points. Standard deviation values can, however be obtained from different tables in the chapter.

FIG 7: Relationship between vegetation cover loss and vehicle runs in the WET season.



100
90
80
70
60
50
40
30
20
10
0
% cover loss
0
30
60
90
No. of vehicle runs
Parallel strips
Turning radii loops

FIG 8: Relationship between vegetation cover loss and vehi
runs in the DRY season.



100
90
80
70
60
50
40
30
20
10
0
% cover loss
0
30
60
90
120
150
No. of vehicle runs
Parallel strips
Turning radii loops

Table 4: Effect of vehicle runs on vegetation cover, in the wet and dry season.

Plots	No. of vehicle runs	Mean veg, cover loss	SD	% cover loss/run
Wet Season				
	30	49.8	13.2	1.7
Parallel	60	88.8	9.3	1.5
strips	90	99.3	3.0	1.1
	30	65.8	5.0	2.2
Turning	60	86.7	11.6	1.4
radii loops	90	99.9	1.9	1.1
	$F_{5,54}$ = 37.09*		$p < 0.05$	
Dry Season				
	30	13.9	10.7	0.5
	60	57.1	4.2	1.0
Parallel	90	66.9	2.3	0.7
strips	120	75.3	2.0	0.6
(wheel-tracks)	150	80.4	4.6	0.5
	30	33.8	4.4	1.1
	60	66.6	3.0	1.1
Turning	90	74.7	1.6	0.8
radii loops	120	83.1	1.3	0.7
	150	99.1	3.3	0.7
	$F_{9,90}$ = 141.07*		$p<0.05$	

* The difference in mean vegetation cover loss for the run categories is statistically significant.

of 80.4 ± 4.6% and 99.1 ± 3.3% along the parallel strips and turning radii loops respectively (Table 4). A one way analysis of variance was used to test whether the variable runs had a similar effect on vegetation cover. There was a significant difference between the mean values of vegetation cover loss, in the different vehicle run categories, for the wet and dry season ($F_{5,54} = 37.09$, $p<0.05$ for the wet season and $F_{9,90} = 141.07$, $p<0.05$ for the dry season). A Tukey's test (Zar 1974) was used to determine which vehicle runs had brought about a significant loss in vegetation cover. In the wet season, the number of runs caused significant differences in cover loss, while the differences between parallel strips and turning radii were insignificant (Appendix 1). In the dry season, there were significant differences between parallel strips and turning radii loops for low and high numbers of runs (30 and 120+ $q_{(90,10)} = 4.56$ and $p<0.05$). The difference was insignificant between intermediate numbers of runs (60 and 90), (Appendix 2).

The Students t-test (Zar 1974) was used to determine whether reduction of vegetation cover by variable runs varied between the two seasons (wet and dry). The mean cover values compared were those obtained from the parallel strips and the associated turning radii loops of 30, 60 and 90 vehicle mean runs. Cover values of 120 and 150 runs were not compared since no corresponding values had been obtained for the wet season.

There was a significant difference between the wet and the dry season mean cover values ($t = 2.101$, $p<0.05$, $d.f.=18$) (Table 5). The mean values for vegetation cover loss were higher in the wet season, indicating that cover reduction was greater in the wet season.

Results of the simulation experiments revealed that one vehicle pass resulted in vegetation cover loss of 1.36% in the wet season and 0.73 % in the dry season.

3:2 Effect of Vehicle Speeds on Vegetation Cover

The percentage values for vegetation cover loss were plotted against the vehicle speeds for the wet (Fig. 9) and the dry seasons (Fig. 10). In both seasons, an increase in vehicle speed increased vegetation cover loss. The percentage cover loss per/km, however, decreased with increased vehicle speeds during both the wet and dry seasons (Table 6).

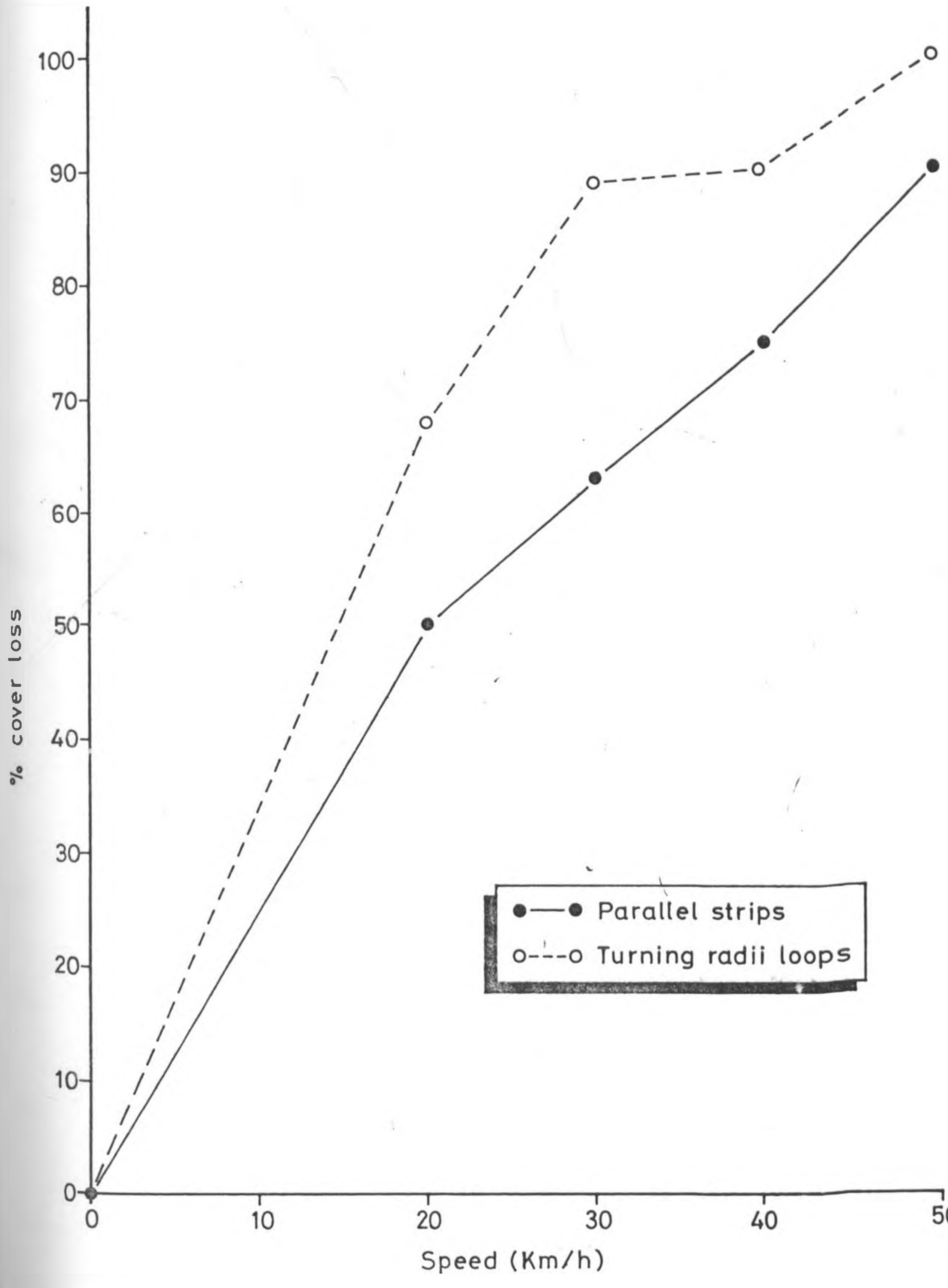
In the wet season the greatest damage to vegetation cover occurred between 20-30 km/h (Table 6) while in the dry season this occurred between 10-20km/h (Table 6). Overall the highest speed, 50 km/h, had a great impact on vegetation cover than the other speeds (10, 20, 30, 40 km/h), causing vegetation cover loss of up to 87.6% along the parallel strips and 99.9% along the turning radii loops in the wet season (Table 6).
Similarly, the highest speed (50 km/h), in the dry season, caused higher vegetation cover loss at the parallel strips and the associated turning radii loops,

Table 5: Comparison of vehicle Runs and their effect on cover in the two seasons. t-test (p=0.05, n = 18).

PLOTS	RUNS	WET	DRY	T-values
	30	49.8	13.9	4.06 *
Parallel strip (wheel-tracks)	60	88.8	57.1	7.65 *
	90	99.3	66.9	49.75 *
	30	65.8	33.8	23.23 *
Turning	60	86.7	66.9	3.71 *
radii loops	90	99.9	74.7	91.38 *

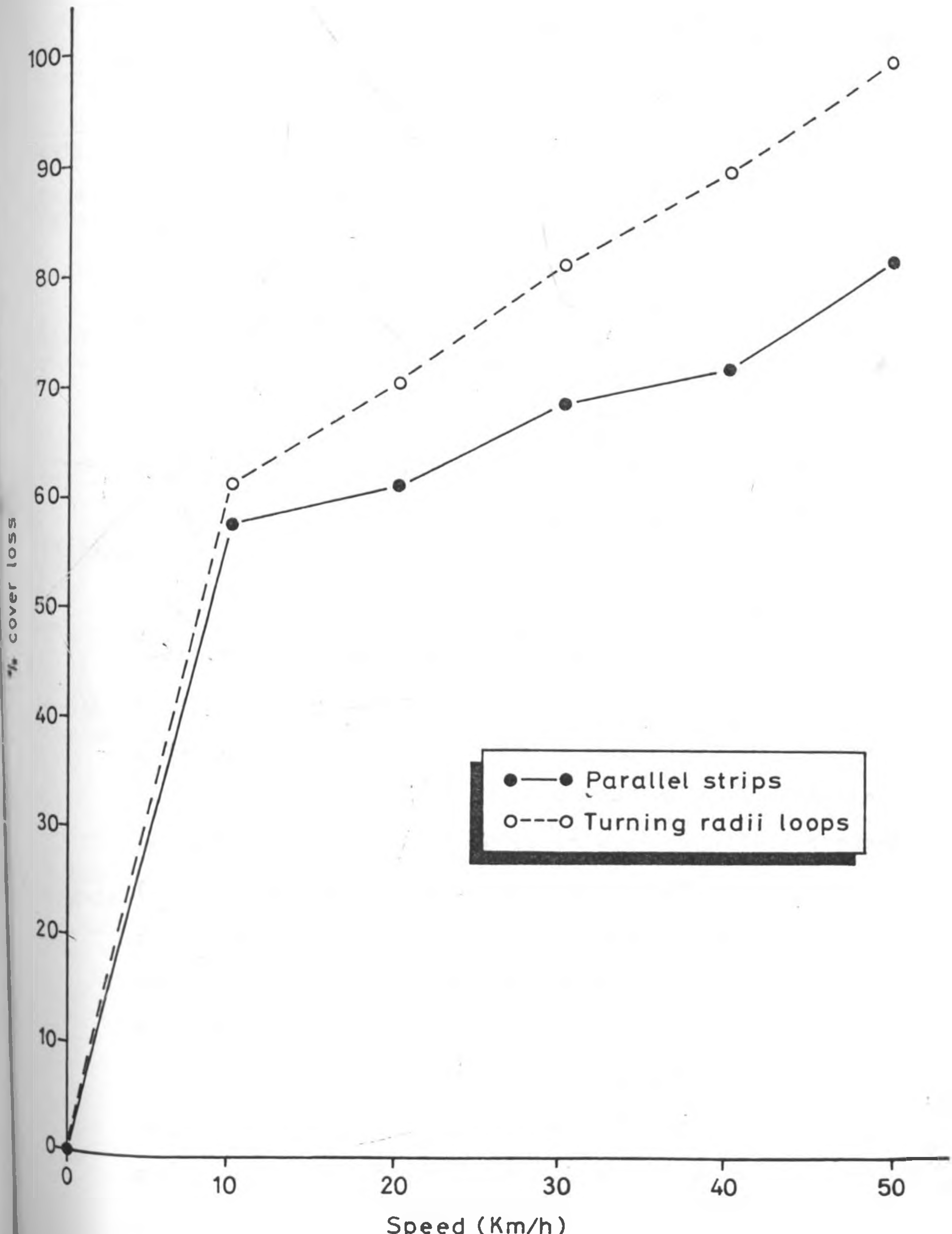
The mean % values of vegetation cover were compared using t-test (p=0.05, n=18)
* indicates the value is statistically significant (p<0.05) at p = 0.05 for 18 degrees of freedom in a two-tailed test.

FIG 9: Relationship between vegetation cover loss and vehi
speeds in the WET season.



% cover loss
0
10
20
30
40
50
60
70
80
90
100
Speed (Km/h)
Parallel strips
Turning radii loops

FIG 10: Relationship between vegetation cover and vehic
speeds in the DRY season.



% cover loss
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
Speed (Km/h)
Parallel strips
Turning radii loops

resulting in cover loss of 82.9% and 97.5% respectively (Table 6).

A one-way analysis of variance showed that there was a significant difference between the mean vegetation cover loss, for all the speed categories in both the wet and dry seasons respectively ($F_{7,72}$= 54.7, $F_{9,90}$=54.6, $p < 0.05$, Table 6).

A Tukey's test was used to compare the variable vehicle speeds and their effects on vegetation cover loss in the wet season. The analysis shows that there was always significantly more damage to cover (with runs held constant) in the turning radii loops than in the parallel strips. In addition increasing speeds caused significantly more damage . The only exception was when speed was increased from 20-30km/h in the parallel strips and from 30-40km/h in the turning radii loops. In these two cases increase in speed resulted in less vegetation cover damage (Appendix 3). Appendix 4 shows that , in the dry season, cover loss was significantly greater for the turning radii than for the parallel strips except at low speeds (20 and 30 km/h). Increases in damage due to increased speed were significant except for comparisons between 10 and 20 km/h (both turning radii and parallel strips), 20 and 30 km/h (parallel strips only), and 30 and 40 km/h (both turning radii and parallel strips).

To test whether the effect of speed on vegetation cover loss varied in the two seasons, a t-test was performed. In order to avoid inflation of the error rate due to multiple t-test, a Bonferroni's correction factor was used (Rice 1989). There was no significant difference in vegetation cover loss between the mean cover values in the 20 and 30 km/h parallel strips, and in the 40 km/h parallel strips and their associated radii ($p>0.006$, $n=8$), (Table 7).

3:3 The Effect of Vehicle Runs on Soil Compaction

Soil compaction measurements obtained from the parallel strips and turning radii loops were plotted against vehicle runs for both the wet and dry seasons (Fig. 11). Soil compaction increased as the number of runs increased. It was not clear when maximum soil compaction occurred during the wet season since no values were obtained for the 120 and 150 vehicle runs. Soil compaction was highest in the 90 runs category in the wet season, (3.25kg/cm^3) and 60 runs in the dry season (4.02kg/cm^3; Table 8). Analysis of variance showed that the means for both wet and dry seasons, for the variable runs, were (respectively) significantly different ($F_{3,76} = 88.5$, $F_{5,96} = 13.48$, $p<0.05$, Table 8).

Tukey's test was used to compare the compaction mean values. In the wet season only the mean values for compaction in the 30 and 60 run categories were not significantly different ($p>0.05$, Appendix 5). Except for the 30 and 120 run categories, for the dry season, there was a significant difference between the control compaction measurements and the 60, 90 and 150 .

Table 7: Relationship between vegetation cover loss and vehicle runs in the wet and dry season.

PLOTS	Speeds (km/h)	mean (%) WET	DRY	t-value	
	20	49.8	61.8	1.63	n.s
Parallel strips	30	62.4	68.4	2.43	n.s
(wheel tracks)	40	76.8	72.1	1.99	n.s
	50	87.6	82.9	4.58	*
	20	65.8	70.1	5.83	*
Turning radii loops	30	88.6	82.5	5.22	*
	40	89.7	91.4	0.37	n.s
	50	99.9	97.5	4.26	*

t-test was used to compare the two means ($p<0.006$, d.f.=2, n=18). * indicates the value is significant ($p<0.006$), and n.s. indicates the value is not significant ($p>0.006$) for 2 degrees of freedom in a two-tailed test.

FIG 11: Effect of vehicle runs on Soil Compaction in the and dry seasons.

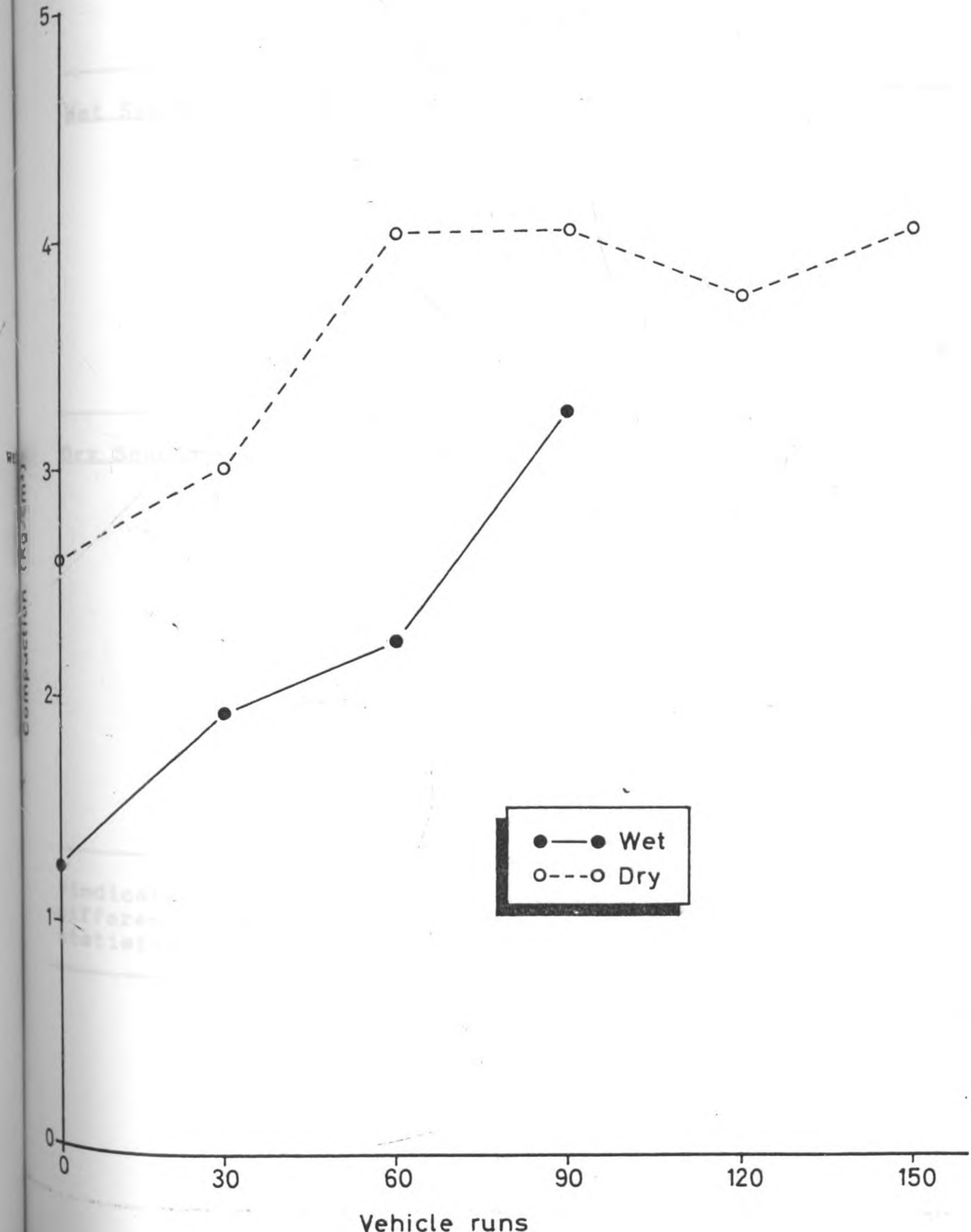

5
4
3
2
1
0
0
30
60
90
120
150
Vehicle runs
Wet
Dry

Table 8: Effect of vehicle runs on soil compaction in the wet and dry seasons simulation experiments.

	RUNS	MEAN (Kg/cm^3)	SD
Wet Season			
	0	1.29	0.3
	30	1.86	0.3
	60	2.25	0.4
	90	3.25	0.5
	$F_{3,76}$= 88.46*	$p<0.05$	
Dry Season			
	0	2.70	0.19
	30	3.16	0.18
	60	4.02	0.13
	90	4.01	0.17
	120	3.74	0.13
	150	4.06	0.14
	$F_{5,96}$= 13.48*	$p<0.05$	

*indicates the difference in mean compaction values for the different categories of runs during the respective seasons are statistically significant at p=0.05.

categories of vehicle runs ($p<0.05$, Appendix 6).

A t-test was used to determine whether there were any seasonal differences in soil compaction. Results of this analysis revealed a significant difference between the wet and dry season compaction mean values (Table 9). Compaction was higher in the dry season, 4.02 and 4.01 kg/cm^3 along the 60 and 90 run parallel strips.

3:4 Recovery of Vegetation Cover in the Off-road Driving Simulation Experiment Sub-plots.

There was no significant recovery of vegetation cover in the parallel strips and their associated turning radii loops in the 120 and 150 vehicle run categories and in the 40 km/h speed category in the dry season off-road driving simulation experiments. There was also no recovery in the parallel strips and their associated turning radii loops in the 50 km/h vehicle speed category in the wet season.

Recovery of vegetation occurred in the other variable vehicle run and speed categories for both the wet and dry season. In order to establish whether recovery amount was significant a t-distribution test with the Bonferroni's correction factor was applied. There was a significant amount of recovery in each case (Table 10).

Table 9: Comparing soil compaction in the wet and dry seasons

	Mean compaction Kg/cm[3]		t - values
RUNS	WET	DRY	
20	1.29	2.70	8.01 *
30	1.83	3.16	8.07 *
60	2.25	4.02	6.46 *
90	3.25	4.01	6.18 *

Mean values were compared using the t-test.
* indicates the value is significant at P=0.05 at 38 degrees of freedom in a two-tailed test.

Table 10. Recovery of vegetation cover in the simulation plots.

Plots	No. of vehicle runs	Mean recovery amount	t-value
Wet Season			
	30	11.6	4.52*
Parallel strips	60	24.2	11.98*
(wheel-tracks)	90	12.1	11.40*
Turning radii			
loops	30	11.4	4.33*
	60	15.5	8.75*
	90	9.7	23.93*
Dry Season	30	5.3	28.89*
Parallel strips	60	2.6	7.23*
	90	0.8	5.00*
Turning radii	30	3.3	18.21*
loops	60	1.3	11.27*
	90	0.4	3.42*
	Vehicle speeds (km/h)	Mean recovery (%)	t-values
Wet season			
	20	11.6	4.52*
Parallel strips	30	15.4	11.50*
	40	8.6	16.71*
	20	11.4	4.33*
Turning radii	30	26.8	21.49*
loops	40	13.5	16.71*
Dry Season	10	7.4	38.55*
Parallel strips	20	4.2	19.44*
	30	2.6	19.21*
	10	4.6	21.82*
Turning radii	20	1.8	7.54*
loops	30	1.4	6.64*

The mean values were compared using the t-test ($p<0.004$, $n=10$)
* indicates that the mean vegetation recovery values were significant at $P=0.004$ at 18 degrees of freedom for a two-tailed test.

3:5 Effect of Vehicle Runs on Recovery of Vegetation cover

Results of off-road driving simulation experiments in the wet season showed that most recovery occurred in the 60 run parallel strips and their associated turning radii, with mean percent values of 24.3% and 15.6% respectively (Table 11). In the dry season most of the recovery occurred in the 30 run parallel strips and their associated turning radii, with mean values of 5.3% and 3.3% respectively (Table 11). Analysis of variance revealed an insignificant difference ($F = 1.76$ $p>0.05$) in recovery amounts between the variable runs in the wet season. There was a significant difference in recovery amounts between the variable runs in the dry season measurements ($F= 16.1$ $p<0.05$, Table 11).

Tukey's test was used to compare the mean recovery values for the dry season experiments. The mean recovery values for the wet season were not compared since the one-way analysis of variance revealed that recovery means were not significant. Analysis revealed that there were no significant differences between recovery rates in parallel strips and turning radii loops for the same numbers of runs or between those for 60 and 90 runs in the turning radii loops. Most differences therefore resulted from the effects of variable numbers of runs in the dry season (Appendix 7).

Table 11: Effect of vehicle runs on vegetation recovery in the simulation experimental sub-plots.

	No. of vehicle runs	Mean recovery %	SD
<u>Wet Season plots</u>			
Parallel strips	30	11.6	13.2
(wheel-tracks)	60	24.2	7.4
	90	12.1	5.3
Turning-radii	30	11:4	13.7
loops	60	15.5	8.0
	90	9.7	2.4
$F_{5,54}=1.76$ n.s.		p>0.05	
<u>Dry Season plots</u>	30	5.3	1.4
	60	2.6	1.2
Parallel strips	90	0.8	3.2
	30	3.3	1.7
Turning radii	60	1.3	1.8
loops	90	0.4	3.2
$F_{5,54}=16.11$*		p<0.05	

n.s. = not significant at P= 0.05 (p>0.05)

* = significant at P=0.05 (p<0.05)

3:6 Effect of Vehicle Speeds on Recovery of Vegetation Cover

Most recovery occurred in the 30 km/h parallel strips and associated radii loops for the wet season measurements. In the dry season, most recovery occurred in the 10 km/h parallel strips and associated turning radii (Table 12).

Analysis of variance test revealed a significant difference in mean values of vegetation recovery for the variable speeds in the wet season and dry season ($F=5.54$, $F=22.39$ $p<0.05$) respectively. In order to locate where the difference in the mean values occurred, the Tukey's test was used. The analysis showed that in the wet season, variable speeds did not significantly affect recovery rates in the parallel strips. Variable speeds, however, affected recovery rates significantly in the turning radii loops (Appendix 8). There was also significantly more recovery in the turning radii loops than in the parallel strips at 30km/h. In the dry season, increasing the speed from 10 to 20 km/h significantly decreased recovery rates in both the turning radii and the parallel strips. No significant effects were observed between 20 and 30 km/h. Recovery was significantly higher in the parallel strips except at the lower speeds (10 and 20 km/h, Appendix 9).

In order to compare seasonal effects on recovery amounts, t-test was used. In order to reduce the inflation of the error rate due to multiple t-tests the

Table 12: Effect of vehicle speeds on vegetation recovery

PLOTS	Vehicle speeds (km/h)	Mean recovery %	SD.
Wet Season			
	20	11.6	13.2
Parallel strips	30	15.4	6 0
	40	8.6	3.1
Turning radii loops	20	11.4	13.7
	30	26.8	4.4
	40	13.6	2.4
	$F_{5,54}=5.54$*	$p<0.05$	
Dry Season			
	10	7.8	1.3
	20	4.2	1.8
Parallel strips	30	2.6	1.5
Turning radii loops	10	4.6	1.7
	20	1.8	3.1
	30	1.4	3.1
	$F_{5,54}=22.39$*	$p<0.05$	

* indicates the recovery values are statistically significant at P=0.05.

Bonferroni's correction factor was used. There was no significant difference in recovery in the 20 km/h speed category along the parallel strips and in the parallel strips and turning radii loops of 30 runs (Table 13). A significant difference occurred for the other variable vehicle speeds and runs (Table 13). Most recovery occurred in the wet season simulation experimental sub-plots.

3:7 Recovery of Species Cover in the Off-road Driving Simulation Sub-plots

Recovery of four species in all the wet season vehicle run simulation experiments was monitored. These species included Themeda triandra. Sporobolus pyramidalis and Cynodon dactylon. Eragrostis tenuifolia was absent in the initial stages of the simulation experiments, but appeared in all the vehicle run simulation experimental plots when recovery measurements were made. The recovery amounts in the different categories of runs were compared using the t-test. The Bonferroni's correction factor was also applied.

Along the parallel strips (wheel-tracks) recovery of Sporobolus pyramidalis was not significantly different among the three categories of runs (30, 60 and 90 , p>0.003, n=16, Table 14). Recovery of Themeda triandra and Eragrostis tenuifolia was not significantly different between the 30 and 60 run parallel strips (p>0.003, n=16). While recovery was significantly higher for both species, between the 60

Table 13: Recovery of vegetation cover in the speed plots - wet and dry seasons.

	Speed km/h	Mean recovey (%) Wet	Dry	t-values
	20	11.6	4.2	1.13 n.s.
Parallel strips (wheel-tracks)	30	15.4	2.6	7.13*
	20	11.4	1.8	4.43*
Turning radii loops	30	26.8	1.4	23.43*
	Vehicle runs	Wet	Dry	t-values
Parallel strips	30	11.6	5.3	1.51 n.s
(wheel-tracks)	60	24.2	2.6	9.61 *
	90	12.1	0.8	10.56 *
Turning radii loops	30	11.'4	3.3	2.06 n.s
	60	15.5	1.3	6.38 *
	90	9.7	0.4	19.37 *

Mean values were compared using the t-test.
* indicates that the differences in the mean recovery values were statistically significant and
n.s. not significant at p=0.05 for 18 degrees of freedom for a two-tailed test.

Table 14: Recovery values for the four common species along the parallel wheel tracks.

Plot	Species	Mean recovery (%) (vehicle runs) 30	60	t-values
Parallel strips (wheel-tracks)	*Themeda triandra*	5.0	7.3	0.82 n.s
	Sporobolus pyramidalis	0.9	0.1	2.01 n.s
	Cynodon dactylon	5.6	15.8	2.68 n.s
	Eragrostis tenuifolia	0.1	0.5	1.82 n.s
		(vehicle runs) 60	90	t-values
	Themeda triandra	7.3	0.3	7.81*
	Sporobolus pyramidalis	0.1	0.04	0.31 n.s
	Cynodon dactylon	15.8	5.1	4.37*
	Eragrostis tenuifolia	0.5	6.1	6.02*

n.s not significant at p= 0.003 (p>0.003)
* significant at p=0.003 (p<0.003), at 12 degrees of freedom for a two-tailed test.

and 90 run parallel strips ($t_{(2)}$=6.02 for Themeda triandra and $t_{(2)}$=7.81 for Eragrostis tenuifolia, p<0.003, n=16, Table 16). Recovery for Cynodon dactylon, in the run plots was not significantly different between 30 and 60 run parallel strips (t=2.676 p>0.003), but was significantly different between 60 and 90 run parallel strips (t=4.369, p<0.003, Table 14).

Effects of turning radii also varied with different species of grasses. Themeda triandra, Sporobolus pyramidalis and Cynodon dactylon did not show a significant difference in recovery, in all the vehicle run plots (p>0 003, n=16, Table 15).

For all the turning radii plots, recovery of Eragrostis varied considerably. Between 30 and 60 recovery of Eragrostis was significantly differently ($t_{(2)}$= 7.40, p<0.003, n=16), but between 60 and 90 no significant differences in recovery was noted ($t_{(2)}$=2.55, p>0.003, n=16, Table 15).

In the 30 run parallel strips (wheel-tracks), results show that recovery of Cynodon dactylon was the highest among the four grass species, with a mean value of 5.6% while in the associated radii loops, Themeda triandra recovered the most with a mean value of 5.3% .

In the 60 run simulation experiments, the species with the highest recovery amount was Cynodon dactylon with a mean value of 15.8% along the parallel strips and 6.5% along the associated radii loops. Eragrostis tenuifolia recovered the most in the 90 run parallel

Table 15: Recovery values for four common species along turning radii loops.

Plot	Species	Mean recovery (%) (vehicle runs) 30	60	t-values
Turning radii loops	*Themeda triandra*	5.3	1.4	1.76 n.s
	Sporobolus pyramidalis	0.4	0.1	1.12 n.s
	Cynodon dactylon	4.5	6.5	0.78 n.s
	Eragrostis tenuifolia	0.3	4.5	7.40*
		(vehicle runs) 60	90	t-values
	Themeda triandra	1.4	0.3	1.70 n.s
	Sporobolus pyramidalis	0,1	0.0	1.87 n.s
	Cynodon dactylon	6.5	1.1	2.22 n.s
	Eragrostis tenuifolia	4.5	7.1	2.55 n.s

n.s not significant at p=0.003 (p>0.003)
* significant at p=0.003 (p<0.003), at 12 degrees of freedom for a two tailed test.

strips and associated turning radii loops with mean cover values of 6.1% and 7.1% respectively.

In order to determine which species had the highest recovery rate, the relative percentage cover for each species was calculated. Cynodon dactylon recovered the most with a value of 41.3%. Themeda triandra recovered fairly well with 27.2%, closely followed by Eragrostis tenuifolia with 25.0%. Sporobulos pyramidalis had the lowest recovery rate of only 6.6%.

3:8 Ecological Impact : An Estimation of Vegetation Cover Loss in the Masai Mara

The formula used in this estimation was adopted by Western in a similar study (1974). The values for the formula adopted by a Western were as follows:

- V= The total numbers of vehicles that entered the Mara in 1989, 23,466.
- r= Average distance driven off-road in km, 67km.
- t= Tyre width of the experimental vehicle, 0.0016km.
- p= Only those areas exposed to high visitation rates were included in this value, 447.4km^2
- L= % loss of vegetation cover per vehicle pass recorded amounted to 1.36% for the wet season and 0.73% in the dry season.

Using the figures above, the approximated loss of vegetation cover in the Mara, due to off-road driving amounted to 15.3% for the wet season in 1989 and 16.4% for the dry season.

3:9 Vehicle Impact on Species Composition

3:9:1 Distribution of Four Key Species Along Existing Tracks in the Sampling Zones

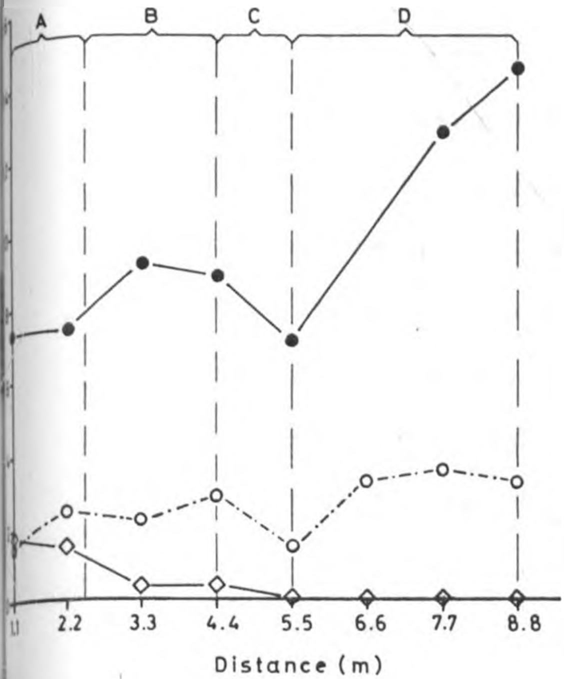
The frequency of four key species was plotted against increasing distance from the tracks for the three categories of track use (High, Intermediate and Low) sampled. These species were Themeda triandra, Sporobulos pyramidalis, Eragrostis tenuifolia and Digitaria velutina. Themeda triandra and Sporobolus pyramidalis are among the most common perennial grasses in the Masai Mara, while Eragrostis tenuifolia and Digitaria velutina are annuals which appeared to be associated with tracks. The distribution of the four species in the four sampling zones was similar. As a result only three graphs, representing the three categories of track use mentioned above (i.e. from one zone), were drawn to show the frequency trends of these species along the existing tracks.

In the low use tracks, frequencies of Sporobolus and Themeda were generally low along the edges of the tracks, and increased towards the centre regions of the tracks where vehicle disturbance was low. At increasing distance from the track edges (adjacent areas), frequencies of both Themeda and Sporobolus increased, though that of Themeda was much higher. Frequency of Eragrostis was higher along the track edges and centres of the tracks, but decreased with increasing distance from the track edges, up to a distance of 5.5 meters, after which, it was absent. Digitaria was absent in the low use tracks (Fig. 12).

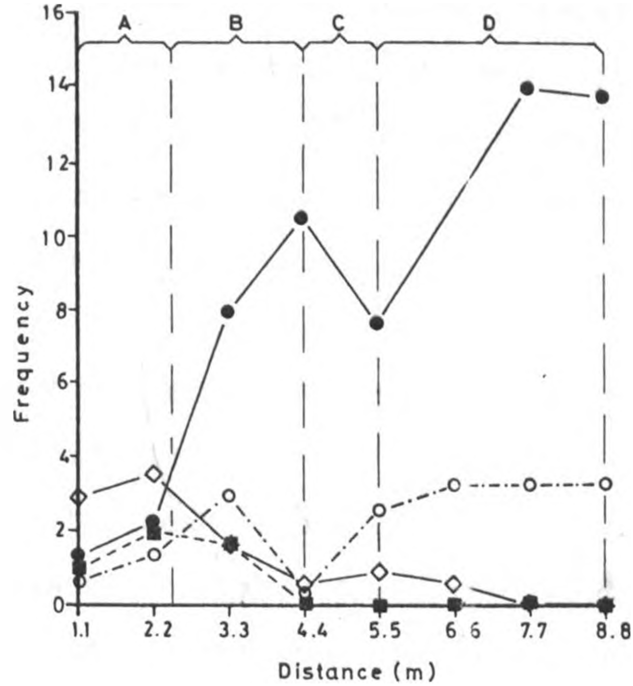
In the intermediate level use tracks, frequencies of Themeda and Sporobolus were low along the edges of the tracks, but increased in the centre regions of the tracks. At increasing distance from the track edges, the frequencies of both species, generally, increased. Frequencies of both Eragrostis and Digitaria were generally higher along the track edges and their

FIG 12: Frequency of four common plant species along thr
categories of tracks.

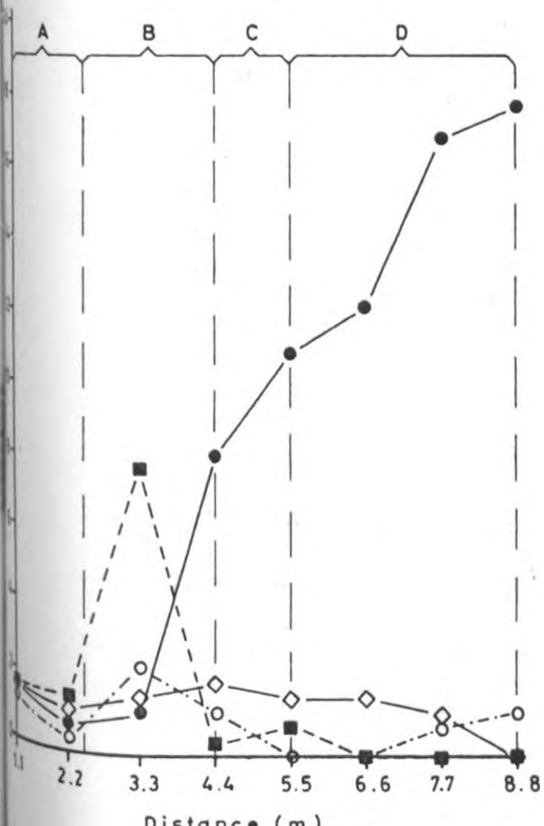
LOW USE



INTERMEDIATE USE



HIGH USE



Key:

A — Edge of track

B — Centre of track

C — Edge of track

D — Adjacent area

●——● *Themeda triandra*

o-·-·-o *Sporobulus pyramidalis*

◇——◇ *Eragrostis tenuifolia*

■- - -■ *Digitaria velutina*

centres, but decreased at increasing distance from the track edges (Fig.12). In the high use tracks, *Digitaria* had the highest frequency in the centres of the tracks. The frequency, however, tended to decrease with increasing distance from the track edges. Frequencies of *Themeda* and *Sporobolus* were very low along the centres of the tracks and along their edges, but increased with increasing distance from the track edges. Frequency of *Eragrostis* did not fluctuate greatly with increasing distance from the track (Fig. 12).

In the three zones, the mean values of vegetation cover for the key species was compared for the three levels of track use using the t-test. In order to reduce the inflation of the error rate due to multiple t-test the Bonferroni´s correction factor was applied and the results are presented below:

(a) Fig Tree - Talek Zone

For all the four species no significant differences in cover between the three categories of tracks (High,low and intermediate use), was noted ($p>0.004$, $n=12$).

(b) Keekorok - Sopa Zone

The mean vegetation cover of *Sporobolus* was significantly different between high and low track use ($t_{(2)}=3.98$, $p<0.004$, $n=12$), but no significant differences were noted between high and low nor between intermediate and high use tracks ($p>0.004$, $n=12$). Vegetation cover of the other three species did not vary significantly between the three categories of track use ($p>0.004$, $n=12$).

(c)Mara Triangle - Serena Zone

Vegetation cover of Themeda, Eragrostis, Sporobolus and Digitaria did not vary significantly between the three levels of track use ($p>0.004$, $n=12$).

3:9:2 Species Diversity of Existing Tracks Sampled in the Four Sample Zones

Species diversity indices obtained from tracks were higher than those obtained from the adjacent areas except in the high use tracks in the Mara Triangle - Serena zone. In this zone species diversity index in the adjacent area was higher than that of the tracks (Table 16).

A t-test was used to compare the species diversity indices of the tracks and the adjacent areas (Table 16). Again the Bonferroni's correction factor was applied in order to reduce the inflation error as a result of multiple t-test. In Keekorok-Sand River zone, there were significant differences between the track and adjacent area in all the three categories of tracks (high, low and intermediate, $p<0.004$, $n=12$, Table 16). Species diversity was higher along the track regions.

In the Fig Tree-Talek zone there was a significant difference between the track and adjacent area in the high use tracks ($t= 5.514$, $p<0.004$), but no significant differences were noted between the track proper and adjacent area in the low and intermediate track use ($p>0.004$, $n=12$, Table 16). In the Keekorok-Sopa area no significant differences were noted between track proper and adjacent areas in the three categories of track use

Table 16: Species Diversity along existing tracks in the Mara.

Sampling zone	Level of Track-use	Spp.Diversity Index track H' proper	Adjacent area H'	D.f	calculated t-values (V)
Keekorok - Sand river	Low	-0.702	-0.5652	652	3.696*
	Intermediate	-0.8277	-0.5067	576	10.151*
	High	-0.7188	-0.6059	1130	4.770*
Fig-tree	Low	-0.7071	-0.6437	712	2.431n.s
Talek	Intermediate	-0.7421	-0.6866	411	2.388n.s
	High	-0.6816	-0.4882	290	5.514n.s
Keekorok-Sopa	Low	-0.5098	-0.4887	239	0.320n.s
	Intermediate	-0.6075	-0.4708	323	2.941n.s
	High	-0.4695	-0.3205	190	3.010n.s
Mara Triangle Serena	Low	-0.6168	-0.5853	746	1.245n.s
	Intermediate	-0.4688	-0.4628	339	0.1926n.s
	High	-0.5325	-0.7070	173	4.418n.s

Indices were compared using the t-test.
n.s. not significant (p>0.004)
* indicates the values are statistically significant at p=0.004 for infinite degrees of freedom for a two-tailed test.

($p>0.004$, Table 16). In the Mara Triangle-Serena zone, again no significant differences were noted between the track and adjacent area in the low use and intermediate use tracks ($p>0.004$, Table 16), however a significant difference was noted in the high use tracks ($t=4.418$, $p<0.004$, Table 16).

Species diversity indices for the three levels of use tracks sampled in the four zones were also compared using the t-test with the Bonferroni's correction factor. In the Fig tree - Talek zone there were no significant differences in species diversity between the three levels of track use (Appendix 10). Similarly there were no significant differences between low and intermediate use and between high and low use ($p<0.004$) in the Keekorok - Sand river zone (Appendix 10) . A significant difference occurred, between intermediate and high use tracks ($t_{(2)}=3.65$, $p<0.004$) in the Keekorok- Sand River area, with species diversity being higher in the high use tracks.

In the Keekorok - Sopa area no significant difference in diversity were observed between the three levels of track use ($p>0.004$, Appendix 10). In the Mara Triangle-Serena zone there was no consequential differences in diversity between intermediate and high use and between low and high use ($p>0.004$, Appendix 10) but a significant difference was observed between low and intermediate use ($t_{(2)}=4.462$, $p<0.004$, Appendix 10). Species diversity was significantly higher in the intermediate use tracks.

CHAPTER FOUR

4:I DISCUSSION

Results from simulation plots reveal clearly that an increase in the number of vehicle passes or runs and speed, led to an increased removal of vegetation cover. Most damage to vegetation cover was caused by the sheer stress at the turning radii loops. This has been reported in similar studies by Western (1978) and Onyenyusi (1980).

Damage to vegetation cover occurred in the variable runs and was higher in the wet season than in the dry season . But in the variable vehicle speeds damage to vegetation cover was higher in the dry season. Vehicle runs during the wet season also created deep ruts which however, was not the case in the dry season. This suggests that the nature of the vegetation cover and the ground surface in the dry season allows it to withstand more vehicle passages, while the vegetation and the ground surface is less tolerant to treading in the wet season. However the results reveal that vegetation is less tolerant to high vehicle speeds in the dry season . Edmond (1962) and Cole (1987), in similar studies in the U.S.A., showed that moisture content was important in determining the degree of visible and physical disturbances and wet areas showed clear signs of disturbance. In terms of visual perception, off-track development in the wet season greatly reduced the scenic beauty of the area.

Off-track movement of tour buses in the Mara Reserve was greatly influenced by the season. During the wet season drivers preferred to remain on tracks which were discernible in order to avoid getting stuck in the mud. In the dry season, however, the drivers did not always follow visible tracks. They formed new tracks in search for game. Damage to vegetation cover as a result of off-track driving was more localised and limited in the wet season. As the wet season progressed, existing tracks already in poor condition deteriorated further and drivers avoided them by driving along their shoulders or along the sides of the tracks. This resulted in formation of one wide track or several other tracks along the main track. This was particularly true in Fig Tree-Talek area, and the Serena-Kichwa Tembo area (Plate 2). Most of the Mara Reserve is easily accessible during the dry season and it is during this time that off-track driving was wide-spread. It appears that most of the off-tracks are formed during the dry season while in the wet season the condition of the existing tracks further deteriorates.

The Mara Reserve has a total length of 582.4 km of official recognised and maintained tracks. An estimated length of unrecognised tracks in the four study zones alone was 1605.09 km. This means that the Mara Reserve has progressively been covered by increased number of unofficial tracks. This is resulting in a reduction in vegetation cover, a change in plant species

Plate 2: During the wet season the condition of some of t
main tracks deteriorates. This forces the to
drivers to drive along the shoulders of the ma
tracks (see plates a & b), or along the side
the tracks (c), particularly along the impassab
sections.

A

B

C

composition and loss of the natural attractiveness of the Reserve as a result of the off-track driving.

Damage to vegetation cover, in terms of dislodging and trampling of grasses, were apparent from the simulation plots. Overall, an estimated loss of vegetation cover amounted to 15.3% for the wet season and 16.45% for the dry season in 1989 alone. This indicated that, in general, vehicle impact on the reserve grasslands was high. In addition to the high ecological damage caused by tour vehicles, the presence of numerous tracks criss-crossing the reserve constituted a large negative visual impact, particularly for the visitors.

Vehicle passes indirectly affected soil properties. The continuous vehicle passes compressed the ground thus increasing soil compaction (Table 8). Increased soil compaction hardened the ground resulting in high penetration resistances. It is clear that changes in soil properties eventually led to a change in plant species composition. Species common on the tracks included Eragrostis tenuifolia which has a shallow root systems and Digitaria velutina which has underground runners.

Studies carried out by Bates (1935) and Salm and Abdullah (1982) showed that species that regenerated on highly compacted soils were those with either shallow root systems or underground runners because very hard ground tends to limit both root penetration and distribution.

From this study it was clear that if an area was left undisturbed for some time, the vegetation cover re-established along the disturbed sites. But recovery of vegetation cover greatly depended on the intensity of disturbance. My assessment of recovery in the simulation experiment sub-plots showed that the ability to recover diminished with increased level of usage (Table 10). This has also been pointed out by Western (1973), Liddle (1975 a & b) Onyenyusi (1980) and Cole (1987).

Level of vehicle use also seemed to influence species recovery. In general Themeda triandra, which is the most common species, recovered well in the parallel strips (wheel-tracks) and turning radii loops subjected to fewer vehicle runs (30 runs), at rates of 5% and 5.3% respectively, but recovered poorly in the 90 run parallel strips and 60 and 90 run turning radii loops. Cynodon dactylon recovered well in the 30 run parallel strips (5.6%) and in the parallel strips exposed to a higher number of vehicle runs (60 runs, 15.8%). At the turning radii loops of 60 and 90 runs, Eragrostis tenuifolia was well established (4.5 and 7.1% respectively). Sporobolus pyramidalis, which was intermixed with Themeda triandra and Cynodon dactylon, recovered poorly in all the variable run parallel strips and turning radii loops. Cynodon dactylon, which was intermixed with Themeda triandra, recovered quite well in all the variable run sub-plots. Cynodon dactylon flourished along both the parallel tracks and turning radii loops which act as localised catchment for rainfall water. Cynodon is probably able to withstand high moisture content which Themeda triandra and Sporobolus pyramidalis cannot (Western pers. comm.). From the simulation sub-plots, Sporobolus pyramidalis displayed very slow recovery compared to the other two perennials (Cynodon and Themeda).

This finding suggests that Sporobolus is more sensitive to disturbance and cannot withstand such disturbance. This may explain why its recovery rate was very low. Other studies on grazing (McNaughton 1979) and trampling (Liddle 1975a, Grime & Hunt 1975) effects show that species which regenerate are usually the fast growing annuals that produce seeds rapidly for colonising bare ground caused by disturbance. This may explain the establishment of Eragrostis tenuifolia in the highly disturbed sections (e.g. turning radii loops) of the simulation experiments. Although determination of recovery was done over a short period of time (after three months), dominant species such as Themeda triandra were the most susceptible to destruction. Bates (1935) and Bayfield (1973), suggested that increased disturbance resulted in reduction or complete removal of the dominant grass in an area. This may explain why Themeda triandra recovered poorly particularly in the 90 run parallel strips and 60 and 90 run turning radii loops.

Further information to supplement the findings of the simulation experiments can be provided by existing tracks in the study area. Tracks resulting from tourist activities over the years provide areas for examination of regeneration. They give information about which species regenerate in disturbed sites. Though plant species in different communities are not identical (Ellenberg & Mueller 1974) the difference in species composition along the tracks and on adjacent areas can be attributed to vehicle disturbance since all other factors such as soil properties, temperature and rainfall were the same. Studies of existing tracks in the Mara Reserve revealed that Eragrostis tenuifolia and Digitaria velutina were commonly associated with tracks. The effect of vehicle use on species composition was localised along the tracks formed. The effect was absent at increased distance from track. Another important species associated with tracks was Chloris virgata. This species appeared during the wet season on the high use tracks. The species occurred along the edges of the tracks where soils washed down by the rain had settled (Plate 3). This is an annual species and has been reported to occur on weathered volcanic soils and disturbed areas of many soil types (Hatch et al 1988). Since it appeared in the wet season, it is possible that the seeds were dispersed by water and germinated along track edges where there was siltation.

Dominant species such as Themeda triandra, Sporobolus pyramidalis, Cynodon dactylon, Chloris

Plate 3 : During the wet season soils are washed down by rain and settle along the edges of the tracks. species noted to occur along the edges where ero soils had settled was Chloris virgata. Note light coloured grass along the center and edge the track (Chloris virgata). Further from tracks is the dominant grass Themeda triandra.

guyana, Bracharia brizantha, Bothriochloa insculpta and Panicum paoeoides occurred either in low frequecies or were completely absent along the tracks. Tracks exposed to low vehicle use (low use), were dominated by Themeda triandra, intermixed with Sporobolus pyramidalis or Chloris guyana all of which are perennials. Annuals such as Eragrostis tenuifolia were present in low densities.

Tracks exposed to intermediate vehicle use, had low frequencies of perennials, while percentage cover of annuals such as Eragrostis was fairly high.

High use tracks, had either very low percentage cover of perennials was or else, they were absent. Annuals, such as Eragrostis tenuifolia and Digitaria velutina were, however, common on these tracks.

Various studies have shown that perennials are generally slow-growing species which cannot survive frequent disturbance such as continuous churning of the ground by tour vehicles (Parmeshwar 1933, Bates 1935, Grime and Hunt 1975). It appears that continuous destruction by vehicles will eventually destroy perennials completely, paving way for other plants (mainly annuals), that can tolerate disturbance. Evidence for this comes from data on species in intermediate and high vehicle use tracks. The more common species along these tracks were Digitaria velutina and Eragrostis tenuifolia which are annual species. This is a clear demonstration that as off-road driving continues to spread, perennials, which are important pasture grasses, will be replaced by annuals which are of less nutrient quality (Fitzgerald 1973; Vickery 1984). This will mean a decrease in biomass availability for the herbivores (Western 1978).

Species diversity in most cases was higher along the track areas than in the adjacent areas. The tracks appear to have provided a heterogeneous habitat that was rich in plant species. In the three levels of track use (high, intermediate and low), species diversity was generally higher in the high use tracks (Appendix 10), though the intermediate level had the highest numner of species. Other forms of disturbance such as grazing (Transley & Adamson 1940) and trampling (Liddle 1975) have also been shown to increase species diversity of a given area.

Results of this study provide strong evidence that the development of tracks destroyed the grassland habitat and resulted in change of plant species composition. Results of the simulation experiments shows that the season and the vehicle variables can cause extensive damage. These experiments further reveal that extensive disturbances influence recovery and brings about a change in species composition. The time required and the number of vehicle passes required to bring about a change in species composition could not, however, be established at the time of the study. Vegetation provides food, water, mineral salts and cover to animals and of these requirements food is the most important (Jarman and Sinclair 1979). When herbivores get less food this is reflected in lower calf survival (McNaughton 1979). A decline in prey number will indirectly affect the predator population. In order to maintain a balance between the prey and predator population, it is important to reduce vegetation damage.

4:2 Conclusion and Management Recommendations

The results of the simulation plots suggest that off-road driving removed 15.3% and 16.4% in the wet and dry season respectively, of the vegetation cover recorded in 1989. The damage will increase if (i) there is an increase in number of vehicles entering the Reserve (ii) if off-road driving is not restricted. Change in plant species composition is also evident along the highly used tracks. Those species regenerating are of low nutritive value to the herbivores. This process is gradual, but if left unchecked, the Mara will lose more of the perennial nutritive grasses such as Themeda triandra, Chloris guyana, Bracharia brizantha, which will be replaced by less valuable annual range grasses such as Eragrostis tenuifolia and Digitaria velutina. Perhaps more important, the development of criss-cross tracks in the Mara will also reduce the naturalness or the aesthetic value of the Reserve. A maze of trucks will reduce the naturalness of the area and will lower the visitors experience.

Wildlife and habitat are the two main amenities of the tourist industry. Wildlife based tourism is a profitable method of exploiting wildlife (Meyers 1975). It is therefore essential to protect and conserve both the animals and the habitat if tourism is to continue playing a role in the economic development of Kenya. It is in this respect that this study makes the following recommendations.

The Reserves management should develop a strict policy on off-track diving. This will hopefully reduce off-track driving. Attempts have been made in Amboseli where the park warden sent those caught off-road driving out of the park with their clients. The efforts of the warden were effective in decreasing off-road driving, particularly in 1973-74 (Henry 1980), but the problem seems to have resurfaced in recent years. This problem can be controlled by constructing viewing tracks, with the aim of enabling the tourist to view wildlife, varying scenery and eliminating unwanted tracks. The tracks in the Mara should be mapped out and a portion of these tracks selected for improvement and upgrading . All-weather tracks should be developed and some of the tracks should be closed during the wet season to avoid ecological degradation. All other tracks should be blocked. This approach will prevent further damage to the habitat. Certain parts of the Park should also be zoned off for rehabilitation, particularly those that are heavily used. In extremely degraded areas access should be blocked entirely.

If the visitors and drivers are to adhere to these regulations, the tour companies, drivers and the visitors should be made aware of the necessity of such restrictions. Information on the impact of vehicles on vegetation should be given to visitors.
This could be made available in brochures, information centres, at the gate and at lodges.

At the national level, the negative impacts of tourism should be included in the curriculum for training drivers, tour guides, and rangers. The knowledge they obtain can benefit their clients and help curtail visitor impact. Such course takes time. Immediate In-service courses should be provided at Utali, Naivasha and at the Research Station in the reserve. Lectures can also be provided to the drivers and tourists in the lodges, particularly in the evening hours, by Narok County Council and Kenya Wildlife Services officers.

The Mara Reserve plays a major role in the development of tourism in Kenya. If this is to continue, attention must be given to the tourist pressures in the Mara and measures taken to resolve them. Further impact will lower the quality of tourism and ultimately reduce tourist numbers and foreign exchange.

In most of the parks in Kenya, visitor distribution is highly clumped. Those habitats exposed to high visitation rates are highly degraded. Animals, particularly the predators located in the highly used parts are also subjected to high visitation rates. Tourist coming to Kenya are willing to pay for a unique experience in the parks, but if congestion, habitat destruction and animal harassment increase visitor will seek alternative, less degraded and congested areas. With other parks opening up in Tanzania, Zimbabwe, Bostwana and South Africa, Kenya can no longer afford to ignore the ecological damage to it's Parks.

Tourism is not necessarily detrimental to conservation, if appropriate planning and management is undertaken. The management of tourism is essential as pointed out by Western and Wesley (1979). A decade latter the tourist industry is booming, but little has been done in way of reconciling conservation and tourism.

The challenge is to avoid degradation of the attractions that the tourism industry relies on. This does not demand a reduction in the number of visitors entering parks. The parks in Kenya can accommodate more visitors if they are redistributed to reduce congestion .

Impacts on the physical and biological resources in the parks should be assessed on a continuous basis. The feedback from this studies can be effective in minimising ecological degradation of the parks.

4:3:1 ISSUES FOR FURTHER RESEARCH.

1. Does Tourism have an effect on the reproductive success of the predators, partioularly the cheetah which is an endanged species.

2. What level of vehicle disturbance and duration is required to change species composition.

3. How tourism is affecting dispersal, home range and territorial sizes of the predators.

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Appendix 1. Mean cover lost as a result of variable runs in the simulation experiments.

Runs	30		60		90	
	P.S	T.R	P.S.	T.R	P.S	T.R
Mean	44.9	54.2	68.7	70.4	85.8	89.0
Ranks	1	2	3	4	5	6

	(1) comparison B vs A	(2) difference ($x_B - x_A$)	(3) q
1	6 vs 1	44.1	15.6*
2	6 vs 2	34.9	13.3*
3	6 vs 3	20.0	7.2*
4	6 vs 4	18.6	6.6*
5	6 vs 5	3.2	1.1n.s.
6	5 vs 1	40.9	14.5*
7	5 vs 2	31.7	11.2*
8	5 vs 3	17.2	6.1*
9	5 vs 4	15.4	5.5*
10	4 vs 1	25.5	9.0*
11	4 vs 2	16.3	5.8*
12	4 vs 3	1.8	0.6n.s.
13	3 vs 1	23.7	8.4*
14	3 vs 2	14.5	5.1*
15	2 vs 1	9.2	3.3n.s.

Mean values for the wet season were compared using the Tukeys test(q),(Zar 1974). D.F=54, k-groups =6, SE= 2.83

Table Format

P.S. represents the mean values of vegetation cover loss along the parallel strips (wheel-tracks).

T.R. represents the mean values of vegetation cover loss along the turning radii loops.

Column 1. represents the comparison between the higher mean(B) and the lower mean(A).

Column 2. represents the difference between the means for each comparison.

Column 3. represents the q test results.

*indicates the values are statistically significant at p=0.05 i.e. ($p<0.05$)

n.s. indicates the values are not statistically significant at p=0.05 i.e. ($p>0.05$)

Appendix 2. Mean cover loss as a result of variable vehicle runs in the simulation experiments.

Runs	30		60		90		120		150	
	P.S	T.R	P.S	T.R	P.S	T.R	P.S	T.R	P.S	T.R
means arc-sine value	21.9	35.6	49.1	54.7	55.0	59.8	60.2	63.7	65.6	84.4
Ranks	1	2	3	4	5	6	7	8	9	10

	(1) B vs A	(2) $(x_B - x_A)$	(3) q
1	10 vs 1	62.5	43.4*
2	10 vs 2	48.9	33.9*
3	10 vs 3	35.4	24.5*
4	10 vs 4	29.7	20.6*
5	10 vs 5	29.5	20.5*
6	10 vs 6	24.6	17.1*
7	10 vs 7	24.2	16.8*
8	10 vs 8	20.7	14.4*
9	10 vs 9	18.8	13.0*
10	9 vs 1	43.8	30.4*
11	9 vs 2	30.1	20.9*
12	9 vs 3	16.7	11.5*
13	9 vs 4	10.9	7.6*
14	9 vs 5	10.6	7.4*
15	9 vs 6	5.8	4.0n.s.
16	9 vs 7	5.4	3.7n.s.
17	9 vs 8	1.9	1.3n.s
18	8 vs 1	41.8	29.0*
19	8 vs 2	28.1	19.5*
20	8 vs 3	14.6	10.5*
21	8 vs 4	9.0	6.3*
22	8 vs 5	8.7	6.1*
23	8 vs 6	3.9	2.7n.s.
24	8 vs 7	3.5	2.4n.s.
25	7 vs 1	38.3	26.6*
26	7 vs 2	24.3	16.9*
27	7 vs 3	11.1	7.7*
28	7 vs 4	5.5	3.8n.s.
29	7 vs 5	5.2	3.6n.s.
30	7 vs 6	0.4	0.3n.s
31	6 vs 1	37.9	26.3*
32	6 vs 2	24.2	16.8*

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Appendix 2. continued,

	(1) B vs A	(2) (x_B-x_A)	(3) q
33	6 vs 3	10.7	7.4*
34	6 vs 4	5.1	3.5n.s.
35	6 vs 5	4.8	3.4n.s
36	5 vs 1	33.2	23.0*
37	5 vs 2	19.4	13.5*
38	5 vs 3	5.9	4.1n.s.
39	5 vs 4	0.3	0.2n.s.
40	4 vs 1	32.8	22.8*
41	4 vs 2	19.2	13.3*
42	4 vs 3	5.7	3.9n.s.
43	3 vs 1	27.2	18.9*
44	3 vs 2	13.5	9.4*
45	2 vs 1	13.7	9.5*

Mean values for dry season are compared using the Tukeys test (q). D.F=90, K-groups =10, SE.=1.44. All other abbreviations are the same as in Appendix 1.

Appendix 3. Mean cover loss as a result of variable speeds (km/h) in the simulation experiments.

Speeds(km/h)	20		30		40		50	
	P.S	T.R	P.S	T.R	P.S	T.R	P.S	T.R
mean (arc-sine) values	44.9	54.2	52.2	70.3	61.2	71.3	69.4	89.0
Ranks	1	3	2	6	4	7	5	8

	(1) B vs A	(2) $(x_B - x_A)$	(3) q
1	8 vs 1	44.1	23.4*
2	8 vs 2	36.8	19.6*
3	8 vs 3	34.8	18.5*
4	8 vs 4	27.3	14.5*
5	8 vs 5	19.6	10.5*
6	8 vs 6	18.7	9.9*
7	8 vs 7	17.7	9.4*
8	7 vs 1	26.3	14.0*
9	7 vs 2	19.1	10.2*
10	7 vs 3	17.1	9.1*
11	7 vs 4	10.0	5.4*
12	7 vs 5	1.9	1.0n.s.
13	7 vs 6	0.9	0.5n.s.
14	6 vs 1	25.4	13.5*
15	6 vs 2	18.1	9.6*
16	6 vs 3	16.1	8.6*
17	6 vs 4	9.1	4.9*
18	6 vs 5	0.9	0.5n.s.
19	5 vs 1	24.5	13.0*
20	5 vs 2	17.2	9.1*
21	5 vs 3	15.2	8.1*
22	5 vs 4	8.2	4.4*
23	4 vs 1	16.3	8.7*
24	4 vs 2	9.0	4.8*
25	4 vs 3	7.0	3.7n.s.
26	3 vs 1	9.2	4.9*
27	3 vs 2	2.0	1.1n.s.
28	2 vs 1	7.3	3.9n.s.

mean values for wet season are compared using the Tukeys test(q). D.F.=72, K-groups=8, SE.= 1.88. All abbreviations are as in **Appendix 1**.

Appendix 4. Mean cover loss as a result of variable vehicle speeds(km/h) in the simulation experiments.

Speeds(km/h)	10		20		30		40		50	
	P.S	T.R	P.S	T.R	P.S	T.R	P.S	T.R	P.S	T.R
mean (arc-sine)	47.9	51.1	51.8	57.4	55.8	65.3	58.1	71.0	65.6	80.7
Ranks	1	3	2	5	4	7	6	9	8	10

	(1)	(2)	(3)
1	10 vs 1	32.8	24.1*
2	10 vs 2	28.8	21.2*
3	10 vs 3	28.6	21.0*
4	10 vs 4	24.9	18.3*
5	10 vs 5	23.2	17.1*
6	10 vs 6	22.6	16.6*
7	10 vs 7	15.4	11.3*
8	10 vs 8	15.0	11.1*
9	10 vs 9	9.7	7.1*
10	9 vs 1	23.1	17.0*
11	9 vs 2	19.2	14.1*
12	9 vs 3	18.9	13.9*
13	9 vs 4	15.2	11.2*
14	9 vs 5	13.6	10.0*
15	9 vs 6	12.9	9.5*
16	9 vs 7	5.7	4.2n.s.
17	9 vs 8	5.4	4.0n. s.
18	8 vs 1	17.7	13.0*
19	8 vs 2	13.8	10.1*
20	8 vs 3	13.5	10.0*
21	8 vs 4	9.8	7.2*
22	8 vs 5	8.2	6.0*
23	8 vs 6	7.5	5.5*
24	8 vs 7	0.4	0.3n.s.
25	7 vs 1	15.3	11.3*
26	7 vs 2	13.4	9.9*
27	7 vs 3	13.2	9.7*
28	7 vs 4	9.5	7.0*
29	7 vs 5	7.8	5.8*
30	7 vs 6	7.2	5.3*
31	6 vs 1	8.2	6.0*
32	6 vs 2	6.3	4.6*
33	6 vs 3	6.0	4.4n.s.
34	6 vs 4	2.3	1.7n.s.
35	6 vs 5	0.7	0.5n.s.
36	5 vs 1	9.5	7.0*

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Appendix 4 continued,

	(1)	(2)	(3)
37	5 vs 2	5.6	4.1n.s.
38	5 vs 3	5.3	3.9n.s.
39	5 vs 4	1.7	1.2n.s.
40	4 vs 1	7.9	5.6*
41	4 vs 2	4.0	2.9n.s.
42	4 vs 3	3.7	2.7n.s.
43	3 vs 1	4.2	3.1n.s.
44	3 vs 2	0.3	0.2n.s.
45	2 vs 1	3.9	2.9n.s.

Mean values for dry season are compared using the Tukeys test(q). D.F.=90, K-groups =10, SE.=1.36. All other abbreviations as in **Appendix 1**.
Columns 1,2 & 3 as in **Appendix 1**.

Appendix 5. The effect for variable runs on soil compaction in the wet season .

Runs	0	30	60	90
Mean compaction values(kg/cm^3)	1.3	1.9	2.3	3.3
Ranks	1	2	3	4

	(1) Comparison B vs A	(2) Difference ($x_B - x_A$)	(3) q
1	4 vs 1	1.96	15.8*
2	4 vs 2	1.39	11.2*
3	4 vs 3	1.00	8.1*
4	3 vs 1	0.96	7.7*
5	3 vs 2	0.39	3.2 n
6	2 vs 1	0.57	4.6*

The mean compaction values were compared using the Tukey's test(q). D.F.=76, K-groups =4, SE.=0.12
All abbreviations are as in **Appendix 1.**

Appendix 6. The effect of variable runs on soil compaction in the dry season.

Runs	0 (control)	30	60	90	120	150
Mean compaction values(kg/cm^3)	2.70	3.16	4.01	4.02	3.74	4.06
Ranks	1	2	5	4	3	6

	(1) Comparison B vs A	(2) Difference (x_B-x_A)	(3) q
1	6 vs 1	1.36	6.18*
2	6 vs 2	0.90	4.09n.s.
3	6 vs 3	0.32	1.46n.s.
4	6 vs 4	0.05	0.23n.s.
5	6 vs 5	0.04	0.18n.s.
6	5 vs 1	1.32	6.00*
7	5 vs 2	0.86	3.91n.s.
8	5 vs 3	0.28	1.27n.s.
9	5 vs 4	0.01	0.05n.s.
10	4 vs 1	1.31	5.96*
11	4 vs 2	0.85	3.86n.s.
12	4 vs 3	0.27	1.23n.s.
13	3 vs 1	1.04	4.73n.s.
14	3 vs 2	0.58	2.64n.s.
15	2 vs 1	0.46	2.09n.s.

Compaction values were compared using the Turkeys test(q), Zar (1974). D.F.=114, K-groups=6, SE.=0.22. All other abbreviations as in **Appendix 1.**

Appendix 7. Effect of variable vehicle runs on recovery of vegetation cover.

Runs	30		60		90	
	P.S	T.R	P.S	T.R	P.S	T.R
Mean (arc-sine)	13.29	10.38	9.18	6.65	5.20	3.66
Ranks	6	5	4	3	2	1

	(1) Comparison B vs A	(2) Difference $X_B - X_A$	q
1	6 vs 1	9.63	10.82*
2	6 vs 2	8.09	9.09*
3	6 vs 3	6.64	7.46*
4	6 vs 4	4.11	4.62*
5	6 vs 5	2.91	3.27n.s
6	5 vs 1	6.72	7.55*
7	5 vs 2	5.18	5.82*
8	5 vs 3	3.73	4.19*
9	5 vs 4	1.20	1.34n.s
10	4 vs 1	5.52	6.20*
11	4 vs 2	3.98	4.47*
12	4 vs 3	2.53	2.84n.s
13	3 vs 1	2.99	3.35n.s
14	3 vs 2	1.45	1.63n.s
15	2 vs 1	1.54	1.73n.s

Tukeys test (q) was used to compare the mean recovery values of vegetation cover for the dry season. (d.f 54, K groups = 6, SE = 0.89). All other abbreviations are as in **Appendix 1**.

Appendix 8. Effect of vehicle speeds on recovery of vegetation cover in the wet season plots.

Speeds Km/h	20		30		40	
	P.S	T.R	P.S	T.R	P.S	T.R
Mean recovery (arc-sine)	19.92	19.69	23.12	31.16	17.04	21.57
Ranks	3	2	5	6	1	4

	(1) Comparison B vs A	(2) Difference X_B-X_A	(3) q
1	6 vs 1	14.12	4.99*
2	6 vs 2	11.47	4.05*
3	6 vs 3	11.24	3.97*
4	6 vs 4	9.59	3.39*
5	6 vs 5	8.04	2.84*
6	5 vs 1	6.08	2.15n.s
7	5 vs 2	3.47	1.23n.s
8	5 vs 3	3.20	1.13n.s
9	5 vs 4	1.55	0.55n.s
10	4 vs 1	4.53	1.60n.s
11	4 vs 2	1.88	0.66n.s
12	4 vs 3	1.65	0.58n.s
13	3 vs 1	2.88	1.02n.s
14	3 vs 2	0.23	0.08n.s
15	2 vs 1	2.65	0.94n.s

The mean recovery values for wet season, were compared using the Tukeys test (q). (d.f = 54, K-groups = 6 SE = 2.83) All other abbreviations are as in **Appendix 1**

Appendix 9. Effect of vehicle speeds on recovery of vegetation cover in the dry season plots.

Speeds Km/h	10		20		30	
	P.S	T.R	P.S	T.R	P.S	T.R
Mean recovery (arc-sine)	16.19	12.44	11.86	7.84	9.22	6.77
Ranks	6	5	4	2	3	1

	(1) Comparison B vs A	(2) Difference X_B-X_A	(3) q
1	6 vs 1	9.42	12.90*
2	6 vs 2	8.35	11.44*
3	6 vs 3	6.97	9.55*
4	6 vs 4	4.33	5.93*
5	6 vs 5	3.75	5.14*
6	5 vs 1	5.67	7.77*
7	5 vs 2	4.60	6.30*
8	5 vs 3	3.22	4.41*
9	5 vs 4	0.58	0.80n.s
10	4 vs 1	5.09	6.97*
11	4 vs 2	4.02	5.51*
12	4 vs 3	2.64	3.62n.s
13	3 vs 1	2.45	3.36n.s
14	3 vs 2	1.38	1.89n.s
15	2 vs 1	1.07	1.47n.s

Mean recovery for Dry season values were compared using the Turkeys test (q) (d.f = 54, K groups = 6 SE = 0.73). All other abbreviations are as in **Appendix 1**.

Appendix 10. Species diversity indices in three levels of track use in the four sampling zones in the Mara Reserve.

Sampling zone	Level of track use	Spp Diversity Index (H′)	t-values
FigTree - Talek	1. Low	-0.687	t_{12}=1.261 n.s
			t_{13}=0.798 n.s
	2. Intermediate	-0.7795	t_{23}=1.850 n.s
	3. High	-0.6459	
Keekorok - Sand River	1. Low	-0.6459	t_{12}=3.224 n.s
			t_{13}=0.491 n.s
	2. Intermediate	-0.6489	t_{23}=3.650*
	3. High	-0.8429	
Keekorok - Sopa area	1. Low	-0.6408	t_{12}=1.441 n.s
			t_{13}=0.601 n.s
	2. Intermediate	-0.4737	t_{23}=2.877 n.s
	3. High	-0.5403	
Mara Triangle-Serena	1. Low	-0.6064	t_{12}=4.462*
			t_{13}=2.094 n.s
	2. Intermediate	-0.5447	t_{23}=1.454 n.s
	3. High	-0.7972	

The indices were compared using the t-test.

Key, (i) t_{12} is the comparison between low and intermediate use tracks.
(ii) t_{13} is the comparison between low and high use tracks.
(iii) t_{23} is the comparison between intermediate and high use tracks.