IMPACT OF HUMAN ACTIVITIES ON THE RANGING BEHAVIOUR OF ELEPHANTS IN THE NILGIRI BIOSPHERE RESERVE, SOUTH INDIA

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(With a text-figure)

INTRODUCTION

Today we find that many animal species throughout the world are threatened with extinction or are becoming increasingly endangered. The situation is even more severe in the developing countries, where the limited resources available for conservation and growing populations with their demand for new land make conservation a truly challenging task. The primary reason for this deplorable situation has been man. Humans have reduced most natural habitats into islands surrounded by land developed for human use. Today, we are faced with a situation where, even if the killing of threatened animals is stopped, there may not be adequate habitat left for them to live in.

An added problem is that of human-animal interactions at the interface of these remaining natural habitats and their surrounding human use areas. As no hard boundaries demarcate the two, there tends to be a diffuse border which results in some animals intruding into the human use areas and causing problems. At the same time humans intruding into the surrounding natural habitat and exploiting its resources results in the degrading of the natural habitat.

The problem caused by animals has been studied in great detail. Taking into consideration only Asian elephants (*Elephas maximus*), studies have been done by Blair *et al.* (1979), Balasubramanian *et al.* (1995); Datye and Bhagwat (1995); Desai *et al.* (1995); Desai and Krishnamurthy (1992); Fernando (1990); McKay (1973); Mishra (1971); Olivier (1978); Ramesh and Desai (1992); Ramesh and Sathyanarayana (1995); Seidensticker (1984) and Sukumar (1985, 1989 and 1990). They range in scope from reporting the problem to quantifying the damage, and discussions on causes for the conflict. The present study does not deal with this issue but looks at how elephants react to human presence and activity within their range.

Studies on the impact of human activities on the adjoining natural habitat have been mostly restricted to the study of human dependence on forests and the consequent degradation of natural habitats (Daniel *et al.* 1987, Johnsingh, Prasad and Goyal 1990, Silori and Mishra 1995, Wesley, Mishra and Johnsingh 1995, Ramesh 1995). While these studies have looked at resource depletion and disturbance, and attempted to relate these factors to the use of the affected areas by elephants, all have failed to take into account the behaviour of elephants. What is lacking in all the earlier research is the study of how elephants actually react to human activities within their ecosystem, while taking into account the social organization and ranging behaviour of elephants.

Social organization and ranging behaviour: In the study area females live in clans while adult males (henceforth referred to as bulls) are mainly solitary. These sub-units (clans and bulls) have different strategies for habitat utilization with well defined home ranges; with seasonal ranges within home ranges and regular routes or migration paths between these seasonal ranges. Thus human impact should affect different sub-units (clans or bulls) differently, depending on the location of their home ranges, seasonal ranges, migration routes, and the degree and type of use of the interface area by individual sub-units and not uniformly by the population as a whole.

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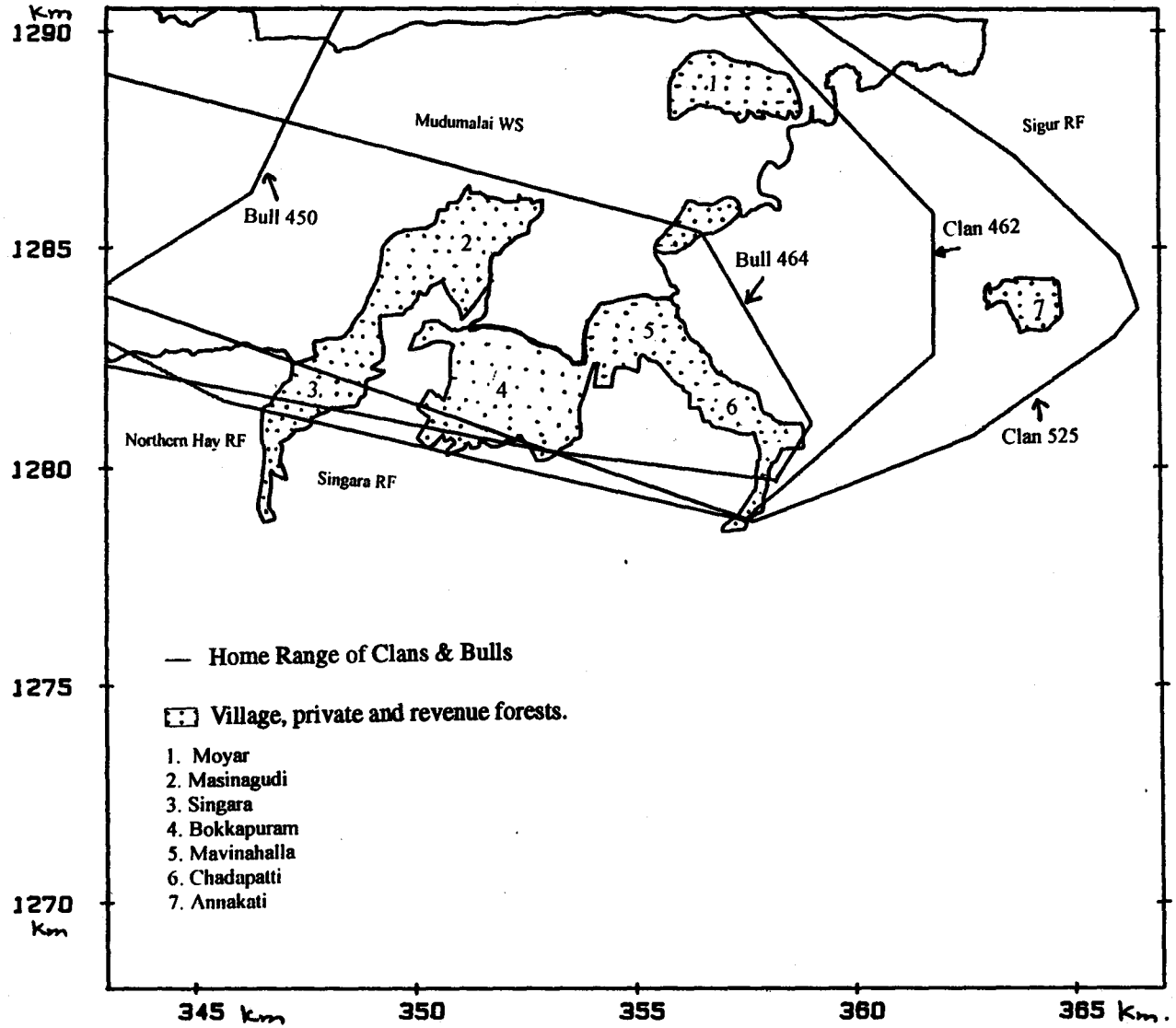

Fig. 1. Study area of Nilgiri Biosphere Reserve

The present study highlights the impact of human settlements and activity on the ranging behaviour (range use) of elephants while taking into account the social organisation and ranging behaviour of the elephants. The findings of this study are not only applicable to the present study area but also to other elephant habitats where elephant ranging still remains normal (not modified by man).

Objective

The main objective was to determine how human activities influence the ranging behaviour of elephants, while taking into consideration that elephant populations have well defined sub-units (clans and bulls) and also that these sub-units have well defined home ranges, seasonal ranges and migration routes within them. We wanted to test the following hypothesis.

Hypothesis: "Clans and bulls use areas with and without human disturbances equally".

Study Area

The Nilgiri Biosphere Reserve lies at the tri-junction of three southern states (Karnataka, Tamil Nadu and Kerala) and covers an area of 5520 sq. km. This area is one of the best elephant ranges for conservation of Asian elephants in Asia (Desai 1991). The study covered the eastern part of Mudumalai Wildlife Sanctuary (MWS) in Tamil Nadu. In addition, the study also covered the adjoining Reserve Forest and Revenue Forest which were used extensively by the study animals.

Mudumalai and the surrounding reserve/ revenue/private forests have a rainfall gradient from 600 to 2000 mm with the western part getting the highest rainfall. The vegetation follows a similar gradient changing from Southern Tropical Thorn Forest in the east to Tropical Moist Deciduous Forest in the west and in between lie the Tropical Dry Deciduous Forests (for details of the study area refer Daniel *et al.* 1987, Sivaganesan 1991).

In the study area there are human settlements within and outside (abutting) the elephant range. These areas vary in size from a few houses to large villages, with a human population of several thousands.

Methods

Study animal: This study was based on the ranging behaviour of two clans (clan 525 and clan 462) and two bulls (bull 450 and bull 464) in the study area. These two clans and two bulls had been radio collared in 1991 along with a third clan (clan 522). Data on various aspects of ranging and behaviour have been collected since 1991 on all these radio collared elephants (Balasubramanian, *et al.* 1995, Baskaran, *et al.* 1995 and Desai *et al.* 1995). The main reason for including only four radio collared animals in the present study was because of their normal ranging behaviour. The fifth animal, Clan 522, had shifted its range (Desai *et al.* 1995) and we felt that it was best not to include it in the present analysis. The two clans represented the ranging behaviour of the females, while the two males, though of different ages, were adults and represented adult male behaviour to a large extent.

Selection of study site: As all the four collared elephants have different (to a certain degree) patterns of ranging, we felt that it would be best to compare their ranging in an area where it had the greatest similarity. In addition, the study site would also have to be an area where human presence (settlements) and human impact on surrounding habitat was most pronounced, so that the elephants' reaction to such areas could be studied easily.

The present study area covered the eastern end of the home range of all four study animals. The cut off point to the west was 76°32' E longitude and extended up to the eastern end of the study animals' home range as defined by *minimum convex polygon* method (Dalke 1938, Mohr 1947). This included the eastern part of Mudumalai Wildlife Sanctuary, Sigur, Singara and Northern Hay Reserve Forests, some Revenue Forests and private forests (Singara estate). Here all the ranges overlap to a large degree and the

influence of habitat and human presence (impact) would be the most common or similar (to a large degree) for all the study animals.

Desai (1991) and Baskaran *et al.* (1995) have shown the importance of home ranges and corridors that facilitate movement of clans and bulls between seasonal ranges. These studies have also highlighted the critical corridors in the Nilgiri Biosphere Reserve (NBR), especially the ones in the northern part of NBR in the Moyar-Masinagudi-Singara area, the same area covered by the present study. This area is a mosaic of human settlements and forests, and over time human activities have spread deeper into the elephant habitat and also increased in intensity. This area provides adequate opportunity for elephants to encounter and react to human settlements and activity.

Analysis: We took into consideration two important variables. First we considered water which is known to play a major role in their distribution (Viljoen 1989, Western 1975 and Williamson, 1975), and as such, water would have a great influence on the way in which clans and bulls used their home range. The second variable was the presence of human settlements (villages) and by extension, human activity and impact on the elephant habitat surrounding these settlements. This would show how the presence of human settlements in an area influenced the elephant's use of the habitat in their vicinity.

Taking these two variables into account, we divided the study site into four areas as follows:

1. Areas < 2 km from a main water source and > 1 km from a village;

2. Areas < 1 km from a village and > 2 km from a water source;

3. Areas < 2 km from a water source and < 1 km from a village;

4. Areas > 2 km from a water source and > 1 km from a village.

These areas are henceforth referred to as "water area", "village area", "water+village area" and "other forest area" respectively.

We considered that the proximity (< 2 km) of a water source or a village (< 1 km) would have maximum influence on the ranging and habitat utilization behaviour of elephants. The influence of both these important factors will certainly extend beyond the distance taken into consideration for the present study but we feel that it would be most apparent and measurable within the distances selected.

The use of these areas was tested for preference and avoidance using the method described by Neu *et al.* (1974) and Byers *et al.* (1984). All four areas were tested together first and then the influence of water and villages were tested separately to study their individual influence on ranging behaviour. All these variables were tested for individual clans and bulls separately.

Study period: The study was carried out from October 1994 to March 1995 (six months) but data from the earlier radio-telemetry study (February 1991 to September 1994) were also used for the analysis.

Results

A total of 471 and 436 locations for Clans 525 and 462 respectively were used for the analysis. For the bulls 464 and 450, a total of 236 and 51 locations respectively were used for the analysis. This data represents only those locations when the study animals were within the present study site and not the entire data set of their ranging within their complete home range.

Of the different areas, "water+village area" (20.8%) and "village area" (4%) together constituted 24.8% of the study site. Human dependence on water is clearly highlighted by the fact that nearly 86% of the village area (area <1 km from a village) lies within 2 km from a water source. Thus nearly a quarter of the study area was within 1 km of a village and therefore exposed to high levels of human activity and subject to severe human impact on the habitat. Of the remaining 75.2% of the study area, "water area" constituted nearly 39.6% while 35.6% was "other forest area". All clans and bulls had access to all these areas, bull 450 did not use the easternmost area of the study site, but (unpublished) data collected

TABLE 1
AVOIDANCE AND PREFERENCE SHOWN TO DIFFERENT AREAS BY CLAN 525.

Area type	Exp. use	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	186.41	248	0.396	0.469	0.584	*
"water+village"	98.15	95	0.208	0.155	0.248	
"village"	18.74	1	0.040	0.000	0.007	*
"other forest area"	167.63	127	0.356	0.219	0.321	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 2
AVOIDANCE AND PREFERENCE SHOWN TO DIFFERENT AREAS BY CLAN 462

Area type	Exp. use	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	172.56	320	0.396	0.681	0.787	*
"water+village"	90.86	51	0.208	0.078	0.155	*
"village"	17.35	1	0.040	0.000	0.008	*
"other forest area"	155.17	64	0.356	0.104	0.189	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at <0.05.

TABLE 3
AVOIDANCE AND PREFERENCE SHOWN TO DIFFERENT AREAS BY BULL 464

Area type	Exp. use	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	93.40	39	0.396	0.105	0.226	*
"water+village"	49.18	124	0.208	0.444	0.607	*
"village"	9.39	50	0.040	0.145	0.278	*
"other forest area"	83.99	23	0.356	0.049	0.146	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05

TABLE 4
AVOIDANCE AND PREFERENCE SHOWN TO DIFFERENT AREAS BY BULL 450

Area type	Exp. use	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	20.18	34	0.396	0.502	0.832	*
"water+village"	10.63	1	0.208	0.000	0.068	*
"village"	2.03	1	0.040	0.000	0.068	
"other forest area"	18.15	15	0.356	0.135	0.454	

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05

TABLE 5

AVOIDANCE AND PREFERENCE SHOWN TO "WATER" AND "WATER+VILLAGE" AREAS BY CLAN 525

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	224.66	248	0.655	0.669	0.777	*
"water+village"	118.30	95	0.345	0.223	0.331	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 6

AVOIDANCE AND PREFERENCE SHOWN TO "WATER" AND "WATER+VILLAGE" AREAS BY CLAN 462

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	243.00	320	0.655	0.822	0.903	*
"water+village"	127.65	51	0.345	0.097	0.178	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 7

AVOIDANCE AND PREFERENCE SHOWN TO "WATER" AND "WATER+VILLAGE" AREAS BY BULL 464

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	106.76	39	0.655	0.164	0.314	*
"water+village"	56.22	124	0.345	0.686	0.836	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 8

AVOIDANCE AND PREFERENCE SHOWN TO "WATER" AND "WATER+VILLAGE" AREAS BY BULL 450

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
"water"	22.92	34	0.655	0.908	1.035	*
"water+village"	12.07	1	0.345	0.000	0.092	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05

on it by one of us (AAD) in the years prior to radio collaring indicated that it did use this area earlier before radio collaring.

Tables 1 to 4 give the results of the test to determine the preference and avoidance shown by the study animals to the four different areas, namely water, water+village, village and other forest areas.

We tested to see the impact of human settlements on area within 2 km of water (an important resource for elephants) by testing just two classes, those areas < 2 km from water and > 1 km from a village, and those areas < 2 km water but < 1 km from a village i.e. "water" and "water+village" areas. This was necessary as villages are often in close proximity to water, which attracts elephants to the vicinity of such villages, and this leading to a bias in the results. Tables 5 to 8 give the results showing the preference and avoidance shown to areas under these two categories.

We also examined the impact of human settlement by testing the preference and avoidance shown to areas <1 km from human settlements and other areas > 1 km from human settlements irrespective of the presence of water in both the areas. Tables 9 to 12 give results of the four study animals.

TABLE 9
AVOIDANCE AND PREFERENCE SHOWN TO AREAS <1KM AND > 1KM FROM VILLAGE (HUMAN HABITATION) BY CLAN 525

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
village < 1km	116.92	96	0.248	0.162	0.245	*
village > 1km	354.07	375	0.752	0.755	0.838	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 10
AVOIDANCE AND PREFERENCE SHOWN TO AREAS <1KM AND > 1KM FROM VILLAGE (HUMAN HABITATION) BY CLAN 462

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
village < 1km	108.23	52	0.248	0.084	0.154	*
village > 1km	327.76	384	0.752	0.846	0.916	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 11
AVOIDANCE AND PREFERENCE SHOWN TO AREAS <1KM AND > 1KM FROM VILLAGE (HUMAN HABITATION) BY BULL 464

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
village < 1km	58.58	174	0.248	0.673	0.801	*
village > 1km	177.41	62	0.752	0.199	0.327	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

TABLE 12
AVOIDANCE AND PREFERENCE SHOWN TO AREAS <1KM AND > 1KM FROM VILLAGE (HUMAN HABITATION) BY BULL 450

Area type	Exp. use.	Obs. use	EPU[1]	LCL[2]	UCL[3]	S[4]
village < 1km	12.66	2	0.248	0.000	0.100	*
village > 1km	38.34	49	0.752	0.900	1.022	*

[1]EPU = Expected proportion of use. [2]LCL = Lower Confidence Limit. [3]UCL = Upper Confidence Limit. [4]S = Significant at P<0.05.

DISCUSSION

The habitat in the study site can be divided into two main areas based on the criteria selected for this study, namely areas close to water (areas with water < 2 km away) and areas away from water (areas with water > 2 km away). Assuming that the vegetation in the two areas remains similar to a reasonable degree, we can expect variations in the area-use to be influenced by the availability of water.

Within these two areas a second variable, human settlements can be introduced. Here we

assume that human impact will be most pronounced on the surrounding natural habitat within a distance of 1 km from the boundary of the settlement. This creates two additional areas from the original two, i.e. areas with water < 2 km and < or > 1 km from villages (i.e. "water" and "water+village" areas) and forest areas > 2 km from water and < or > 1 km from villages (i.e. "village" and "other forest areas"). It is important to note that most of the villages are located close to water sources as human beings are also very dependent on water. This creates a situation where the influence of human settlements are mostly present close to water, only 16% of the area within 1 km of a village was > 2 km from water while 84% was < 2 km from water, therefore human settlements affect areas closer to water more than they do areas away from water.

The importance of water for clans is evident from Tables 1 and 2, both the clans show significant preference to "water" areas while avoiding "other forest areas". This indicates the importance of water for clans. This is similar to the findings of several studies on African elephant (*Loxodonta africana*) which have shown that ranging is strongly influenced by water availability (Viljoen 1989, Western 1975, Williamson 1975). Most of these studies were carried out in semi-arid areas where water is fairly scarce. Though the importance of water and its influence on the ranging behaviour of the Asian elephant has been suggested by some authors it has not been substantiated by data. Given the abundant and closely spaced water sources in Asia, as compared to those of the African studies, it was important to determine the influence water has on the ranging behaviour of Asian elephants, especially in view of the importance of water for humans also and their tendency to locate their settlements close to water.

If elephants are significantly dependent on water then the management implication would be to look at the water distribution in conservation areas with a view to provide or facilitate the uniform distribution of water resources in the area. In the NBR which is dominated by deciduous forests water is patchily distributed and if the management objective is to maintain high elephant numbers it would be better to facilitate more uniform use of the available habitat rather than patchy use, with concentrations in patches and the resultant elephant impact on these patches. We would like to emphasize that increasing elephant numbers cannot be indefinitely supported by limited habitat irrespective of uniform or patchy use of habitat. We are only suggesting that higher numbers can be maintained with less impact on habitat if their use of the habitat is more uniform than patchy, by virtue of patchy water distribution.

In the case of bulls, bull 450 showed significant preference for "water" areas but used "other forest areas" in the expected proportion, showing neither avoidance nor preference (Table 4). But bull 464 showed significant avoidance to both "water" and "other forest areas" (Table 3). This does not show an overall avoidance to water as it showed strong preference for "water+village" areas (Table 3) indicating that water does play an important role in its range use strategy.

Considering the proximity of villages to water and the importance of water to elephants we can expect elephants to use some areas close to villages as they need water. This is seen in clan 525 which shows use of "water-village" areas at the expected proportion (Table 1) while bull 464 shows preference for such areas (Table 3). Clan 462 and bull 450 significantly avoided "water+village" areas (Tables 2 and 5 respectively). We further tested "water" and "water+village" areas separately to see if the study animals avoided them. Both the clans 525 and 462, and bull 450 significantly preferred "water" areas while avoiding "water+village" areas (Tables 5, 6 and 8 respectively), indicating that the presence of a village near water significantly reduced the use of that area. Bull 464 was just the opposite and significantly preferred to use "water+village" while avoiding "water" areas (Table 7). This bull was a chronic crop raider and was always present in the vicinity of villages. Whether the presence of the bull in this area was a result of its crop raiding habit or because its core home range incidentally happened to be located in that area is open to debate.

Since the presence of villages has a significant impact on the ranging behaviour of elephants, we tested to see if villages were avoided irrespective of the presence or absence of water in the habitat. As already mentioned villages are closely linked to water and this would, to some degree, bias the results in favour of elephants using areas around villages more than areas further away from water. Only 16% of the area around (< 1 km) villages was > 2 km from water while 47.3% of the area > 1 km from villages was > 2 km from water. Despite this bias we find that clans 525 and 462, and bull 450 used areas away from villages (> 1 km away) significantly more than areas close to villages (< 1 km away), indicating that areas around villages are avoided by elephants (Tables 9, 10 and 12).

Earlier studies (Balasubramanian *et al.* 1995) have shown that these two clans and bull 450 do not raid crops and that their home ranges are to a large extent intact. We can, therefore, reasonably conclude that clans and bulls whose home ranges have not been disrupted significantly and whose ranging and behaviour remains normal will avoid using areas around human settlements. Human settlements and activity within the elephants' habitat has a detrimental impact on elephants directly by rendering the surrounding habitat unusable to elephants. Considering that the area of human influence (< 1 km from a village) in the present study site is 24.8% of the area, it represents a significantly large part of the habitat being unavailable to normally ranging elephants. This loss is even more significant if we consider that nearly 84% of this area is < 2 km from water, an area highly preferred by elephants. So human settlements not only deny the use of significantly large areas they also deny the use of significantly important (preferred) areas for elephants.

Only bull 464 showed a significant preference to areas < 1 km from villages while avoiding areas > 1 km from villages. As already mentioned, this bull was a regular crop raider and whether its use of such areas was a function of its core home range being in such areas or because of its raiding behaviour is debatable. To say the least, this bull came into regular conflict with humans and was shot at, as are most chronic crop raiders and frequently injured, resulting in the bull not coming into musth in the two years of study. This would translate into loss of reproductive success at a time when the bull was supposed to be in its prime breeding phase of life.

The results do not support the hypothesis "Clans and bull use areas with and without human disturbances equally". Overall two clans and one bull avoided areas < 1 km from human settlement even when such areas were within 2 km from a water source, an area preferred by all study animals. Only bull 464 showed a preference to areas close to human settlement, but whether its use of such areas was a function of it core home range being in such areas or because of its raiding behaviour is debatable.

Conclusions and recommendations

1. The availability of water is a major factor in the elephants' strategy of range use. Clans and bulls with normal (not man modified) home ranges significantly prefer areas closer to water than away from water. This can be interpreted as, water governs elephant distribution and range utilization.

Water, especially in the deciduous forests is patchily available and this results in patchy use of habitat by elephants. The elephants impact on vegetation is therefore uneven over the protected area. If elephant populations in protected areas are to be maintained at high levels then it is better to ensure that the elephants' utilization of the habitat (and resultant impact) is more uniform. One waterhole in a forage rich, water deficient, low use area is more useful than ten waterholes in an existing high use area (Desai 1995).

2. Human settlements have a dual impact on elephant habitat. The directly visible and measurable one is that of habitat loss through conversion of elephant habitat for human use. The second which is equally, if not more, harmful but rarely visible is that of area denial. Human influence and impact on elephant habitat extends well beyond the boundary of human use areas (village and agriculture) into the

surrounding elephant habitat. Normally ranging clans and bulls significantly avoided areas close to human settlements, resulting in vast areas being denied to the elephants

In addition, human settlements are almost always in close proximity to water sources as humans are also dependent on water. As already mentioned areas close to water are the preferred areas for elephants, loss of such areas has much more serious impact on elephants than areas away from water. Thus human settlements not only deprive the elephants of the use of significantly large areas of habitat but also deprive them of significantly preferred habitat.

Managers should try and ensure that new settlements are not allowed within or adjoining protected areas as the actual detrimental impact of the settlement extends well beyond the settlement's boundary. If new settlements are a must (tribal resettlement, etc.) then these should be attached to existing human use areas rather than creating new enclaves which would have the problem of larger perimeters and therefore area of influence, and at the same time create problems in new areas. It should also be remembered that the growing human population and development of existing settlements will also result in the expansion of the area of influence of these settlements, as human impact will extend from the settlement with increasing demand for resources from the natural habitat.

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References

Balasubramanian, M., N. Baskaran, S. Swaminathan & A.A. Desai (1995): Crop raiding by Asian elephant (*Elephas maximus*) in the Nilgiri Biosphere Reserve, India. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

Baskaran, N., M. Balasubramanian, S. Swaminathan & A.A. Desai (1995): Ranging behaviour of elephants and its implication for the management of Nilgiri Biosphere Reserve, India. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

Blair, J.A.S., G.G. Boon & N.M. Noor (1979): Conservation or cultivation: the confrontation between Asian elephant and land development in peninsular Malaysia. *Land Development Digest 2*: 27-59.

Byers, C.R., R.K. Steinhorst & P.R. Krausman (1984): Clarification of a technique for analysis of utilization-availability data. *J. Wild. Manage, 48*: 1050-1053.

Dalke, P.D. (1938): The cottontail rabbits of Connecticut. State of Connecticut. *Geological and Nat. Hist. Surv. Bull. 65*: 1-97.

Daniel, J.C., A.A. Desai, N. Sivaganesan & S. Ramesh Kumar (1987): The study of some endangered species of wildlife and their habitat - The Asian Elephant. Report 1985-1987. Bombay Natural History Society, Bombay.

DATYE, H.S. & A.M. BHAGWAT (1995): Estimation of crop damage and economic loss caused by elephants and its implications in the Management of elephants. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

DESAI, A.A. (1991): The home range of elephants and its implications for the management of the Mudumalai Wildlife Sanctuary, Tamil Nadu. *J. Bombay nat. Hist. Soc. 88 (2)*: 45-56.

DESAI, A.A. (1995): Final Technical Report: Consultancy on elephant management and research including radio-telemetry. FAO project 001/GEF/SRL/UNO. FAO. Colombo. Sri Lanka.

DESAI, A.A. & V. KRISHNAMURTHY (1992): Elephants in Meghalaya State, India: Status, conservation and conflict with agriculture. In the Asian Elephant: Ecology, Biology, Disease and Management. Proceedings of the National Symposium on Asian elephants. Eds. Silas. E.G., M. Krishna Nair and G. Nirmalan. Kerala Agricultural University, Trichur.

DESAI, A.A., M. BALASUBRAMANIAN, N. BASKARAN & S. SWAMINATHAN (1995): Radio-telemetry: Elephant Ecology: Final technical report 1991-1994. *In*: Daniel *et al.* Ecology of the Asian Elephant Final Report - 1995, Bombay Natural History Society, Bombay.

FERNANDO, A.B. (1990): Past and present interactions, location and intensity. Proceedings of the Seminar on the Conservation of Elephants Sri Lanka. Colombo, Sri Lanka. Dept. of Wildlife Conservation, Ministry of Land, Irrigation and Mahaweli Development and USAIS.

JOHNSINGH, A.J.T., S.N. PRASAD & S.P. GOYAL (1990): Conservation of Chillah-Motichur corridor for elephant movement in Rajaji Corbett National Park area, India. *Biol. Conserv. 51*: 125-138.

MCKAY, G.M. (1973): The ecology and behaviour of the Asiatic elephant in southeastern Ceylon. *Smithsonian Contribution to Zoology 125*: 1-113.

MISHRA, J. (1971): An assessment of annual damage to crop by elephants in Palamau District, Bihar. *J. Bombay nat. Hist. Soc. 68*: 307-310.

NUE, C.W., C.R. BYERS & J.M. PEEK (1974): A technique of analysis of utilization-availability data. *J. Wild. Manage. 38*: 541-545.

OLIVIER, R.C.D. (1978): On the ecology of the Asian elephant. Ph.D. thesis, University of Cambridge, Cambridge.

RAMESH, S.K. (1995): Resource partitioning and utilization by Elephant and people. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

RAMESH, S.K. & A.A. DESAI (1992): Elephant translocation in Tamil Nadu, using the drive method. In the Asian Elephant: Ecology, Biology, Disease and Management. Proceedings of the National Symposium on Asian elephants. Eds. Silas, E.G. M. Krishna Nair and G. Nirmalan. Kerala Agricultural University, Trichur.

RAMESH, S.K. & M.C. SATHYANARAYANA (1995): Crop raiding pattern in Hosur and Dharmapuri forest divisions, Dharmapuri District, Tamil Nadu. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

SEIDENSTICKER, J. (1984): Managing elephant depredation in agricultural and forestry projects. A World Bank Technical paper. ISSN 0253-7494. The World Bank, Washington DC., USA.

SILORI, C.S. & B.K. MISHRA (1995): Pressure and resource dependency of Masinagudi group of villages on the surrounding elephant habitat. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

SIVAGANESAN, N. (1991): The ecology of the Asian elephant in the Mudumalai Wildlife Sanctuary, with special reference to habitat utilization. Ph.D. thesis, Bharthidasan University, Trichirapally.

SUKUMAR, R. (1985): Ecology of Asian elephant (*Elephas maximus*) and its interaction with man in south India. Ph.D. thesis, Indian Institute of Science, Bangalore.

SUKUMAR, R. (1989): Ecology of Asian elephant in south India. I. Movement and habitat utilization pattern. *Journal of Tropical Ecology 5*: 1-18.

SUKUMAR, R. (1990): Ecology of Asian elephant in south India. II. Feeding and crop raiding pattern. *Journal of Tropical Ecology 6*: 33-53.

VILJOEN, P.J. (1989): Spatial and movements of elephants (*Loxodonta africana*) in the northern Namib Desert region of the Kaokoveld, South West Africa/Namibia. *J. Zool. Lond. 219*: 1-19.

WESLEY SUNDARRAJ, S.F., B.K. MISHRA & A.J.T. JOHNSINGH (1995): Johnsingh Elephant use of Rajaji - Corbett forest corridor, North West India. *In*: Proceedings of the International Seminar on the Conservation of the Asian Elephant. Mudumalai Wildlife Sanctuary, June 1993. Bombay Natural History Society, Bombay.

WESTERN, D. (1975): Water availability and its influence on the structure and dynamics of a savannah large mammal community. E. Afr. Wildl. J. 13: 265-286.

WILLIAMSON, B.R. (1975): The condition and nutrition of elephant in Wankie National Park. *Arnoldia, Rhodesia 7*: 1-19.