

THE ENVIRONMENTAL LIMITATIONS AND FUTURE OF THE ASIATIC LION¹

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(With six text-figures)

These findings first appeared in a more expanded thesis form in 1972, and were distributed to the respective government and non-government agencies which had assisted in the study. At about the same time the shorter version given here was submitted for publication, intended as one of several papers to be prepared by the various research staff at the Gir Ecological Research Station that were to appear in a special issue of the Journal. However, for a number of reasons, not the least of which was funding, the project did not come to fruition.

More than a decade has since passed, during which time there has been great changes in the Gir Sanctuary. Thanks to far sighted government action, the numbers of lions are now up, the population of other wildlife are improved and the habitat is substantially richer and more luxuriant. However, rather than re-write the report to reflect the changes, it has been decided to publish the original version in order to best describe the conditions as they originally existed during the three year study period, and to report separately on the results of a more recent, but less exacting study, carried out over a period of less than one month.

INTRODUCTION

This study was undertaken because of an interest in investigating the problems and ways of conserving an endangered species. The Asiatic lion (*Panthera leo persica*) was chosen from the International Union of Conservation of Nature Resources list of rare and endangered species in 1966, in consultation with Dr. Lee Talbot, Mr. Noel Simon and others. It was thought to be a typical example of an endangered mammal because more than half of the recently extinct mammals were predators, and most of these were large (Talbot 1959). The Asiatic lion was suitable for an intensive study because, although rare, its dis-

tribution was concentrated into a single 1300 km area in Gujarat State, western India. There had also been repeated requests to have it investigated (Daniel 1956, Talbot 1959, Spillet, unpublished report; Indian board for wildlife in 1956).

ACKNOWLEDGEMENTS

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DESCRIPTION AND HISTORY

The Asiatic lion resembles the African with only a few apparent differences. Along the

length of the abdomen it has a prominent fold of skin which seldom is found in African lions. Comparing the skulls, in African lions, as in all mammals, there is only one infra-orbital foramen below the eyesocket on each side, while Todd (1965) found that in more than fifty per cent of skulls of Asiatic lions taken from the single remaining population there was pairing of either one or both of the infraorbital foramen (fig. 1). Behaviorally

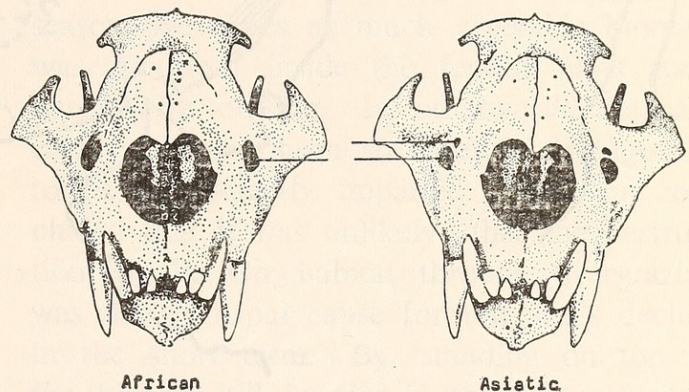


Fig. 1. Comparison of infraorbital foramen between lion skulls from Africa and from the Gir Sanctuary. they are astonishingly docile and tolerant of visitors on foot, the means by which most visitors see them. A few lions have actually been touched in the wild. The adult males are responsible for nearly all the potential territorial advertisement, such as roaring, scraping or spraying of scent, whereas among African lions Schaller (1972) has found that such advertisements are by no means limited to the males alone.

The range of the Asiatic lion once extended from Syria, across the middle east to eastern India (fig. 2). However between 1850 and 1900, when firearms came into popular usage, most of the lions were killed, although a few dwindled on in Iran until 1942 (Heaney 1943). Credit for the survival of lions in the Gir hills in Gujarat State, was due to the limited hunting permitted by the Nawab of Junagadh on whose land the lions existed. At the time of



Fig. 2. Known distribution since 1781.

independence the area was designated a reserve, and in 1965 it was upgraded to be called the Gir Forest Wildlife Sanctuary.

POPULATION SIZE AND DECLINE

In June 1968 the Gujarat State Forest Department undertook a census of the lion population and concluded that there were approximately 177 lions remaining within the 1265 sq. km. sanctuary and surrounding lands. This count was about 40 per cent lower than any of the previous counts within recent years. To verify their enumeration I made five estimates of the size of the lion population. Three estimates were ascertained from road counts, counts at waterholes and density assessments of known prides. The fourth and fifth assessments were extrapolated from an approximation of the total amount of domestic bovids

consumed per year and two estimates of the amount of food required per lion per year. The object in making five estimates was to partially overcome the problem of known and unknown biases and sources of error associated with any one estimate. The average of the five determinations was 190, or not significantly different from the government count. That the government was also right in pointing out a decline was evident by the marked decrease in the lion's range. In 1955 half the lion population counted was found outside the present boundary of the reserve, while in 1968 only 17 per cent of the total lion population could be located outside. Moreover lions could no longer be found in the Girnar range to the north or in the Mithila range to the east where in 1955 they still existed.

POISONING

The decline could not be attributed to hunting, as there had not been any for many years. Instead poisoning was blamed, especially by the news media. Lions were attacking domestic stock which resided both in and around the sanctuary, and occasionally the owners would retaliate by poisoning their losses, and allowing the lions to feed. However when I examined the government files on each case between 1963 and 1969 I found that poisoning was rare, or at least its discovery was rare, for only an average of one case of foul play was uncovered per year. Certainly such incidental cases would not bring about a reduction in the lion population. However poisoning was dramatic. It involved both adult lions and young. It brought about police action and court proceedings. In essence it lent itself to popular attention.

OVERGRAZING

When Dr. Lee Talbot visited the area briefly in 1956, he was aware even then that the lion population was declining, and he provided an alternative explanation. By standing in the middle of the sanctuary in the dry season one can see either a teak forest, or an acacia scrub forest. By moving more towards the edge of the sanctuary much of the forest gives way coincidental with the sharp build up in the concentration of domestic graziers. Outside the sanctuary one sees almost no forest. Talbot (1959) reported that the amount of overgrazing and associated misuse was so bad that within a mere 20 years the Gir Forest would be gone, and with it the lions. However he had come only at the height of the dry season, when conditions looked particularly bad. He did not have a chance to see

how tenaciously the forest hangs on aided by the monsoon rains. So attuned had evolution adapted the Gir forest to the clockwork onset of the monsoon that in the weeks before its arrival more than 50 species of trees and scrubs would begin growing new shoots and fighting back.

From 1968 to 1970 Hodd (1970) monitored the effects of overgrazing by fencing some areas and comparing the amounts of growth inside and outside. During the first growing season five times as much vegetable biomass was produced inside the fenced plots compared with outside. In other words the sanctuary had not been so severely damaged as to be permanently impaired. Thus he concluded that it was unlikely that the destruction of the Gir habitat through overgrazing was the principal cause for the lion's decline in the short term. By, standing on top of the highest hill in Gir in the monsoon and seeing how extensive and productive the forest still appeared with 13 of the 20 year prediction having passed, it was apparent to me that perhaps a century or more would pass before overgrazing could totally destroy the forest. So another more important reason for the lions' decline had to be sought.

CULTIVATION

The most likely contender was the 'green revolution'. The replacement of grazing land by cultivation meant the displacement of range, cover and more importantly the wild and domestic animals upon which the lion depended for food. Black cotton soil, one of the best substrates for crop development, formed a major part of the surrounding low lying areas, and in a country where man was hungry it would have been surprising if these lands were not converted to crops.

I made several reconnaissance flights over the southern boundary of the sanctuary, which was fairly typical of the areas surrounding the sanctuary. It was only possible to take oblique aerial photos. In any single photograph, therefore, the actual amount of cultivated land existing below could not be determined. However by taking a large number of photographs at random so that any one land use had as much likelihood of being in the foreground or background as the next, and averaging the results, it was found that approximately 70 per cent was cultivated. Of that remaining only 13 per cent appeared suitable for lions—that is forest, scrub and riverside cover. The rest was largely denuded fragments of limited value to lions.

The 'green revolution' was in progress outside the sanctuary, and it was outside where the bulk of the lion population had disappeared since 1955. Where lions still existed on the outside was in the few remaining forested regions adjoining the sanctuary which had not yet been cleared for cultivation.

Within the sanctuary the extent of cultivation was very limited. By combining my findings from oblique aerial photos with estimates made by forest department surveyors in 1968 and 1970, and allowing for areas of overlap, I estimated that six per cent of the sanctuary was either cultivated or allocated for development. Such a limited amount of damage to the sanctuary was not of much consequence to the indigenous lion population. However, since much of the cultivation was in the processes of expanding, it is reasonable to assume that it would have serious repercussions if not curbed.

SIZE AND COMPOSITION OF PREY POPULATION

WITHIN SANCTUARY

In the dry season some 49500 ungulates

were estimated to be using the sanctuary daily, consisting of approximately 11 per cent wild ungulates and 89 per cent domestic bovids. The species composition was 53 per cent buffalo, 30 per cent cow, 5 per cent oxen, 8 per cent spotted deer and 3 per cent other wild and domestic species, including nilgai, sambar, wild boar, four-horned antelope, Indian gazelle, camel, horse, sheep and goat.

The wild ungulate population was assessed by night road counts in 1968 and the species composition crosschecked with casual counts made mostly in daytime, and counts at water-holes. Extrapolating for the sanctuary I estimated there were approximately 5600 wild ungulates. The following year Berwick repeated the road counts. His population estimate did not differ significantly from my own (Berwick and Jordan 1971).

The number of resident domestic stock was assessed by counting the animals in a sample of 20 villages during the evening milking period when all were corralled, and extrapolating for the sanctuary. A second determination was made by extrapolating from the 178 km sampled area to that of the total sanctuary. The two figures, which were within six per cent of each other, averaged 19650. Similar assessments were made for the forest settlement village stock which bordered the sanctuary and the non-resident stock which grazed within the sanctuary for part of each day. These totalled 5550 and 18700 animals respectively.

FOOD HABITS BASED ON FAECAL ANALYSIS

I next looked at the diet of the lion as reflected in their faeces. Over 1800 carnivore scats of unknown species origin were collected. From a sample of 95 scats of known species origin, be it lion, leopard, hyaena or dog, it

was found that 90 per cent of the lion faeces measured 45 mm or more in diameter, while the other species were all smaller. Applying this dimension to the unknown sample, I then selected 480 faeces which I could assume were of pure lion origin. The next task was to identify the prey species which they contained from the remnants of hair.

After trying various methods, it was found that hair cross sections were the best means for identification. For example buffalo hair was characterized by its oval shape, grey medulla, slight pigmentation of the cortex due to cortical pigment granules, and an average cross sectional length of about 90 microns. Nilgai hair, in contrast, was less oval in shape, with a black medulla which was slightly pointed and flattened on one side, a cortex without pigment, and an overall cross sectional length averaging 140 microns. Sambar hair was highly elongated in cross section, the medulla divided into 30 or more segments, and occupying most of the cross section leaving only a thin cortex. The cross sectional length averaged 300 microns or more.

After working out a reliable key and applying it to the sample of lion faeces, it was found that some 75 per cent contained hair of domestic stock, which was not at all surprising considering the preponderance of domestic stock which had been shown to exist in the sanctuary.

LION PREDATION ON DOMESTIC STOCK

I next offered rewards to cattle graziers for cooperating in an inquiry into their domestic losses. Those graziers who reported lion kills within 24 hours of the event, and took me to see them were given ten rupees. This was a very productive part of the study. Information was gathered on some 330 car-

casses and data established on some 18 variables, ranging from type of prey, age, time of attack, where killed in relation to the village of origin, where killed in the sanctuary, amount of carcass eaten, etc. With the aid of a 360/50 computer a systematic analysis of the data was made by associating each variable against each of the other 17. Those results which are of primary importance are discussed here.

Prey selection : Cow, buffaloes and to a lesser extent oxen were attacked more often than other domestic prey. In a sample of 330 animals 40 per cent were cows, 41 per cent were buffalo, 13 per cent were oxen and only 6 per cent consisted of the combined totals of camel, sheep, goat, horse and dog. Because the latter five species were very much in the minority in the live population, their poor representation in the kill record was to be expected. However, sheep, goat, and dog were all small prey of little or no value to the herdsmen, and hence might not have been considered worth reporting (although I paid an equal reward for all cases investigated). It was illegal to graze sheep within the sanctuary, which may have contributed to there being no reports of sheep loss.

Sixty-one per cent of bovid kills were from sanctuary villages, 25 per cent from villages outside the sanctuary, and 14 per cent from forest settlement villages. Stock from sanctuary villages remained inside the sanctuary, and hence were always available to lions, while stock from outside villages came into the sanctuary for only variable parts of each day, and never at night, thus accounting for their poor representation among lion kills. Few animals were from forest settlement villages probably because they contained only 10 per cent of the available prey population.

The three village classes, sanctuary nesses,

forest settlement villages and villages outside the sanctuary, also kept different proportions of cows, oxen and buffalo. To determine the lions' food preferences, I compared the kill records with the bovid stock maintained by each class of village. While predation always reflected prey abundance to some extent, cow and oxen were preferred over buffalo in all three village classes (fig. 3). The probability of obtaining

herd in 61 per cent, buffalo occupied the middle and rear in 81 per cent, and herdsmen occupied the middle and rear in 93 per cent. In other words, adult cows were located where the protective influence of herdsmen was weakest. Moreover cow and oxen herds normally fled when attacked, while buffalo herds were commonly belligerent towards lions, sometimes succeeding to drive them away before the herdsmen came to their rescue. Ninety-seven per cent of 32 herds consisting only or mostly of cows were reported to have fled when attacked while 36 per cent of 75 herds consisting only or mostly

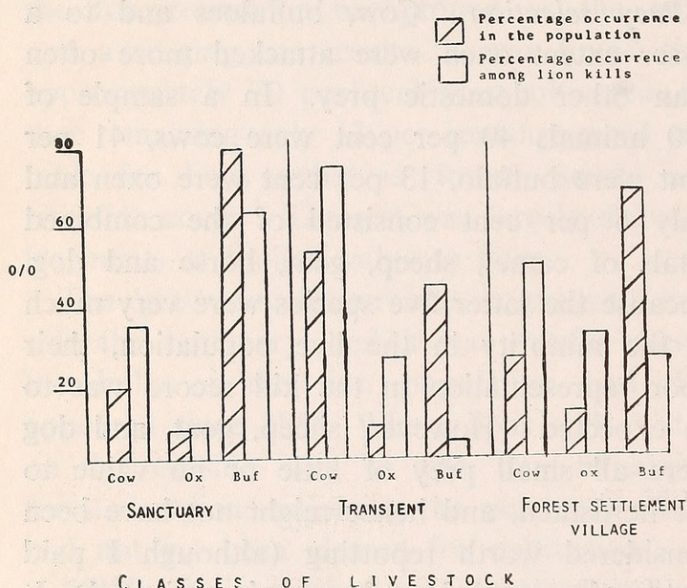


Fig. 3. Lion selection of prey from three classes of livestock.

such a result three times due to chance was less than 0.02. Averaging the results for the three village situations, twice as many cows and oxen were killed as would have been expected if they were killed directly in proportion to availability, while the proportion of buffalo kills was less than half that expected.

There was evidence that cow and oxen were more available than buffalo. First, their placement within the herd was at greater risk to predation. Miss Dorothy Brewster (pers. comm.) collected data on the position of cow, buffalo and herdsmen within herds. In a total of 27 observations she found that adult cows predominantly occupied the front of the

S T O C K

Adult (N = 135)

Young (less than 5 years) (N = 74)

S Sanctuary village

F Forest settlement village and non-sanctuary village

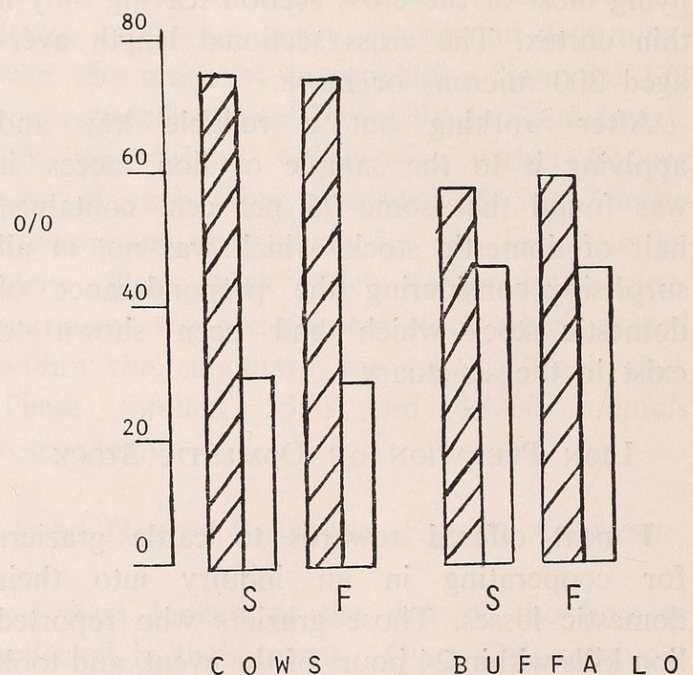


Fig. 4. Percentage occurrence of adult and young stock among lion kills from two village classes (S and F) and for two types of prey.

of buffalo behaved aggressively. Seven of 8 herds consisting only or mostly of oxen fled when under lion attack. While oxen thus appeared to exhibit little defence, these data were too few to be conclusive. However, it was further substantiated by 96 per cent of 24 herds containing mostly cows and some oxen, which fled when under attack.

Age selection : Thirty-seven per cent of 240 kills of bovid stock examined for age were young animals less than five years old. The true proportion of young animals killed was probably higher because herdsmen valued mature animals more highly, and were more likely to report their loss, despite an equal reward offered for the report of kills of any age. In sanctuary villages 41 per cent of the live bovid population and 35 per cent of kills were young stock.

More young were available inside villages than outside, and this was reflected in 20 per cent more young killed inside villages than outside (number of cases investigated = $N = 240$; Chi square = $X^2 = 4.47$; degrees of freedom = d.f. = 1; probability of occurrence = $p < 0.05$). Lions killed approximately 20 per cent more young buffalo than among cows. The same pattern emerged no matter whether the losses were from villages inside or outside the sanctuary (fig. 4). Lions killed approximately 40 per cent more young among oxen than among buffalo ($N = 126$; $X^2 = 6.44$; d.f. = 1; $p < 0.05$), excluding those cases where oxen had been left alone overnight outside villages. Under such favourable conditions lions killed all stock regardless of prey type or age. A disproportionate number of adult oxen had been left out overnight, while only an insignificant number of buffalo and cows had been left out. The selection of young oxen was largely due to their greater availability. In daytime most adult oxen were employed

outside the sanctuary either as plough animals or to draw carts.

Time of attack : In the 24 hour cycle there were two peaks in the numbers of prey attacked. Twenty-three per cent of attacks occurred between 0630-1130 hours and 33 per cent between 1530-1930 (fig. 5). A number

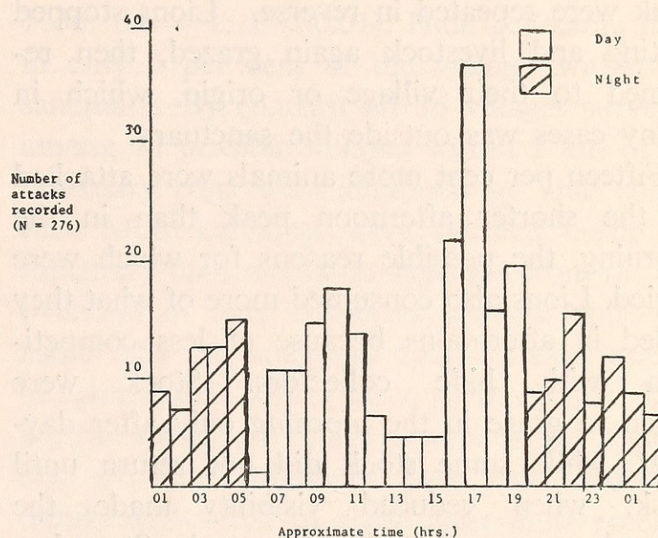


Fig. 5. Number of lion attacks upon domestic stock during each hour of the 24 hour cycle, as reported by herdsmen.

of factors accounted for these peaks. In the morning there was a build up in attacks, starting from a minimum at approximately 0600 hours and increasing to a maximum by 1000 hours. This was associated with the increase in the number of animals grazing in the sanctuary. Few attacks were made between 1130-1530 hours, when the combination of high air temperatures and direct exposure to the sun was most severe. Of those attacks which occurred between 1130-1530 hours, all but one took place either in the monsoon or early in the cool season, when daytime temperatures were moderate (less than 29°C). In the hot season most lions rested in shade through the middle of the day. The herdsmen also contributed to the lack of contact between predator and prey by

resting their stock for approximately 2 hours during that time.

Between 1530-1730 hours there was a dramatic build up in numbers of attacks, followed by an appreciable decline over the next 3 hours. At the same time the pattern of activities which paralleled the morning's peak were repeated in reverse. Lions stopped resting and livestock again grazed, then returned to their village or origin, which in many cases was outside the sanctuary.

Fifteen per cent more animals were attacked in the shorter afternoon peak than in the morning, the possible reasons for which were varied. Lions also consumed more of what they killed in afternoons because of less competition with hide collectors. Stock were taken to graze in the morning only after daylight, while some stock did not return until dusk, when reduced visibility made the animals more vulnerable to attack. Stragglers were more apparent in herds by mid afternoon than in the morning, and perhaps were not given all the due care and attention by the herdsmen who were tired and anxious to return home. It was also apparent that herdsmen allowed their stock less time to graze in the afternoon, and instead kept them moving. This both increased the likelihood of a lion encounter and made conditions more unfavourable for stragglers attempting to keep up.

Only 39 per cent of attacks were made at night (approximately 1930-0530 hours). These included 11 night attacks not recorded in figure 5 because the herdsmen did not know at what hour the attack occurred. Lions were much more active at night. However, their domestic prey, which had moved about the sanctuary in daytime, was confined to village corrals at night. Only by entering the periphery of villages was it possible for lions to make an

attack at night. Secondly, before any animals could be attacked, lions had to penetrate either thorn scrub fencing or rock walls which had been used as corral material specifically to prevent predation. An thirdly, much of the stock which had grazed within the sanctuary in the daytime was unavailable at night because it had been taken to villages outside the sanctuary.

Within villages the fewest night attacks occurred between 1930-2030 hours, presumably because herdsmen were not yet bedded down for the night. Some stock were also attacked outside villages at this time because a few herdsmen were late in returning their stock from grazing. No pattern was discernible among attacks in the remainder of the night. However this may have been because herdsmen were unable to estimate the time of attacks at night with much accuracy unless they occurred early.

Food consumption: Although 74 per cent of kills were reported to have involved more than one lion, the meat available was poorly utilized. In a sample of 173 kills, lions ate nothing from 24 per cent and 1-10 kg from approximately 22 per cent (table 1). Lions ate less from prey killed at night. They ate nothing

TABLE 1

AMOUNTS CONSUMED BY LIONS FROM EACH KILL

Amount removed from carcass	Number of animals	Adjusted per cent Per cent	
Nothing	42	24	24
1 - 5 kg	13	8	11
6 - 10 kg	13	8	11
A large portion (approx. half)	33	19	26
Fully utilized	35	20	28
Some	37	21	—
Total	173	100	100

from 41 per cent of night kills, 19 per cent of kills made between sunrise and noon, and 2 per cent of kills made between noon and sunset. Lions ate more than 10 kg from 11 per cent of night kills, 30 per cent of morning kills, 45 per cent of afternoon kills.

At night lions obtained most of their prey from villages. Few animals killed inside villages were eaten, while most animals killed outside villages were fed upon. The pattern was similar for carcasses from which lions ate more than 10 kg. Feeding was completely prevented in villages unless the prey was dragged outside the fences before the lions were driven off. Lions were able to feed better by day when stock was out grazing, but still lost substantial amounts.

Hide collectors: Lions failed to eat much of what they killed in the day time, because they were driven off by the graziers and because hide collectors appropriated the carcasses for the hide and meat. Herdsmen reported that they attempted to drive lions away in 72 per cent of 169 lion attacks. Once driven off, lions sometimes did not return or did so only after some time had passed. In the did so after a period of absence. In the meantime the herdsmen informed hide collectors who paid them for the meat and hide. If lions were present when hide collectors arrived, they drove the lions off. Hide collectors claimed 56 per cent of 210 kills examined. They did not bother so much with calves as with adults ($N = 168$; $X^2 = 3.07$; d.f. = 1; $0.1 > P > 0.05$). The largest hides also represented the greatest amounts of potential lion food. Whenever hide collectors claimed lion kills outside villages, lions fed from fewer livestock and ate lesser amounts. Lions were more successful in feeding from afternoon kills because hide collectors were sometimes

informed too late to claim the carcasses before dark.

Lions utilized 25 per cent more kills inside the sanctuary than outside ($N = 177$; $X^2 = 7.82$; d.f. = 1; $P < 0.01$), probably because hide collectors claimed about 25 per cent fewer kills inside than outside ($N = 210$; $X^2 = 7.36$; d.f. = 1; $P < 0.01$). Hide collectors lived in only 5 per cent of the villages within the sanctuary. By contrast all 36 villages surveyed among 70 possible villages within 2 km of the sanctuary edge were inhabited by hide collectors. More carcasses were claimed inside the sanctuary than would be expected from the distribution of hide collectors because collectors came into the sanctuary from outside, mainly to claim cattle belonging to their villages. During the village to village census of the population of hide collectors each hide collecting family was asked to show their most recently collected skin and asked the cause of death. The skin was examined for evidence of tooth impressions and claw marks. In a total of 100 such hides examined, 20 to 25 per cent I classified as lion kills. In otherwords lion kills were representing quite a sizeable part of the hide collector's livelihood. Any program that recommended preventing them from approaching lion kills would have to take this account.

Hide collectors did not take the meat if the distance to carry it was too great, or they already had meat at home. However when meat was left it was usually taken by vultures, predominately white backed vultures (*Gyps benghalensis*), and only rarely by lions. Hide collectors attracted vultures by pulling carcasses into the open. Skinned carcasses were easily eaten by vultures. It took only 13-30 minutes to consume three adult bovids. In contrast less than 3 kg was consumed by

vultures from two intact adult bovids after 30 minutes of intense activity. Vultures were able to penetrate the hide only at the anus, mouth, nostrils, eyes and ears. Even after the abdominal cavity of a third carcass had been penetrated, they consumed less than 20 kg in 3 hours. These marked differences in the rates by which vultures were able to consume skinned and unskinned carcasses was corroborated by Dr. Robert Grubh (pers. comm.).

Compensation: Payments were made by the Gujarat government to herdsman whose bovid stock had been killed by lions. Its purpose was to discourage the herdsman from poisoning lions in retaliation, and so maintain the system of lions preying on domestic stock with the minimum of hardship to the herdsman. The number of reported cases of poisoning averaged about one per year, as pointed out earlier in this paper; presumably of minor importance to the lion population as a whole. Whether such a low level was attributable to compensation payments was questionable. When I asked herdsman who lost stock whether they intended to request assistance, only 49 per cent replied in the affirmative. In many cases the herdsman only had to walk 100 m from my office to the government office in order to make notification. They could have been paid compensation of Rs. 100-250 for each animal, while I only offered Rs. 10 for the opportunity of seeing their loss, independent of the number of animals involved. Probably fewer than 49 per cent of the people whom I did not interview applied for compensation, because my sample consisted of herdsman who had shown initiative in the first place.

Many complained about the compensation system. Few understood the conditions for eligibility, all had to wait months for payment, and when it was not forthcoming they

were rarely told why. The sanctuary superintendent kindly made available the application records between April 1969 and January 1971. In that time 430 applications were received, and 25 per cent rejected. Compensation was not given to those;

- a) whose stock was killed more than two furlongs (approximately 400 m) from their village;
- b) who possessed more than 20 head of stock;
- c) who lived outside the sanctuary, but grazed their stock more than two furlongs inside the sanctuary;
- d) who lost camels, goats, horses and other non-bovids.

Sixty-two per cent of 252 lion kills which I examined were further than two furlongs from the village of origin. Ignorant of the importance of distance, 45 per cent of herdsman who lost stock beyond two furlongs said they were intending to apply for compensation. Similarly in 35 per cent of 150 cases herdsman possessed more than 20 animals. None knew that they were not eligible for compensation. These results show that the compensation system was of limited practical benefit to herdsman.

THE EFFECT OF FOOD LIMITATIONS ON THE LION POPULATION

Considering first the adult male lions, they were far more active than their female counterparts, moving about twice as often, and averaging more than double the distance travelled per move. Males usually travelled either singly or in pairs, and attempted to keep out all other mature males. As far as food procurement went, when they killed an animal and the herdsman drove them off, they simply moved on and killed again some place else. They

also appropriated kills made by lionesses whenever they came across any. Although there were far fewer adult males in the population than there were adult lionesses, I believe they regulated their numbers by driving males out of the area. They especially persecuted sub-adult males nearing maturity, which if driven out of the pride before they were old enough would starve for lack of success in food procurement. I rarely saw sub-adult males over two years of age.

Lionesses in contrast were more sedentary because of having to raise cubs. They had to procure more food than males in order to maintain both themselves and the cubs. Additionally whenever a lioness with cubs killed an animal and was driven off by a farmer, she usually had to kill locally because a lioness's method of feeding solid food to cubs is to bring them to the kill site, greatly limiting the size of area over which she can hunt. By having to fetch cubs, lionesses also gave hide collectors more time to get to the carcasses before being extensively damaged. In short, in contrast to the males, food procurement for lionesses was difficult. The ones who suffered were the cubs.

Of 45 lions seen in the field which were less than 18 months old, 29 were between 1-6 months, 11 between 7-12 months and 5 between 13-18 months. Assuming that the sample representative of the population, and these figures are a reflection of mortality rates, then 53 per cent of cub mortality occurred between 1-6 months and 7-12 months, and another 17 per cent between 7-12 months and 13-18 months. These results agreed reasonably well with observed losses. Ten out of 17 cubs first seen between 1-3 months were missing and presumed dead within 12 months after birth. (These results do not include mortality at birth for which there are no data.) In contrast, in three years only one

adult lioness was known to have died in my study group of 16 adults.

POPULATION TREND

Although the lions have dramatically declined outside the sanctuary. I do not know, apart from there being a very high cub mortality, what effect the serious food limitations are having on the lion population within the sanctuary's boundaries, because little reliable data existed on which to determine the population trend. However, in lieu of the magnitude of the food limitations, it is reasonable to err on the side of conservation, and assume that the impact on the lion population is significant.

Ever since the first estimate of the lion population size was made in 1936, investigators have attempted to make trend determinations by comparing new estimates of the population size with the old. However absolute numbers are very difficult to measure. Moreover all but one of the counts has been based on one method—lion recognition on the basis of track size—which in itself makes comparisons between counts suspect unless differences are exceedingly gross, such as the three fold reduction in lion numbers outside the sanctuary boundary in recent years.

However assessing the trend by no means needs to be dependent on any knowledge about actual population size. For example, changes over time in the number of lion tracks and scats found along roads, or changes in the number of cattle killed by lions in villages are alternative, easier ways to determine change in the lion population size.

In 1971 I estimated data on lion tracks, scats and kills as a base against which future

changes could be assessed. Considerable effort was made to simplify and streamline the means of gathering data in a standardised manner that could be easily repeated.

Track recognition: Before assessing the density of lion tracks, it was necessary to

develop a method for differentiating lion tracks from leopard, the only other species with which it can be easily confused. Separation of lion from leopard tracks was done on the basis of size. Firstly each of nine sets of tracks of known leopard origin never exceeded

- + Lion
- o Leopard
- . Lion or leopard

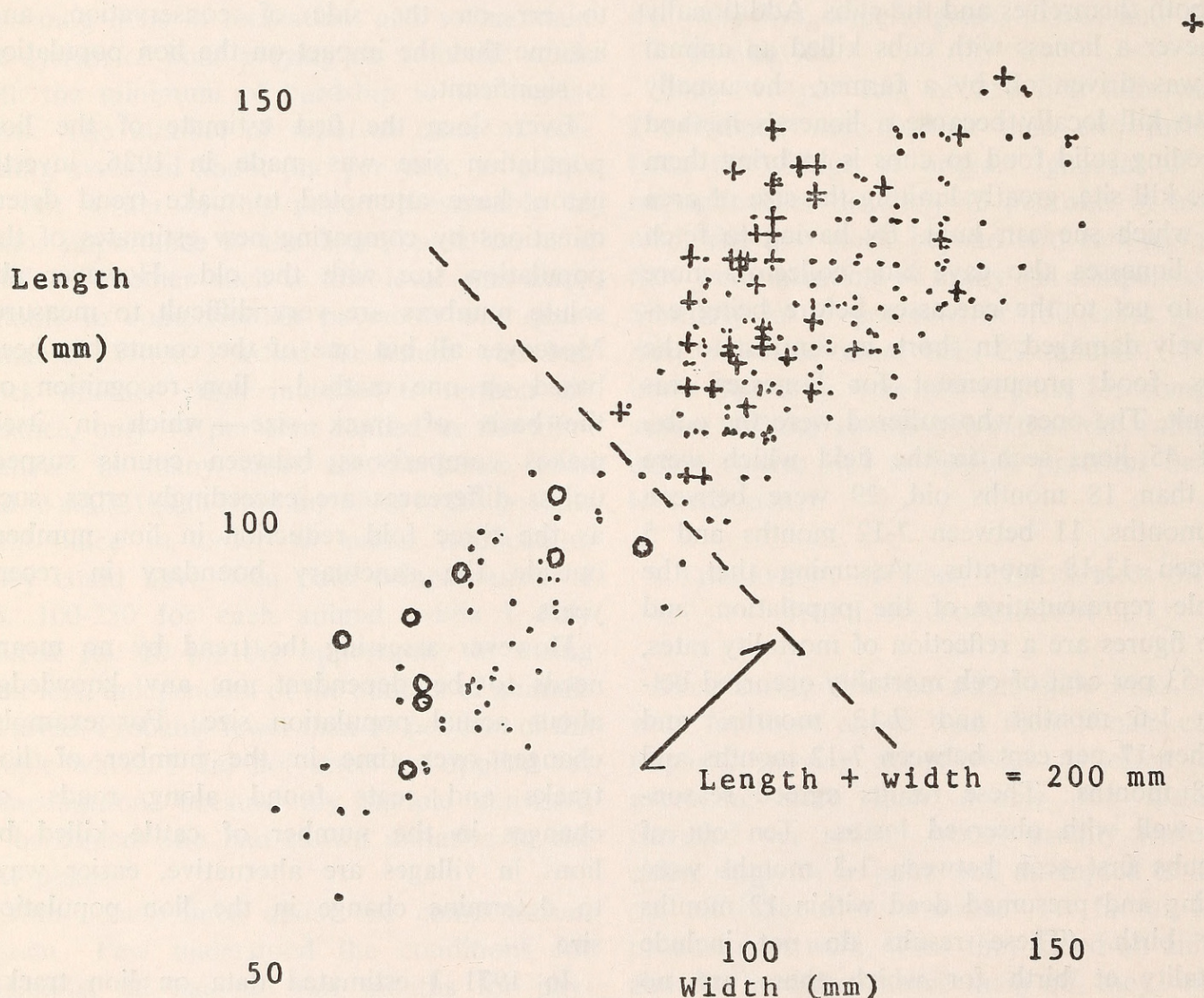


Fig. 6. Dimensions of lion and leopard tracks.

200 mm when length and width were added, while 41 sets of tracks of known lion origin exceeded this minimum. Secondly 212 recorded tracks of either lion or leopard origin indicated a bimodal distribution which separated at approximately these limits (fig. 6). Almost all of the tracks falling within the leopard size range were of solitary animals, while those falling within the lion size range were frequently of animals in groups, reflecting the difference in social behaviour between leopards and lions.

Assessment of track and scat numbers :
In April 1970, 275 km of road crossing all major types of habitat within the sanctuary, except hilltops, were surveyed for scats and tracks. The survey was repeated in February 1971, covering most of the routes which had been searched the previous year. It was designed so as to make the minimum use of labour in finding sign while restricting track and scat identification to myself. Each morning at dawn I stationed 4-6 men at 4-8 km intervals along a route to be surveyed; approximately 20 km being surveyed daily. Early morning was chosen before cattle or vehicular traffic destroyed tracks. Each enumerator marked the beginning of his route and walked the distance to the start of the next beat. Scats were similarly marked. After the men had walked their beats I drove the length of the route, stopping at each location to identify tracks and scats and to record the location in kilometers when tracks were found. I assumed that all cat tracks having a length and width totalling greater than 200 mm and all scats which had a diameter greater than 4.5 cm (see 'food habits based on faecal analysis') were lion.

While both track and scat assessments were made along roads, and therefore had some of the same limitations, there were however

important differences. Tracks recorded in the morning indicated only the presence of lions in the area the previous night. Scats indicated the presence of lions over several days. Miss Dorothy Brewster kindly assisted me by finding that the average time taken for scats to disintegrate or be destroyed was 6.7 days in a sample of 94 initially fresh scats inspected once daily. Another difference was that the number of scats was affected by the size of pride, whereas in the method used in assessing track density no discrimination was made between one or more lions travelling the same distance at the same time.

Seven hundred and fifty-five kilometres were travelled for track assessments; the presence or absence of tracks was recorded in units of one kilometre; 111 kilometres with tracks were recorded; on average lion tracks were found in every 7.2 km surveyed.

In order for the density of tracks to be used in determining the trend of the lion population it is essential that a constant relationship exist between the number of tracks recorded and the number of lions present. However the number of tracks which could be recorded depend on several factors. For example, the nature of the substrate determined the visibility of tracks. When the ground was soft and dusty, lions sometimes left hundreds of tracks, while on stony ground only a few were visible. The presence or absence of tracks was for this reason recorded in units of 1 km, assuming that any lion which walked some portion of this distance would leave at least one visible track.

Track density was also a function of topography and the presence or absence of alternative routes, such as buffalo trails and dried creek beds. Large, slightly raised roads appeared to be walked less by lions than smaller roads at grade level. Lions some-

times used roads to cross streams. They may often have travelled on roads in areas of teak forest to avoid a noisy walk over a forest floor of dried leaves. In addition the behaviour of lions also varied from making no use of roads on some nights to walking three or more kilometres on other nights. The biases could not be easily removed, but they could be averaged and made constant by increasing the total distance surveyed until local variations in track density had no significant effect on the average density of tracks recorded. Variations in the ratio of lion track-kilometres over kilometres surveyed leveled out after 200 km had been searched.

Five hundred and fifty-one kilometers were travelled for scat assessments, and 86 scats were collected, an average of one scat in every 6.4 km. As with lion track-kilometres, variations in the ratio of lion scats over kilometres surveyed leveled out after 200 km had been searched.

The methods used in assessing scat and track densities ignored the influence of cubs. Lions whose scats had a diameter of less than 4.5 cm and whose track total length and width was less than 20 cm were not recorded. In the case of scats it was my impression that this eliminated most cubs below one year old. Young cubs were usually kept in hiding, so their tracks and scats were rarely seen along roads. When not in hiding, cubs usually travelled in the company of lionesses and so were not detected because the method of assessing track densities did not take group size into account. Failure to record evidence of cubs means that the data can only be used to determine the trend of the adult lion population. This limitation may be highly desirable from the standpoint of management, if the stability of the lion population in the

long term is more dependent upon the stability of the adult population.

Assessment of lion kills : One method was to ask herdsmen the number of days or weeks since their last animal was killed. In this method herdsmen had to recall both the event and the day. Because herdsmen find it difficult to remember dates, I used another, more laborious method. Each herdsmen was visited twice. The first time each herdsman was asked to participate in a scheme to record his losses, and given a certificate to reinforce the occasion of our meeting. Within approximately 10-15 days each herdsman was visited a second time, and his losses recorded for the intervening period. Because the time interval was known, the herdsmen was only required to remember whether an animal had been killed and not when. The time between visits was short to ensure that the event was fresh in the herdsmen's mind, and could be confirmed. Data on the rate of killing was collected in February-March 1971 in all six districts within the sanctuary, involving a sample of 49 villages. Every herdsman in each village was interviewed.

Twenty-seven kills were recorded in 652 days assessed, an average killing rate of 0.55 animals per village, or an estimated 15.1 animals per village per year. The average killing rate per village in the time interval between visits leveled out after 30 villages had been visited. The average number of days between kills was 24, and this figure became more or less constant after data for 400 days had been assessed.

RECOMMENDATIONS

Outside the sanctuary nothing is being done about the expansion of cultivation, nor should there be, although there can be little doubt

that this has been the major cause for the lion's decline. Food for people is far more important than food for lions, particularly in light of present severe shortage.

Within the sanctuary cultivation is of some concern, for although it occupies less than 6 per cent of the area, much of it is illegal and rapidly expanding. Most cultivated lands encroaching upon the boundary are associated with forest settlement villages, which have themselves developed largely since the turn of the century. It is strongly recommended that further expansion be curbed.

In 1972 the government of Gujarat sanctioned the construction of a wall around parts of the sanctuary which should greatly assist the forest department in combating illegal encroachment by cultivators, as well as curb the influx of cattle. Also sanctioned was a proposal to relocate to the outside of the sanctuary the majority of the indigenous cattle graziers along with their stock. Both of these actions should help a great deal in bringing the impact of cattle grazing within the sanctuary more in line with the carrying capacity of the land, removing the long term problems of overgrazing. While the Gujarat government is to be commended on its plan, the effects of even a limited reduction in domestic stock numbers on the lion population should be carefully studied, because of the lion's high dependence on domestic stock for its own survival. The earliest descriptions of Gir refer to cattle being there in large numbers, which makes it even more imperative that the reduction be very carefully monitored as to its impact on the lion.

The food chain is further complicated by the large amount of food stuffs imported into the sanctuary each year. Herdsmen interviewed in 50 villages reported feeding a daily average of 3.8 kg of cotton seed and ground

nut to each adult buffalo and smaller amounts to cow and oxen, or an estimated 19 million kg fed to all domestic bovids within the sanctuary each year.

As a result of having demonstrated that hide collectors claim over half of the lion's kills, steps have been taken to make this activity illegal. However, although this will most assuredly make more food available to lions, I am concerned for the welfare of the hide collectors. Lion kills represent 20-25 per cent of the skins taken by hide collectors, representing quite a sizeable part of the hide collector's carcass claiming livelihood. Moreover these people belong to the lowest social strata, and do not do their unprofitable work by choice. There have been a number of good and successful schemes elsewhere in the country to resettle such people as cultivators, giving them a chance to succeed according to their own abilities. Would it not be better to give the hide collectors of the Gir a chance to cultivate outside the sanctuary, as some have asked, and in this way benefit not only the lion but the people as well?

Hide collectors are not the only reason why lions are required to kill far more than they need to get enough to eat. Feeding was poorest at night, when lions made kills within villages and were driven off by villagers before they had fed. They ate nothing from 41 per cent of domestic animals killed at night. Much of this loss of food would be reduced, and fewer stock lost as a result, if herdsmen made kills available to lions by moving carcasses to the outside of villages immediately following an attack. The means by which this could be made operative is by making it one of the conditions for compensation. At present farmers are paid amounts ranging from 100 to 300 rupees whenever a lion kills one of their stock. However the system

of payment would have to be greatly improved before it could be used to ensure that the lion ate what it killed. Of the herdsmen to whom I paid a mere ten rupees in order to see their loss, less than 50 per cent said they intended to apply for government compensation, and fewer actually did. Of the estimated several thousand livestock killed between 1969 and 1971, only 430 applications for payment were made of which 25 per cent were rejected. Few herdsmen understood the conditions for eligibility, all had to wait months for payment, and when it was not forthcoming they were rarely told why.

While preservation of the lion is easily justifiable on the grounds that it is a significant part of India's wildlife heritage, it is difficult to financially justify it when the resources of the country are so limited. The future of the lion in the long run perhaps ought to include more schemes which can make it a better resource capable of paying

its own way. For instance, only a few thousand tourists visit the Gir annually, while the cost to the government in providing just the tourist facilities is twice that which the tourist revenue contributes. The Gir Wildlife Sanctuary would benefit from greater promotion, especially outside the country where the lion's existence is little known, let alone knowledge that within a few hours after leaving Bombay visitors can both see lions in their natural habitat and approach them on foot.

At present the majority of tourists who do come do not stay overnight because after seeing the lions there is little else for them to do. Improvement in the habitat of the Gir through a gradual reduction in the number of cattle should result in substantial increases in the populations of many native wildlife species, all of which should benefit the development of a more varied program of wildlife related activities which visitors could participate in.

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