

Available online at www.sciencedirect.com

Biological Conservation 111 (2003) 385–393

BIOLOGICAL
CONSERVATIONwww.elsevier.com/locate/bicon

Status of tiger and leopard in Rajaji–Corbett Conservation Unit, northern India

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Received 20 November 2000; received in revised form 26 August 2002; accepted 4 September 2002

Abstract

Rajaji–Corbett Tiger Conservation Unit (RCTCU), in northern India, is one of the 11 Level-I Tiger Conservation Units (TCU) identified in the Indian subcontinent for the long-term conservation of the tiger. This TCU of about 7500 km² stretches from the Yamuna River in the west to Sharda River in the east and includes portions of the Outer Himalaya and the Shivalik hills. Little less than one third of this TCU comes under protected area status (Rajaji National Park—820 km², and Corbett Tiger Reserve—1286 km²) and the rest are under 12 reserve forest divisions, five of which have largely been converted into monoculture plantations. Between November 1999 and March 2000, we evaluated the status of tiger and leopard in RCTCU by counting the number of different pug marks on 3–5 km transect walks along 52 dry stream beds ('raus'), for a total distance of 479 km in these reserve forests and plantations. People and cattle seen along the transects, were also counted, as an index of disturbance. In this TCU, the tiger occurs in three isolated populations: between the west bank of River Ganges and River Yamuna, from the east bank of Ganges to Kathgodam–Haldwani–Lalkuan Highway and between the Highway and River Sharda. Owing to increasing biotic pressures, the tiger has become rare in Rajaji–Corbett corridor and has become extinct in four divisions. There is a growing threat of further degradation and fragmentation of its habitat. To implement a recovery programme, we suggest several management measures such as control of poaching, resettlement of local tribes (Gujjars) and five villages, creation and strengthening of forest corridors, conversion of monocultures into polyculture plantations and establishment of several mini-core areas including Nanda Valley National Park. We recommend the reliable and user-friendly method used by us to evaluate and monitor the status of leopard and tiger in this conservation unit. A suggested Greater Corbett Tiger Reserve (2000 km²) should be kept as inviolate as possible.

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Keywords: Northern India; *Panthera tigris*; *P. pardus*; Gujjars; Corridors; Plantations; Mini-core area

1. Introduction

The rate at which the tiger (*Panthera tigris*) is losing its range, has lost three subspecies and is declining in number from ca. 100,000 at the beginning of the twentieth century to ca. 6000 now, is a sure indication that this magnificent species is racing towards extinction. The conservation status of the tiger is worrying even in India, which has about half the total population in the wild (Jackson, 1997; Thapar, 1999). There are two major reasons for this sorry state of affairs. One is the unprecedented increase in human population, which in India, for example, was 361 million in 1951 and now

stands at one billion (10⁹), one sixth of the world's human population. This colossal human mass and its growing requirements puts enormous pressure on wildlife habitats. The other reason is the special requirements of the tiger, which as a species needs large undisturbed habitats with abundant ungulate prey (Johnsingh and Negi, 1998). These requirements conflict with those of an expanding human population, which destroys or disturbs tiger habitats and competes directly with the tiger for prey. Also, most tiger populations, particularly in northern India during the last two decades, have been subjected to heavy poaching for bones, an important component in Traditional Chinese Medicine (Wildlife Protection Society of India, 1998).

The need of the hour is to identify, protect and manage tiger habitats assiduously so that as many tiger populations as possible can be protected across its

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range. Two studies (Johnsingh et al., 1991; Dinerstein et al., 1997) have identified such landscapes for India and the Indian subcontinent respectively. What is now urgently needed is to identify the threats to each of these areas, quantify biotic pressures and assess the status of tiger and its associated species. Such studies will provide information to enable us to evolve suitable conservation programmes for each area to maintain and restore habitat integrity, reduce biotic pressures and safeguard the future of the tiger.

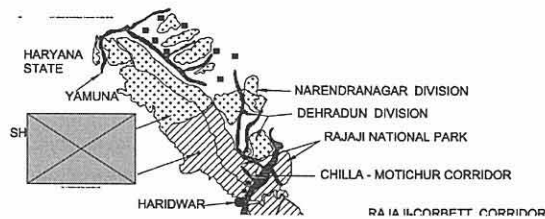
This paper assesses the status of the endangered tiger and the still common leopard (*Panthera pardus*), and quantifies biotic pressures in terms of people and cattle use in the Rajaji–Corbett Tiger Conservation Unit (RCTCU) in north India, to form the basis for broad management recommendations for the recovery of the tiger population.

2. Study area

The RCTCU is one of the 11 Level-I Tiger Conservation Units (TCUs) identified in the Indian subcontinent for the long-term conservation of the tiger (Dinerstein et al., 1997). This TCU includes portions of the outer Himalaya and the Shivalik hills northeast of Delhi, which in summer (March–June) have very little water for wild ungulates. This was formerly in the state of Uttar Pradesh but since November 2000 most parts of the RCTCU, except the Shivalik and Bijnor divisions, come

under the new state of Uttaranchal. The TCU extends from the Yamuna River in the west to the Sharda River in the east (Fig. 1). This tract is drained by numerous rivers and streams running north to south, most of which remain dry in late winter and summer. These dry beds are locally called 'raus'. Until 30 years ago, this sal-dominated (*Shorea robusta*) forest tract, which is ca. 300 km long and 7500 km² in area, was continuous and much more extensive. Sal forest, with an understory of unpalatable shrub species such as *Ardisia solanacea*, *Clerodendron infortunatum*, *Colebrookia oppositifolia*, *Desmodium* spp., *Flemingia* spp. and a sparsity of grass, does not offer much forage to wild ungulates.

Over the years the growing human population and its demand for more forest land for agriculture and various development projects have broken the forest continuity along the west bank of the River Ganges and along the Kathgodam–Haldwani–Lalkuan Highway (hereafter the Highway). The pressures on the remaining forests by the pastoral gujjars people in the adjacent towns and villages, and their livestock, grow day by day, severely threatening the wildlife values of this area. In the past the gujjars migrated with their buffaloes and other livestock to the Himalaya in summer and returned to the foothills in winter. Now, because of resentment from the people living in the mountains, most of the gujjars are forced to stay in the foothills with their animals throughout the year, which causes sustained damage to the habitat. Yet this TCU is the most vital conservation area in northern India for large mammals (Johnsingh et



al., 1991; Johnsingh and Panwar, 1992; Anon, 1993; Dinerstein et al., 1997).

About one-third of this TCU is under protected area status: the proposed Rajaji National Park (Rajaji NP, 820 km²) and Corbett Tiger Reserve (Corbett TR, 1286 km²). The rest is reserve forest under various forest divisions (Fig. 1). Corbett TR has a national park of 521 km², Sonanadi Wildlife Sanctuary (WLS, 302 km²), which was part of Kalagarh forest division till 1987, and a buffer of 463 km² formed by part of Kalagarh, Ramnagar and Terai West forest divisions. Rajaji NP is divided by the Ganges into an eastern half (Chilla WLS) and a western half (Rajaji and Motichur WLSs). The tenuous habitat connection between the two halves, the Chilla–Motichur corridor (Johnsingh et al., 1990), is rapidly degrading under increasing biotic pressures. From west to east the forest divisions in this Tiger Conservation Unit are Shivalik, Dehra Dun, Narendranagar, Haridwar, Lansdowne, Bijnor, Terai West, Ramnagar, Terai Central, Haldwani, South Pithoragarh and Terai East. Five of these [Haridwar (part), Bijnor, Terai West, Terai Central and Terai East] consist of large-scale mechanised plantations of softwood (e.g. *Eucalyptus* spp., *Ailanthus excelsa*, *Populus diata*) and hardwood (e.g. *Acacia catechu*, *Dalbergia sissoo*, *Tectona grandis*) which were raised in the 1960s to meet industrial needs, replacing the mixed forests and grasslands on the terai. These monoculture plantations, which still exist, have changed the habitat composition drastically as agricultural crops were also raised in the interspaces resulting in round-the-year disturbance to tiger and its prey species. Exotic weeds like *Lantana camara* and *Parthenium hysterophorus*, and native weeds like *Adhatoda vasica*, *Cannabis sativa* and *Cassia tora*, are problems throughout this TCU, which reduce the suitability of the habitat for ungulates.

3. Methods

Information on tiger and leopard and disturbance factors—livestock (cattle *Bos indicus* and buffalo *Bubalus bubalis*) and people—was collected with the assistance of staff working with a non-governmental organisation (NGO), 'Operation Eye of the Tiger—India', and the staff of the Uttar Pradesh Forest Department. Since we did not have the manpower to survey all the raus (dry river beds) in the ca. 5400 km² area (other than Rajaji NP and Corbett TR) we selected 52 raus in the forest divisions in locations where there was considered to be less disturbance and greater chance of seeing tiger pug marks. The staff were chosen and trained by us to locate and identify tiger and leopard pug marks. They worked in teams of two and walked 3–5 km transects along these raus searching a width of ca. 4 m and covering the two sides of the rau

separately on the outward and return journey if it was > 10 m wide. The length and breadth of the pug marks were measured irrespective of the fact that whether they were either of fore or hind foot. The measurements and the continuity of the pug mark trails were used to distinguish those made by different individuals in the same rau, but not to identify different individuals between raus.

Although Rajaji NP was not surveyed as part of this study, based on camera trap studies, we have estimated the number of tigers using Dholkhand area of the Park, which is free from gujjar settlements, to be around eight. Our research on elephants in the Park from 1995 to 2000 has given us ample opportunities to survey and record tiger pug marks from other parts of the Park enabling us to estimate that there could be 10–15 tigers in the Park.

The transects were walked early in the morning, before cattle reached the signs, and in winter when the rau beds were wet when conditions were ideal for locating pug marks. The data were expressed as encounter rate (number/km) in the analysis. This methodology is explained with one example. In Ramnagar division (487 km²) in December 1999 within 3 days 10 transects in 10 different raus totalling 48 km were walked. The number of tiger pug marks seen were 2+1+1+1+1+1+1+2+1+1+1 (12) and leopard 2+1+1+1+1+1+0+1+1+1+1 (10). Number of cattle 7+2+0+0+39+0+0+0+0+25 (73) and people seen were 4+4+0+2+32+2+7+11+24+15 (101). The encounter rate for tiger and leopard pug marks was 0.25 and 0.21, respectively and for cattle and people 1.52 and 2.10 (Table 1).

Between November 1999 and March 2000 we surveyed a total of 479 km in the forest divisions listed earlier and also 7.7 km on the west bank of Ganges in the Chilla–Motichur corridor. We did not survey the two protected areas (Rajaji NP and Corbett TR) and relied on the regular Forest Department census figures available for these two areas (Tables 2 and 3).

4. Results

Table 1 summarises the results of the transects related to the number of kilometres walked, number of tiger and leopard pug marks seen and cattle and people encountered. Tigers occur in three habitat blocks in Rajaji–Corbett Tiger Conservation Unit. One is from Yamuna to the west bank of the River Ganges, which includes the forest divisions of Shivalik, Dehra Dun, Narendranagar (total tiger habitat ca. 1000 km²), and the Rajaji–Motichur (ca. 500 km²) part of Rajaji NP. Our additional surveys along the west bank of the Ganges, in the proposed Chilla–Motichur corridor area, showed that tigers (0/km) do not use the west bank but

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Table 1

Counts and encounter rates in parentheses (no./km) of tiger and leopard pug marks, and cattle and people seen in 12 forest divisions of the Rajaji–Corbett Tiger Conservation Unit, November 1999–March 2000

Forest division, area in km ²	Km walked	Tiger pug marks	Leopard pug marks	Cattle	People	Habitat block
Shivalik, 332	33	0	14 (0.42)	233 (8.88)	147 (4.45)	I
Dehra Dun, 510	39	1 (0.02)	4 (0.10)	62 (1.59)	36 (0.92)	
Narendranagar (part), 150	15	0	6 (0.40)	53 (3.53)	21 (1.40)	
Haridwar, 370	20	0	8 (0.40)	163 (8.15)	50 (2.50)	II
Rajaji–Corbett corridor, 250	155	3 (0.02)	87 (0.56)	1140 (7.35)	791 (5.10)	
Bijnor, 344	15	0	3 (0.20)	94 (6.27)	113 (7.53)	
Ramnagar, 487	48	12 (0.25)	10 (0.21)	73 (1.52)	101 (2.10)	
Terai West, 350	15	5 (0.33)	4 (0.27)	838 (55.87)	97 (6.47)	
Terai Central, 404	15	2 (0.13)	4 (0.27)	218 (14.53)	51 (3.40)	
Terai East, 801	15	1 (0.07)	4 (0.27)	192 (12.80)	40 (2.67)	III
Haldwani, 768	50	6 (0.12)	8 (0.16)	209 (4.18)	118 (2.35)	
South Pithoragarh, 400	16	1 (0.05)	3 (0.19)	120 (7.50)	15 (0.94)	

leopards (0.26/km) still do. Our data on pug marks and use of camera traps indicate that there could be 6–10 adult tigers in this 1500 km² habitat block, largely confined to the Rajaji–Motichur area (ca. 500 km²) of the Rajaji NP (Johnsingh and Goyal, unpublished data). The two tiger pug marks seen by forest department staff in Dehra Dun division during the 2001 census (Table 2) are probably from animals straying from Rajaji NP.

The second habitat block is from the east bank of the Ganges to the Highway. This tract is about 4000 km² and includes the Chilla part of Rajaji NP, Corbett TR, Lansdowne, Haridwar, Bijnor, part of Kalagargh, Ramnagar, Terai West and Terai Central forest divisions. There could be ca. 50 adult tigers in this stretch of habitat. The tiger habitat from the eastern end of the Rajaji–Corbett corridor (Khoh River and Kotdwar town) to the Highway is about 3000 km². Its eastern part, an area of ca. 1000 km² east of Boar River, comes under the Terai West and Terai Central forest divisions, and is highly disturbed by plantation activities.

The third block, ca. 1800 km², is from the Highway to Sharda River and includes the Haldwani, South Pithoragarh and East Terai forest divisions. East Terai forest division has tenuous habitat connectivity with the Pilibhit forest division of Uttar Pradesh which is west of Sharda River. During the survey in this block eight tiger pugmarks were seen, six of them in the Haldwani forest division (Table 1) which, in terms of combined encounter rate with cattle and people (6.54), was relatively less disturbed than Terai East (15.47) and South Pithoragarh (8.44). Besides this, the Haldwani forest division has the fairly undisturbed Nanda Valley (ca. 100 km²). The Uttar Pradesh Forest Department censuses also indicate that Haldwani forest division consistently has more tigers than the other two divisions (Table 2).

Two disturbing results emerged as a result of the survey. One is the near absence of tigers in the ca. 1000 km² forest area in Shivalik, Narendranagar and Dehra Dun

forest divisions west of Rajaji–Motichur. Here 87 km were surveyed, and the mean encounter rate for tiger pug marks was 0.01, leopard 0.28, cattle 4.68 and people 2.34. The Forest Department has not censused tigers in Narendranagar forest division but the information available for Shivalik and Dehra Dun divisions (Table 2) clearly indicates absence of tigers here. It should be noted that west of Yamuna, in the state of Haryana (Fig. 1), only tigers straying from forests east of Yamuna are reported.

Table 2

Counts of tiger pugmarks in Rajaji–Corbett Tiger Conservation Unit according to Forest Department censuses

Division/protected area	Year						
	1984	1989	1993	1995	1997	1999	2001
Shivalik	1	6	0	0	0	0	NC
Dehra Dun	10	2	0	0	0	0	2
Rajaji NP (820 km ²)	13	33	18	22	32	28	30
Lansdowne	25	30	15	7	NC	15	9
Bijnor	7	10	0	0	0	0	NC
Kalagargh	44	48	35	NC	NC	NC	NC
Sonanadi WLS* (302 km ²)	NA	NC	NC	24	15	15	22
Corbett National Park (521 km ²)	90	91	88	90	91	83	85
Buffer of Corbett TR ^b (463 km ²)	NC	NC	NC	27	32	28	30
Ramnagar	40	42	17	25	31	29	34
Nainital	13	10	3	4	0	0	0
Terai West	30	31	19	7	5	5	4
Terai Central	13	17	19	11	5	5	4
Haldwani	42	43	20	15	11	11	16
Pithoragarh ^c	20	0	0	0	NC	NC	3
Terai East	12	17	9	8	7	5	12
Grand total	360	380	243	240	229	224	251

0—No pugmark was seen. NC—Not counted. NA—Not available.

* Sonanadi WLS was carved out of Kalagargh division formed in 1987 but separate counts for the Sanctuary were made only from 1995.

^b Buffer of Corbett TR includes portions of Kalagargh, Ramnagar and West Terai forest divisions.

^c Pithoragarh was divided into North and South Pithoragarh in 1994. After 1995 the tiger number given is only for South Pithoragarh.

Table 3
Counts of leopard pugmarks in Rajaji-Corbett Tiger Conservation Unit according to Forest Department censuses

Division/protected area	Year					
	1984	1989	1993	1995	1999	2001
Shivalik	19	41	18	NC	NC	NC
Dehra Dun	23	4	NC	NC	NC	23
Rajaji NP	38	89	110	NC	177	236
Lansdowne	21	110	53	NC	44	47
Bijnor	23	79	4	NC	9	NC
Kalagarh	30	48	59	NC	NC	NC
Sonanadi WLS ^a (302 km ²)	NA	NA	NA	NC	14	66
Corbett National Park (521 km ²)	43	41	42	NC	36	33
Buffer of Corbett TR ^b (463 km ²)	NA	NA	NA	NC	NC	NC
Ramnagar	9	5	15	NC	10	10
Nainital	6	4	14	NC	0	0
Terai West	6	12	19	NC	7	4
Terai Central	2		3	NC	6	1
Haldwani	6	14	10	NC	8	13
Pithoragarh ^c	63	55	NA	NC	96	226
Terai East	1	3	9	NC	18	9
Grand total	290	505	356	NA	425	668

0—No pugmark was seen. NC—Not counted. NA—Not available.

^a Sonanadi WLS was carved out of Kalagarh division formed in 1987 but separate counts for the Sanctuary was made only from 1995.

^b Buffer of Corbett TR includes portions of Kalagarh, Ramnagar and West Terai forest divisions.

^c Pithoragarh was divided into North and South Pithoragarh in 1994. After 1995 the leopard number given is only for South Pithoragarh.

The Rajaji–Corbett corridor (250 km², Fig. 1), which is part of Lansdowne division (400 km²), is a vital habitat link between Rajaji NP and Corbett TR and was intensively surveyed. Only three tiger pug marks were recorded over the total 155 km walked, while the leopard encounter rate was the highest of the whole survey (Table 1). Disturbance in this narrow corridor arises largely from Kotdwar town and the adjacent villages. The larger number of tiger signs recorded by the Forest Department in the Lansdowne division as a whole (Table 2) may be because of the availability of relatively disturbance-free wildlife habitat (ca. 200 km²) east of the corridor which is also abutting Corbett TR where breeding is still vigorous. There have been occasional sightings of a mother with four grown-up cubs.

The status of tiger in the eastern part of the Tiger Conservation Unit (between the Highway and Sharda), including the Terai East, Haldwani and South Pithoragarh forest divisions is better than that of Dehra Dun, Shivalik and Narendranagar divisions in the west. In the eastern part we walked 81 km and the encounter rate of tiger pug marks was 0.10, leopard 0.19, cattle 6.43 and people 2.14. Biotic disturbances here are as high as in the western portion of this Tiger Conservation Unit (cattle 4.68 and people 2.34), yet more tigers still use this area.

Leopard pug marks were encountered in all the divisions including the ones where tiger pug marks were absent (Table 1). Ecologically and behaviourally, the leopard is much more adaptable than the tiger (Johnsingh,

1983), and Forest Department censuses in 1999 and 2001 gave pug mark counts of 425 and 668, respectively for this conservation unit (Table 3). Indeed, there is no evidence of any decline in leopard numbers since standard records have been made there over the past decade.

5. Discussion

We have demonstrated here that it is possible to gather basic vital information on the status of tiger, leopard and biotic pressures crucial for monitoring and planning conservation at a landscape level. This is achieved by systematic preselection of tracts, where we had a greater chance of seeing pug marks during winter months and which can serve as reference points for future monitoring, and by working in teams of two and covering 3–5 km transects. Karanth (1999) and Rabinowitz (1999) have recommended such simple repeatable methods for surveying vast areas. Miquelle et al. (1999) and Smith et al. (1999) have demonstrated the feasibility of such methods in the Russian Far East and in Nepal, respectively.

We suggest that the information collected in this way is much more reliable than the total count by the Forest Department who usually equate sighting of one trail of pug marks with one tiger. Our estimate of tiger number for the Rajaji NP in 2000 was 10–15 (Johnsingh and Goyal, unpublished data). The Forest Department assumed that the numbers of tigers in the Park

increased from 13 in 1984 to 33 in 1989, declined to 18 in 1993 and increased again to 30 in 2001, two to three times our estimate. Such fluctuations are quite unrealistic and the equation of pugmark counts with tiger numbers involves many biases (Karanth, 1987).

Censusing tiger and leopard purely by counting pug marks in other parts of this Conservation Unit also highlights the unreliability of this method. Corbett TR has a total area of 1286 km², including the National Park, Sonanadi WLS and the Buffer Zone. A total tiger figure of 137 (Table 2) would give a crude density of 10.65 tigers/100 km² which is close to the recorded ecological density of 11.7–1.93 tigers/100 km² in Kanha TR and 11.9–1.71/100 km² in Nagarhole NP (Karanth and Nicholas, 1998). This is not feasible for sal-dominated Corbett TR, which is hilly and facing increasing biotic pressures. Two-hundred and thirty-six leopards recorded for Rajaji NP (a density of 29/100 km²) and an increase from 96 in 1999 to 226 leopards in 2001 in Pithoragarh division (ca. 700 km²), which gives a density of 32/100 km², are also not possible.

Although the leopard population estimates are questionable the population in this conservation unit may still be a single population, with occasional movement across the Ganges in the Chilla–Motichur corridor area, upstream of Haridwar where there are many bridges across the Ganges and north of Kathgodam where there is suitable habitat for leopard all around.

Nevertheless, the challenge before us is to ensure the long-term survival of tiger in this conservation unit, using the information gathered. Data available (Table 2) indicates a declining trend in tiger numbers in this TCU over the recent decades and extinction seems imminent in some forest divisions. For example, Shivalik and Bijnor divisions, which each had more than five tigers about 12 years ago, has none now. Extinction in the Shivalik division can be attributed to high biotic pressures, which include the presence of gujjar settlements and intense bhabar grass (*Eulaliopsis binata*) collection for rope making from the steep Shivalik hills between November and March. The poverty-stricken grass cutters not only disturb the area but also steal the large kills of leopard and tiger. Poaching and livestock grazing, major conservation problems throughout India, are also prevalent here. Yet leopards still survive against all the odds, with the second highest pug mark encounter rate recorded (0.42/km, Table 1).

Another major reason for the disappearance of tigers in the Shivalik division is the absence of a source population nearby. Populations at the extreme end or the periphery of the range of a species are usually sparse (Hengeveld and Haeck, 1982) and have a greater chance of going extinct (Beddington et al., 1976; Lawton, 1995). Extirpation of tigers in the Shivalik division stands as an example of this statement. Tigers are absent across Yamuna to the west and there is lack of

sufficient breeding to maintain the population in the Rajaji–Motichur area to the east. One explanation for the poor breeding, besides stealing of kills, might be shortage of prey. Sambar (*Cervus unicolor*) is a preferred prey of tiger in the Indian subcontinent (Schaller, 1967; Tamang, 1982; Johnsingh, 1992) and we have recorded a decline in sambar abundance over the years in Dholkhand area. Along one of our transects known as Burnt Ridge transect (1.6 km) we walked nine times in the summer of 1988 and the encounter rate of sambar was 5.33. In 1999 in the same season we walked eight times and the encounter rate of sambar was 2.12 which is considerably less (Mann–Whitney Test, $z = 2.67$, $P < 0.006$, Johnsingh and Goyal, unpublished data). This may be due to a decline in habitat quality for sambar perhaps through the preponderance of Lantana camara, an exotic noxious weed in the diet of sambar. Poaching can not be blamed as the major factor since Dholkhand receives the best possible protection in Rajaji NP and if poaching were the reason it would have also affected the chital (*Axis axis*) population which has not declined: the encounter rate was 1.6 in 1988 and 8.69 in 1999 (Johnsingh and Goyal, unpublished data). Because of the behaviour of yarding for the night in groups in open areas chital are not suitable prey for tiger (Johnsingh, 1992).

Tiger extinction in the Bijnor division can be traced to one or a combination of several factors: (1) conversion of natural vegetation (which offers cover to tiger, and cover and forage to prey species such as sambar and wild pig) to Eucalyptus plantations, (2) human disturbances (encounter rate 7.53, the highest recorded) including gujjar settlements, (3) poaching and (4) cattle grazing. Interestingly, tigers still occur in Terai West and Terai Central divisions, which are also plantation divisions and subjected to enormous biotic pressures. This may be largely due to the 4-km wide Nihal–Bhakhra corridor, which is still used by tigers and connects Terai Central division with the Ramnagar division, which is next to Corbett TR.

Although there are no major developments along the Rajaji–Corbett corridor (250 km²) sighting of only three pug marks after walking 155 km creates a very strong impression that tigers are very rare here. If total fragmentation occurs, we will have another isolated population of four to six tigers between the Ganges and Rajaji–Corbett corridor, a total area of about 600 km² including the Chilla part of Rajaji NP and Haridwar division (Fig. 1).

As a result of enormous day and night traffic, and human settlements along the Highway, we believe that, for large mammals, the forests east of the Highway (Haldwani–Terai East) are now isolated from the forests west of the Highway (Terai Central). We believe that there could be occasional immigration of tigers from forest areas east of Sharda River, which include

Sukhlaphanta Reserve in Nepal, and from Pilibhit Forest Division with Kishanpur Wildlife Sanctuary. Sugar cane fields and patches of forests give some habitat continuity between these forests and in summer the Sharda River should not be a barrier to a strong swimmer like tiger. This immigration may be the major factor that still enables tigers to occur more in Haldwani–Terai East than in the western part of this Tiger Conservation Unit.

The history of tiger extinction and conservation in this tract clearly demonstrates that the most crucial factor that has helped the survival of tiger west of Ganges is the protected area status given to Rajaji and Motichur areas way back in 1966–1967. Before the formation of these sanctuaries, the forests west of Ganges came under Shivalik, East Dehra Dun and West Dehra Dun divisions. In 1966, 90 km² of Dehra Dun division was upgraded as Motichur Wildlife Sanctuary and an area of 249 km² of the Shivalik division was notified as Rajaji Wildlife Sanctuary (Johnsingh, 1991). Before the formation of these sanctuaries, all these divisions had tiger, although at a density of one per 40 km², which is low when compared to the density of one per 22.5 km² in the Himalayan foothills and one per 16.5 km² in the terai region (Singh, 1969). But conservation of a protected area is more expensive than managing a Reserve forest. The average conservation cost for Rajaji NP, for the period 1997–2000 was Rs. 125,000 (US \$2840)/km². The cost for Shivalik division was Rs. 43,015 (US \$979)/km² and Dehra Dun Division Rs. 60,570 (US \$1377). The 820 km² National Park, although fragmented by developments on the west bank of Ganges (Johnsingh et al., 1990), still has 10–15 tigers.

In a populous country like India, where about 36% of the people live below the poverty line (Manorama Year Book 2000), conservation, particularly of tiger, which needs vast undisturbed well-managed habitats, is even more difficult. It should be remembered that although this TCU is about 7500 km², the habitat used by tiger is only about 4000 km², because of disturbances in the rest of the area. To enable tigers to thrive in Rajaji Corbett Tiger Conservation Unit, which would include a comeback in areas where it has been extirpated in the recent years, we make the following recommendations:

6. Recommendations

6.1. Control of poaching

Our surveys around this conservation unit have shown that there are about 20 shops, which sell guns and the local people have 40,000–50,000 licensed guns. Although legal hunting is banned in India these shops sell about 100,000 cartridges every year most of which may be used for poaching.

We suggest the following:

Replace all guns around this conservation unit with specially made guns with short barrels which cannot be used for poaching. Gun owners will have rights over their guns which, however, should be kept in the safe custody of the Government. International conservation agencies and Government of India should come up with sufficient funds for this gun replacement programme. Champion (1934) recommended sawing off the barrels of crop protection guns to make them ineffective for poaching.

Reward anyone apprehending a wild ungulate poacher with an incentive amount of US\$1000

Train staff in anti-poaching measures

Control India–Nepal cross-border poaching through close collaboration with wildlife staff in Nepal.

6.2. Relocation of people and ecodevelopment programmes

Relocate gujjars from Shivalik, Rajaji NP, Lansdowne (which includes Rajaji–Corbett corridor area) and Kalagarh divisions to the periphery of reserve forest areas.

Resettle Ganga Bhagpur Thalla village with ca. 30 families (ca. 300 people) situated between river Ganges and the Kunaun–Chilla power channel to strengthen the Chilla–Motichur corridor and protect the only patch of riverine forest along the entire length of Ganges River which is still being used by tiger (Johnsingh et al., 1990).

Shift three villages (Ringora, Amdanda and Tedha) each with ca. 20 families (ca. 200 people) to strengthen the connectivity between Corbett TR and Ramnagar forest division.

Move Laldhang village ca. 100 families (ca. 1000 people) for whom forest land has already been deared in Ramnagar forest division which will significantly strengthen conservation in the southern boundary of Corbett TR.

Do not allow any development between Mahand and Kumaria villages so as to retain the 5-km broad forest connectivity between Corbett TR and Ramnagar forest division. Shift the Indian Medicines Pharmaceutical Corporation Limited from its present location, closer to Ramnagar town, as most of the 200 or so employees come from this town, which is about 15 km away and close down Gargia Chemicals, where fewer than 10 people work now (Johnsingh et al., in press).

Initiate ecodevelopment measures all along this forest tract with the sole objective of reducing the biotic pressures like grazing and wood cutting arising from the human habitations. The ecodevelopment measures should be intense in and around the identified corridors.

6.3. Use of user-friendly methods for monitoring

The simple easily repeatable reliable methods used by us could be adopted by the forest staff, at least every second year, to evaluate the status of leopard, tiger and biotic pressures in this conservation unit.

6.4. Landscape management

6.4.1. Conversion of monoculture to polyculture plantations

Convert monoculture plantations along the southern boundary of Corbett TR, and in Terai West, Terai Central and Terai East divisions into patches of polyculture plantations of native species. This might be achieved by planting species such as *Dalbergia sissoo*, *Derris indica*, *Holoptelia integrifolia* and *Syzygium cumini* which are not palatable to ungulates but give good cover and shade to ungulates and tiger. Do not allow cultivation of agricultural crops in these plantation divisions.

6.4.2. Creation of mini-core areas

Identify at least one mini-core area with a minimum area of about 20 km², the best wildlife area with water and natural vegetation, in each forest division and protect them from all forms of disturbances.

6.4.3. Creation of Nandaurl Valley National Park (NVNP)

Establish NVNP (100 km²) in Haldwani Division to protect the catchment area of the picturesque Nandaurl River. This area has no permanent village but only temporary cattle camps, which are in the danger of becoming permanent. The National Park could become a breeding site for tigers.

6.4.4. Establishment of corridors

Establish a Chilla–Motichur corridor enclosing the islands on the river Ganges and a Lalkuan corridor between Central and East Terai divisions.

Protect and strengthen the habitat connectivity between Corbett TR and Ramnagar forest division including both the banks of the Kosi river and the 4-km wide Nihal–Bhakhra corridor between Ramnagar and Terai Central Division. Johnsingh et al. (in press) give details of these corridors.

6.4.5. Conservation of Greater Corbett TR

Ensure the future of ca. 2000 km² habitat block from east of Rajaji–Corbett corridor to the Boar River as inviolate as possible. Do not allow ecologically incompatible developments like mushrooming of tourism resorts and building an all-weather highway either along the northern or southern boundary of this tiger habitat.

We are aware that, in this human, cattle and weed-dominated landscape, it will be extremely difficult to fully implement a recovery programme like the one we have recommended. Yet we wish to try and make a change which would be better for both tigers and people. We believe, like Burge (1999), that by saving the tiger we save complex ecosystems and habitats that would otherwise be destroyed in the relentless march of human need. We agree with Sædensticker et al. (1999) that landscapes with tigers are worth more than landscapes without them. We conclude with a fervent hope and plea that a massive and sustained conservation effort will be launched as early as possible to save the tiger in this habitat which would otherwise dwindle and degrade day by day and disappear eventually.

Acknowledgements

Chief Wildlife Warden, Uttar Pradesh permitted us and Director, Wildlife Institute of India encouraged us to do this survey. Dr. S.P. Goyal, Dr. Nima Manjrekar, Mr. R. Jayapaul, Mr. Christy A. Williams, and Mr. K. Yoganand gave critical comments on the manuscript. Two anonymous reviewers contributed significantly to improve the manuscript to its present form. Mr. Dhananjai Mohan, Indian Forest Service, gave information on the Nihal-Bhakhra corridor and the possibility of Lalkuan corridor. Mr. N.S. Negi and Mr. P.D. Sharma, Field Officers, Operation Eye of the Tiger-India, supervised the surveys. Mr. M.P. Aggarwal word processed the text. SAVE THE TIGER FUND provided financial support. We thank them all.

References

- Anon., 1993. Anon (Project Elephant). Ministry of Environment and Forests, New Delhi.

- Beddington, J.R., Free, C.A., Lawton, J.H., 1976. Concepts of stability and resilience in predator-prey models. *Journal of Animal Ecology* 45, 791–816.
- Burge, R., 1999. Foreword. Riding the Tiger, Tiger Conservation in human dominated landscapes. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *The Zoological Society of London. Cambridge University Press, Cambridge*, pp. XIII–XIV.
- Champion, F.W., 1934. No 4. United Provinces. *Journal of Bombay. Natural History. Soc.* 37, 105–111.
- Dinerstein, E., Wikramanayake, E., Robinson, J., Karanth, U., Rabinowitz, A., Olson, D., Mathew, T., Hedao, P., Connor, M., Henley, G., Bolza, D., 1997. A framework for identifying high priority areas and actions for the conservation of tigers in the wild. *World Wildlife Fund, USA*.
- Hengeveld, R., Haek, J., 1982. The distribution of abundance—I measurements. *Journal of Biogeography* 9, 303–316.
- Jackson, P., 1997. The status of the tiger in 1997 and threats to its future. *Cat News* 27, 8–10.
- Johnsingh, A.J.T., 1983. Large mammalian prey-predators in Bandipur. *Journal of Bombay Natural History Society* 80, 1–57.
- Johnsingh, A.J.T., 1991. Rajaji. *Sandhuary XI* 14–25.
- Johnsingh, A.J.T., 1992. Prey selection in three sympatric carnivores in Bandipur. *Mammalia* 56, 517–526.
- Johnsingh, A.J.T., Negi, A.S., 1998. Only disturbance-free well managed habitats can save the tiger. *Cat News* 28, 4.
- Johnsingh, A.J.T., Panwar, H.S., 1992. Elephant conservation in India—problems and prospects. In: Per Wegge (Ed.), *Mammal Conservation in developing countries. Proceedings of a workshop held at Vth Theriological Congress in Rome, Italy, August 1989*, pp. 36–56.
- Johnsingh, A.J.T., Panwar, H.S., Rodgers, W.A., 1991. Ecology and conservation of large felids in India. In: N. Maruyama et al. (Eds.), *Wildlife conservation: present trends and perspectives for the 21st century. Proceedings of the International Symposium on wildlife conservation in Tsukuba and Yokohama, Japan, 21–25, August 1990*, pp. 160–166.
- Johnsingh, A.J.T., Prasad, S.N., Goyal, S.P., 1990. Conservation status of Chilla-Motichur corridor for elephant movement in Rajaji–Corbett National Parks area, India. *Biological Conservation* 51, 125–138.
- Johnsingh, A.J.T., Qureshi, Q., Mohan, Dhananjai and Williams, A. Christy. Conservation of North-Western Elephant Range, India. Action Plan, Asian Elephant Specialist Group, IUCN/SSC. Pp 14 with two figures (in press).
- Karanth, K.U., 1987. Tigers in India: A critical review of field censuses. In: Tilson, R.L., Seal, U.S. (Eds.), *Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species*. Noyes Publications, Park Ridge, New Jersey, pp. 18–33.
- Karanth, K.U., 1999. Counting tigers, with confidence. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London. Cambridge University Press, Cambridge*, pp. 350–353.
- Karanth, K.U., Nicholas, J.D., 1998. Estimating tiger densities in India from camera trap data using photographic captures and recaptures. *Ecology* 79, 2852–2862.
- Lawton, J.H., 1995. Population dynamic principles. In: Lawton, J.H., May, R.M. (Eds.), *Extinction rates. Oxford University Press, Oxford*, pp. 147–163.
- Manorama Year Book, 2000. Malayala Manorama. Kottayam, India.
- Miquelle, D.G., Merrill, T.W., Dunishenko, Y.M., Smirnov, E.N., Quigley, H.B., Pikunov, D.G., Hornocker, M.G., 1999. A habitat protection plan for the Amur tiger: developing political and ecological criteria for a viable land-use plan. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London, Cambridge University Press, Cambridge*, pp. 273–295.
- Rabinowitz, A., 1999. The status of the Indo-Chinese tiger: separating fact from fiction. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London, Cambridge University Press, Cambridge*, pp. 148–165.
- Shaller, G.B., 1967. *The Deer and the Tiger*. University of Chicago Press, Chicago.
- Sidensticker, J., Christie, S., Jackson, P., 1999. Preface. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London, Cambridge University Press, Cambridge*, pp. XV–XIX.
- Singh, V.B., 1969. The Tiger in Uttar Pradesh. *Chester* 12, 106–113.
- Smith, J.L.D., McDougal, C., Ahearn, S.C., Joshi, A., Conforti, K., 1999. Meta-population structure of tigers in Nepal. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London, Cambridge University Press, Cambridge*, pp. 176–191.
- Tamang, K.M., 1982. The Status of the Tiger (*Panthera tigris*) and its impact on Prindpal Prey Populations in Royal Chitwan National Park, Nepal. PhD Dissertation, Michigan State University, East Lansing.
- Thapar, V., 1999. The tragedy of the Indian tiger: starting from scratch. In: Sidensticker, J., Christie, S., Jackson, P. (Eds.), *Riding the Tiger, Tiger Conservation in human dominated landscapes. The Zoological Society of London, Cambridge University Press, Cambridge*, pp. 296–306.
- Wildlife Protection Society of India, 1998. *India's tiger poaching crisis*, fourth ed. Thapar House, 124 Janpath, New Delhi 110001, India.