IMPACT OF IRON ORE MINING ON THE ELEPHANT HABITAT OF SINGHBHUM FORESTS, BIHAR

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I certify that all work presented in this thesis has been done by Sri Rakesh Kumar Singh under my guidance and supervision, between July 1994 to April 1998. The thesis or any part of it has not been utilized or submitted for any degree or diploma so far.

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Prologue

The greatest challenge in front of the forest managers today is to relate the sequence of landuse changes in and around the forests and protected areas that can influence the biological communities, shared natural resources and environment. Elephant habitat in Singhbhum forests facing threats of several biotic factors and iron-ore mining pollution is the concern felt by the Central India Task Force of Asian Elephant Specialist Group, IUCN/ SSC, while working on the status of the elephants in Orissa and Bihar, between the years 1980-85. Taking full cognizance of this report, in the year 1993, Wildlife Institute of India developed a research project for evaluating habitat fragmentation and impact of iron ore mining activities on elephants and its habitat in Singbhum forests. The later issue eventually formed the major topic for this thesis.

Saranda Forest Division of Singhbhum district is in spate of growing iron ore mining landuse where biological diversity and elephant conservation are also the important issues to the extant and sizable elephant population. Mining and ore processing activities are the major source of air and water pollution recurrent through process failure and inadequate environmental safe guards. The former source being small in scale was kept beyond the scope of the present study.

Unmanaged waste discharges from one of the mechanized mine polluted the long catchment of the river Koina and brought visible coloration of river water and moralities among large number of riverine trees. Lack of information on the impacts of such mining pollution in altering river water quality and its effect to the dependent plant and animal communities prompted to develop a scientific knowledge base on various iron ore mine pollutants sensitive to environmental management.

The thesis has been organized in six chapters. Initial part that provided in Chapter 1 presents an up-dated review of mining pollution and its environmental effect on habitat, ecosystem and life forms. Adequacies of present environmental and conservation laws were critically viewed for meeting future outstanding challenges. Developments of mining landuses in Saranda Forest Division over the years are examined and reported in Chapter 2. This further provided methodologies undertaken for sample collection and analysis.

The Chapter 3 focuses on the physical and chemical constituents, their behavior and interactions for altering water quality of the Koina river with space, time and situations. The factors for altering water quality (Chapter 4) have been taken to examine and relate with animal use of the riverine habitat. How regulated discharge situation can improve the habitat use by wild animals has also been examined for understanding and taking several ameliorative management measures? Heavy metals loading in river sediments, soil and impacted biological communities (Chapter 5) have also been examined for knowing metal uptake and their possible toxicity. Changes in the heavy metal loads were related to the soil nutrients, which could be factor for reducing soil fertility and overall productivity of the ecosystem. The restorative management can only be initiated when impacts are measurable in terms of river stretch is the issue for investigation in Chapter 6, knowing of which can develop a proper monitoring guidelines through suggested necessary recommendations.

It is hope that the finding of this study will contribute in providing necessary guidelines for managers and environmental regulatory authorities to take appropriate actions for habitat restoration and integrated development of Singhbhum forests for mining and wildlife conservation. The focused attention of 'Project Elephant' initiated since 1993 on this habitat will eventually help the elephants and its habitat to restore in years to come.

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Chapter 1

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CHAPTER 1

Ecological and environmental effects of mining: a review

1.1 Introduction

India is well known for its rich mineral resources. Among all naturally occurring principal minerals iron (Fe) constitute a major reserve in the metallic sector both in terms of quality and quantity. The statistical records from Indian Mineral Yearbook 1993 revealed that during the year 1990, India ranked fifth in iron producing countries and fourth among the major exporting countries. The total output of iron-ore produced in the year 1990-91 was as recorded in the range of 55.52 million tones. Besides India, other iron-ore producing countries of the world are erstwhile Soviet Union, China, Brazil and Australia.

The geological and metallogenic history of India is believed to be dated back with the pre-historic land mass formation referred to as Gondwanaland. In India, historical accounts of mining and metallurgy is available since 4000 BC with the development of civilization from the days of Harrapa and Mohanzodaro, and passing through different metallic ages till recent. From the past reminiscence to the present state of informed knowledge, mining of all kinds have always been associated with the negative images of environment and landscape destruction (Roy, 1985; Ali, 1988; Ghosh, 1988). In spite of all these, there has been progressive increase of metalliferous mining worldwide due to social, economical and technological demands. The recent technological breakthrough in metal processing economically even from the low-grade ore bodies further posed different level of challenges and also the concerns for ecological and human environmental standards. The Rio Declaration of 1992 on Environment and Development through agenda 21 and Convention on Biological Diversity is a clear testimony of growing concern for environmental awareness by the global community at large.

In consonance to the concerns and expectations of the environmentally conscious society there is a need to develop a new knowledge base for assessing the performances of siting industries on its ecological and environmental fronts. This will eventually help in reviewing and making decisions for environmental management. This chapter provides an exhaustive review on the aspects of mining and its environmental effects on habitat, ecosystems and life forms. A review of legal framework, policy guidelines related to environment, forests and wildlife are also discussed in the light of their adequacy to meet the present and outstanding challenges.

1.2 Nature and extent of mining in India

After independence in 1947, Indian mining industry has shown rapid growth from production of 20 minerals valued Rs. 70 Crore (= US$ 18 million) in 1950 to 84 minerals valued Rs. 33,075 Crore (= US $ 847 million) in 1996 – 97. The contribution of total mineral sector in Gross Domestic Production (GDP) is 3.5%. The country at present produces 4 fuel minerals, 11 metallic minerals, 49 non- metallic minerals and 20 minor minerals. The fuel minerals accounted for 90.2%, metallic minerals 6.6% and nonmetallic 3.2% of total value of mineral production (Banerjee, 1993). In entire mining sector though 80% mines are privately owned yet 91% production come from the Government – owned ventures. The employment in the mining sector is 800,000 people.

According to a very conservative estimation more than 8,00,000 ha land of the country is under direct mining activities of various kinds (Soni *et al.*, 1994). However, even a much larger area is disturbed with the other activities associated with mining. According to Soni *et al.* (1994) there are 5,510 mining leases spread all over the country, of which 516 mines are in coal sector and rest 4,994 mines comprising are in metallic, non-metallic, atomic and minor mineral sectors. More recent information available further documents enhancement of total mining lease area of 9,43,380 ha with 7,356 active mines spread over the country (Soni, 1998). Further, the idle mine leases have been reported 22% of the total mined area. The open-cast mining which is a major reason for environmental degradation constitutes 90% of all mining operations existing in India (Soni, 1998).

1.3 The impact of mining

The information related to mining as a causative factor for ecological and habitat degradation is well documented. However, mining as a singular factor for habitat and species loss are less known. Combination of factors through land fragmentation, reduction of habitat and other biotic factors could be possible reasons for thinning out of a species. Excessive mining disturbances in such situations often become a point of slow recovery of the habitat. According to the report available through Tata Energy Research Institute (TERI), Energy Data Directory & Yearbook 1994 – 95, all the five coal regions of India till 1989 – 90, alone leased 56,013 ha of forests and additional forest areas required to work further is 21,342 ha, till 1994-95. Deforestation in such cases is one of the major issues on which data availability is rather insufficient. Vijayan and Chaterji (1991) made extensive survey of flora of Bhanora West colliery (West Bengal) of Eastern Coalfield Limited (ECL) and recorded 127 species of Angiosperm. According to them, soil acidity and high disturbance in soil substratum are the reasons for less plant species density around the mining area. Rawat and Suri (1994) recorded 33 pollutant tolerant plant species in the impacted coal mining areas.

Until recently, inventories for plant and animal species are rarely been monitored before setting up a mining industry. With the advent of better Environmental Impact Assessment (EIA) guidelines pre and post floral and faunal survey is considered to be desired activity by the siting mining industry. This provides a scope for monitoring habitat recovery in post mining restoration programs to ensure protection of local flora and fauna.

Mining does bring both short and long term changes in the habitat. The severity of these changes depends on geographic location, terrain features, kind of mining operations – *i.e.* open-cast or underground, chemical reactivity of the ore being excavated and degree of ore processing carried out on site. The impacts on the environment may be – vegetation clearance, land disturbances, floral and faunal depletion, changes in the land forms, noise &

vibrations, air pollution, water pollution, socio-economic problems and human health hazard etc.

1.3.1 Vegetation clearance

The vegetation clearance for mining activities located in forested area may range from few hectares in case of small open-cast mine or underground mine to several thousand hectares for large open-cast mine (Plate 1.1). The process involves mechanical removal of vegetation, topsoil and excavation of rocks, which are the reasons for soil erosion, nutrient loss, alteration of soil profile and run-off for altering the drainage system. Area strip mining, in relatively flat terrain for iron ore since 1961, has destroyed 50,000 ha of forest in Goa (Valdiya, 1988). Vegetation decrease from 4.9% in 1925 to 0.7% in 1974 due to the coal mining in Jharia Coal field has also been reported by Ghosh (1989). Indiscriminate mining in the hilly region of Mussorie has induced land slides and aggravated erosions when such activities were undertaken in steep slopes of 30° – 50° (Valdiya, 1988). Overburden management in contour strip mining in hilly region is a major problem and often a greater cause of damage to the springs and streams.

1.3.2 Land disturbance

Unplanned underground mining without proper stowing creates chances of land subsidence resulting from mine fires. Planning control of such subsidence is a major issue for coal mining areas in Jharia coalfield of Bihar (Kumar *et al*, 1975; Banerjee, 1981; Ghosh and Ghosh, 1992). Various underground mining hazards have been major reasons for mine accidents and loss of human life over 3,400 since the turn of the century (Valdiya, 1988).

1.3.3 Floral and faunal depletion

In surface mining natural vegetation is usually removed which may impact the animal species living within it. The nature of disturbance depends upon the duration and scale of mining. Waggoner (1978) reported displacement of several woodland species such as raccoon, red fox, gray fox, bobcat, gray squirrel, fox squirrel, flying squirrel, beaver, swamp rabbit and white tailed deer due to the lignite mining in Texas. Allaire (1978) while working on an active strip mine site reported recovery of the avian species after 2-3 years of termination of mining operation. Crowford *et al.* (1978) also reported that strip mined area in Southern West Virginia had fewer bird species diversity. He further reported that such diversity in mining areas become well after 8-10 years of mining.

1.3.4 Changes in the land form

Open-cast mining often results in large loss of substrate, its dislocation and finally brings changes in the landform. The pit lake formation due to deep pit mining are known results of the land form alteration in Western Northern America (Miller *et al.*, 1996).

1.3.5 Noise and vibration

Blasting of rocks for excavation and operation of large machinery are the prime sources of noise and vibration for environmental disturbances.

Gupta (1990) reported that in a blasting meager 25% of explosive energy are utilized in rock breaking while major balance energy is dissipated in causing several environment problems such as: noise, vibration, dust and noxious gases leading to lowering of water table and disturbance to the wildlife. Bhattacharya *et al.* (1994) carried out a systematic noise monitoring at various sites of Meghatauburu (MBR) iron-ore mine and concluded a major concern for far exceeding noise level in forest area of Perdih Pump House to a level of 96.2 db(A), as against the level of 50 db(A) for the silence zone prescribed in Environmental (Protection) Act, 1986.

1.3.6 Air pollution

Release of Suspended Particulate Matter (SPM) in air is one of the major concerns related to the siting mining industries (Plate 1.2). This may occur through blasting, operation of large machinery, crushing and processing of ore. Gaseous release can take place through mining – related smelting and roasting. Several studies have been conducted for the SPM distribution and their behavior with meteorological conditions (Munn, 1973; Demuynck and Damis, 1975; Nair and Singh, 1990; Sinha and Banerjee, 1994). The presence of toxic trace elements in SPM is other associated problem with the atmospheric pollution. Central Mining Research Institute (CMRI), Dhanbad have undertaken several studies (Ghosh, 1983; Nair and Singh, 1990) in Jahria Coalfield, Bihar and reported high SPM with toxic trace elements and dust fall as a cause of human respiratory diseases. Banerjee and Hussain (1989), Singh and Sharma (1991) and Sharma and Singh (1992) have carried out other similar studies in the same study area.

1.3.7 Water pollution

Surface mining could be a greater source of water pollution when the waste generated get escaped through tailing process and find its path into a river system (Plate 1.3). Pumped out water from under ground mine and washeries discharges are also a source of water contamination. The entering of these wastes in a river system can disturb the hydro-geological system (Valdiya, 1988; Ghose and Kumar, 1993) and result in physical and chemical changes to surface and ground water qualities (Jambrik and Bartha, 1994; Mitra, 1997; Sen and Ghose, 1997). Tiwary and Dhar (1994) presented an account of water quality deterioration due to coal washery effluent discharge in the basin of Damodar River because of high load of Total Suspended Solids (TSS), SO_4, Hardness etc. They further reported that the TSS as a physical pollutant for degradation of river channels and reduction of biodiversity in the system. Bandopadhyay (1994) reported that the extreme pollution of the river Damodar due to coal mining and other ancillary activities leading to quantum TSS load to a range of 1000 to 40,000 mgL^{-1}. Singh (1990) has presented a similar picture for the same river system in Jahria coalfield area. He further reported occurrence of low level of Dissolved Oxygen (2.6 – 4.5 mgL^{-1}) and excessive turbidity due to high coloration.

Many effluents and mine discharges also contain toxic metals that remain in water and sediments from where it can be taken up in the biotic communities through bio-geochemical cycling. Gupta *et al.* (1994) while working on tailing disposal of the Zawar Zinc mine, Rajsthan has reported Zn toxicity among several flora and fauna. They further stated that the presence of excessive Zn in tailing has affected water bodies by eliminating several algal species. Several floral species such as *Falasia ogina, Wringtonia, Tictonia, Wnotoxia* were heavily impacted with increased Zn toxicity up to a distance of 50 – 60 km in downstream of the Tiri river. Ahmad *et al.* (1994a) also reported presence of several heavy metals such as Pb, Cu, Cd, Fe, Co, Ni and Mn from the mill tailing of Zawar mine. The non-ferrous ore mining and dressing activities in South Bulgaria is reported to impact water quality mainly through heavy metal, causing toxicity to the fish and *Daphnia magna*. The polluted water used for irrigation further has been reported to cause soil deterioration due to heavy metal inputting of As and CN and its mobility in soil micro-organism and plants (Panayotova, 1997).

1.3.8 Socio-economic problem

The socio-economic dimension in a mining scenario begins with human settlements for various mining related activities. The colonization of human settlements and their socio-economic status are major reason for exerting biotic pressures on adjoining forest resources (Plate 1.4). Severe forest losses and degradation of natural forests by the mining settlers have been reported for demand of fuel wood and timber (Varma *et al.*, 1989).

1.3.9 Health hazard

Impact on human health is an associated environmental problem of siting mining and ore processing industry. The causative factors could be noise & vibration (Pal *et al.*, 1992 and Pal *et al.*, 1994), fugitive & airborne dust (Sinha and Banerjee, 1996) for various health hazards. Impairment of hearing (Pal *et al.*, 1992) is a health impact due to excessive noise while back pain, disk vertebra degeneration, gastro-intestinal disorder and hemorrhoids are associated problems with high frequency vibrations (Pal *et al.*, 1994). Pneumoconiosis or 'black lung diseases' is the major reported health hazard among coal miners through out the world (Das, 1988; Pai and Shenoi, 1988).

1.4 Legislation for environmental protection

Legislation is the primary tool used for protecting natural environment and resource utilization by ensuring ecologically sound and responsible, socially acceptable, economically possible and politically feasible practices. The Stockholm (Sweden) Declaration on the 'Human Environment' organized by United Nation, in 1972, was the first of its kind that emphasized the need of environmental pollution control and management. Outcomes of this conference become a greater concern for all over the world. Consequent to this new legislation/amendments was adopted in India to have a uniform law all over the country for prevention of water and air pollution by creating Central and State Pollution Boards. The two subsequent Acts enacted for these were – The Water (Prevention and Control of Pollution) Act, 1974 amended in 1978 & 1988 and The Air (Prevention and Control of Pollution) Act, 1981, amended in 1987. After the gas tragedy of Bhopal, in 1984, which claimed 3000 human lives, Central Government enacted a comprehensive Environmental (Protection) Act, 1986. This Act provided a stringent framework of legislation to protect the environment from pollution, prescribed the safe limit of pollutant, handling of hazardous substances, speedy response in event of accidents, and punishments to those who endanger environment safety and human well being. Environment, under this act, got wider connotation for the well being of human and all living creatures including plants, microorganisms and property.

The liberalization of investment regimes for mining over past decade has encouraged identifying forest and/or non-forest areas for proposing mineral exploration. All proposals for diversion of forest areas for any non forest purposes, even if the area is privately owned, would require prior approval of the Central Government under The Forest (Conservation) Act, 1980. However, dereservation or diversion of forest areas issued by the State Government before 25.10.1980 need not be referred to the Central Government. Prior approval of the Central Government will be require when the renewal comes after the enforcement of Forest (Conservation) Act, 1980. A mandatory environmental clearance required for any proponent to a land above 20 ha of forest need to go through Forest Advisory Committee constituted under the provisions of Forest (Conservation) Act, 1980. In such cases an Environmental Management Plan (EMP) is a prerequisite by the proponent to the Department of Environment for approval and clearance. This will then be examined by the Environment Impact Agency, and make separate recommendation on the advice of Expert Committee (Mining) constituted under the provision of Environment (Protection) Act and Rule. Wildlife (Protection) Act, 1972, amended in 1991 & 1993, will be enforceable if mining activity impact the habitat of any protected area and species enlisted therein. The new Mineral Policy, 1993 also emphasized the need of minimizing adverse effect of mineral development on forest, environment and ecology through appropriate protective measures.

In spite of all above legal protection measures there are several outstanding environmental problems and challenges: i) development of objective and standardized criteria for assessment of mining impact and reconstruction of habitat; ii) development and recognition of best environmental practices through environmental-friendly technology; iii) Dealing of mining landuse conflicts through speedy disposal by environmental courts; iv) developing integrated environmental professionals for mine site monitoring; and v) involvement of communities for planning and evaluation of mining operations etc.

Plate 1.1: A view of open-cast iron ore mine in the Saranda FD

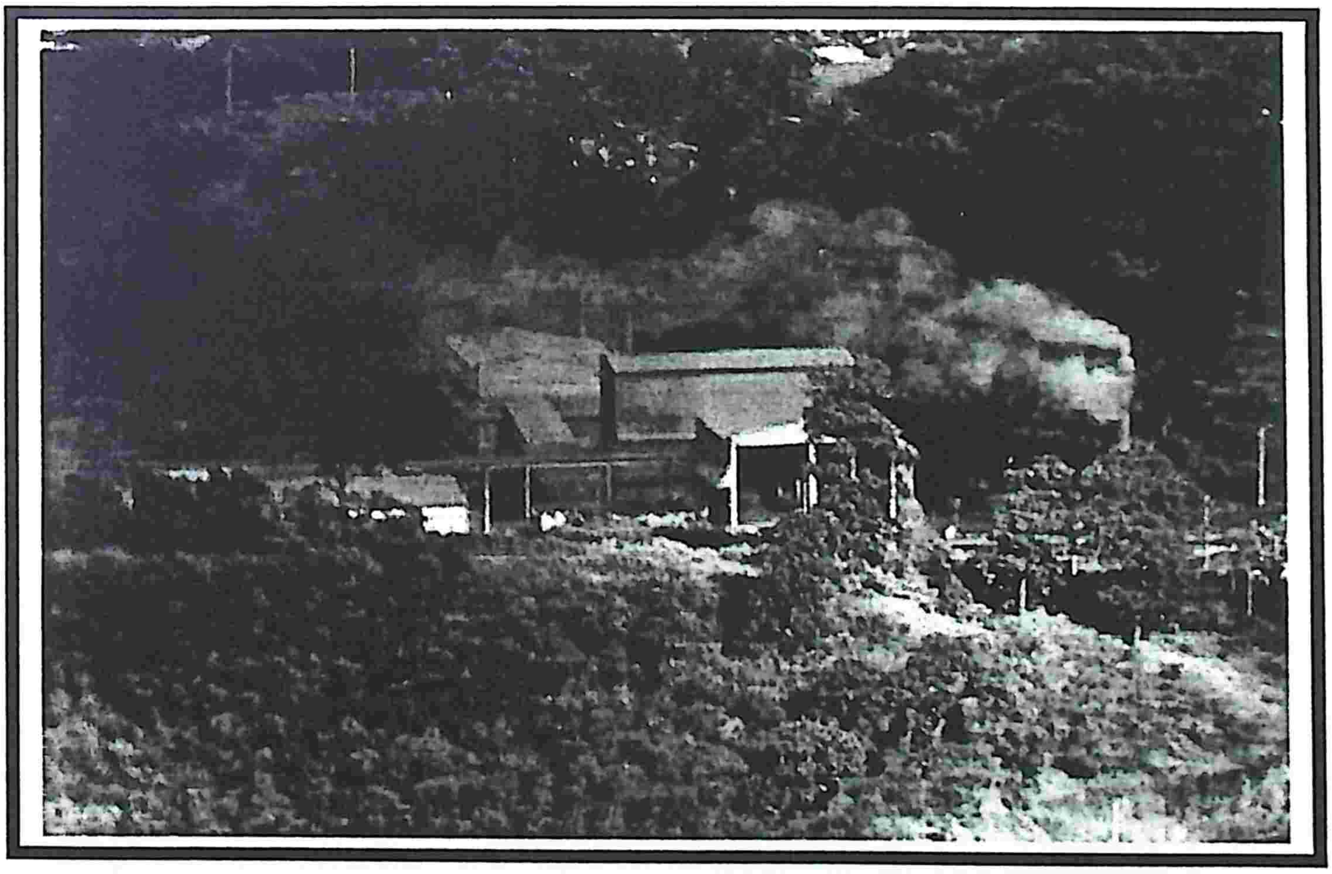

Plate 1.2: SPM release at Gua iron-ore mine through cold bonded pellet plant in the Saranda FD

Plate 1.3: Unmanaged effluent a source of river Pollution in the Saranda FD

Plate 1.4: Fire wood collection pressure in the Saranda forest

Chapter 2

CHAPTER 2

The study area and methods

2.1 Introduction

Singhbhum district with its forests lies between $21^0 58'$ and $23^0 36'$ north and between $85^0 0'$ and $86^0 54'$ east in the Chotanagpur plateau of Deccan Peninsular Biogeographic Zone (Rodgers and Panwar, 1988). The three major forest divisions – Saranda, Kolhan and Porhat comprising a total area of 2225 km^2 constitutes the major elephant habitat in south Bihar in terms of its area and elephant population (Figure 2.1). According to a conservative estimate the present area represents 59% of total available elephant habitat in Bihar. The recent estimate of elephants is approximately 500, constituting 58% of total elephant population known from the State (Annon, 1996). Though, two other Forest Divisions Chaibasa North and Chaibasa South are the part of Singhbhum forests but elephants rarely resides in this area except for their occasional ranging. The forests of Singhbhum on the northeast are bound with Dalbhum tract of Chotanagpur plateau that dips in Gangetic Plains of West Bengal in Midnapur district. On the south these forests continue with hilly tracts in Bonai forests of Sundergarh district of Orissa. The IRS-IC FCC through Wide Field Sensor (WiFS) shows the linkages of Singhbhum forests with Dalbhum tract on the north, extending to Gangetic plains on the east, and Bonai forests on the south (Plate 2.1).

On geological considerations Singhbhum district is one of the most important area in terms of its mineral resources. There are 3 major geological formations known to this area since Archaean age: a) granites and gneisses is the oldest sedimentary rocks, now highly metamorphosed and known as the Singhbhum granite and gneiss, the Chotanagpur granite-gneiss and Akarsani granophyric granite-gneiss; b) the iron ore Series are mostly metamorphosed, ancient sediments with contemporaneous basic igneous rocks and are equivalent to the Dharwar system; and c) the adjoining hill range Dalma in north is constituted through volcanic lava flows (Chaudhury, 1958).

In the erstwhile south Singhbhum and presently west Singhbhum district, iron-ore series of rocks reach their maximum development as banded haematite-quartzites containing enriched sources of iron ore in the country. The banded haematite-quartzites outcrops as ridges, most of which are arranged in the form of a narrow horse-shoe formation open to north and closed to south in Keojhar and Bonai districts of Orissa State. The ridge forming western side of this horse-shoe is known as 'iron ore range' mostly confining in Saranda Forest Division and partly in South Chaibasa Forest Divison falling out of the study area.

The scope of iron ore mining and its environmental problems presented in successive Chapters are limited only to the Saranda Forest Division as spate of mining activities at present is limited to this area. However, the biological entities, especially the elephants (Plate 2.2), which are impacted through the iron ore mining move beyond the range of this limit.

2.2 Study site

The intensive study site is located between $22^0 0'$ to $22^0 26'$ north and $85^0 0'$ to $85^0 26'$ east forming the Saranda Forest Division comprising an area of approximately 857 km^2 excluding areas of human habitation. There are two other contiguous Forest Divisions – Kolhan and Porhat forming the habitat of elephants located on northeast and northwest side of the Saranda Forest Division. These contiguous forests are more fragmented while Saranda FD provides a more intact forests (Figure 2.1). The presence of only one major perennial river systems, Koina in the Saranda Reserve Forests make it more important for wildlife use during summer months. The riverine forests along this river also provide shady vegetation as cover for elephants during summer months. Therefore, importance of this crucial habitat for elephants is immense in terms of water and availability of forest cover (Plate 2.3).

2.3 Topography and soil

The name "Saranda" derived for the forest division refers seven hundred hills in the region. The general landscape is hilly upland tract thickly vegetated with several streams. The general elevation varies from 305 m to 610 m, however, the highest peak (927 m) is located in Sasangda buru hill range. Two major mechanized iron ore mine projects – Kiriburu (KBR) and Megahatuburu (MBR) are located on the ridge of the Sasangda buru hill range. Samta valley located on the south in Saranda represent the lowest elevation (229 m).

Three major soil types – rocky soil, red soil and yellowish gray & gray soil in the forest division are derived from Dharwar rocks. The rocky soil is mostly uncultivated and is found while coming down the hills and hillocks. The red soil, which is abundantly found, is sandy and loamy in uplands and mid land respectively. Its fertility is poor and acidic in nature. *Sal* forests of good to moderate quality are found to grow in red soil, where soil profile is much thicker. In low soil quality wet and dry mixed forests are generally met. Yellowish gray soil is found in the low elevation areas and is deficient in organic matter.

2.4 Hydrology

There are two main drainage systems Karo and Koina flowing northwesterly and submit into the Koel river system (Figure 2.2), which ultimately feeds to the Brhamani river system. Most of the courses of Karo river system remain out side the limit of Saranda Forest Division and therefore has less importance as a water resource for wildlife. On contrary, the river Koina and its tributaries have a major role to wildlife for providing perennial water by meandering through forests of Saranda covering a total length of approximately 83 km from the points of its origin in Bhangaon village bordering Bihar and Orissa. Approximately 305 km^2 of reserve forest falls in the catchment of river Koina. The precipitous Sasangda hill range has several perennial streams on the western slope, which are threatened due to siting of two major mechanized iron ore projects. A large forest clearance in Karampada block for mining settlement has affected water table in the area.

Moreover, unmanaged mine waste disposal and run off are major source of clogging of stream channel in the upper reaches.

2.5 Climate

The climate is represented through three distinct seasons – summer, rains and winter. Summer is intense extending from March to June. The mean maximum and minimum temperature varies from 43^0 C in summer and 7^0 C in winter. The maximum and minimum temperatures based on 30 years data (1968-98) as recorded at Kiriburu Mines Meteorological Station is presented in Figure 2.3. This data over the years indicate general trend of increase in minimum temperature due to continuous forest losses in the area. Monsoon commence in the 2^{nd} week of June with lowering of temperature. The rainy season extends from July to October, and represented through highest rainfall period between July and August. Average annual rainfall is 1895 mm, while 50% downpour occur between July and August. The rainfall pattern of 33 years (1965-1997) at two meteorological stations, Gua and Kiriburu, located in the study area are presented in Figure 2.4. Monthly rainfall data collected during the study period (1995-97) available through nearest meteorological station (Kiriburu) is presented in Figure 2.5. Winter season begins from November and prolongs till February. Frosts are only known from the deep valleys.

2.6 Vegetation

The majority of the vegetation can be classified broadly under tropical moist and dry deciduous categories. While the former constitute far and wide, later is confined mostly on the ridges. The forest of Saranda is well known for its best quality Sal, *Shorea robusta*, a predominant species occurs in all types of soil. In favorable localities it attains a height of 40 – 45 meters. According to Champion and Seth (1968) the forest types are classified as: northern dry mixed deciduous forests, dry peninsular *sal* forests, moist peninsular *sal* forests, moist mixed deciduous forests, northern tropical evergreen and semi evergreen forests and dry deciduous scrub forests.

Northern dry mixed deciduous forests with its various sub types are found on steep slopes particularly on southern facing aspect. The species associates are *Lannea coromandelica, Sterculia urens, Anogeissus latifolia, Lagerstroemia parviflora* and *Haldina cordifolia*.

Along the valley slopes forests of dry peninsular *sal* (Plate 2.4) are found with the associates *Anogeissus latifolia, Boswellia serrata, Zizyphus xylopyrus* and *Madhuca indica* etc.

Moist peninsular *sal* forests are generally found in the middle, lower slopes or in sheltered position towards northern aspect. Important associated species with *Shorea robusta* are: *Syzygium cumini, Dendrocalamus strictus, Bauhinia spp., Terminalia alata, Cedrela toona, Callicarpa arborea, Pterocarpus marsupium, Bridelia retusa, Helicteres isora, Bauhinia vahlii, Haldina cordifolia, Mitragyna parvifolia, Gmelina arborea, Dillenia pentagyna, Diospyros melanoxylon* etc.

Moist mixed deciduous forests occur in valley flats having low lying badly drained ground with deep moist alluvial soil. The species found are *Terminalia alata, Diospyros peregrina, Kydia calycina, Mallotus philippinensis, Colebrookia oppositifolia* etc.

Northern tropical evergreen and semi-evergreen forests occur in small patches in narrow belts along the perennial streams. This is an edaphic type with high moisture content in sandy loam or loamy clay soil. The important species found are *Litsaea spp., Michelia champaca, Actinodaphne angustifolia, Macaranga peltata* etc.

Dry deciduous scrub forests are found in degraded and low moisture areas. The species associations with poor quality *sal* are *Buchanania lanzan, Terminalia alata, Terminalia chebula, Cleistanthus collinus, Boswellia serrata, Cordia myxa, Combretum decandrum* etc.

2.7 Legal status and threats to the forests

On legal count the forests of Saranda Division is constituted by approximately 817 km^2 of reserve forests, 39 km^2 of protected forests and 1 km^2 unclassed forests. At present there is no Protected Area in this region despite of large availability of contiguous forests with other two adjoining forest divisions *i.e.* Kolhan and Porhat. Though there was an old game sanctuary at Tholkobad but this was never been renotified under the provisions of Wildlife (Protection) Act, 1972. With the advent of the Project

Elephant in 1993 this area has been identified as a Reserve for the conservation of elephants.

The major threats to flora and fauna due to biotic interference in this region are: encroachment of forest land (Plate 2.5), illicit felling of forest (Plate 2.6), poaching and tribal hunt (Plate 2.7), iron ore mining and its associated environmental problems, forest fire and grazing (Chowdhury *et al.,* 1985). The study area though suffer from all these threats in the elephant habitat of three forests divisions (Saranda, Kolhan and Porhat) yet iron ore mining and it associated environmental problems are the major issues of Saranda Forest Division only. In the successive Chapters this problem has been quantified and related with its impact on elephants and other wildlife.

2.8 Landuse pattern

There are three categories of landuse in the Saranda Forest Division and majority of which is represented through 85.84% forests (Figure 2.6). The human settlements and arable land constitute next major landuse (13.46%). There are three revenue village complexes namely Chotanagra, Kodlibad and Ponga. Besides, there are 10 forest villages, which were established earlier for various forestry works in the area. The mining areas with its established townships constitute 87.26 km^2, out of which 99.74% is forest and 0.25% is non-forest area.

2.9 Mining and environmental problems in the study area

2.9.1 Development of mining

The Saranda forest in Singhbhum district is well-known for its large reserves of haematite iron ore. The estimated reserves is approximately 25% of the total known reserves of India (Annon, 1993). Mining began in early 1900s and is limited within the Saranda Forest Division, but coincides with areas used by elephants. In its early days, at the beginning of the 20th century, the impact of mining on the habitat was limited because it was largely unmechanized and the extraction capacity was low. Large scale mechanised extraction of iron ore started in about 1921, and the activities had few environmental safeguards. A 30-year lease was granted to the National Mineral Development Corporation in early 1960's. In 1968 this was transferred to the Steel Authority of India Limited (SAIL), for two major mechanised mines, Kiriburu (KBR) and Megahatuburu (MBR). The growth of iron ore mining in Saranda Forest Division between 1910-1993 has been represented in Figure 2.7.

At present, there are 15 operational mines in the Saranda Forest Division which all occur within elephant habitat. The extraction and processing of ore in this region is a major concern for environmental pollution, resulting in extensive habitat degradation. A similar environmental situation exists in the adjoining areas due to several other mineral extraction activities for copper, uranium, talc, manganese, kynite and barite.

The operative mines occupy a lease area of 87.26 km^2 (Figure 2.8), out of which 24% (21 km^2) have been opened up for iron ore extraction. Table 2.1 shows the mine owner ships, their establishment years, production rate and stripping ratios etc. Out of 15 mines, 4 mines also extract Manganese (Mn) along with iron ore. The location of the mines their leased and broken area, waste generation and township population of human beings are given in Table 2.2.

2.9.2 Ore processing and water pollution

Most of the iron ore mines despatch their products without processing on-site. Only during the rains, when runoff brings sediments into the natural drainage courses does pollution result from these activities. The three major iron ore mines – KBR, MBR & Gua (Figure 2.8) process their ore on-site. These occupy 53% (42.9 km^2) of total mining lease area. At present only 30% of the lease area of above three major mines has been opened up for mining. Dry circuit processing largely causes air pollution, which is beyond the scope of this study. This is carried out all year at Gua mine. However, at MBR dry circuit processing is carried out for most of the year, but in rainy season, wet circuit processing is practised. Waste disposal through dry circuit processing from the MBR mine causes some pollution of river Koina during summer season. During rainy season, run off further increases total load of solids in the river, leading to high coloration. At this time wide spread water availability allows elephants to use more extensively rather than being restricted to zone nearest to the river.

The KBR mine undertakes wet circuit ore processing exclusively through out the year using a water-spraying technique. In this process about 1900 $m^3 day^{-1}$ of waste water are released, containing 2491 tonnes of effluent known as 'slime'. This consists of inferior quality iron fines with particle size less than -150 μm. Usually the slime generated is recoverable, through a settling process, while excess water with un-recovered waste is allowed to spill out for further settling in a tailing dam (Plate 2.8). Until recently, the KBR mine authorities did not observe discharge norms set by the Central Pollution Control Board (CPCB), and allowed all waste to pass directly into the Sankoja *nala* (Plate 2.9) without passing through a tailing dam. This caused major problems of water pollution in river Koina (Plate. 2.10). Non-functioning of thickener unit (Plate 2.11) in wet-circuit ore processing and lack of dredging of sediment by the company caused the tailing dams (TD-1 & TD-2) to fill with waste, thus reducing their effectiveness in holding back the slime, which then entered into the main river course (Figure 2.2)

2.9.3 Visible impact of waste discharge

The impact of waste discharge was visible due to high colouration of the Koina river water, and deposition of fine dust along the river contributed bed load component (Plate 2.12). At many a places large number of trees along the river course were found wilted/dead (Plate 2.13) which were reasons for investigation in subsequent Chapters. During our study period two kind of situations *i.e.* unregulated (April'95 – June'95) and regulated (July'95 onwards) were prevailed based on presence and absence of the excessive coloration of river water due to mine discharge (Plate 2.14 and

2.15). The coloration was further reduced after control of mine discharge when strict regulation was imposed from January 1996 (Plate 2.16).

A total 1283 completely wilted/dead trees were enumerated in 1.3 km^2 (130 ha) area (Figure 2.9). The high forests along the Koina river have an average stand characteristic of 273 trees/ha comprising 144 trees/ha, *Shorea robusta*; 18 trees/ha, *Terminalia alata* and 14 trees/ha *Anogeissus latifolia* (FSI, 1990). In comparison to this, in total surveyed area of 1.3 km^2, 7 trees/ha (4.8%) *Shorea robusta*, 2 trees/ha (11%) *Terminalia alata* and 0.07 trees/ha (0.5%) *Anogeissus latifolia* were found wilted/dead. The impacted zone along the river Koina horizontally varied from 1 – 50 meter extending up to 35 km river length from the confluence of Sankoja *nala* and Koina river.

2.9.4 Biotic pressures due to mining settlement

Biotic pressures due to mining settlements are the reasons for degradation of forested habitat of the Saranda. At present there are 3 major township complexes in the Saranda forest namely Kiriburu-Megahatuburu (KBR-MBR), Gua and Chirya (Table 2.1) with a total population of 21,400 human being as per the records of respective mines. However, the population growth of these complexes between 1951-1981 is shown in Figure 2.10. The KBR-MBR and Chirya complexes are brought under urban population since 1971 and 1981 respectively. The profiles of mining worker and non-worker in three complexes are shown in Figures 2.11 and 2.12 respectively. Besides, above three main complexes, 4 more small settlements are there for mine working constituting a population of 642 human being.

The biotic pressures exerted by the three major complexes are concern for forest degradation through fire wood and timber extraction and also through cattle grazing on the neighboring forests.

2.10 Study methods

2.10.1 Mapping of mining areas

The mining areas in Saranda Forest Division were delineated through ground validation and overlaying on Survey of India toposheet (1:50000) in GIS/GRASS domain (Figure 2.8). Some of the mining areas become very small in size could not be shown properly.

2.10.2 Analysis of mine effluent and river water

Effluents and water samples were collected every months from several samplings stations as per the laid out scheme (shown in the respective Chapters) to know the impact of mine discharge on river water quality. Samples were collected in an one litre wide mouth plastic bottle from April'95 to March'96. The river flow, temperature (Temp), turbidity (Turb), total dissolved solids (TDS), pH, were measured at the sampling sites. For quantifying dissolved oxygen (DO) the samples were fixed by following modified Winkler's Azide Method (APHA, 1992). Samples were preserved by following the methods suggested by MtCalf and Edd Inc. (1986) for rest of the other parameters *viz.* total solids (TS), total suspended solids (TSS), total hardness (THard), total phosphate (Phos), reactive silica (Silica), chloride (Chlo), nitrate (Nitra), nitrite (Nitri) and Sulphate (Sulph). All fixed and preserved samples were analysed at the laboratory established at base camp. The methods employed for quantification of various parameters were adopted from Trivedy and Goel (1986) and APHA (1992).

2.10.3 Analysis of river sediment and soil

The river sediments were collected in May'1997 from various sampling stations for quantifying heavy metals (Fe, Mn, Cu, Zn and Pb) load and their transportation along the river gradient. In each sampling site sediments were collected from both the banks as well as from middle of the river with the help of Eckman Dredge Sampler (Trivedy and Goel, 1986).

Soil samples were collected once in April'97 near to the wilted/dead tree sites to know the heavy metals load (Fe, Mn, Cu, Zn and Pb) and to determine changed soil nutrient status. Reference soil samples were collected from the nearest possible site where a similar tree was standing healthy. On each impacted (wilted/dead) and reference sampling sites three soil samples were taken around the tree within a distance of one meter from tree base.

All sediment and soil samples of each site was thoroughly mixed and three sub-samples were prepared for analysis. Oven dried samples were analysed for Loss on ignition (LOI), pH, oxidation redox potential (ORP), organic carbon, nitrogen, major (Na, Mg, Si, P, K, Ca, Fe, Mn) and minor (Pb, Zn, Cu) elements.

2.10.4 Analysis of plant tissue and dung

The plant tissue from wilted/dead trees (impacted) and nearest reference site were collected to quantify the uptake of heavy metals. Three tissue samples of each species were collected by drilling at chest level up to the centre of tree diameter. The plant tissues were oven dried and digested for heavy metals (Fe, Mn, Cu, Zn and Pb) analysis (Allen, 1989).

The elephants dung were also collected from the mining, near mining and non-mining sites in the study area during February – March 1997 to quantify the heavy metals (Fe, Mn, Cu, Zn and Pb). The dung samples were also been collected from the Dalma Wildlife Sanctuary as a reference. The washed and sieved plant residues of dung were oven dried and digested for heavy metals analysis.

2.10.5 Collection of habitat use data

Two-meter belt transacts along the selected zones of river Koina and Sankoja *nala* (Chapter 4) were surveyed in mid May 1995 and 96 for presence of accumulated dungs. Dung decay for 50 dung piles were monitored for calculating mean decay rate in the study area up to a stage of broken or flat masses to maintain a consistency in observation at various river sectors.

Table 2.1: Basic information about operational mines in the Saranda FD

S. No.	Name of the Mines	Owner Name	Year of Initiation	Type	Ore Deposit	Reserve (Million tones)		Production Rate (MT/Day)	Stripping ratio
						Estimated	Proved		
1.	Gua Iron Ore	IISCO Ltd. (SAIL)	1921	Mechanized	Fe	225	-	3000	1:0.34
2.	Baraiburu Tatiba Iron & Manganese	Rameswar Jute Mills Ltd.	1966	Manual	Fe	20.07	1.24	12	1:1
					Mn	0.124	0.075	-	
3.	Manoharpur Groups	IISCO Ltd. (SAIL)	1910	Semi-mechanized	Fe	1970	-	800	1:07
4.	Kiriburu (KBR)	SAIL	1964	Mechanized	Fe	200	192	9,165	1:0.92
5.	Megahatuburu (MBR)	SAIL	1985	Mechanized	Fe	121.81	100.82	12,000	1:0.2
6.	Ajitaburu Iron & Manganese	Dewki Bhai Velji	1953	Manual	Fe	1.488	0.608	100	1:2
					Mn	4.668	1.495	40	
7.	Orissa Mining Mine	Orissa Manganese & Mineral (P) Ltd.	1976	Manual	Fe	67.08	25.780	150	1:2
8.	Baraiburu & Tatiba Iron & Manganese (Lease - 1)	K.S. Ahluwalia	1949	Manual	Fe	8.97	2.87	65	3:1
					Mn	2.188	0.227		
9.	Baraiburu & Tatiba Iron & Manganese (Lease - 2)	K.S. Ahluwalia	1949	Manual	Fe	8.52	-	20	3:1
					Mn	0.70	0.37		
10.	Ghatkuru Iron Ore Mine	Rungta Mines (P) Ltd.	1953	Manual	Fe	68.36	12.87	100	1:4.76
11.	New Karampada	R. McDill & Co. Pvt. Ltd.	1957	Manual	Fe	4.25	2.41	25	1:4
12.	Karampada	M.L. Jain & Sons.	1958	Manual	Fe	9.77	4.81	150	1:6
13.	Tatiba Village	Nirmal Kr. Pradeep Kr.	1992 Restart	Manual	Fe	1.5	-	100	1:1
14.	Raja Bera	Gyan Chand Jain	1993-94 Restart	Manual	Fe	1.0	-	150	1:1.5
15.	Karampada RF	Singhbhum Mineral Co.	1993-94 Restart	Manual	Fe	-	-	30	-
				Total	Fe	2707.818	343.408	25867	
					Mn	7.68	2.167	40	

Table 2.2: Environment parameters of various mines in the Saranda FD

S. No.	Name of the Mines	Elevation	Lease Area (Ha)		Mining Area (Ha)	Ore Processing Unit	Employment		Township population	Waste generation (MT/Day)	
			Total	Broken			Per day	Local:Outsider		Solid	Slime
1.	Gua Iron Ore	890	1443.73	635.98	635.98	Yes	980	1:5.1	6,000	0.61	-
2.	Baraiburu Tatiba Iron & Manganese	440 - 700	259.00	35.84	23.05	No	17	1:0	Nil	12	-
3.	Manoharpur Groups	890	2540.79	NA	445.47	Yes	890	NA	4,800	20.32	-
4.	Kiriburu	794 - 896	2897.49	688.07	84	Yes	1719	3:2	7,600	50.14	2513.71
5.	Megahatuburu				59	Yes	1238	3:2	5,000	2438.4	3657.60 (June-Sep)
6.	Ajitaburu Iron & manganese	440 - 630	46.62	15.57	NA	No	60	1:0	58	Fe=127m^3 Mn=49 m^3	-
7.	Ghatkuru RF	440	275.51	141.52	NA	No	63	1:0	Nil	127 m^3	-
8.	Baraiburu & Tatinba Iron & Manganese - 1	405 - 545	257.74	31.45	NA	No	95	46.5:1	Nil	200 m^3	-
9.	Baraiburu & Tatinba Iron & Manganese - 2	410 - 450	129.50	19.26	31	No	31	9.33:1	Nil	70 m^3	-
10.	Ghatkuru Iron	804	230.36	31.32	120	No	135	20:1	474	50 m^3	-
11.	New Karampada	500 - 800	110.07	19.62	70	No	14	1:0.13	25	8 m^3	-
12.	Karampada	500 - 700	202.30	49.20	176	No	75	1:0.1	85	45	-
13.	Tatiba Village	655	149.63	13.96	NA	No	53	9:1	Nil	NA	-
14.	Rajabera	350	41.64	41.64	NA	No	149	9.8:1	Nil	NA	-
15.	Karampada RF	868	141.64	18.97	11.69	No	30	9:1	Nil	45	-
		Total	8726.02	2187.87			5549		24042	2611.47 + Fe = 582 m^3 Mn = 49 m^3	

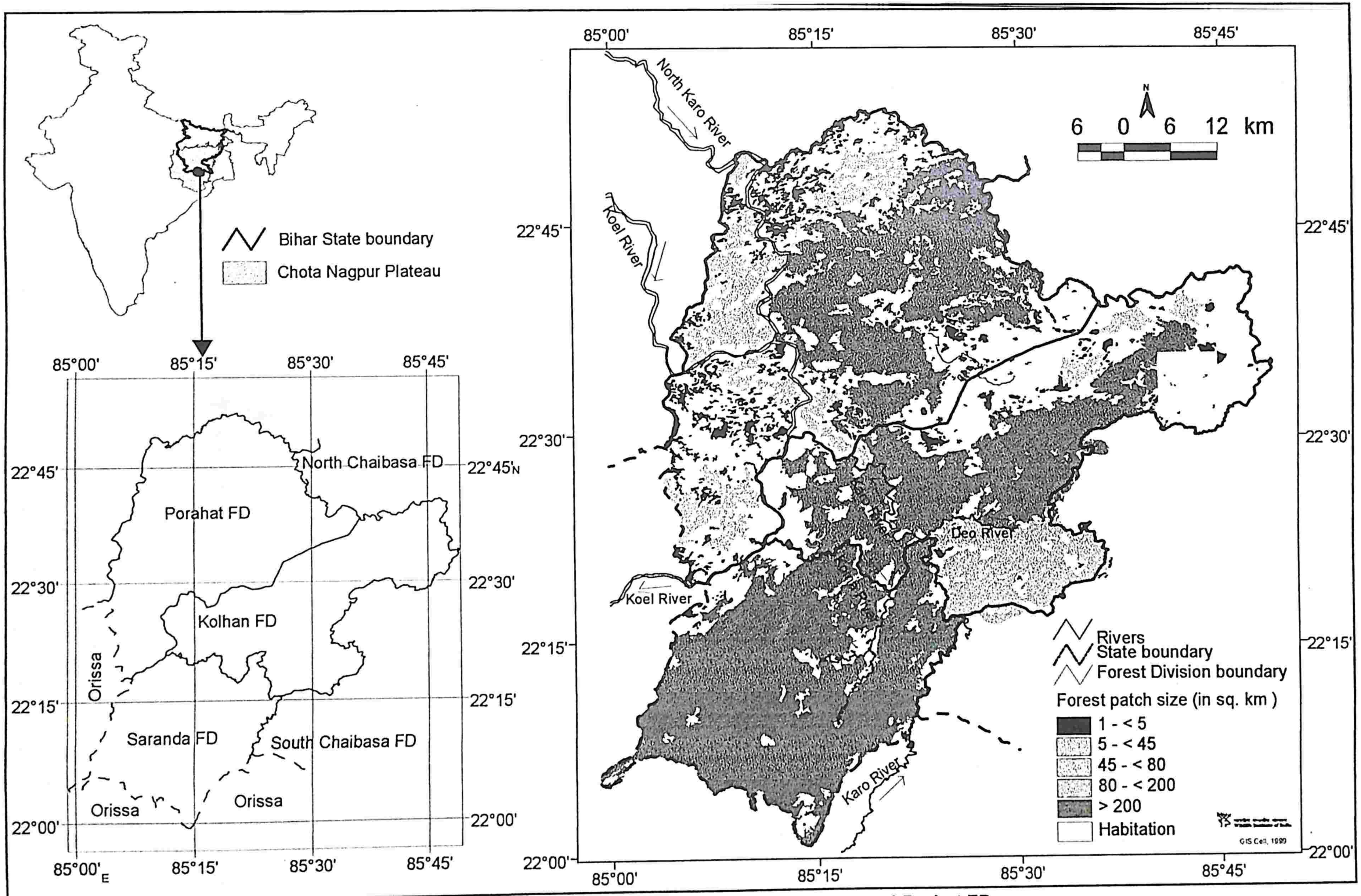

Figure 2.1: Level of forest fragmentation in Saranda, Kolhan and Porhat FDs

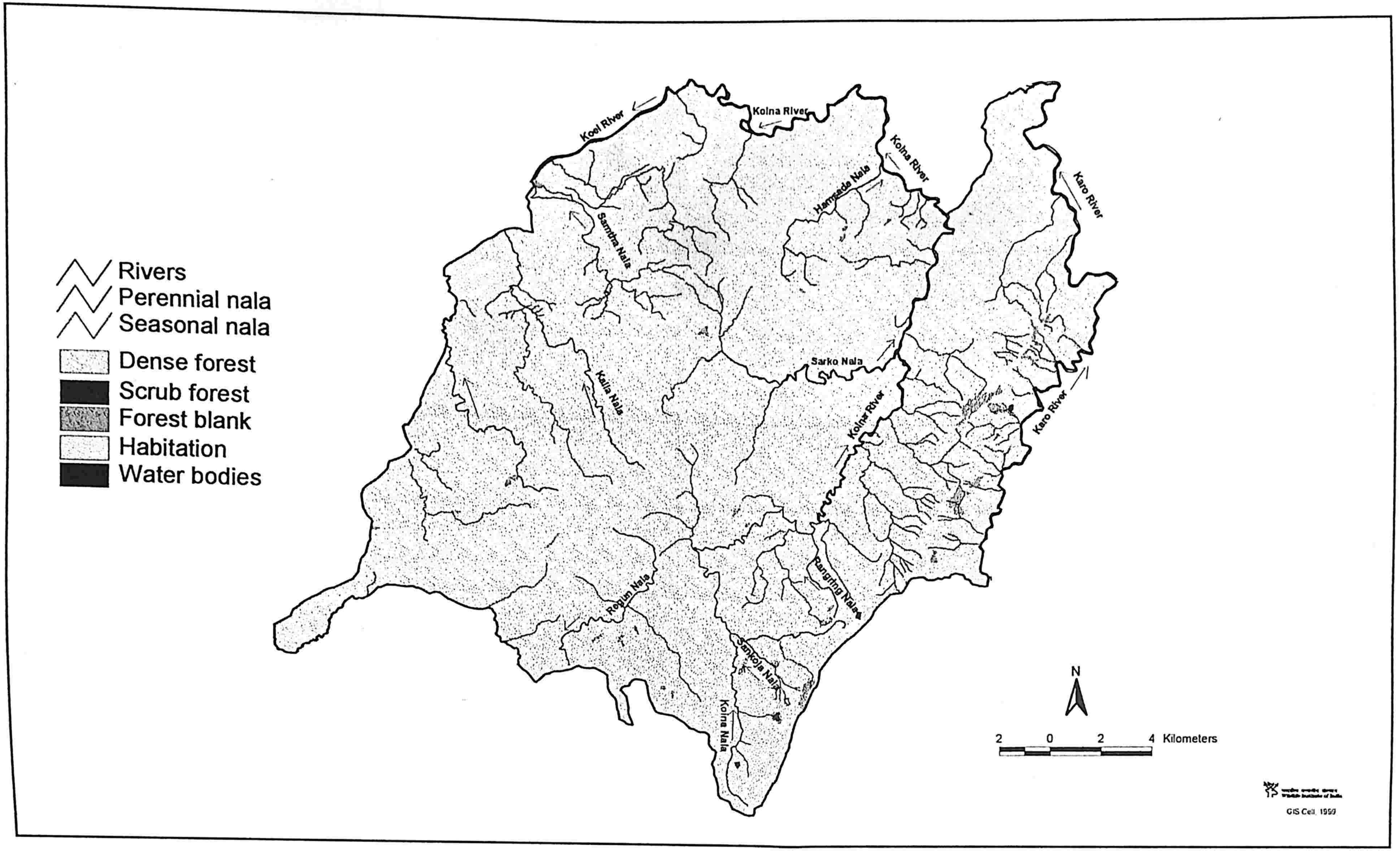

Figure 2.2: Map of the Saranda FD showing major drainage of Koina, Karo and Koel River

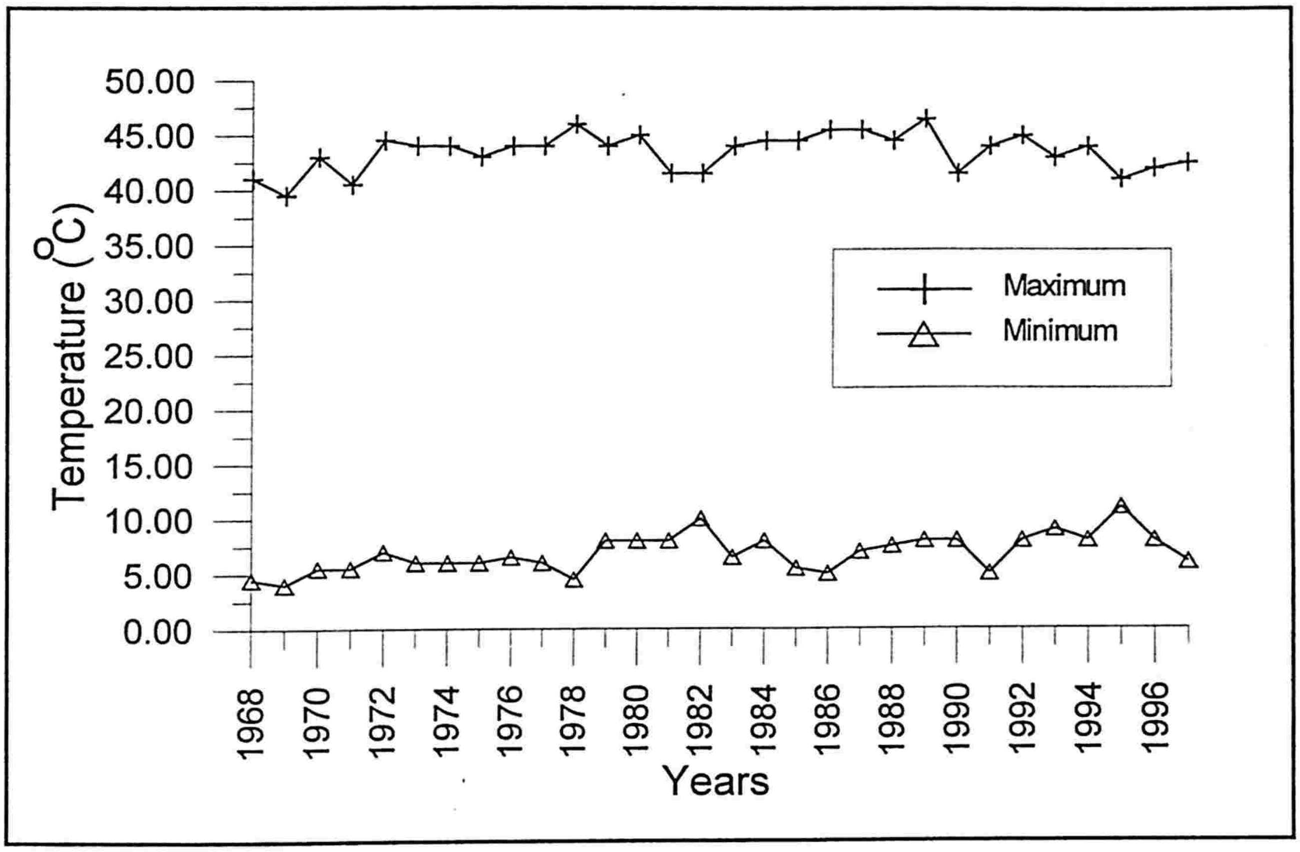

Figure 2.3: Fluctuation in maximum and minimum temperatures (1968-97) recorded at Kiriburu meteorological station

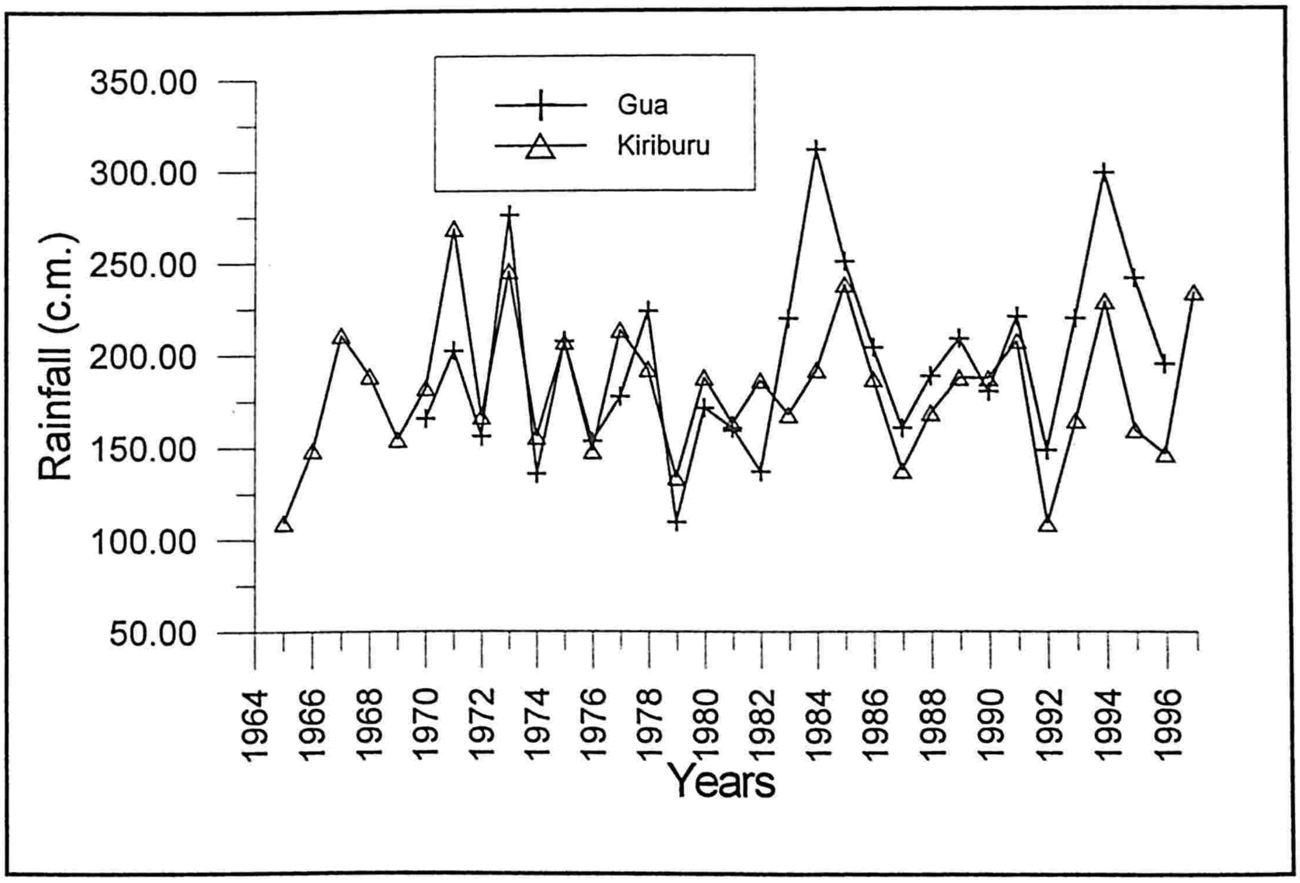

Figure 2.4: Fluctuation in annual rainfalls (1965-97) recorded at Gua and Kiriburu meteorological stations

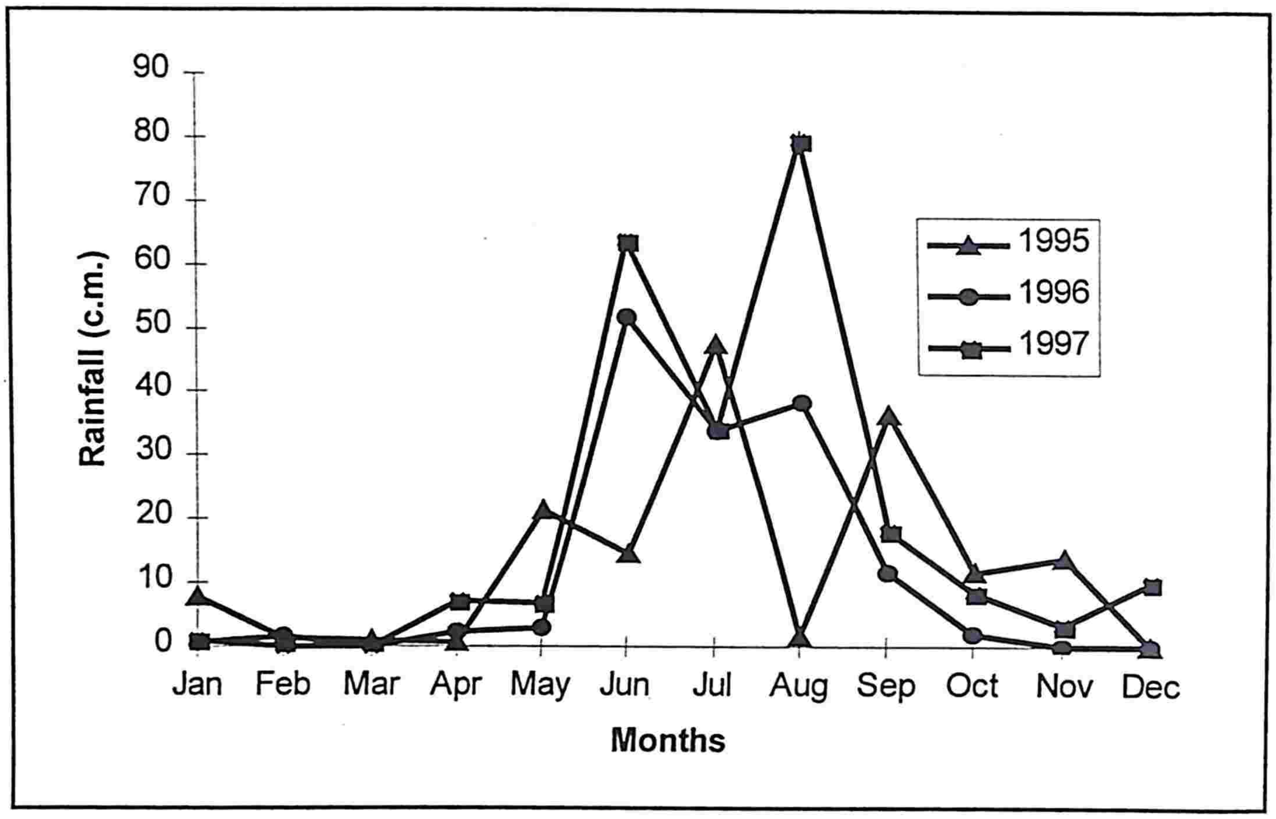

Figure 2.5: Fluctuation in monthly rainfalls recorded at Kiriburu meteorological station during study period (1995-97)

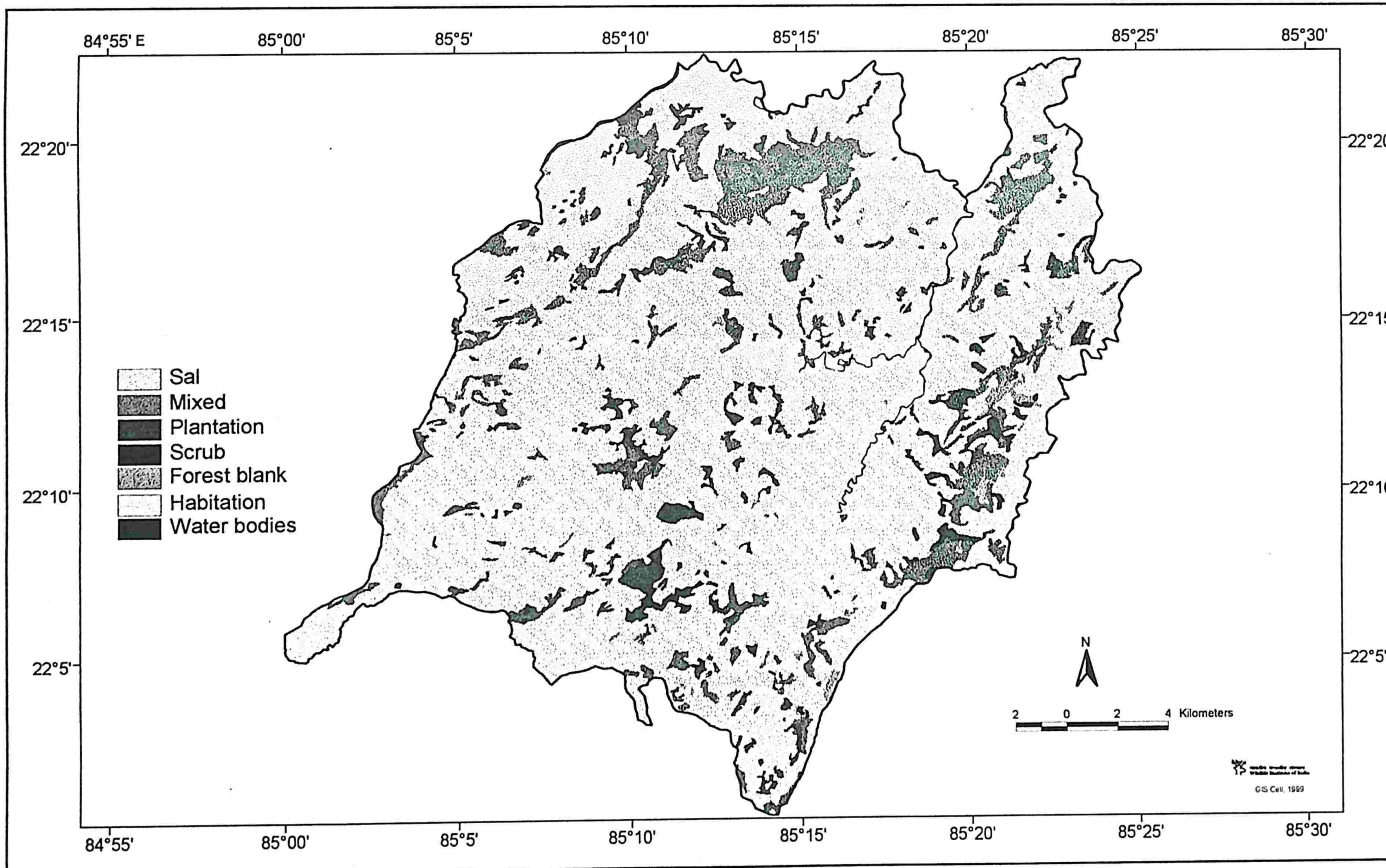

Figure 2.6: Forest and Non Forest areas in the Saranda FD

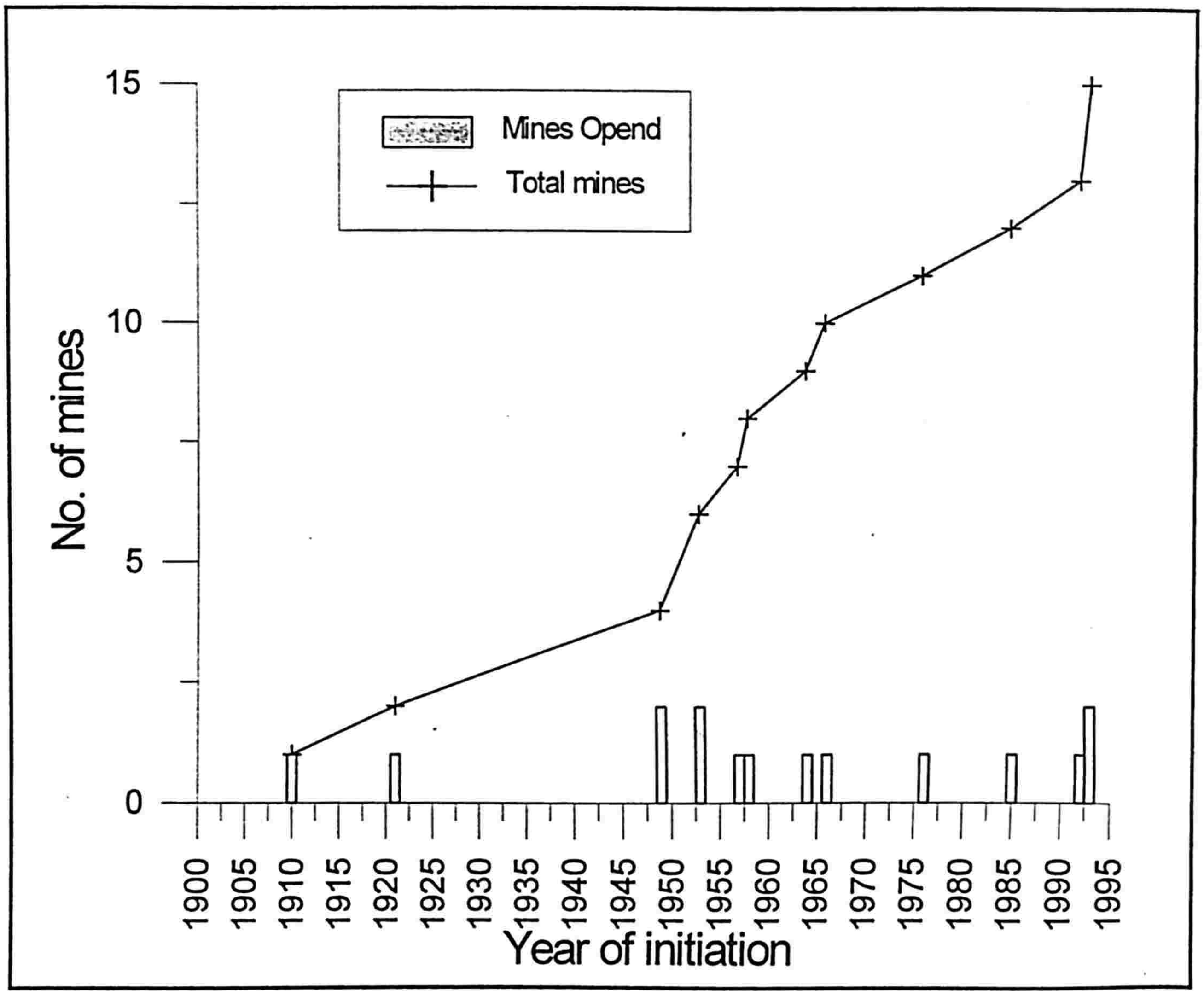

Figure 2.7: Year wise increase of iron-ore mining in the Saranda FD

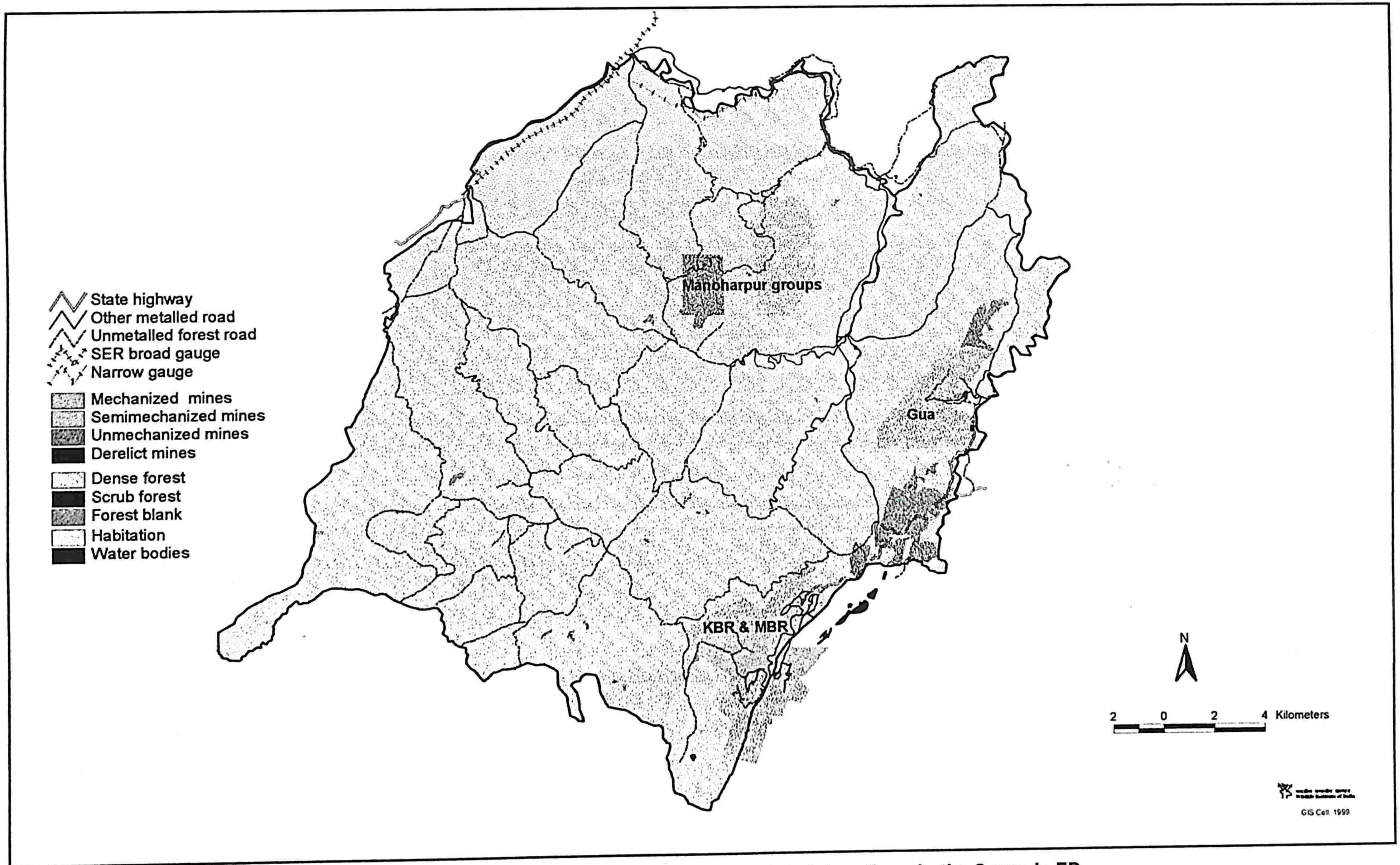

Figure 2.8: Extent of Mining leases and their locations in the Saranda FD

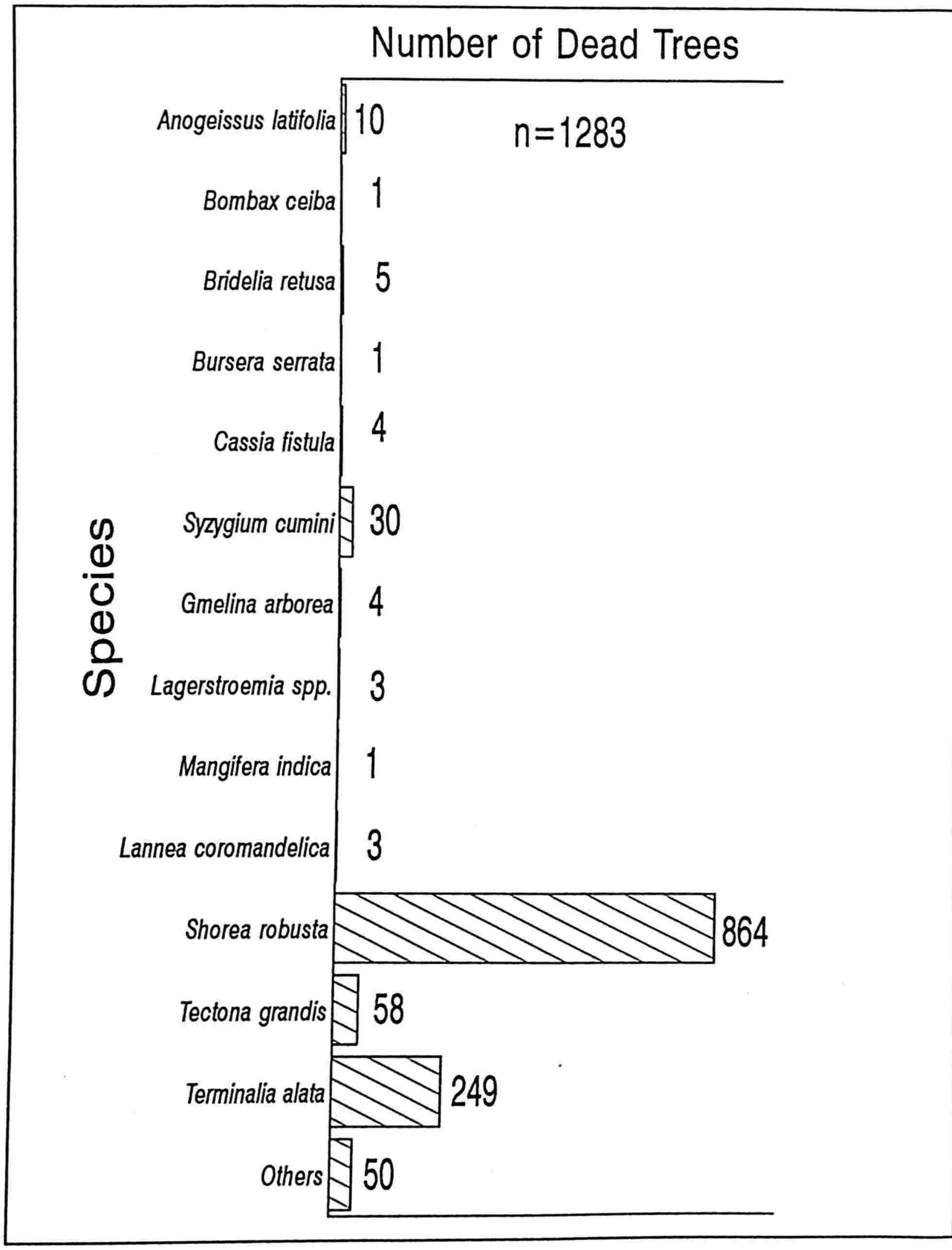

Figure 2.9: Enumeration of wilted/dead tree species along the river Koina

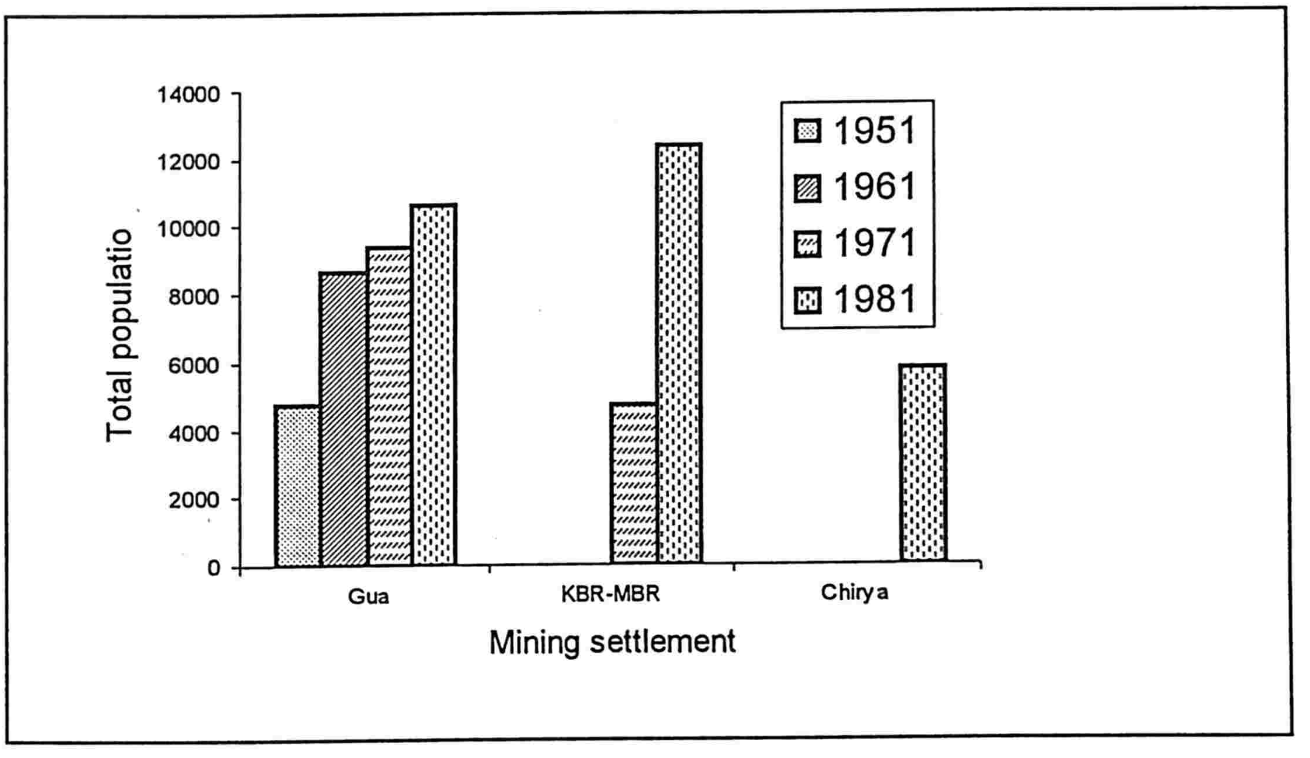

Figure 2.10: Human population increases in the three major mining complexes between 1951-81

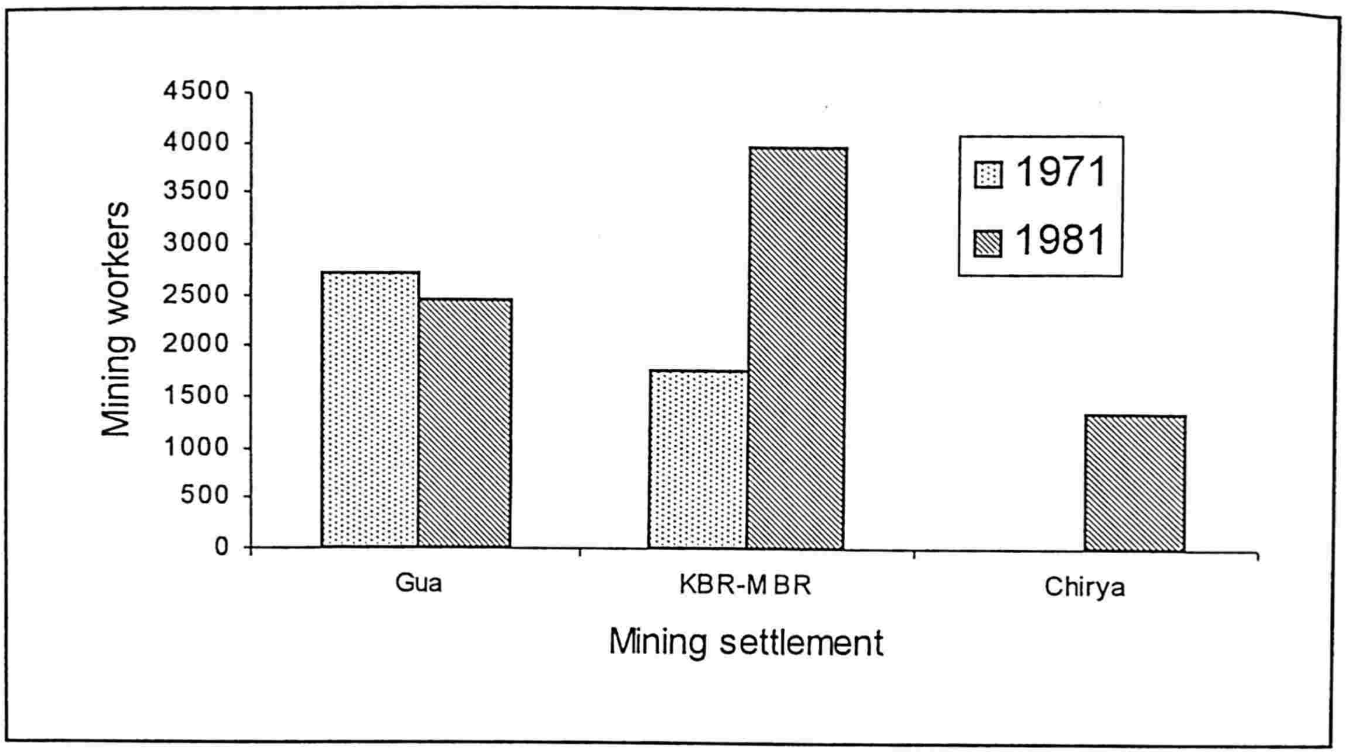

Figure 2.11: Mining workers in the three major mining complexes

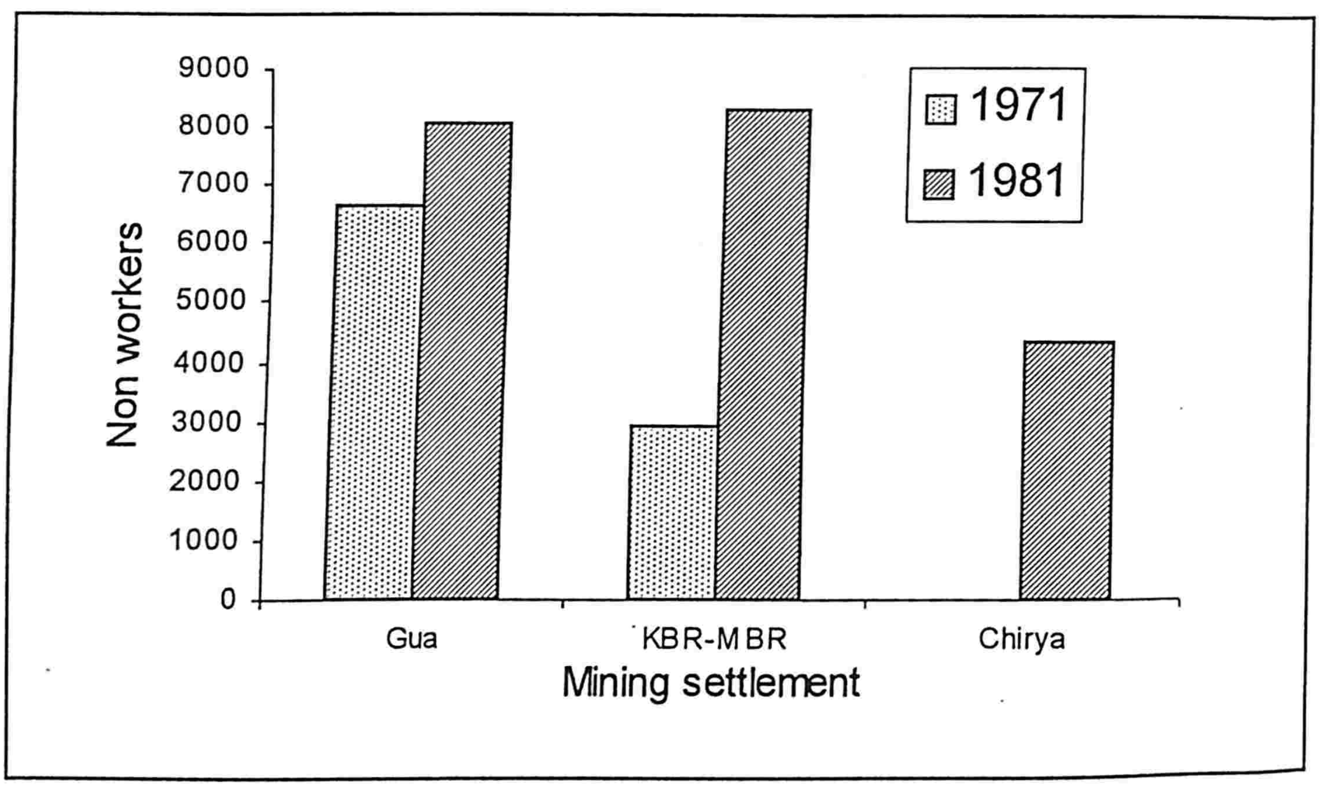

Figure 2.12: Non workers in the three major mining complexes

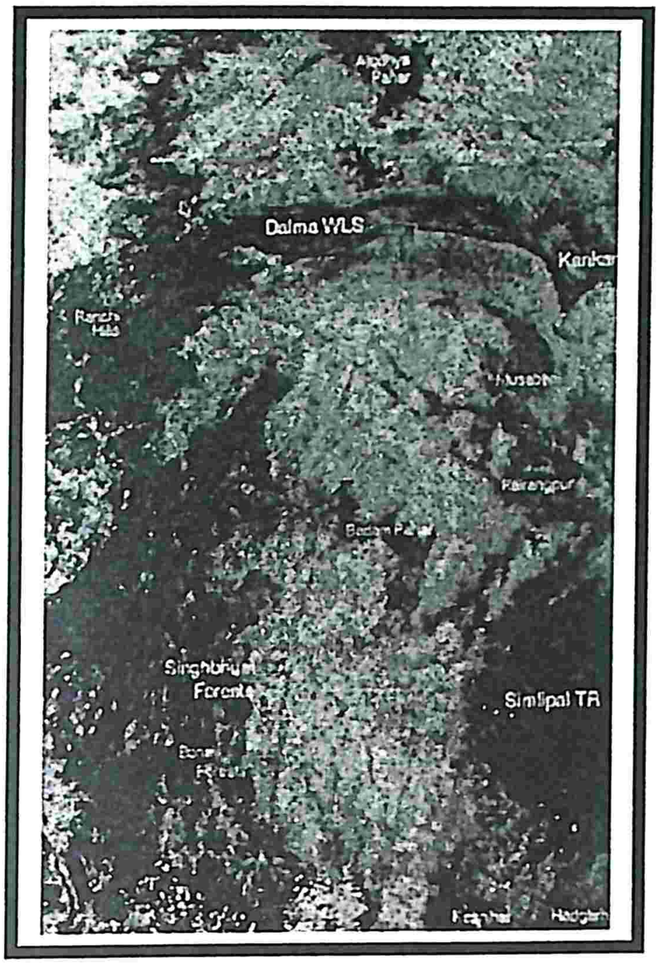

Plate 2.1: WiFS image showing linkages of the Singhbhum forests with other adjoining areas

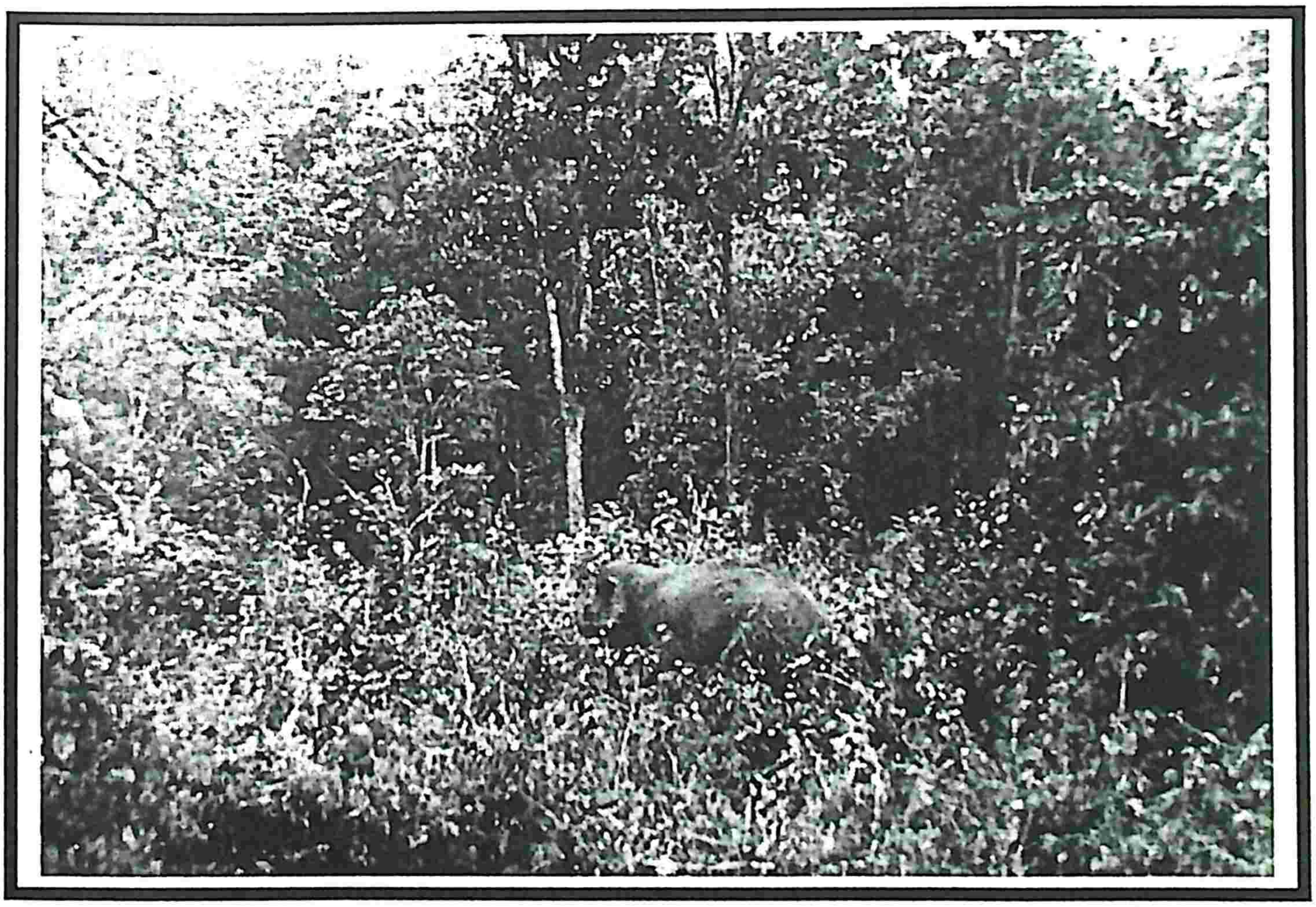

Plate 2.2: An elephant using the riverine habitat

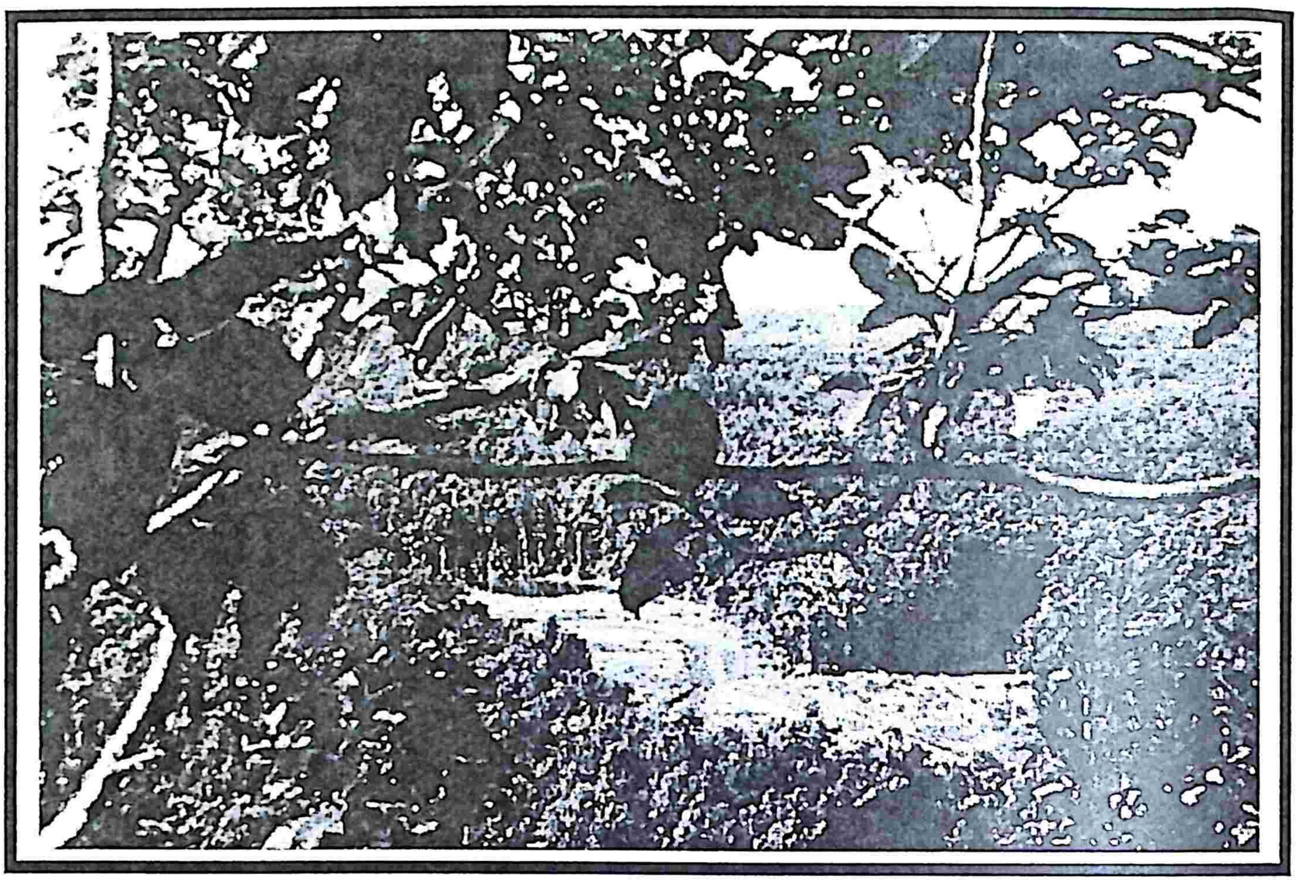

Plate 2.3: Showing the Koina river catchment and crucial habitat of elephant

Plate 2.4: Showing dry peninsular *sal* forest

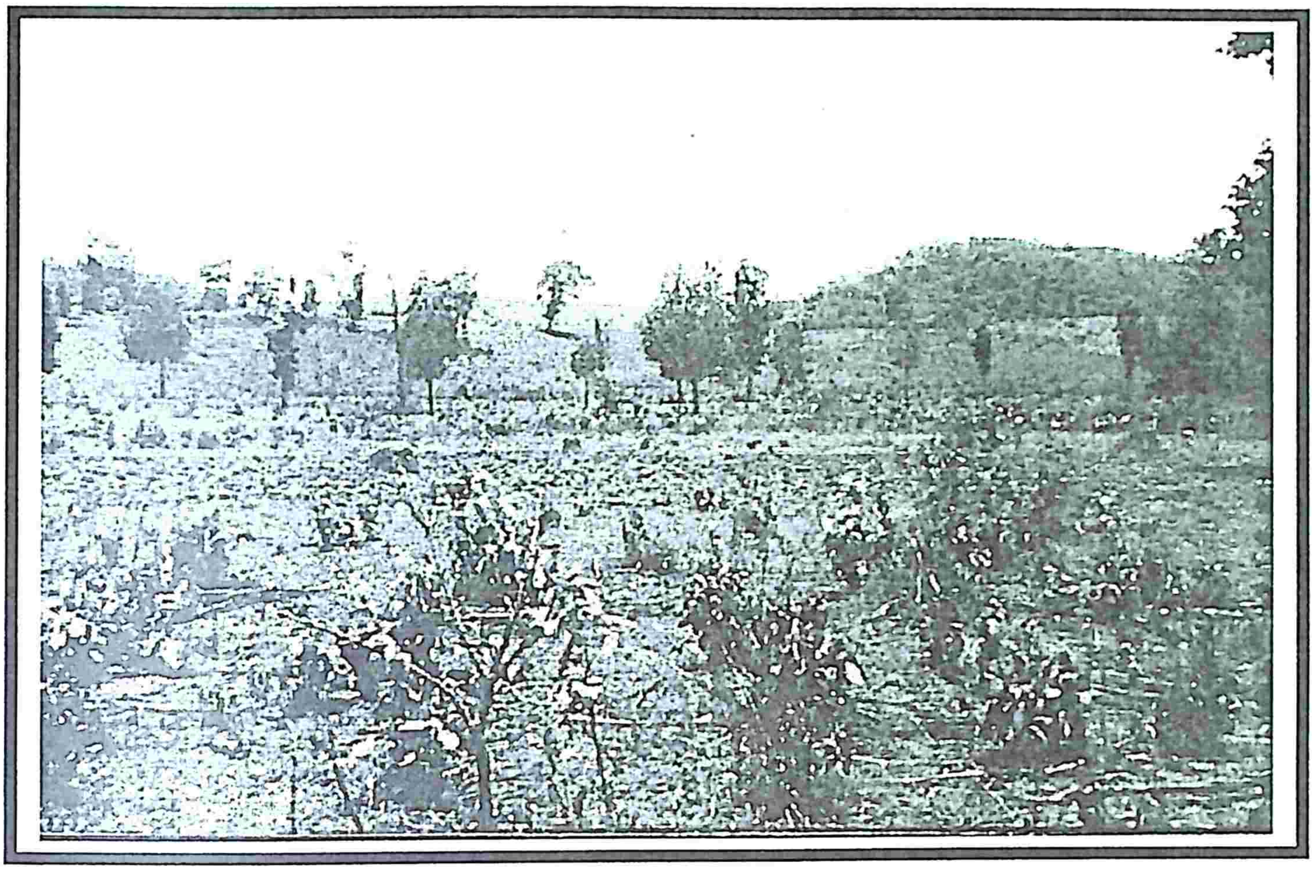

Plate 2.5: Encroachment of forest land for cultivation in the Saranda FD

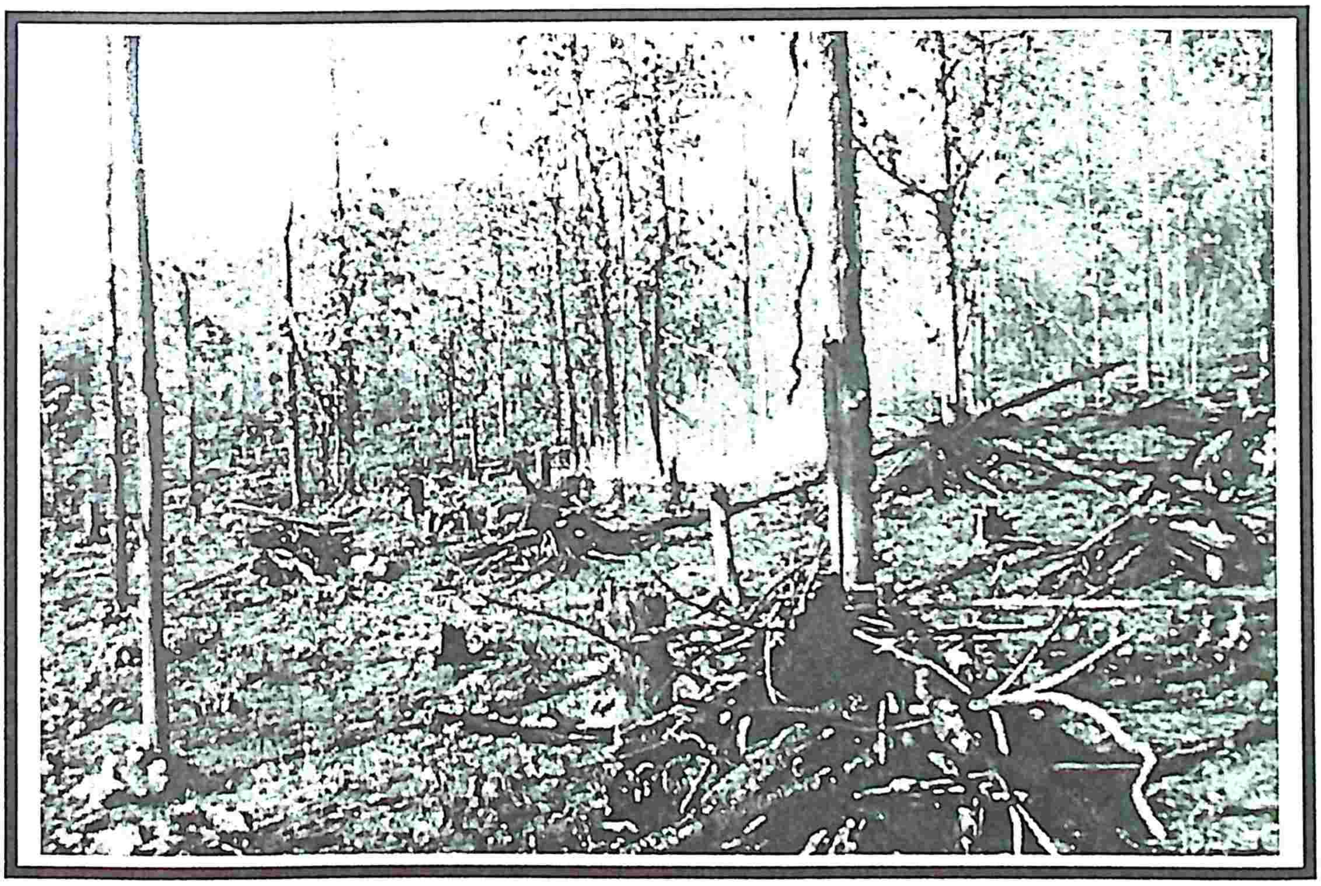

Plate 2.6: Showing illicit forest felling and burning

Plate 2.7: Showing tribal hunt

Plate 2.8: Showing tailing dam of the MBR mine

Plate 2.9: Showing high coloration in water of Sankoja *nala* due to effluent release by the KBR mine

Plate 2.10: Polluted river Koina with impacted tree on the background

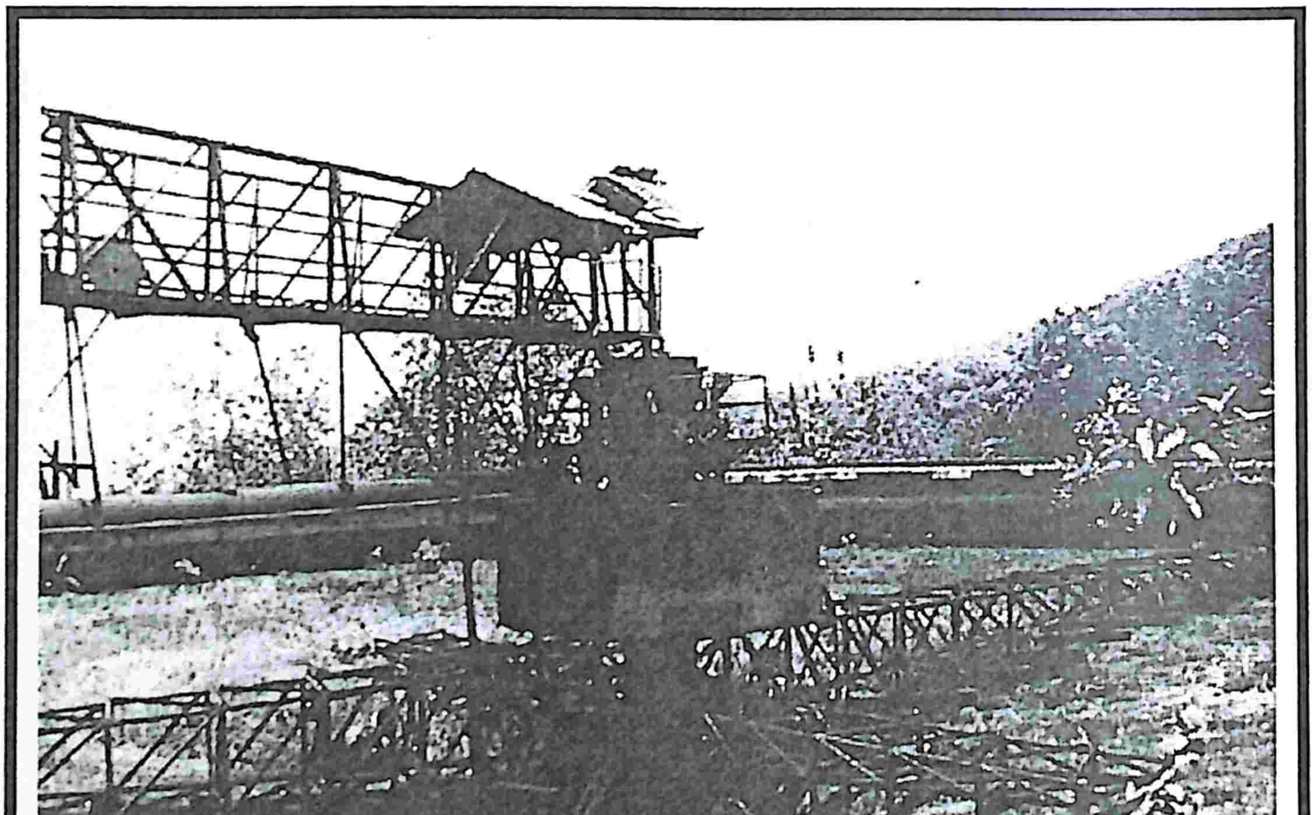

Plate 2.11: Inactive thickener unit of the KBR mine during unregulated period

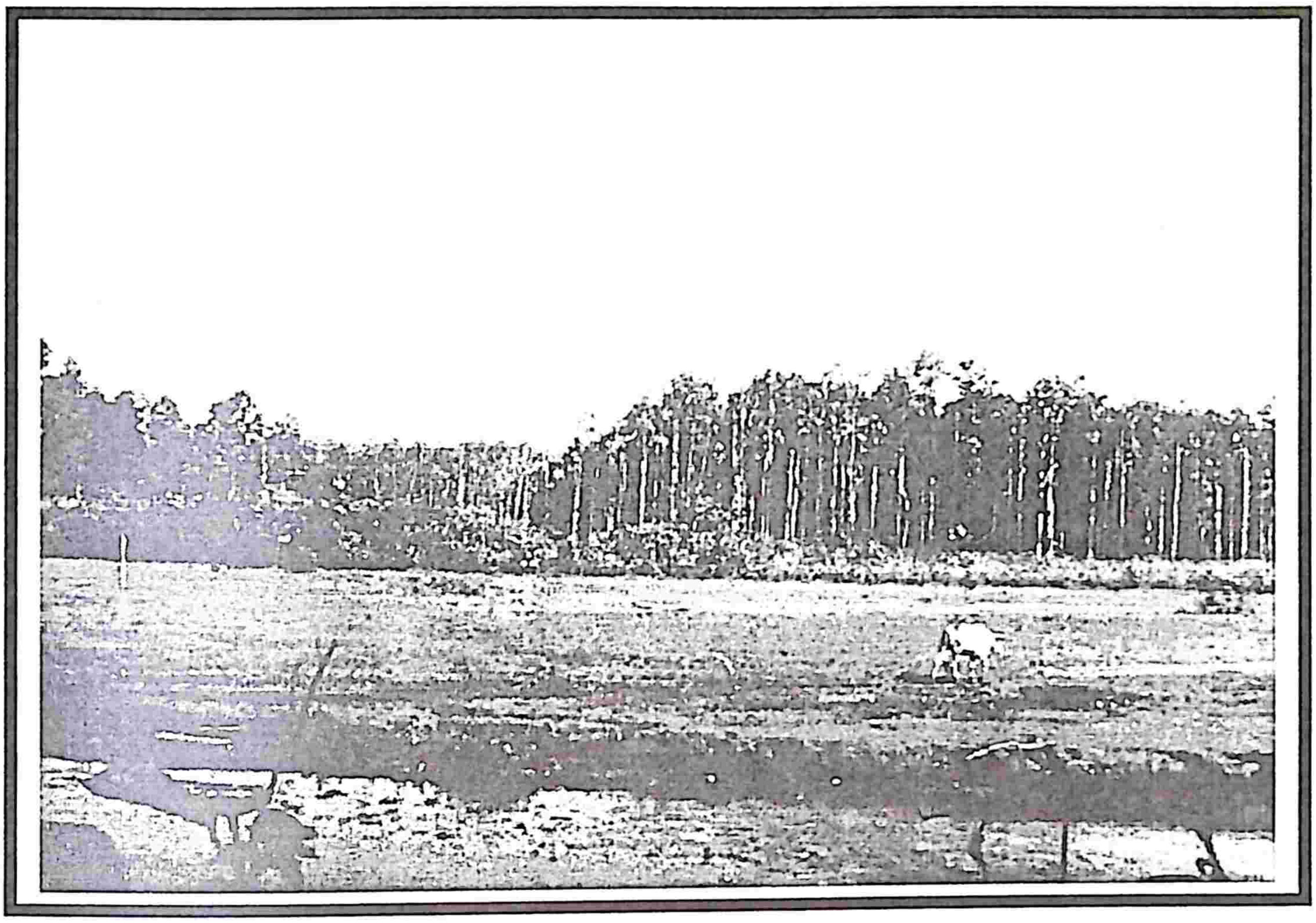

Plate 2.12: Polluted Koina river with bed load deposit

Plate 2.13: Showing complete wilting and dying of riverine tree communities

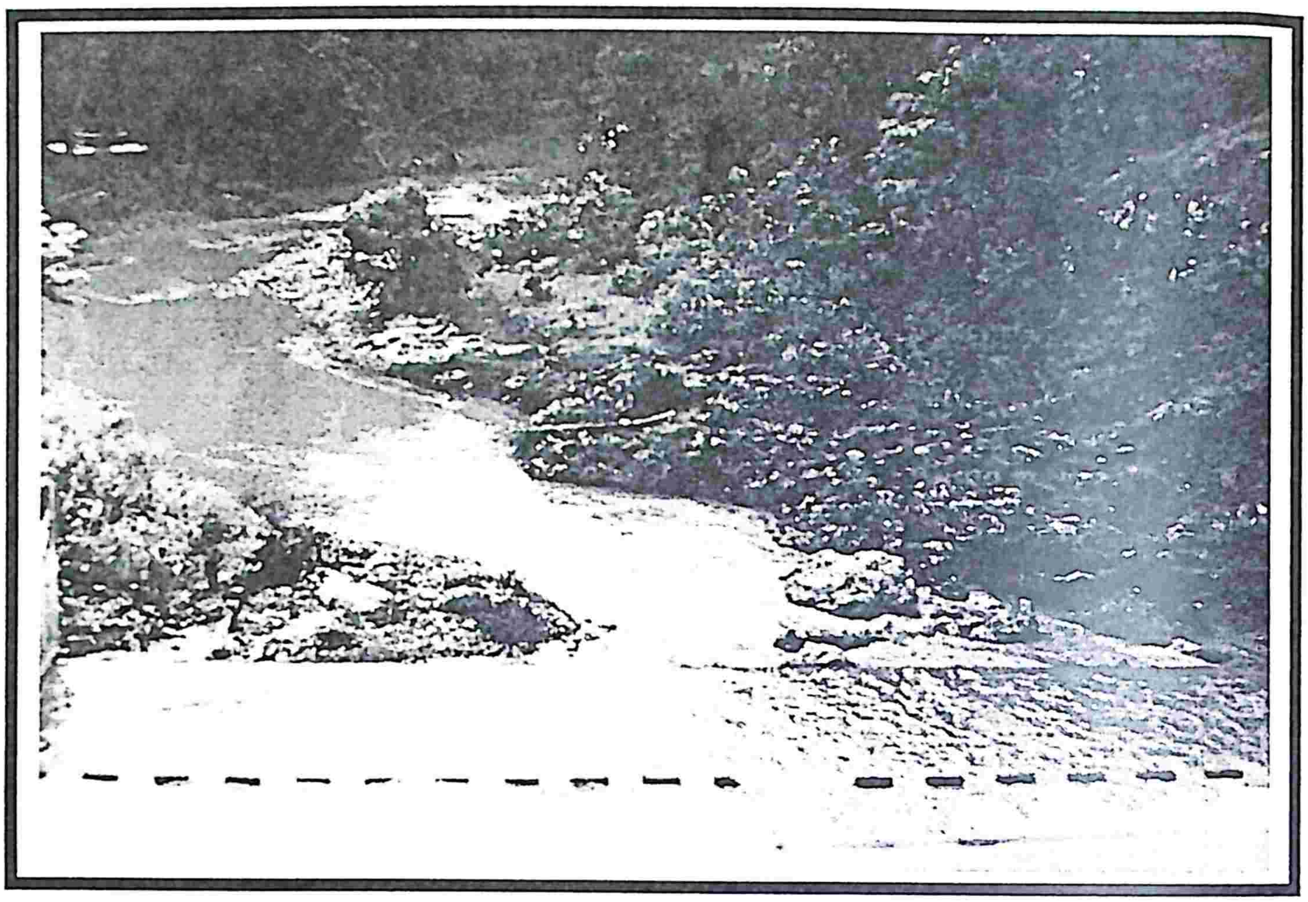

Plate 2.14: High coloration in the Koina river water during unregulated period at Kumdi Dam

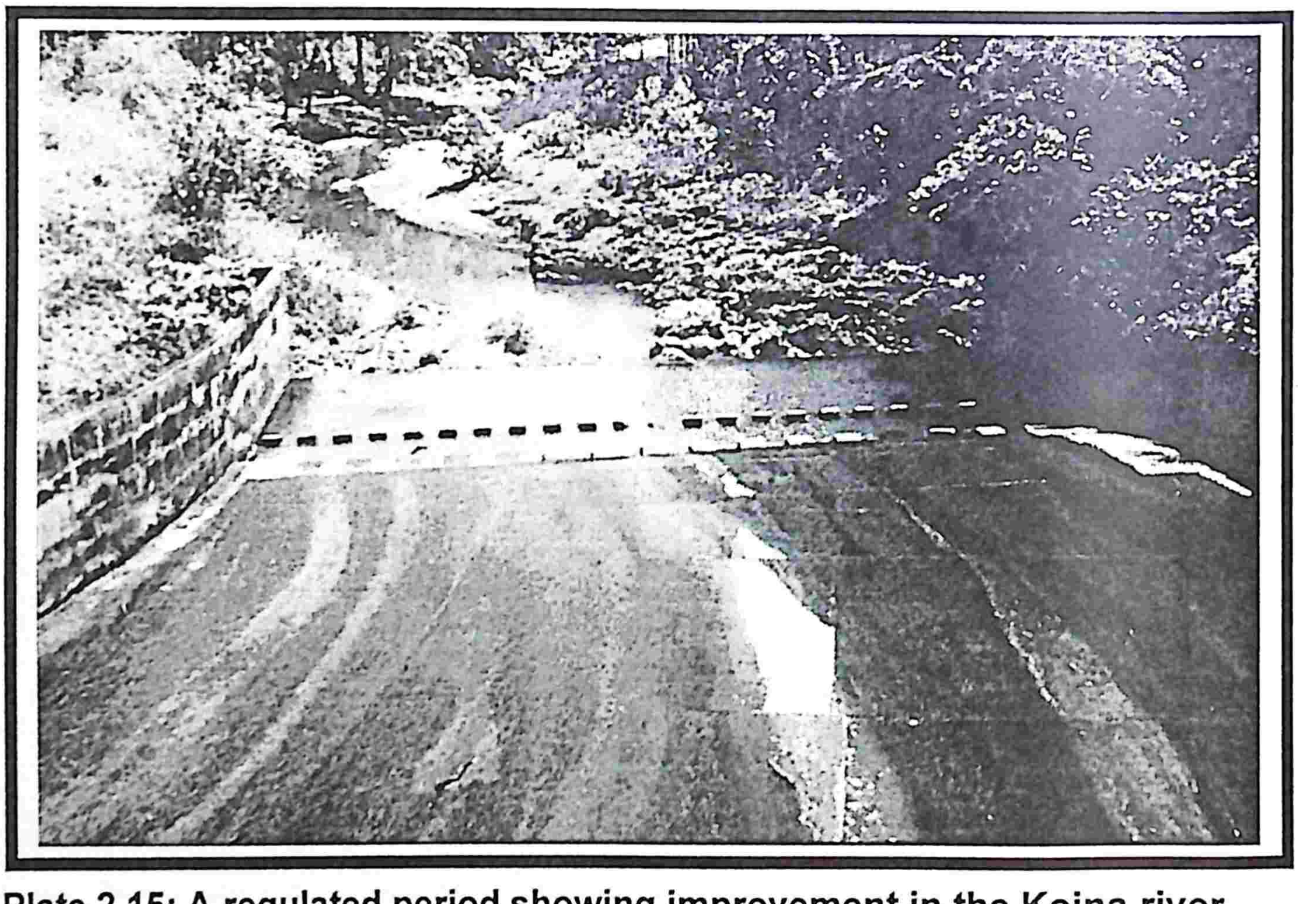

Plate 2.15: A regulated period showing improvement in the Koina river water at Kumdi Dam

Chapter 3

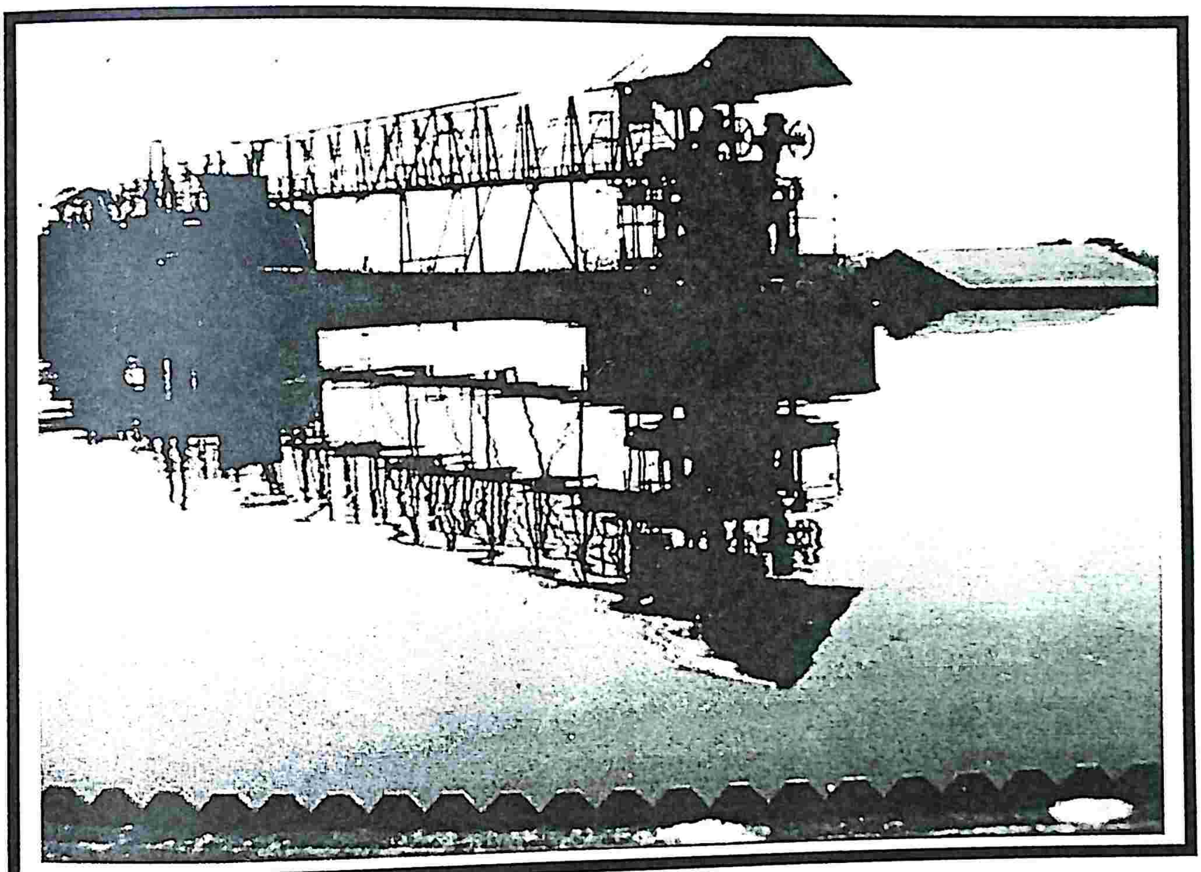

Plate 2.16: Active thickener unit of the KBR mine during regulated period

CHAPTER 3

Effect of mine tailing on water quality of the river Koina

3.1 Introduction

Availability of natural surface water resources are critical to several living organism including wild animal (Davis, 1976; Hocutt *et al.*, 1978; Hellawell, 1988) and vegetation (Walling and Webb, 1994). The river Koina, a perennial water source in Saranda Forest Division has undergone marked alteration due to unmanaged mine discharges through one out of two major iron-ore mines, located on its upper reaches. Presence of considerable water coloration and deposition of mine wastes along the river has been concerns for deleterious environmental changes and deterioration in water quality. Absence of any base line information prompted to undertake this study to monitor and assess the state of Koina river and determine the variability of its water quality due to mine waste discharges. The outcome of which was considered to enhance and ameliorate water quality through active management and regulations.

To achieve the above objective various physical (river flow, temperature, turbidity, TS, TDS and TSS) and chemical (pH, DO, total hardness, phosphate, silica, chloride, nitrate, nitrite and sulphate) parameters were compared in 4 river zones from March'95 to Feb'96 through monthly monitoring at several stations. Presence of two identifiable river situations 'unregulated' and 'regulated' due to mine discharges enabled to compare concentrations of water quality parameters within zones and situations. Interactions of the various physical and chemical parameters for water quality were also discussed and documented.

3.2 Methodology

3.2.1 Physico-chemical analysis of effluent and river water

The samples of effluent in tailing and post settling discharges of two major mines (KBR and MBR) were collected on their releases. The locations of 4 sampling stations (KD, KD-1, MD and MD-1) are shown in Figure 3.1.

The samples of river water were collected from 18 sampling stations along the river Koina (Figure 3.1) following the guidelines of Trivedy and Goel (1986). The distances between sampling stations along the Koina river are parenthesised besides their name. Out of the 18 sampling stations, two (S-1 & S-2) were in Sankoja *nala* and ten (KoD to KoD-9) along the Koina downstream. Both these zones Sankoja *nala* and Koina downstream were polluted due to mine discharges. Four sampling stations (KoU-1 to KoU-4) were selected in the upstream of Koina river which served as reference points. Furthermore, two sampling stations (AR-1 & AR-2) were identified in two-river tributaries i.e. Sarko and Hamsada *nala* joining to the Koina downstream (Figure 3.1). These two sampling points were also additional reference points, as both were unpolluted.

The temperature, TDS and pH were determined at the site through direct reading meters following methods prescribed by APHA, 1992. Turbidity was quantified by absorption method through Orbeco-Hellige, portable colorimeter, USA. Dissolved Oxygen was quantified through titration following modified

Winkler's Azide Method (APHA, 1992). TS and TSS were quantified by gravimetric and calculation method respectively (Trivedy and Goel, 1986). The amount of total hardness and chloride were determined by EDTA complexometric and argenometric titration method respectively as described in APHA, 1992. Sulphate was determined by turbidimetric method. The silica (reactive), total phosphate, nitrate and nitrite were analysed by molybodosilicate-heteropoly blue, ascorbic acid, cadmium reduction and diazotization methods respectively following the procedures prescribed for Orbeco-Hellige, USA water analysis kit.

3.2.2 Statistical analysis

All monthly water quality monitoring data of the Koina river was pooled in two groups comprising the periods March'95 to May'95 and June'95 to Feb'96. The period from March'95 to May'95 was referred as 'Unregulated' for Sankoja *nala* and Koina downstream because of excessive mine discharge. With discharge regulation the period from June'95 to February'96 was referred as 'Regulated' for same river sectors. While for Koina upstream and additional reference zones these were referred according to the periods as they were reference zones.

The One Way ANOVA (Das and Giri, 1991) was performed to derive significant differences in physical and chemical attributes in mine effluents. ANOVA was also performed for various physico-chemical parameters of water in four river zones, unregulated & regulated situations and their interactions between river zones & situations. Scheffe test for Post Hoc Multiple Comparison

(O'Neill and Wetherill, 1971) was performed to determine statistically homogenous groups for individual physico-chemical parameters in mine effluents and four river zones.

3.3 Results

3.3.1 Physico-chemical characteristics of mine effluent

The derived outcome of one way ANOVA on physical and chemical parameters of two mine effluents in tailing and post settling discharges is placed in Appendix A (Table A.1). Further analysis of this for group homogeneity (at 5% significance) through Post Hoc Multiple Comparison is presented in Table 3.1. The significantly similar groups of physical and chemical parameters in tailing and post settling discharges are labeled with same alphabets. Table 3.1 presents the variations in physical and chemical parameters of two mine effluents in tailing and post settling discharges. It can be seen that the mean values of all physical parameters (Turbidity, TS, TDS and TSS) have shown remarkable reduction in post tailing discharge. The chemical parameters (Silica and Sulphate) responded in same manner in post settling discharges, except in case of DO, where it increased. No significant changes were found in mean value of physical (Temperature) and chemical (pH, Phosphate, Chloride and Nitrite) parameters in tailing and post settling discharges.

The characteristics of suspended waste load (Turbidity, TS and TSS) were approximately 5 times higher in case of KBR mine in tailing discharges than MBR mine (Table 3.1). However, in post settling discharges they were comparable in case of both the mines. TDS in tailing on contrary was much higher in MBR mine (51.25 mgL^{-1}) compared to KBR mine (26.25 mgL^{-1}) and same picture also presented in post settling discharges too.

The characteristics of dissolved oxygen in post settling discharges improved in both the mines compared to tailing (Table 3.1). Occurrence of higher DO (6.25 mgL^{-1}) in MBR tailing over KBR (2.64 mgL^{-1}) was noteworthy. No significant changes in nitrate was found in tailing and post settling discharges of both the mines. However, higher concentration of nitrate in KBR effluent was also noteworthy.

3.3.2 Physico-chemical characteristics of river water

The diversion of KBR mine effluent through Sankoja *nala* without passing through settling process was the major reason for pollution of the river Koina. This situation was prevailing much before the initiation of present study and was further continued till June 95. Thereafter regulation on discharge provided a better situation and opportunity for comparison.

The variation in physical and chemical parameters of river water was compared in four zones and in two situations when discharges were unregulated (UR) and regulated (R). Mean values of all quantified physical and chemical parameters with their ranges in all sampling stations are annexed in Appendix A (Table A.2 to A.6). The summary of ANOVA result for all four river zones, situation and their interaction is placed in Appendix A (Table A.7). Further analysis of this for group homogeneity (at 5% significance) through Post Hoc Multiple Comparison is shown in Tables 3.2 and 3.3. The significantly homogenous groups of physical and chemical parameters in four river zones are labeled with same alphabets superscripted on their values (Tables 3.2 and 3.3).

The physical and chemical parameters in general for two periods (March'95 to May'95 and June'95 to Feb'96) did not fluctuate much in Koina upstream and additional reference zones (Tables 3.2 and 3.3). However, little fluctuations registered possibly because of seasonal variation in the river discharge and climatic factors.

The physical and chemical parameters varied in greater levels in Sankoja *nala* and Koina downstream due to mine discharges in two periods (March'95 to May'95 and June'95 to Feb'96) when they distinguished as unregulated (UR) and regulated (R). Water quality changes for all physico-chemical parameters were compared against the values of the reference zones.

Among the physical factors river flow did not form any homogenous group (s) in any river zones (Table 3.2). The temperature in Koina upstream remained lower (24.82 ^{0}C) while it was highest in Sankoja *nala* (28.54 ^{0}C) at par with additional reference zone (27.78 ^{0}C) and followed by 27.09 ^{0}C in Koina downstream (Table 3.2). The turbidity, TS and TSS was lowest and comparable in Koina upstream and additional reference zones, whereas the highest values were found in Sankoja *nala* followed by Koina downstream (Tables 3.2). Noteworthy, was the TDS lowest in Koina upstream (16.87 mgL^{-1}) but comparable to Sankoja *nala* (22.50 mgL^{-1}) whereas, highest in additional reference zone (47.08 mgL^{-1}) and at par to 40.67 mgL^{-1} in Koina downstream (Table 3.2).

In the chemical parameters pH was found slightly acidic (6.75) in Koina upstream. However, in all three zones it was slightly basic and at par to each other (Table 3.3). The dissolved oxygen, phosphorus and nitrite do not formed any homogenous groups in all river zones (Table 3.3). Silica was found lowest in Koina upstream (8.50 mgL^{-1}) and highest in Koina downstream (11.92 mgL^{-1}) at par with additional reference zone. The concentration of silica in Sankoja *nala* (10.16 mgL^{-1}) showed overlapping homogeneity group (Table 3.3). The chloride was found in lowest concentration (0.63 mgL^{-1}) in Sankoja *nala* and highest in additional reference zone (2.41 mgL^{-1}) showing similar homogeneity with remaining two zones (Table 3.3). The nitrate content was found lowest in Koina upstream (0.19 mgL^{-1}) showing similar homogeneity with Koina downstream and Sankoja *nala* (Table 3.3). However, it was found highest in additional reference zone (0.39 mgL^{-1}). The sulphate concentration was lowest in Koina upstream (0.31 mgL^{-1}) and was highest in additional reference zone (1.87 mgL^{-1}). The rest two zones also formed heterogenous groups in sulphate concentration (Table 3.3).

3.4 Discussion

Variation in concentrations and interactions of various physical and chemical parameters were the major reasons for changes in water quality of river Koina. The passing of effluent tailing through a settling process is very important step in reducing the suspended sediment load in many folds. Sen and Ghose (1997) also emphasized the importance of tailing pond and its location for efficient and safe disposal of iron ore mine tailing. When this step is not properly taken up by the siting mining industry water pollution can result as it was in the present case.

The increased sedimentation can influence turbidity (Ghose and Kumar, 1993; Walling and Webb, 1994) and also temperature (Walling and Webb, 1994) to rise in a river system which can damage aquatic organisms (Richardson, 1985; Walling and Webb, 1994) and alter their habitat by bringing changes in the river morphology (Ahmad *et al.*, 1994b; Nagarajan *et al.*, 1994; Pentreath, 1994). The tailing effluent in both the mines (KBR and MBR) had greater suspended solid loads to result in higher turbidity and temperature as compared with post settling effluents having lower suspended solid loads and also the lower turbidity and temperature. When unmanaged tailing effluent without settling process has been released through Sankoja *nala* during the unregulated period a same kind of situation has been observed for turbidity and temperature to increase due to excessive suspended solids. Venkataraman *et al.* (1994) also reported high turbidity and coloration of Sankani river, Madhya Pradesh due to non functioning of tailing dam and resulting heavy suspended solid load from Bacheli iron ore mine.

The increase of suspended solid loads also can reduce dissolved oxygen level (Ghose and Kumar, 1993; Gupta and Singh, 1995) in a river system and in turn affect the aquatic organisms (Wetzal, 1975; Trivedy, 1988). The nearly 5 times increased load of TSS in KBR tailing effluent (78275.38 mgL^{-1}) compared to MBR tailing effluent (15140.13 mgL^{-1}) had reduced dissolved oxygen level (2.64 mgL^{-1}) by over 2 times than MBR (6.25 mgL^{-1}). Similarly decreased TSS resulted in having higher DO in post settling effluent discharges which further highlights the importance of proper settling process. In the river zones high TSS load also resulted in lowering of DO levels of Sankoja *nala* and Koina downstream during unregulated period. Increase in DO level in reference zones during the regulated period resulted with lowering of water temperature due to seasonal variations irrespective of any TSS load. Inverse relationship between DO and temperature in aquatic system are reported by several workers (Palharya *et al.*, 1993; Seymore *et al.*, 1994; Ramasamy and Sridharan, 1998).

While working on the seasonal variation of phytoplankton in relation to water quality of Lege Dadi reservoir in Addis Ababa, Ethiopia, Mesfin and Belay (1989) reported drop in silica and nitrate content in the river system between November to February. This is the period they considered was available with maximum sun shine resulted in reduction of nitrate and silica concentration through photosynthetic activities by phytoplanktons. In our study, high level of silica and nitrate during unregulated period was due to less photosynthetic activity, possibly of phytoplankton. This might have occurred through high TSS and turbidity levels, which did not allow sunlight to penetrate for phytoplankton's activity and survival.

Table 3.1: Post Hoc Multiple Comparison Test of different physico-chemical parameters of two mine effluents

	Kiriburu effluent		Megahatuburu effluent	
Parameters	In tailing n = 8	Post settling n = 6	In tailing n = 8	Post settling n = 13
Temp (^{0}C)	25.99	22.80	27.19	26.31
Turb (NTU)	61912.50 ^{b}	109.17^{a}	14071.13^{a,b}	71.85^{a}
TS (mgL^{-1})	78301.63 ^{b}	227.50^{a}	15191.38^{a,b}	124.00^{a}
TDS (mgL^{-1})	26.25^{a,b}	10.00^{a}	51.25^{b}	37.69^{a,b}
TSS (mgL^{-1})	78275.38^{b}	217.50^{a}	15140.13^{a,b}	86.31^{a}
pH	7.26	6.85	7.32	6.83
DO (mgL^{-1})	2.64 ^{a}	6.15^{b}	6.25^{b}	7.55^{b}
Thard (mgL^{-1})	21.50^{a,b}	15.83^{a}	31.25^{a,b}	37.77^{b}
Phos (mgL^{-1})	3.67	2.96	2.42	2.81
Silica (mgL^{-1})	10.34^{b}	3.45^{a}	17.99^{c}	4.95^{a,b}
Chlo (mgL^{-1})	0.70	0.82	1.01	1.05
Nitra (mgL^{-1})	0.69^{b}	0.65^{b}	0.055^{a}	0.13^{a}
Nitri (mgL^{-1})	0.007	0.0045	0.0069	0.0015
Sulpha (mgL^{-1})	2.12^{a,b}	0.33 ^{a}	3.75^{b}	0.54^{a}

Same alphabets represent statistically homogenous group

Table 3.2: Means of interaction between period and zone for physical parameters of the Koina river water

Parameters	Periods	Zones: Koina Upstream[†]	Additional Reference[†]	Sankoja *Nala*	Koina Downstream	$\bar{x}$
Flow ($msec^{-1}$)	UR	12.15	13.33	5.48	13.14	11.03
	R	9.92	12.36	7.25	10.71	10.06
	$\bar{x}$	10.48	12.60	6.80	11.32	
Temp (^0C)	UR	27.87	28.28	34.03	29.09	29.82
	R	23.80	27.62	26.71	26.42	26.14
	$\bar{x}$	24.82[a]	27.78[b]	28.54[b]	27.09[a,b]	
Turb (NTU)	UR	8.50	15.00	2392.17	775.93	797.90
	R	24.36	34.00	75.50	249.53	95.85
	$\bar{x}$	20.39[a]	29.25[a]	654.67[b]	381.13[a,b]	
TS (mgL^{-1})	UR	88.00	91.67	13322.83	1829.50	3833.00
	R	82.68	174.72	209.47	1074.58	385.36
	$\bar{x}$	84.01[a]	153.96[a]	3487.81[b]	1263.31[a,b]	
TDS (mgL^{-1})	UR	20.83	51.67	26.67	46.67	36.46
	R	15.56	45.56	21.11	38.67	30.22
	$\bar{x}$	16.87[a]	47.08[b]	22.50[a]	40.67[b]	
TSS (mgL^{-1})	UR	67.17	40.00	13296.17	1782.83	3796.54
	R	67.12	129.17	188.36	1035.91	355.14
	$\bar{x}$	67.13[a]	106.87[a]	3465.31[b]	1222.64[a,b]	

Same alphabets represent statistically homogenous group

[†] marked zones UR and R refers the period March'95 to May'95 and June'95 to Feb'96 respectively.

Table 3.3: Means of interaction between period and zone for chemical parameters of the Koina river water

Parameters	Periods	Zones: Koina Upstream†	Additional Reference†	Sankoja *Nala*	Koina Downstream	$\bar{x}$
pH	UR	6.91	7.37	7.58	7.51	7.34
	R	6.69	7.36	7.02	7.52	7.14
	$\bar{x}$	6.75[a]	7.36[b]	7.16[b]	7.51[b]	
DO (mgL^{-1})	UR	6.51	6.48	4.10	4.10	5.30
	R	9.00	9.84	9.59	9.44	9.47
	$\bar{x}$	8.37	9.00	8.22	8.10	
Thard (mgL^{-1})	UR	28.58	32.00	24.67	73.97	39.80
	R	19.32	48.78	23.61	36.88	32.15
	$\bar{x}$	21.63[a]	44.58[b]	23.87[a]	46.15[b]	
Phos (mgL^{-1})	UR	7.47	5.60	8.82	10.31	8.05
	R	3.06	3.52	3.41	3.39	3.35
	$\bar{x}$	4.16	4.04	4.76	5.12	
Silica (mgL^{-1})	UR	9.41	11.32	10.78	14.58	11.52
	R	8.20	11.69	9.96	11.04	10.22
	$\bar{x}$	8.50[a]	11.59[b]	10.16[a,b]	11.92[b]	
Chlo (mgL^{-1})	UR	2.94	3.38	0.63	2.14	2.27
	R	1.18	2.08	0.63	1.42	2.08
	$\bar{x}$	1.62[b]	2.41[b]	0.63[a]	1.59[b]	
Nitra (mgL^{-1})	UR	0.26	0.37	0.48	0.28	0.35
	R	0.16	0.39	0.07	0.25	0.22
	$\bar{x}$	0.19[a]	0.39[b]	0.17[a]	0.25[a]	
Nitri (mgL^{-1})	UR	0.13	0.17	0.17	0.17	0.16
	R	0.021	0.0061	0.02	0.0095	0.014
	$\bar{x}$	0.047	0.047	0.058	0.051	
Sulpha (mgL^{-1})	UR	0.58	3.5	0.00	0.33	1.10
	R	0.22	1.33	1.33	0.40	0.82
	$\bar{x}$	0.31[a]	1.87[b]	1.00[b]	0.38[a,b]	

Same alphabets represent statistically homogenous group

† marked zones UR and R refers the period March'95 to May'95 and June'95 to Feb'96 respectively.

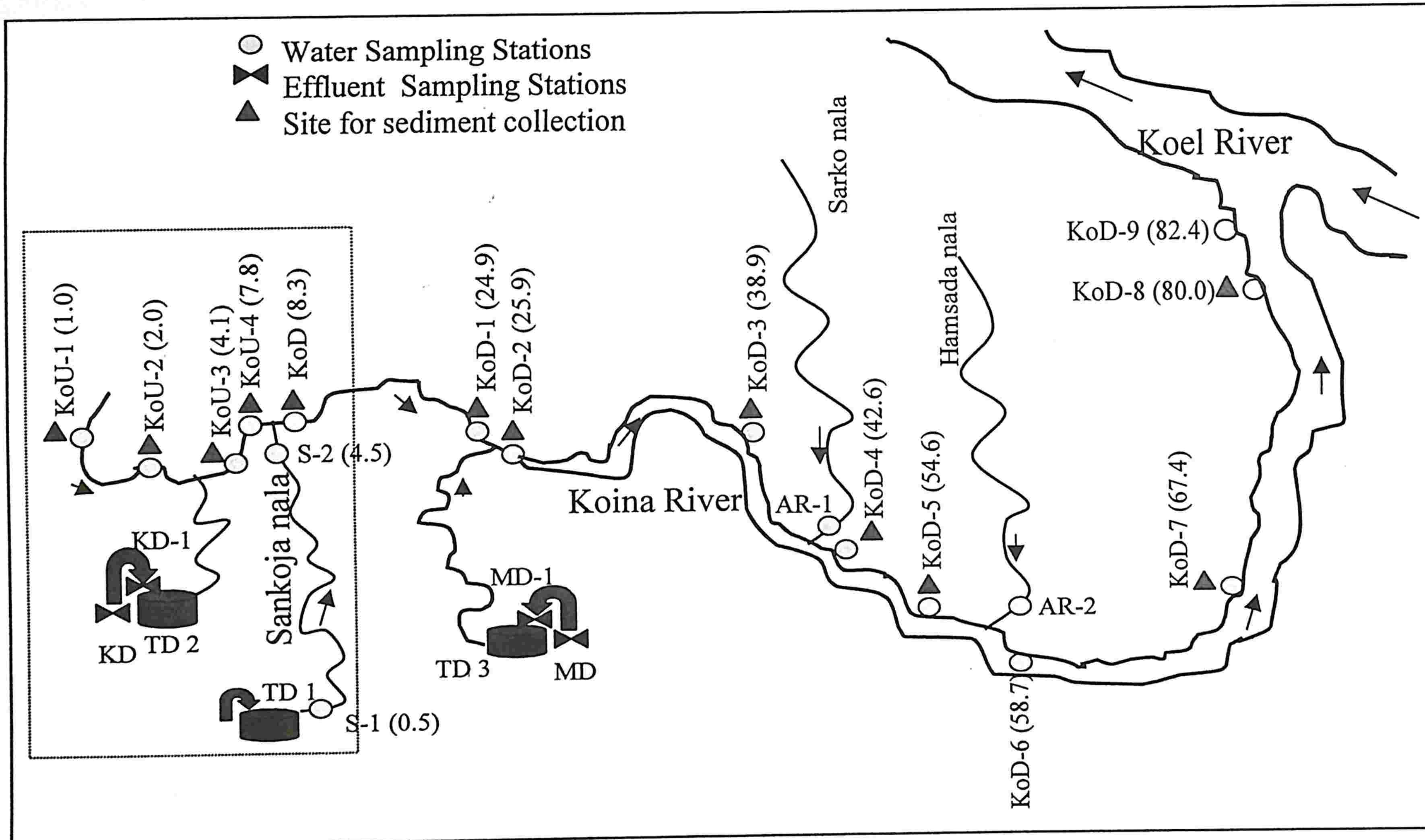

Figure 3.1: Diagrammatic layout of sampling stations along the river Koina. Figures in parenthesis are distance in km from the origin

Chapter 4

CHAPTER 4

Relating water quality and riverine habitat use

4.1 Introduction

In the metal mining industry, mineral processing is a prime source of waste generation in the form of slime (Prugger, 1992) and slurry (Sen, 1988; Ahmad *et al.*, 1994b; Gupta *et al.*, 1994). Environmental pollution results when these wastes are not properly managed so that they find their way into the natural watercourse (Down and Stocks, 1977; Ahmad *et al.*, 1994a). The dispersal and deposition of these wastes along a river results in several morphological changes including braiding, silting, and widening of the river channel system (Ahmad et *al.*,1994a; Nagarajan *et al.*,1994; Pentreath, 1994), and also modifies the physico-chemical properties of the river water (Ahmad *et al.*,1994a; Gupta *et al.*, 1994; Muthreja and Paithankar, 1994; Pentreath, 1994). This in turn affects the life forms within the aquatic ecosystem (Davis, 1976; Hocutt *et al.*, 1978; Hellawell, 1988) and also life forms that are dependent upon it (Heath *et al.*, 1992).

The description and quantification of sub lethal pollutants in ecosystems, and their effect on individuals and populations, are major thrusts for ecological assessment of pollution-induced alterations in habitats (Hellawell, 1988; Nriagu, 1988). Exposure to pollutants, even in low concentrations, can elicit changed behavioural responses (Sheehan, 1984) as has been documented in several invertebrates (Saliba and Vella, 1977; Wentsel *et al.*, 1977) and lower vertebrates (Sprague, 1971). However, in case of higher vertebrate groups such documentation is lacking. It is believed that the most immediate behavioural response to increased pollution by higher vertebrate groups is avoidance of contaminated habitat.

Mine waste is released as a result of iron-ore extraction and on-site processing of ore in the study area. The uncontrolled production of tailings through wet-circuit ore processing by Kiriburu (KBR) mines is major source of pollution of the river Koina, a major perennial source of running water in the Saranda Forest Division (Chapter 2; Figure 2.2). The high colouration of river water, as a result of mine waste, and consequent reduction in water quality values of the Koina catchment, are present concern for both people and wildlife in the area. Since, the start of present study in July 1994, mine discharge remained above permissible threshold level of Total Solids (2200 mgL^{-1}) prescribed by Central Pollution Control Board (CPCB) of India. Regulation of mine discharge by the KBR mine authority was observed from June 1995 onwards. This control was further regulated due to public concern and media attention (special correspondent, *The Telegraph* dated 2nd Feb. 1996 and later through United News of India in other dailies) on the Koina river pollution and its high coloration.

Elephants are attracted to dense shady deciduous woodland habitats. These occur in summer months along tributaries and main flowing river courses in the study area. The 70-km length of river Koina with a catchment area of 300 km^2 is therefore very important for elephants during this time of year. The spatial and temporal movement of elephants in these habitats during summer months are governed by the availability of this dense shady vegetation (Kumar, 1995) and water (Western, 1975; Leuthold, 1977; Easa, 1988). Importance of such riverine habitats and their increased use during dry spell, have been reported on the basis of studies undertaken on Asian Elephants (Sukumar, 1989) and African Elephants (Buss, 1961; Williamson, 1975; Leuthold, 1977; Allaway, 1979).

The aim and objectives of this chapter is to relate physico-chemical variables of Koina river water and to compare factors influencing riverine range utilisation by elephants and other mammals, made up mostly of domestic livestock belonging to local residents, during periods of `regulated' and `unregulated' mine discharge. An understanding of these contrasts could provide better information to help strengthen elephant conservation through habitat management for an elephant reserve identified under `Project Elephant', launched in 1993 by the Ministry of Environment & Forests, Government of India. River channel morphology was not considered in this study due to the lack of baseline data. However, its influence may be important for the use of river by elephants because they use pools within river channels.

4.2 Methodology

4.2.1 Elephant habitat mapping

Elephant habitat and mining areas were delineated using Survey of India 1:50,000 toposheet maps and Indian Remote Sensing Satellite (IRS-LISS II) False Colour Composite (FCC). Major land use and land cover categories were classified through visual interpretation and ground validation. The GRASS GIS was used to develop a comprehensive map of the area (Chapter 2; Figures 2.1 & 2.6). The major land cover classes identified and mapped are: *Sal* forests (687.57 km^2; 69.86%), Mixed forests (96.47 km^2; 9.81%), Plantations (54.22 km^2; 5.50%), Scrub forests (0.16 km^2; 0.02%), Forest blank (6.32 km^2; 0.64%), Water bodies (7.01km^2; 0.71%) and Habitation (132.46 Km^2; 13.46%). The land use categories delimited are: forests (61.44%), habitation & agricultural land (36.56%) and mining (2.00%). The habitat map with overlaid drainage features was used to locate 7 sampling stations for regular monitoring of physico-chemical parameters of river water.

4.2.2 Chemical analysis of River Water

The boxed portion of the Koina river stretch (Chapter 3; Figure 3.1) having 7 sampling stations were only taken for quantifying physico-chemical variables affecting water quality following the guidelines provided by Trivedy and Goel (1986). Four sampling stations (KoU-1 to KoU-4) were located upstream in Koina River; two further sampling stations (S-1 and S-2) were located in Sankoja *nala*, and one additional station (KoD) in downstream in the Koina.

Detail methods for quantifying physico-chemical parameters for water quality, namely Temperature (Temp), pH, Total Dissolved Solids (TDS), Turbidity (Turb), Total Solids (TS), Total Suspended Solids (TSS), Total Hardness (THard), Total Phosphate (Phos) as ortho (reactive), poly & organic and Silica are presented in Chapter 3.

From April to June 96 only two variables TSS and Turbidity were measured at 7 sampling stations because they were identified as key parameters through PCA analysis.

4.2.3 Habitat utilisation by Elephants

A 2m belt transact on both the sides of three river segments, Koina upstream (5km), Koina downstream (0.5 km) and Sankoja *nala* (4 km) were surveyed in mid May 1995 and 1996 for the presence of accumulated dung of elephants and other mammals. Our experimental design on 50 elephant dung piles revealed mean decay rate 0.0151± 0.0002 per day in the study area up to a stage of broken or flat masses of elephant dung. In two consecutive years 1995 and 1996, dung counts of elephants were taken only up to this stage of broken or flat mass to distinguish and avoid any inconsistency. The observed dung count per km was taken as an index of habitat utilisation for comparison between two summer seasons (March to May) of 1995 and 1996.

4.2.4 Data analysis

Principal Component Analysis (PCA) (Daehler *et al.*, 1994) was used to examine the variations in physical and chemical properties of Koina river water, by taking cases (n=84) between April 1995 to March 1996. This one analysis identified responsible key parameters in determining whether a river is polluted or unpolluted. An F-test (Haynes, 1982) was performed by taking the responsible key parameters (TSS and Turb) to compare significant differences between the same river segments between summer (March to May) 1995 and 1996. A Chi-square test (Haynes, 1982) also was performed to compare significant differences between presence of Dung km^{-1} as an index for habitat use patterns by elephants and other mammals in the same river segments between summer (March to May) 1995 and 1996.

4.3 Results

4.3.1 Climatic Conditions

The total annual rainfall was 1455 mm in 1996 as recorded at nearby Kiriburu Meteorological Station compared with 1585 mm in 1995. Thus the area was wetter and the river levels higher in 1995 than 1996.

4.3.2 Physico-chemical properties of river water

Various physico-chemical parameters of Koina river water in three river segments during their polluted (April 95 to June 95) and unpolluted (July 95 to March 96) situations are presented in Table 4.1. PCA extracted two factors; the results are summarized in Table 4.2. Factor 1 constituted mainly physical parameters (accounting for 51.2% variance). However, phosphate was also been found as an associated variable in this Factor. In contrast to the Factor 1, Factor 2 was associated with mainly chemical parameters; it accounted for 13.7% of the total variance, including temperature as an associated variable. Scatter plot shows a clear demarcation between the polluted and unpolluted regimes of river segments along the axis of Factor 1 (Figure 4.1).

Figures 4.2 and 4.3 show the TSS and Turbidity load of Sankoja *nala*, which brought mine discharge into the Koina river system at various months. It can be seen from Figure 4.2 that the TSS level in Sankoja *nala* was elevated (133 times above the prescribed limit of Central Pollution Control Board, CPCB), during the more polluted period, 1995. The level of Turbidity during the same period remained high and showed same trend as of TSS (Figure 4.3).

Table 4.3 summarises results of Turbidity and TSS load in the 3 river sectors. The F-test revealed that there was a significant decrease in level of Turbidity and TSS in Koina downstream and Sankoja *nala* during summer 1996 as compared to summer 1995. However, no significant difference in TSS and Turbidity levels were observed in the Koina upstream sector, above the discharge points from the mine. Hence, this sector serves as a reference point against which comparisons can be made.

4.3.3 Fodder Quality

The growth of riverine vegetation and resulting quality of the fodder along the river Koina is influenced by climatic factors especially rainfall. These parameters are often difficult to quantify because of low rainfall during summer months, which can occur in sudden storms. On an annual basis the rainfall was 130 mm higher in 1995 compared with 1996, and in seasonal terms, during summer months (March to May) it was 23.32 mm in 1995 against 5.31 mm in 1996. The high use of riverine habitat in 1996 (Table 4.4) occurred in spite of low summer rainfall that eliminates the possibility of fodder quality and quantity improvement over 1995.

4.3.4 Elephant habitat use

Table 4.4 shows the results for dung encounter rate (Dung km^{-1}) for elephants and livestock for three river sectors in summer (March to May) 1995 and 1996. These data were analysed using the Chi-square test, and showed a significant increase in habitat use during summer 1996 over summer 1995, for the two downstream river sectors (Sankoja *nala* and downstream Koina). The dung deposition in case of Koina upstream sector (Table 4.4) showed a small increase in 1996, however, it was not significant ($P>0.05$).

4.3.5 Anthropogenic factors

The mine discharge was regulated during 1996 as compared with 1995 which was unregulated (Table 4.4), with a resulting improvement in water quality. Less sediment was allowed to enter the river system in 1996, and both TSS and turbidity were lower and the colouration of the water was less.

In addition, increasing human activity pressure is occurring in the area and this is a factor that would have occurred in all river sections of the study period. This disturbance factor is considered to be important to elephants, and may have caused a reduced occurrence of elephants if considered on its own. However since it was even over the study area, it is not significant for the purposes of this study and this disturbance factor was offset by other factors in the drainage basin which caused a rise in elephant occupancy.

4.4 Discussion

The observations have shown that the increased occurrence of elephants in the area in 1996 coincided with lower rainfall. It is possible to discount most of the other influences on elephant occurrence because the changes were uniform over the study area. This includes rainfall, and therefore vegetation quantity and quality, and human use of the area, which though it is increasing has not, changed significantly over the study period. Therefore, the change in the riverine habitat use by elephants must be due to other factors.

The literatures for elephants suggest that maintenance of water quality in aquatic ecosystems is an essential component because of its overall ecological benefits. In the present study, the modification of physico-chemical properties of the Koina river water occurred due to solids in wastewater from KBR iron-ore mine. The near neutral level of pH prevented solids from becoming dissolved, and they therefore remained mostly in suspended form causing high Turbidity in river water. Furthermore, phosphate becomes proportionately associated with solids (dissolved and suspended) in fresh water systems in the form of ortho (reactive) phosphorus (Wetzel and Likens, 1991), and therefore is represented in the Factor 1 of PCA (Table 4.2).

A comparison of Table 4.3 & 4.4 clearly indicates that the excessive Turbidity and TSS during uncontrolled discharge regime coincides with a reduction in riverine habitat use pattern by elephants and other mammals during the summer 1995. While the lower annual rainfall (1455 mm) in 1996, as compared to 1995 (1585 mm), might not have brought any pronounced changes in the riverine habitat structure, the animal response is marked. It is thought that the increased use of riverine habitat was due to improved water quality following regulated mine discharge. An increase in riverine habitat use of 2-3 times by elephants and 4-6 times by other livestock was observed when Turbidity and TSS levels were reduced by 42-55 times and 56-67 times respectively, during summer 1996 over summer 1995. Graphical representations of these are shown in Figure 4.4 for the downstream section of Koina and Sankoja *nala*.

Kurt (1971) reported the low use of shallow water holes compared to deeper ones by elephants during summer months. He reports that shallow water holes are contaminated because of heavy churning by water buffaloes, rendering them unfit for elephant use. Similar findings from Sri Lanka have shown the avoidance of such contaminated water holes by elephants (Eisenberg *et al.*, 1990). Churning is a mechanism that leads to an increase in the levels of Turbidity and TSS of small-stagnated water bodies. This situation is similar to the river contamination through heavy mine discharge which results in high sediment loads and corresponds to avoidance of the riverine habitat by elephants.

4.5 Conclusions

This study suggests that the unregulated mine discharge is potentially damaging to a river system, and can reduce its habitat values for wildlife. Decreased use of the Koina downstream and Sankoja *nala* riverine habitats during the dry spell in summer 1995 is a surprising result, given the higher precipitation in that year. Information available from African studies reveal that the dry season home ranges of elephant cover only about 10% area of wet season, and are based around the permanent water sources (Owen-Smith, 1988). This indicates that water quality is important to elephants. Significant increase in use of the above two riverine habitats by elephants, 2-3 times during the dry spell of summer 1996 attracts management attention to maintain water quality of the river Koina. The dry year also experienced regulation of mine wastes and so the water quality was higher both in terms of sediment loads and pollution levels.

It is concluded that the turbidity and TSS levels in mine discharges should not be allowed to exceed mean values of 60 NTU and 200 mg/L respectively before allowing it to mix with the Koina river water (Table 4.3; mean Turbidity and TSS values for Sankoja *nala* in column 4). Turbidity and TSS above these mean values in the discharges affect water quality for low use of habitat. The CPCB guidelines recommend the waste discharge limit 100 mg/L for TSS and do not prescribe any limit for turbidity. However, it emphasises reduction of coloration as low as possible in waste water. Controlling the Turbidity and TSS level as suggested above will eventually help in restoring and maintaining the aquatic and terrestrial ecosystems for the benefit of elephant conservation. Furthermore, this will also help 12,000 tribal people who at present are solely dependent on this perennial water source for domestic consumption and irrigation.

The present study showed Turbidity and TSS are the two key parameters for monitoring water quality impacted through iron ore mine discharge. Therefore, regular monitoring of these parameters should form an integral part for evaluating the Koina river system by the Bihar State Pollution Control Board (BSPCB) according to the laid guideline of CPCB.

Table 4.1: Physico-chemical properties of water in three river segments in polluted (April'95 to June'95) and unpolluted (July'95 to March'96) situations

Parameters	Koina Upstream	Sankoja *Nala*		Koina Downstream	
	Reference zone n = 48	Polluted n = 6	Unpolluted n = 18	Polluted n = 3	Unpolluted n = 9
TSS^{+}	65.26 ± 61.47	13296.00 ± 14384.49	188.36 ± 139.32	6696.67 ± 4549.51	141.77 ± 116.99
TS^{+}	84.01 ± 68.68	13322.83 ± 14387.53	209.47 ± 140.13	6720.00 ± 4551.83	159.54 ± 117.73
Turb*	21.23 ± 21.60	2392.17 ± 996.67	74.28 ± 89.54	2290.00 ± 1008.60	55.67 ± 47.18
Phos^{+}	4.16 ± 2.32	8.82 ± 2.72	3.41 ± 2.10	5.27 ± 0.37	2.91 ± 0.76
Silica^{+}	8.44 ± 1.84	10.78 ± 2.81	9.98 ± 3.12	10.90 ± 3.62	9.37 ± 2.86
Temp^{++}	24.74 ± 2.84	34.03 ± 1.35	26.82 ± 1.25	29.37 ± 1.17	24.00 ± 2.78
TDS^{+}	16.87 ± 5.46	26.67 ± 4.71	21.11 ± 8.75	23.33 ± 4.71	17.78 ± 6.20
Thard^{+}	21.63 ± 8.51	24.67 ± 9.69	23.61 ± 4.89	66.33 ± 41.47	20.89 ± 3.18
PH	6.75 ± 0.34	7.58 ± 0.11	7.02 ± 0.46	7.60 ± 0.08	6.96 ± 0.54

+ = mg/L; * = NTU; ++ = °C

Table 4.2: Summary of the Principal Component Analysis (PCA) for water quality parameters of the Koina river. Cases (n = 84). Kaiser-Meyer-Olkin measure of sampling adequacy=0.72386.

	Factor 1	Factor 2	Communalities
Eign Value	4.60357	1.34484	
Variance			
Percentage variance	51.2	13.7	
Cumulative variance	51.2	64.9	
TSS	0.95161	0.19041	0.949
TS	0.95136	0.19155	0.949
Turb	0.86038	0.35309	0.861
Phos	0.50384	0.49362	0.493
Silica	0.11699	0.80784	0.659
Temp	0.33810	0.76621	0.610
TDS	0.13697	0.75001	0.557
Thard	0.29760	0.53636	0.409
Ph	0.35958	0.37180	0.276

Table 4.3: Levels of Turbidity (NTU) and TSS (mgL^{-1}) in three river segments during Summer'95 and Summer'96

River Segment	Parameter	Seasons		F – test	
		Summer 1995	Summer 1996	Value	Probability
Koina Upstream	Turb	3 – 33 n = 11 8.72 ± 10.03 S^2 = 100.61	9 – 37 n = 12 20.16 ± 10.30 S^2 = 106.15	1.055	P>0.05
	TSS	6 – 99 n = 11 46.72 ± 35.55 S^2 = 1263.81	9.2 – 76.40 n = 12 30.87 ± 22.43 S^2 = 503.30	2.510	P>0.05
Koina Downstream	Turb	1070 – 3540 n = 3 2290 ± 1235.27 $S^2 = 1.52x10^6$	26 – 60 n = 3 42 ± 17.08 S^2 = 292.00	5225.68	P<0.001
	TSS	263 – 9979 n = 3 6696.66 ± 5571.99 $S^2 = 3.10x10^7$	10.60 – 208.60 n = 3 118.43 ± 100.17 $S^2 = 10.03x10^3$	3093.85	P<0.001
Sankoja *Nala*	Turb	1093 – 3540 n = 6 2392.16 ± 1091.79 $S^2 = 1.19x10^6$	26 – 107 n = 6 55.66 ± 33.88 $S^2 = 11.47x10^2$	1038.46	P<0.001
	TSS	117 – 42170 n = 6 13296 ± 157574.16 $S^2 = 2.48x10^8$	77.20 – 456.20 n = 6 196.51 ± 160.53 $S^2 = 25.77x10^3$	9634.59	P<0.001

Table 4.4: Dung km^{-1} in three river segments during Summer'95 and Summer'96

River Segment	Species	Seasons		Chi-Square Test	
		Summer 1995	Summer 1996	Value	Probability
Koina Upstream (5 Km)	Elephant	10	15	1.00	P>0.05
	Livestock	20	24	0.36	P>0.05
Koina Downstream (0.5 Km)	Elephant	45	98	19.64	P<0.001
	Livestock	50	207	95.91	P<0.001
Sankoja *Nala* (4 Km)	Elephant	16	47	15.23	P<0.001
	Livestock	8	48	28.57	P<0.001

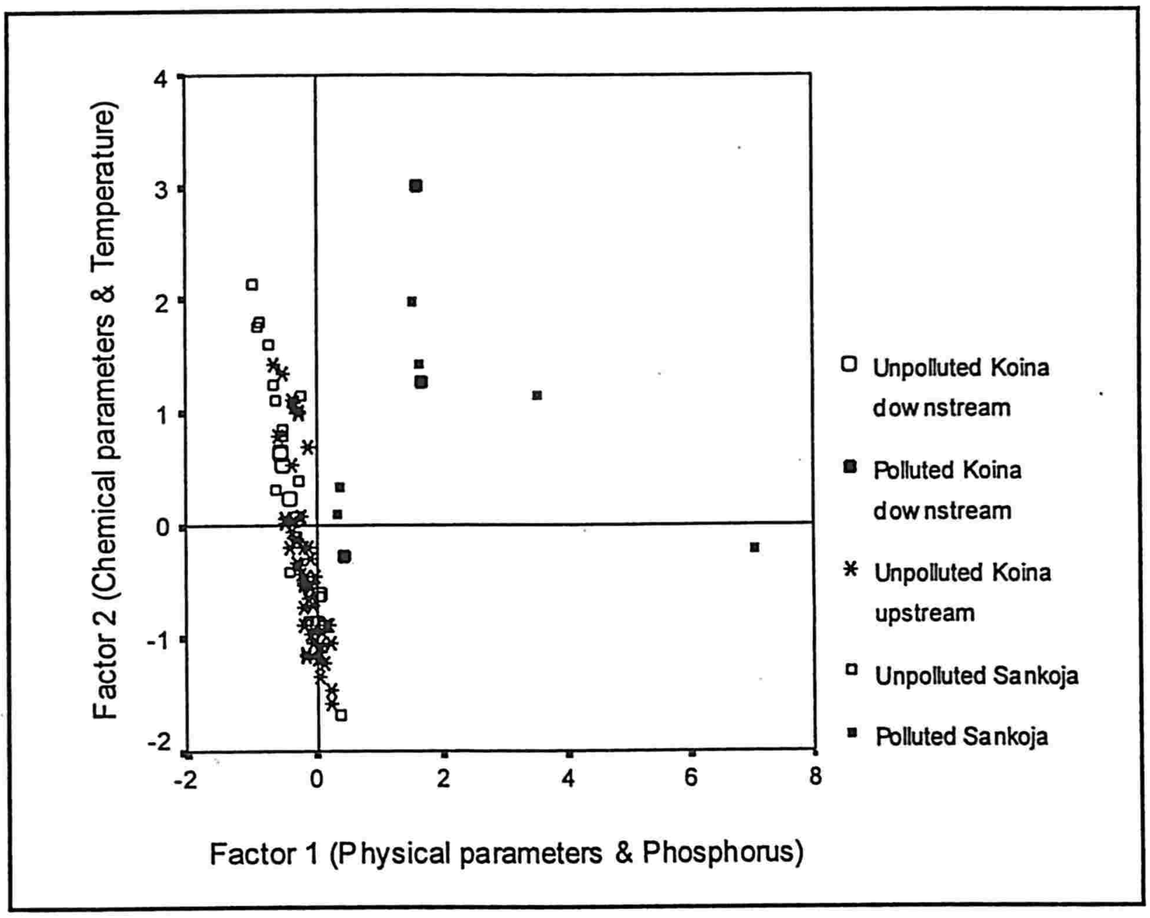

Fig. 4.1: Scatter plot of two Factors of PCA showing separation of polluted and unpolluted conditions of river segments

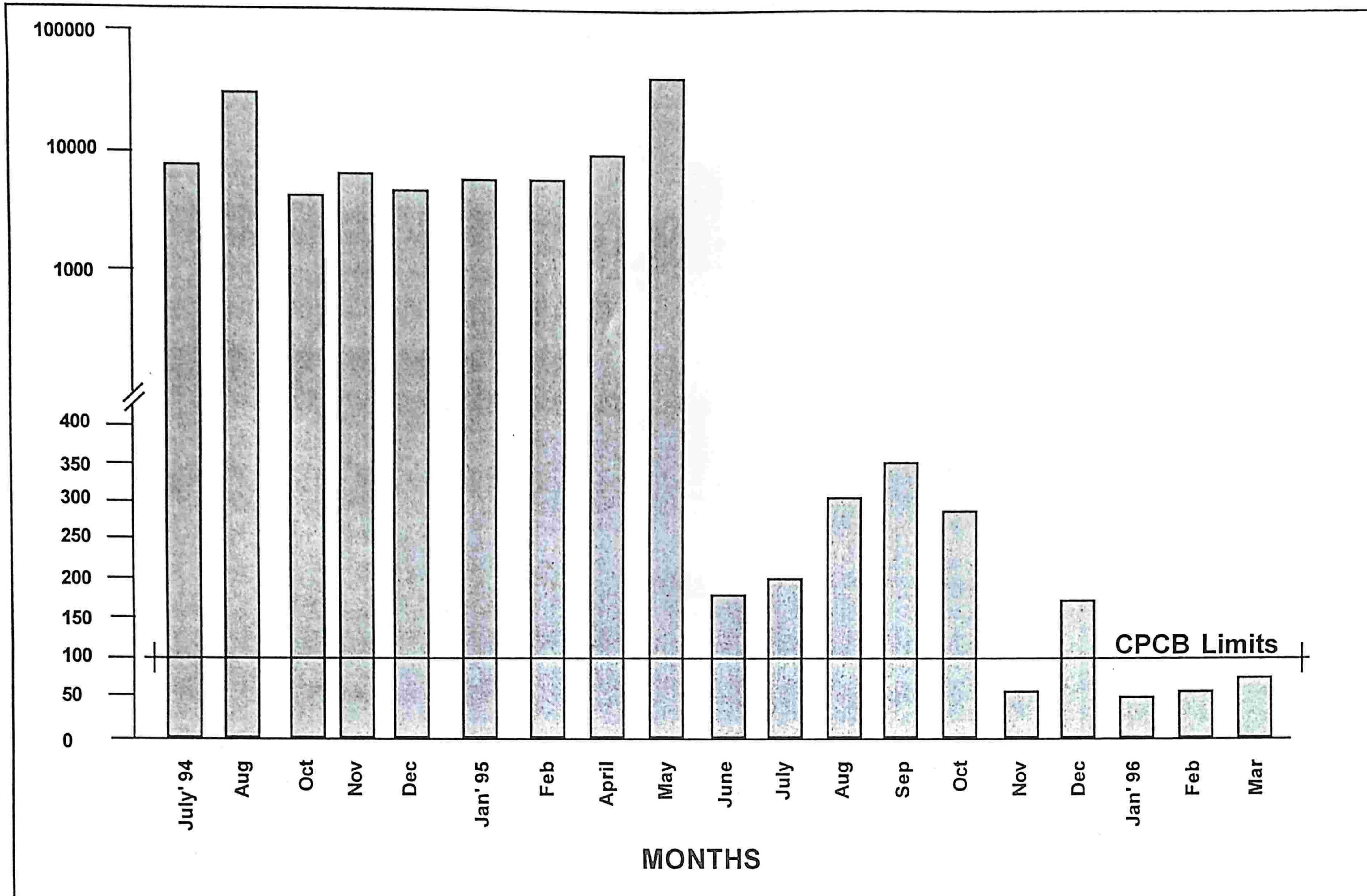

Figure 4.2: Levels of Total Suspended Solids (mgL^{-1}) in Sankoja *nala* due to mine discharge from July'94 to March'96

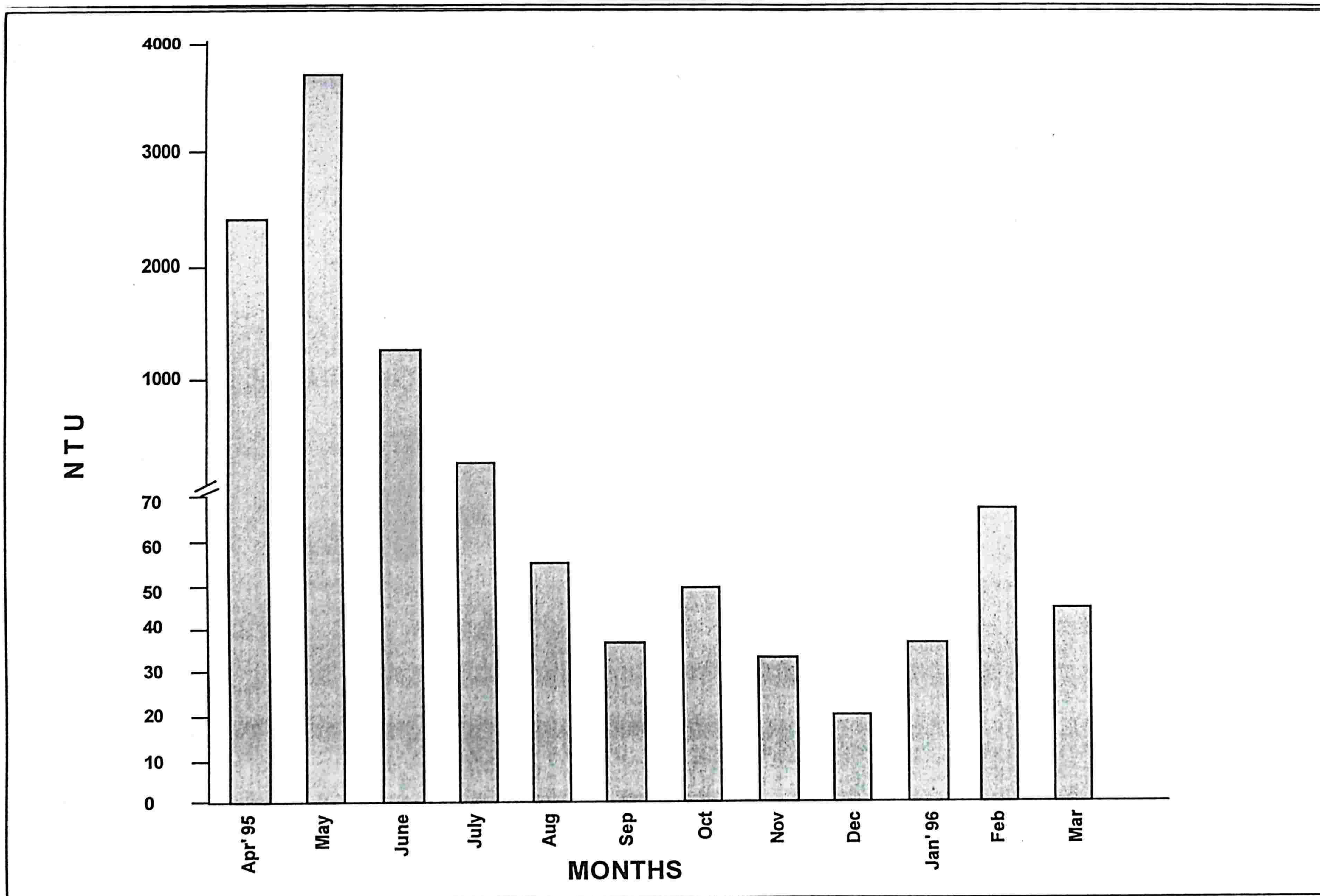

Figure 4.3: Levels of Turbidity (NTU) in Sankoja *nala* due to mine discharge from April'95 to March'96

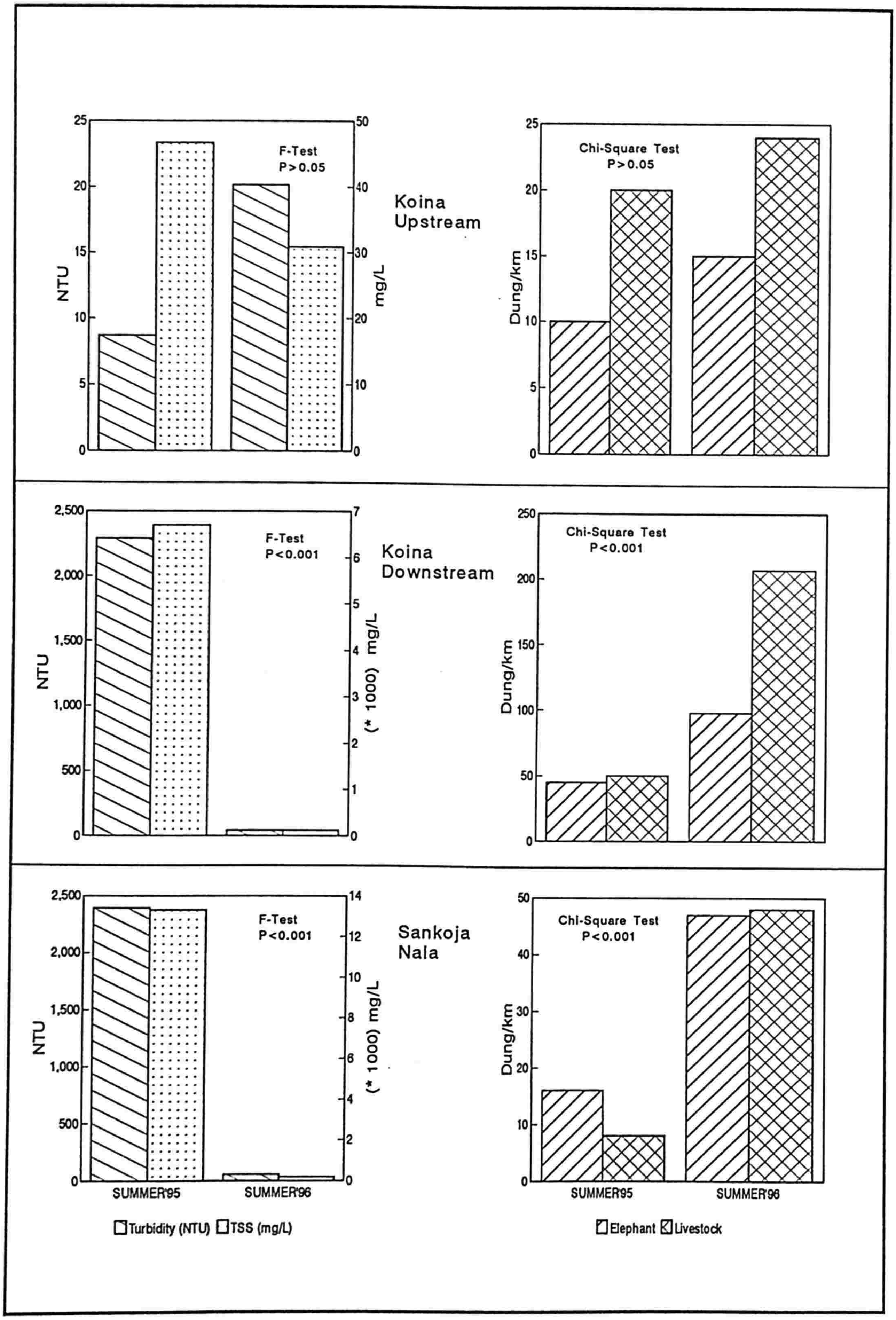

Figure 4.4: Effect of Turbidity (NTU) and TSS (mg/L) on the riverine habitat use by elephants and other mammals in three river segments-Koina upstream, Koina downstream and Sankoja *nala* during Summer'95 and Summer'96

Chapter 5

CHAPTER 5

Heavy metals in soil and plant communities

5.1 Introduction

Unmanaged mine tailing having high suspended solids load besides reducing the water quality (Desai, 1990a; Miller *et al.*, 1996; Mitra, 1997; Sen and Ghose, 1997) can also contaminate a river and its biological communities through toxic heavy metals (Axtmann *et al.*, 1997; Kassim *et al.*, 1997; Panayotova, 1997; Zaranyika *et al.*, 1997). The distribution and transport of these toxic metals depend on sediment enrichments received through mine tailing and water discharge of the river system for their aggradation along stream bed and flood plains (Förstner and Wittmann, 1979; Salomons and Förstner, 1984; Steven and Moore, 1996). The Koina River with a length of 83 km forms an integral habitat for several wildlife including elephant in the region. The flood plains and river channels stretching 16-km length of river Koina from Jambai to Kumdi dam was affected with extensive deposits of waste sediments disposed through the iron ore mines. Wilting and dying of large number of tree species along deposited flood plains of the river (Chapter 2; Plates 2.12 & 2.13) is a major concern for habitat degradation and possible input of toxic heavy metals in the biological communities.

With the above concern it is important to establish a base line information on heavy metals in source, their distribution in sediments of river bed & flood plains, and further uptake in plant communities. Five major tree species in affected sites along the Koina River were compared for their metal enrichment with unaffected sites. The concentration factor (Chamberlain, 1983) and affinity sequence (Ross, 1994) of various metals in plant communities were also documented. An effort has been made to examine the patterns of metal concentration in forages of elephants through dung analysis between various sites of mining, near mining, non-mining and reference areas.

5.2 Methodology

5.2.1 Analysis of river sediment and soil

For detecting and quantifying heavy metals in crushed ore and mine waste, samples were taken from 5 different sites and digested with mixed acid to facilitate chemical analysis using an Atomic Absorption Spectrophotometer (Allen, 1989). This initial analysis was essential to detect the presence of heavy metals in the source.

The river sediments were collected during summer 1997 along the sampling stations of Koina up and down streams (Figure 3.1). River sediments were collected from both the banks and also from middle of the river with the help of Ekman Dredge Sampler. All three sediment samples from each site was mixed thoroughly to prepare 3 sub samples.

Three soil samples were also collected around each wilted tree at 5 different sites for quantification of heavy metals. Reference soil samples were collected from the nearest available site where the same tree species was found un-impacted. The soil samples were collected from 0-15 cm deep below humus layer with the help of soil auger.

After sieving with 2mm mesh the soil and sediment samples were oven dried at 60^0 C for further analysis. The dried samples were analyzed for pH, oxidation redox potential (ORP) and Electrical Conductivity (E. Cond.) in 1:5 soil solution (Trivedy and Goel, 1986). Organic carbon and total nitrogen were determined by wet oxidation and Kjeldhal method respectively (Kalra and Maynard, 1991). For all other major elements (Na, Mg, Si, P, K, Ca and Al) and heavy metals (Fe, Mn, Cu, Zn and Pb) the samples were analyzed through WD-XRF techniques on Siemans Sequential X-ray Spectrophotometer (SRS-300) equipped with Rh end-window X-ray tube. The sample processing and analysis was according to the techniques suggested by Saini *et al.,* 1998.

5.2.2 Analysis of plant tissue and dung

Plant tissues of tree species were collected from impacted and reference sites to quantify the heavy metals. Approximately 25 grams of tissue samples from three trees of each species were collected with the help of hand driller, at a level of chest height, reaching up to the center of tree. The collected tissue samples were oven dried and stored for further analysis.

Elephant dungs were collected from four selected sites for prospecting the heavy metal enrichments in elephant forage. The locations of these sites were in mining area, near to mining area and non-mining area from where 15, 15 and 12 dung samples respectively were collected from the study area. Further, 3 dung samples were collected from a nearby Protected Area *i.e.* Dalma Wildlife Sanctuary where there is no mining and could serve as a reference. The collected dung samples were thoroughly washed in running distilled water to separate plant remains. These were then oven dried and stored for further analysis.

The dried and ground samples were digested with H_2SO_4 - H_2O_2 digestion method (Allen, 1989). The digested samples were analyzed for heavy metals in Atomic Absorption Spectrophotometer.

5.2.3 Statistical analysis

Paired t-test was performed for establishing the significant difference in mean values of different variables between sediments of river sectors and soil of affected and unaffected sites. The One Way ANOVA (Das and Giri, 1991) was performed to derive significant differences in concentration factors (CF) due to heavy metal enrichment. Scheffe test for Post Hoc Multiple Comparison (O'Neill and Wetherill, 1971) was performed to determine statistically homogenous group for CF values in different plant species affected through heavy metal enrichment.

5.3 Results

5.3.1 Heavy metals in source

Table 5.1 shows concentration of 10 heavy metals in crushed ore and mine waste sampled during study. Out of these 5 heavy metals (Fe, Mn, Cu, Zn and Pb) were found at detectable levels whereas rest others (Cd, Co, Cr, As and Ni) were below the detection limit of AAS.

5.3.2 Heavy metals in river sediment

Table 5.2 presents mean concentration of heavy metals in upstream and downstream zones of river Koina. A t-test analysis revealed significant differences in metal concentrations in case of Fe, Cu, Zn and Pb. The mean concentration of Fe was found approximately 1.5 times higher in downstream compared to its upstream (294983.5 ppm) zone. Noteworthy was mean lower concentrations of Cu, Zn and Pb in downstream zones than the upstream (Table 5.2). Various chemical characteristics of sediments such as pH and ORP were found significantly different between upstream and downstream zones. Among all macro elements only Carbon (C) concentration was found significantly different in two river zones and mean value was more in upstream zone. Absence of total nitrogen in both river sectors was spectacular in the finding.

The affinity sequence of heavy metals (Fe>Mn>Cu>Zn>Pb) in river sediments was similar in both upstream and downstream zones of the river. A sequencing of macro elements in order of Si>Al>K>Ca>Mg>P>Na was recorded for both sectors of the river.

5.3.3 Heavy metals in soil

The heavy metal concentration in soil along deposited river plains to the sites where tree moralities were recorded (Affected) and to nearest reference sites (Unaffected) are presented in Table 5.3. The site comparison through t-test analysis revealed significant differences in concentration all 5 heavy metals (Fe, Mn, Cu, Zn and Pb) between affected and unaffected sites. The mean concentration of Fe was found almost 3.5 times higher in affected site compared to the unaffected site (121708.1 ppm). Whereas, remaining four heavy metals were found in higher concentrations in unaffected sites compared to the affected sites (Table 5.3). An affinity sequence among the heavy metals were in order of Fe>Mn>Cu>Zn>Pb in both the sites and also were comparable with the characteristics of river sediments.

5.3.4 Nutrient status in soil

Changes in the chemical parameters including soil macro elements between affected and unaffected sites are presented in Table 5.3. The soil pH at both the sites were found slightly acidic in nature. However, ORP value was recorded significantly more in affected compared to unaffected sites. The electrical conductivity showed reverse outcome of having significantly more in unaffected sites. Macro elements in soil *i.e.* C, N, K, Na, Mg, Ca, Si and Al were found higher in unaffected compared to the affected sites. The t-values for all these were found significant, except for Al. Concentration of P was found higher in affected sites compared to the unaffected sites. However, it was not found significant. The affinity sequence of soil macro elements were in order of Si>Al>K>Ca>Mg>Na>P>N in unaffected sites. Whereas this sequencing was found little altered Si>Al>K>Ca>Mg>P>Na>N in the affected sites and of similar nature to that of river sediments.

5.3.5 Heavy metals in plant tissue

Table 5.4 presents concentration factor (CF = Metal concentration in plant/Metal concentration in Soil) of five heavy metals in several affected tree species along the river Koina. It can be seen from the table that mean CF value for Fe in unaffected site is 0.0063, which is higher than the affected sites (0.0015). For rest other heavy metals (Mn, Cu, Zn and Pb) the mean CF value were higher in case of affected sites compared to unaffected sites. The noteworthy was the CF value (1.12) of Pb for Asan, *Terminalia alata* in affected sites due to higher uptake of this metal. Similarly, for Zn, CF value (0.87) in affected sites was higher due to high uptake in Kendu, *Diospyros malabarica* .

The Post Hoc analysis revealed formation of homogenous groups in case of only Fe and Mn on the basis of their CF values in different plant species (Table 5.4). Fe forms and individual group with highest CF value (0.0071) in Teak, *Tectona grandis* followed by Jamun, *Syzygium cumini* (0.0066) and Kendu (0.0025). Whereas, Sal, *Shorea robusta* and *Asan* were on the lowest side in terms of CF values (Table 5.4). For Mn, uptake in *Asan* had highest CF values (0.09) followed by *Sal* (0.08) and *Kendu* (0.021) and lowest among *Teak* and *Jamun*.

5.3.6 Heavy metals in elephant dung

The concentration of five heavy metals in the defecated plant materials of elephant dung at different sites is presented in Table 5.5. All the five heavy metals were found in elevated levels to the mining sites compared to non-mining and reference sites. Zn and Pb were not detected in the reference site, whereas, their concentration in mining site was 31.36 ppm and 18.25 ppm respectively. Fe was found in similar concentration to the reference and near mining sites while at mining site its level was approximately 4 times above. Mn and Cu concentrations were also found elevated in the mining sites by approximately twice the level of reference site.

5.4 Discussion

The input of Fe and Mn in Koina river sediment has taken place more than their mean concentration in upstream or reference zone. However, this variation was only statistically significant for Fe (Table 5.2; $p<0.05$). Other heavy metals Cu, Zn and Pb were present significantly low mean concentration in the river sediment in comparison to the upstream. This indicated that the mine discharges had low concentration of these metals that were subsequently diluted with hydraulic sorting in downstream sediments. Decreased concentration of metal contaminants in a downstream river section from pollution source due to hydraulic sorting have been reported by several authors (Edwards-Hudson *et al.*, 1996; Helgen and Moore, 1996; Axtmann *et al.*, 1997; Kassim *et al.*, 1997).

The metal enrichment in the soil of flood plains of river Koina has also shown a significantly higher Fe concentration similar to that of river sediment. While, remaining heavy metals Mn, Cu, Zn and Pb were significantly lower in their mean concentration as compared to the affected sites. The site examination of sediments and soils of Koina flood plain invariably suggest that Fe enrichment could be a factor for tree mortalities along the catchment. The thick deposition of iron ore fines containing above 35% Fe, a derivative of haematite iron (Fe_2O_3) with specific gravity 4.9 – 5.3 could be a major cause of soil compaction (Chapter 2; Plates 2.12 and 2.13). Drake and Ririe (1981) reported that soil compaction can cause degradation of soil structure by formation of plough pan. This is a layer overly dense from repeated compaction of topsoil, which do not allow ion movement, water and air, essential for plant growth (Albrecht and Thompson, 1982). Desai (1990b) reported that iron ore reject extracts of different concentration particularly above 50%, exerted very harmful effect on root growth of several potted crop species. However, such references on long-lived forest trees are lacking.

Presence of organic carbon level in the soil is an indicator of organic matter returned through litter decomposition by nutrient cycling in a forest ecosystem (Meentemeyer, 1978; Blair, 1988). The inhibitory effects of metal on litter decomposition or respiration rate varies with the magnitude of metal inputting have been reported by several authors (Laskowski *et al.,* 1994; Niklinska *et al.,* 1998). In heavily polluted environment this results in accumulation of undecomposed organic matter that harms forest health and productivity (Rühling and Tyler, 1973). While working on the heavy metals and their impact on basal respiration rate, Niklinska *et al.,* (1998) reported $EC_{50respiration}$ values (ppm) for Cu = 3880, Zn = 5610 and Pb = 24800. In present study the concentration of these heavy metals in soil of affected and unaffected sites were much lower and possibly not having any major reason for individual metals to alter the organic carbon level. Kabata-Pendias and Pendias (1984) have reported the toxic concentration of metals in soil for Cu (60-125 ppm), Zn (70-400 ppm), Pb (100-400 ppm) and Mn (1500-3000 ppm). The mean concentration of Mn in soil of affected and unaffected sites was also below the reported toxicity range in the present study (995.10 ± 67.15, Table 5.3).

In study sites concentration of Fe in soil was 3.5 times higher in affected compared to the unaffected sites. Increase of iron concentration as Fe_2O_3 is likely a stand-alone factor among rest other heavy metals (Mn, Cu, Zn and Pb) for reducing %organic carbon in the soil of affected sites. The low decomposition of organic matter in affected site is also reflected through lower concentration of essential nutrients *viz.* N, K, Na, Mg and Ca (Table 5.3). The low electrical conductivity value for soil in affected sites also reflects low concentration of soluble nutrients. A similar finding by Jameel (1998) reports that excess iron depresses the available P, K, and Mg contents of soil. The tree mortalities along Koina flood plain therefore could be due to cumulative effect of soil compaction with iron fines deposit (*vide supra*) leading to nutrient stress in top soil.

The metal concentration factor in case of Pb (1.12) in Asan and Zn (0.87) in *Kendu* within the study sites were a concern for metal uptake in plants and their further transfer into animal food chain particularly for elephants. Presence of higher concentration of Fe, Mn, Zn and Pb in the residual forage of elephant to the mining site is alarming and need further monitoring and review. Working on Asian elephants, Jayasekera and Kuruwita (1996) reported elevated lead concentration in the blood plasma of domesticated compared with free ranging elephants. They related this elevated level to water contamination through engine exhausts by burning of fossil fuel as a source of below the reported toxicity range in the present study (995.10 ± 67.15, Table 5.3).

In study sites concentration of Fe in soil was 3.5 times higher in affected compared to the unaffected sites. Increase of iron concentration as Fe_2O_3 is likely a stand-alone factor among rest other heavy metals (Mn, Cu, Zn and Pb) for reducing %organic carbon in the soil of affected sites. The low decomposition of organic matter in affected site is also reflected through lower concentration of essential nutrients *viz.* N, K, Na, Mg and Ca (Table 5.3). The low electrical conductivity value for soil in affected sites also reflects low concentration of soluble nutrients. A similar finding by Jameel (1998) reports that excess iron depresses the available P, K, and Mg contents of soil. The tree mortalities along Koina flood plain therefore could be due to cumulative effect of soil compaction with iron fines deposit (*vide supra*) leading to nutrient stress in top soil.

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Table 5.1: Detection of heavy metals in crushed ore and mine waste

Heavy Metals	Crushed Ore (in ppm)	Mine Waste (in ppm)
Fe	334.90×10^4	348.66×10^4
Mn	61.40	62.40
Cu	12.80	26.20
Zn	38.80	45.80
Pb	251.80	241.00
Cr	+	+
Cd	+	+
As	+	+
Ni	+	+
Co	+	+

+ below the detection limit of AAS

Table 5.2: t-test for elements (ppm ± SE) in the sediments of the river Koina

Parameters	Upstream Zone n = 12	Downstream Zone n = 24	Value of t
pH	5.69 ± 0.058	6.23 ± 0.073	-4.76*
ORP (mv)	260.00 ± 7.49	285.00 ± 5.10	-2.80*
E. Cond. (mS)	0.13 ± 0.04	0.19 ± 0.41	-0.96
C (%)	1.04 ± 0.12	0.45 ± 0.11	3.37*
P	840.23 ± 66.3	987.24 ± 43.84	-1.89
K	4361.91 ± 697.06	3160.04 ± 511.78	1.37
Na	287.76 ± 69.50	434.45 ± 99.27	-0.98
Mg	1636.46 ± 252.82	1454.44 ± 258.25	0.45
Ca	1929.67 ± 139.94	1969.35 ± 162.57	-0.16
Si	122555.5 ± 12660.29	87948.57 ± 13012.73	1.69
Al	98901.10 ± 4711.66	44094.94 ± 4840.47	7.18*
Fe	294983.5 ± 26526.17	426774.6 ± 32060.10	-2.675*
Mn	842.65 ± 64.64	949.56 ± 251.56	-0.296
Cu	68.70 ± 3.94	40.42 ± 4.21	4.29*
Zn	48.45 ± 2.74	35.62 ± 3.20	2.597*
Pb	24.62 ± 1.82	12.16 ± 0.98	6.604*

* indicates significance of difference at $p < 0.05$

Table 5.3: t-test for elements (ppm ± SE) in the soil of affected and unaffected sites

Parameters	Affected sites n = 15	Unaffected sites n = 12	Value of t
pH	6.24 ± 0.11	6.53 ± 0.16	-1.53
ORP (mv)	287.07 ± 13.08	223.50 ± 8.87	3.81*
E. Cond. (mS)	0.14 ± 0.014	0.23 ± 0.156	-4.29*
C (%)	1.36 ± 0.23	3.78 ± 0.47	-4.88*
N	63.61 ± 20.61	198.76 ± 49.75	-2.71*
P	881.22 ± 44.28	712.88 ± 90.47	1.78
K	3977.99 ± 727.79	10233.09 ± 1077.75	-4.96*
Na	394.21 ± 101.50	1074.73 ± 193.10	-3.30*
Mg	1555.75 ± 299.40	3478.49 ± 1072.22	-5.05*
Ca	2341.54 ± 272.66	4021.92 ± 386.45	-3.65*
Si	73043.91 ± 16569.47	223469.2 ± 27132.16	-4.93*
Al	69226.30 ± 6536.99	88753.12 ± 10294.93	-1.66
Fe	432118.3 ± 37959.72	121708.1 ± 19766.49	6.734*
Mn	715.34 ± 69.29	995.10 ± 67.15	-2.852*
Cu	35.32 ± 2.50	70.02 ± 13.72	-2.770*
Zn	29.43 ± 2.85	58.65 ± 4.45	-5.733*
Pb	10.16 ± 0.97	23.45 ± 0.90	-9.839*

* indicates significance of difference at $p < 0.05$

Table 5.4: Means of interaction of concentration factor in plant species of affected (and unaffected (UA) sites

Heavy metals	Sites	Plant Species					$\bar{x}$
		Sal	Asan	Teak	Jamun	Kendu	
Fe	A	0.00078	0.0017	0.001	0.003	0.00093	0.0015
	UA	0.0018	0.002	0.013	0.01	0.0041	0.0063
	$\bar{x}$	0.001[a]	0.0019[a]	0.0071[c]	0.0066[b,c]	0.0025[a,b]	
Mn	A	0.087	0.11	0.0062	0.02	0.035	0.052
	UA	0.058	0.064	0.026	0.011	0.0074	0.033
	$\bar{x}$	0.08[a,b]	0.09[b]	0.016[a]	0.015[a]	0.021[a,b]	
Cu	A	0.104	0.105	0.077	0.074	0.13	0.097
	UA	0.003	0.016	0.13	0.038	0.094	0.056
	$\bar{x}$	0.078	0.061	0.104	0.056	0.110	
Zn	A	0.41	0.41	0.40	0.25	0.87	0.47
	UA	0.00	0.079	0.17	0.27	0.056	0.11
	$\bar{x}$	0.31	0.25	0.28	0.26	0.46	
Pb	A	0.33	1.12	0.00	0.00	0.00	0.29
	UA	0.00	0.00	0.00	0.00	0.24	0.05
	$\bar{x}$	0.25	0.56	0.00	0.00	0.12	

Same alphabets represent statistically homogenous group

Table 5.5: Post Hoc Multiple Comparison Test of heavy metals (ppm) in elephant dung collected from different sites

Heavy Metals	Dalma WLS n = 3	Sites in Study Area		
		No mining n = 12	Near Mining n = 15	Mining n = 15
Fe	3861.63	2396.64	3670.68	15693.47
Mn	137.08[a]	136.74[a]	174.40[a,b]	303.03[b]
Cu	10.31[a]	13.96[a]	16.72[a,b]	19.84[b]
Zn	0.00[a]	25.55[b]	16.81[a,b]	31.36[b]
Pb	0.00	1.15	3.98	18.25

Same alphabets represent statistically homogenous group

Chapter 6

CHAPTER 6

Impact assessment of the river Koina for restorative management and setting guidelines for monitoring

6.1 Introduction

Water quality (Chapter, 3) and heavy metals contamination in river sediments (Chapter, 5) were the two major identified threats for impacting river Koina in the Singhbhum forests ecosystem due to unmanaged tailing and disposal from iron-ore mines. Impact of these threats can reduce aquatic and riverine habitat values for several life forms, or to a particular target species as in case of elephants (Chapter, 4). More than this, it also affect large number of human beings, those are dependent on this water resources for drinking and agricultural purposes.

Prevalence of these threats along the river distance is important for understanding the risk factors and system resilience to cope up with such exposures. Knowing of these can help in planning an effective restoration and monitoring program. The present chapter is an effort in this direction to map out an 80-km stretch of the river Koina exposed to such threats by the siting iron-ore mine and its unmanaged tailing.

6.2 What are the targets?

In the present study targets for ecological risks were deterioration of Koina River water quality, effects on dependent animal and human being and dying of plant communities along the river. For water quality deterioration the responsible factors came out as suspended sediments, high turbidity and resultant decrease of DO level in the aquatic ecosystem (Chapter, 3). Our study in chapter 4 revealed that riverine habitat use by elephants also get affected when TSS and turbidity were high during unregulated mine discharge period. We have further investigated that the riverine tree mortalities could be due to the result of excessive metal input and resultant decrease of nutrient status essential for plant growth (Chapter, 5). Further the water use of Koina River can not be less overemphasized as approximately 25,000 human beings inhibiting in 30 villages are solely dependent for drinking and agricultural purposes.

6.3 Methodology

The means of Turbidity, TSS, DO (Appendices A.1 to A.3) and heavy metals in sediments (Appendix C.1) were plotted against the river distance of Koina by using nearest neighbor girding method in Surfer6 computer package. The methods for collection of samples and analysis for Turbidity, TSS and DO are discussed in Chapter 3. While, for heavy metals this is discussed in Chapter 5.

6.4 Results

6.4.1 River impact due to water quality parameters

In unregulated tailing disposal situation the river impact with Turbidity, TSS and DO are depicted in Figure 6.1. It can be seen from the figure that for TSS and Turbidity in reference stretch *i.e.* 7.8 km of the river was the lowest (19.34 mgL^{-1} and 3.0 NTU respectively). However, on contrary this sector had the highest DO value (7.03 mgL^{-1}). The water quality alteration in river Koina took place soon the unmanaged tailing entered through Sankoja *nala* (Chapter 3; Fig 3.1) resulting in increase of Turbidity (2323.33 NTU) and TSS (7678.66 mgL^{-1}) to its highest level beyond 7.8 km up to a distance of 25 km. Then afterward with the dynamics of river system the TSS and Turbidity started decreasing. While, the TSS get reduced and arrives to its near reference value within a distance beyond 32 km of river but Turbidity still takes a longer distance (62.5 km) to regain its normalcy. Noteworthy, was the abrupt decrease of DO immediately after entry point of tailing just after 7.8 km and prolonging to a distance of over 55 km of the river stretch. In spite of the recovery of TSS and Turbidity level beyond 62.5 km of river distance, the DO level never comes to its available higher value (7.03 mgL^{-1}), as in the reference section. However, this ought to be higher in the downstream sector of river. The most critical sector of this river was between 7.8 to 35 km due to TSS and Turbidity when their values varied from 1000-6750 mgL^{-1} and 825-2250 NTU respectively. This sector of the river is valuable for wildlife point of view as it meanders through undisturbed forests. The critical distance of river due to DO was from 7.8 km to 57 km.

6.4.2 River impact due to heavy metals in sediment

The distribution and load of heavy metals (Fe, Mn, Cu, Zn and Pb) in river sediments is depicted in Figure 6.2. It can be seen from the figure that for Fe, Cu, Zn and Pb concentration increased in river sediments just after reference stretch *i.e.* 7.8 km of the river distance. This however, quickly recovered after a river distance of 16 km onward, except for Fe. In case of

Mn there was a sudden rise in concentration after 36 km of river distance and remains higher up to 42.5 km. A near similar rise was again seen between a stretch of 52-74 km. This therefore suggests that the likely influence of other tributaries (Sarko and Hamsada *nala*) and their load rather than the mine discharge through Sankoja *nala*. For Cu, Zn and Pb also the influence of other tributaries were seen between a river stretch after a distance of 42.5-km (Figure 6.2). The major input of metals in the river sediments was mainly due to elevated Fe load (4.0 x 10^5 – 6.5 x 10^5 ppm) between river stretch of 12.5 to 36 km. The critical sector for heavy metals input due to Fe was between the stretch 12.5 to 42.5 km of the river distance. This is corroborated through the occurrence of large number of wilted/dead trees along river floodplain only within this stretch.

6.5 Conclusions

The river Koina unlike any other river system is known to fluctuate on diurnal, seasonal and annual cycles in response to environmental and biotic pressures. In normal circumstances these cycles are repetitive, and therefore, the biota of the systems are adapted to such changes. Drastic alteration can occur only when an outside influence takes place and brings profound impact on the river system and its resilience.

The unmanaged discharge of iron-ore waste was a factor for altering river system, water quality, habitat values and also exerting stress on the plant communities along the flood plain. The suspended solids caused turbidity to increase and also to lower DO value in the Koina river system.

These inter linked process impacts the river and the life forms within it. Several aquatic species including fishes are known to avoid such kind of river zone impacted through high TSS and Turbidity (Ingle *et al.,* 1955). Buermann *et al.*, (1995) while working on the impact of silt release from Phalaborwa barrage in the lower Olifants river inside the Kruger National Park reported that increase amount of silt >25,000 mgL^{-1} caused drastic reduction of DO concentration of water reducing it from 6 mg^{-1} to 0 mgL^{-1}. Moore *et al.*, (1991) also reported silt release above 24,665 mgL^{-1} caused several fish species to die. Hocutt *et al.*, (1978) also recorded the influence of Barite pond tailing rupture and reduction of fish fauna in Mill Creek tributary of Big river, Missouri in the year 1975. All these studies therefore suggests that high load of TSS could be vulnerable for several aquatic species. The Koina river stretch between 7.8 km to 42.5 km therefore needs to be monitored specially with reference to the several life forms. Our study in Chapter 4 also highlighted the management of this river stretch to arrest the avoidance of elephant utilization. The monitoring of DO need to be carried out in entire stretch of river Koina as it could be an important factor for the sustainability of micro flora and fauna.

The reduction of waste discharge through proper regulation will eventually decrease the load of heavy metals, of which Fe is an important element in the present case. Unless this is controlled the river ecology can be highly impacted through the channel morphology, clogging and compaction of the flood plain topsoil.

6.6 Planning a restorative management

A restorative management of the Koina river system can only be thought of if strict regulatory process for ore beneficiation, management of waste dumps, and reclamation of mined areas can be planned with proper environmental safeguards. The responsibilities of mining authorities in following prescribed guidelines of effluent discharge into inland surface water mentioned under Environmental (Protection) Act (EPA), 1986 is mandatory. The relevant parameters and their standards set in the EPA are summarized in Table 6.1 along with the Central Pollution Control Board (CPCB) classification for inland surface water. The quality of receiving water is an ideal indicator for the health of river catchment. If water quality is poor, it certainly indicates faulty mining landuse and land management within the catchment. The existing Forest Acts do not have any provisions for challenging such inland water quality deterioration leading to ill health of wildlife habitats due to siting industries out side the protected areas. The authorities appointed under both the Acts (EPA and Forest) have their separate jurisdictions and their in-coordination is the major legal shortfalls for controlling such inadequacies and offences. In recognition of this limitations following measures of responsibilities have been identified which can improve discharge quality and land management for restoration of the Koina river ecosystem.

6.6.1 Management of the ore beneficiation process

Ore beneficiation through wet circuit is a process for categorizing and classifying the iron-ores. The slimes containing particle size -150μm are generated as waste through mine tailing that constitutes 10-25% by weight of iron ore mined (Singh and Singh, 1997). Improper functioning of classifier allows bigger size of particle to enter in the effluent, which are further detrimental in terms of suspended load in the receiving river system. In an efficient process the waste particle in slime is separated through the settling process in thickener. During unregulated period the thickener of the Kiriburu mine was non-functional and completely clogged (Chapter 2; Plate 2.11) which became the reasons for excessive sediment load in Koina river system. Improvement in water quality was the reflection of refunctioning of thickener (Chapter 2; Plate 2.16). The effluent after thickener is carried through pipeline into a tailing pond. Further settling is facilitated before its accesses into the natural drainage system. Clogging and leakage of pipeline were also been a reason for the Koina river pollution during unregulated time period. Improper management of the tailing pond may lead into early filling with silt and become inefficient for particle retention. The mining authorities with required check and balances should observe above three major steps for effluent treatment *i.e.* efficiency and functioning of classifier, thickener and tailing pond.

6.6.2 Management of waste dumps and reclamation of mined land

Majority of iron-ore mines in the Saranda Forest Division is located on the hill ridge tops. Management of waste generated due to mining activities is an essential step to avoid escaping of waste into the main river course through run off during rainy season. These dump areas should be restored with indigenous suitable plant species to stabilize the soil against erosion. Mechanical measures such as construction of retention wall, terracing, gully plugging, provision of adequate drainage should be adopted (Singh and Sinha, 1993). All derelict mine sites also should be revegetated by adopting various reclamation techniques (Ghose and Ghose, 1990; Ghose, 1991; Ghose and Ghose, 1993; Ghose, 1996), application of raw sewage (Maiti, 1995) and use of *Mycorriza* (Maiti, 1997). Revegetation of mine site and proper landscape planning can also provide an alternate mosaic habitat for wildlife use (Yearsley and Samual, 1980; Nichols and Watkins, 1984; Brenner, 1992).

6.7 Guidelines for monitoring programme

Monitoring the impact of siting iron-ore industry on biodiversity of the Singhbhum forest ecosystem was seen as essential, using appropriate objective criteria applicable to aquatic and terrestrial ecosystem. The underlying objectives for this monitoring will be:

1. Determining the permissible content of suspended solid wastes in effluent;
2. Estimating loads of suspended solid, turbidity and DO in receiving water system;
3. Heavy metals load in river sediment;
4. Response of biotic communities specially the micro flora and fauna.

Knowing of these through a regular record should be a essential compliance for the siting iron-ore mine industry with proper verification on ground by the local forest authorities. To deal with pollution offences and breaching, the surface water quality standard enactment – Environmental (Protection) Act, 1986; Water (Prevention & Control of Pollution) Act, 1974 &

1977 and Air (Prevention & Control of Pollution) Act, 1981 are available. Ameliorative waste management and treatment of wastewater also should be taken up. As per the Forests (Conservation) Act, 1980, cost benefit analysis report along with proper Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) should be drawn up by those siting iron-ore industries. These preventive and ameliorative measures will ensure the restoration of elephant habitat quality in Singhbhum forests. Such measures are important given the present mining regime, which is planned to continue for another 40 years at present extraction levels.

Table 6.1: Guidelines for discharge of effluent and classification of inland surface water

Parameters	Discharge norms as per EPA, 1986	CPCB classification for inland surface water				
		A	B	C	D	E
TSS	100	-	-	-	-	-
TDS	2100	500	-	-	-	-
pH	5.5 to 9.0	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	6.0 – 8.0
Temp (^{0}C)	Shall not exceed 5^{0}C above the receiving water temperature	-	-	-	-	-
Chloride	1000	250	-	600	-	600
Phosphate	5.0	-	-	-	-	-
Sulphate	1000	400	-	400	-	1000
Nitrite	10	20	-	50	-	-
DO	-	6.0	5.0	4.0	4.0	-
Bio-assay test	90% survival of fish after 96 hours in 100% effluent	-	-	-	-	-

Except pH for all other parameters in mgL^{-1} otherwise mentioned

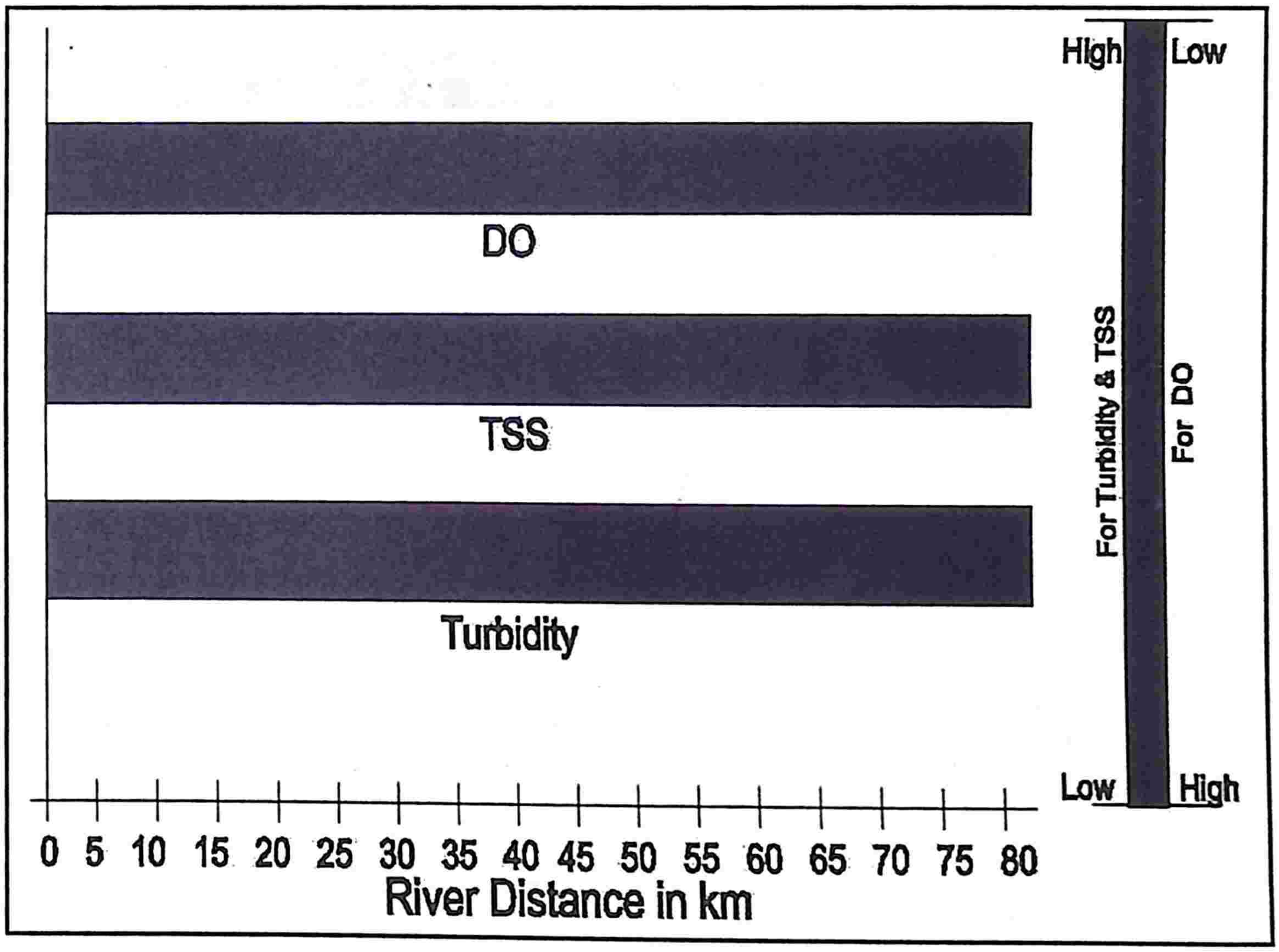

Figure 6.1: Impact levels of the river Koina due to Turbidity, TSS and DO during unregulated mine discharge

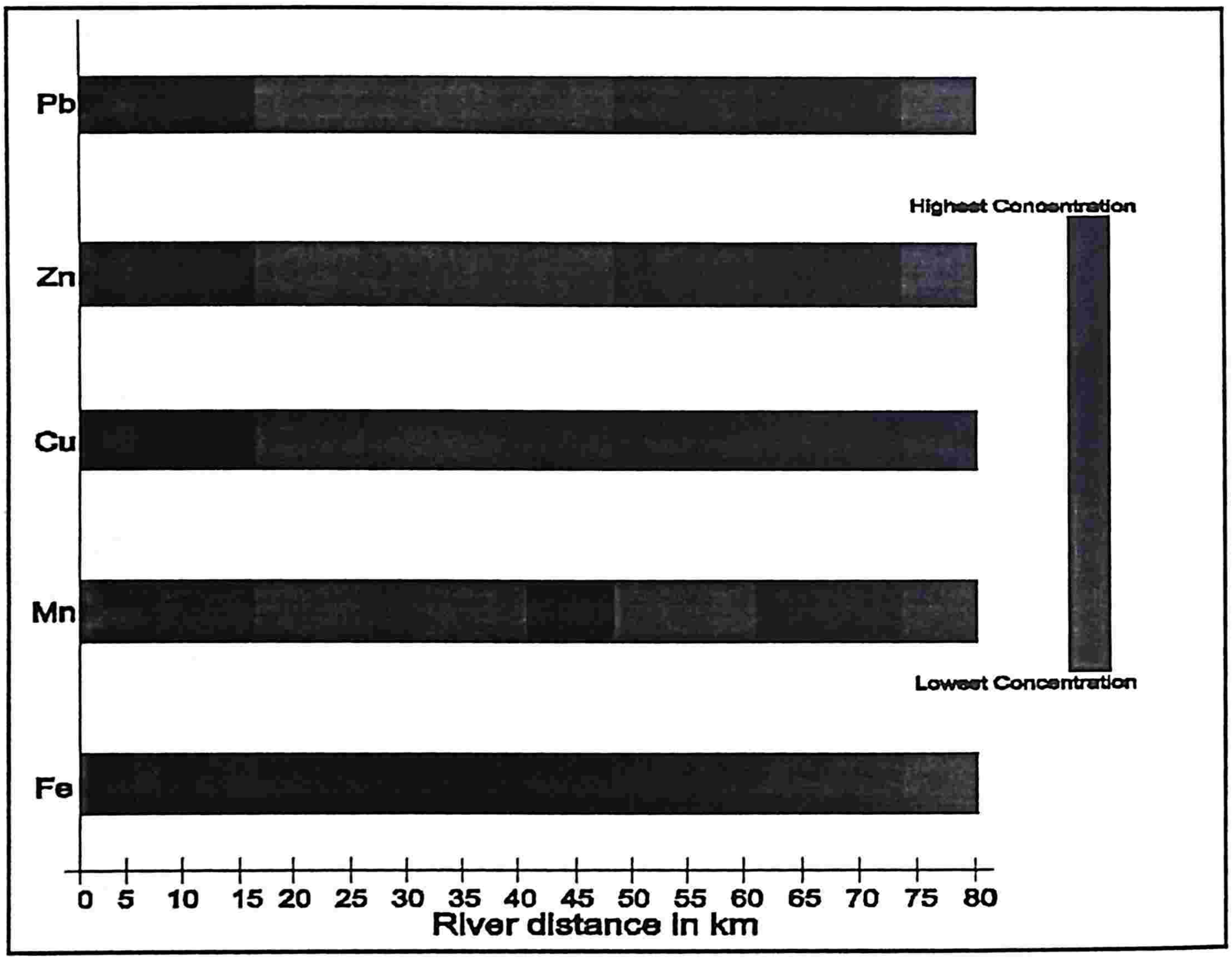

Figure 6.2: Impact levels of the river Koina due to heavy metal load in sediment

Summary

SUMMARY

The thesis consists of a Prologue stating the importance of this study and Acknowledgements followed by six chapters.

Chapter 1 is titled "Ecological and environmental effects of mining: A review" contains a general account of mining scenario and mine with special reference to iron-ore in India. Impact of mining on several ecological and environmental aspects were documented with reference to the scope of present study. The existing legal framework and policy guideline related to environment, forest and wildlife are also discussed in the light of their adequacy to meet the present outstanding challenges.

Chapter 2 is titled "The study area and methods". In this chapter the mining landuse in Saranda Forest Division is quantified and mapped. Waste disposal through wet circuit ore processing by Kiriburu iron-ore (KBR) mine have been a reason for Koina river water pollution. The impact of this was visible through excessive water coloration and reduction of amenity value of the river Koina, whose catchment is an essential element for several wildlife in terms of its use. The methodologies for chemical analysis of mine effluent, river waters, sediment, soil, plant tissue and elephant dung are presented. Method for habitat use of elephant and other mammals are also given.

Chapter 3 is titled "Effect of mine tailing on the water quality of river Koina". It contains an account of water quality changes due to effluent discharge into the river Koina. Spatio-temporal variations in physico-chemical characteristics of

mine effluents and river water were presented under two situations for comparing the changes. Increased suspended load was the reason for high Turbidity and low dissolved oxygen (DO) concentration in river water.

Chapter 4 titled "Relating water quality and riverine habitat use". This chapter aimed at assessing the influence of water quality on occurrence of, and utilization by, elephants in a riverine habitat. The main contrasts between regulated and unregulated situations were Turbidity and TSS, which were higher in unregulated reaches of the rivers. The increase in riverine habitat use by elephants throughout the catchment of regulated river sections in 1996 identified the special value of this habitat during summer for elephant and other mammals. The regulated river sector showed that an increase of 300% use by elephants and 600% by other mammals over the unregulated mine discharge situation ($p<0.001$). While habitat use remained unchanged ($p>0.05$) throughout the study period in control situation.

Chapter 5 titled "Heavy metals in soil and plant communities" contains an account of heavy metals load in river sediments and soil along the river Koina flood plain. Out of five studied heavy metals (Fe, Mn, Cu, Zn and Pb), only Fe enrichment was likely a factor for nutrient deficiency and soil compaction resulting into tree mortalities. The metal concentration factors (CF) in case of Pb (1.2) in *Asan* and Zn (0.87) were the major concern for metal uptake and their transfer into animal food chain particularly for elephants.

Chapter 6 titled "Impact assessment of river Koina for restorative management and setting guidelines for monitoring" contains an account of risk factors of water quality (TSS, Turbidity and DO) and heavy metals on the Koina river system resilience. During the unregulated phase river sector 7.8 to 35 km was critical due to high TSS and Turbidity load. However, DO was more critical to a longer river distance and remained unrecovered after 57 km. Among the heavy metals, iron (Fe) enrichment in soil was critical between 12.5 to 42.5 km river distance, where large number of wilted/dead trees was recorded. A restorative management of the Koina River has been suggested through proper ore beneficiation and dump management. The future monitoring objectives of river Koina were identified and listed.

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Appendices

Appendix – A

Table A.1: **ANOVA for different physical and chemical parameters of mine effluents**

a. Physical parameters

Source of Variation	df	Mean Sum of Square				
		Temp	Turb	TS	TDS	TSS
Between Groups	3	24.36	$7.21 \times 10^{9*}$	$1.16 \times 10^{10*}$	2160.93*	$1.16 \times 10^{10*}$
Error	31	15.01	1.39×10^{9}	2.32×10^{10}	506.64	2.32×10^{10}

* indicates significance of difference at $p < 0.05$

b. Chemical parameters

Source of Variation	df	Mean Sum of Square								
		pH	DO	Thard	Phos	Silica	Chlo	Nitrate	Nitrite	Sulpha
Between groups	3	0.61	40.45*	842.99*	2.24	352.61*	0.24	0.91*	0.000071	21.15*
Error	31	0.52	2.46	179.50	3.47	14.47	0.77	0.008	0.000035	3.13

* indicates significance of difference at $p < 0.05$

Table A.2: Mean and ranges of physical parameters at 18 sampling stations

Sampling Stations	Flow (m sec^{-1})		Temperature (^{0}C)		Turbidity (NTU)	
	UR n = 3	R n = 9	UR n = 3	R n = 9	UR n = 3	R n = 9
AR-1†	14.16 (11.67-16.67)	13.19 (6.67-18.33)	27.93 (25.80-30.10)	27.35 (20.70-31.50)	27.00 (3.00-72.00)	29.22 (0.00-200.00)
AR-2†	12.50 (11.67-13.33)	11.53 (6.67-18.33)	28.63 (26.60-30.70)	27.88 (21.30-32.10)	3.00 (3.00-3.00)	38.78 (0.00-290.00)
KoU-1†	8.33 (6.67-10.00)	10.00 (6.67-26.67)	27.50 (26.00-28.60)	23.73 (18.40-26.60)	3.00 (3.00-3.00)	15.55 (3.00-55.00)
KoU-2†	17.50 (14.17-20.00)	10.09 (3.33-18.33)	27.87 (26.40-29.00)	23.59 (18.60-27.10)	3.00 (3.00-3.00)	20.00 (3.00-72.00)
KoU-3†	9.44 (6.67-13.33)	7.17 (3.33-15.00)	28.00 (26.40-29.20)	23.90 (20.10-26.00)	5.00 (3.00-6.00)	32.67 (6.00-124.00)
KoU-4†	13.33 (5.00-26.67)	12.40 (5.00-26.67)	28.13 (26.60-29.60)	23.97 (19.70-26.70)	23.00 (16.00-33.00)	29.22 (16.00-64.00)
KoD	6.67 (6.67-6.67)	14.81 (3.33-91.67)	29.37 (27.00-31.00)	25.42 (19.30-31.70)	2323.33 (1070.00-3540.00)	54.00 (22.00-167.00)
KoD-1	24.25 (16.67-30.00)	9.54 (3.33-30.00)	28.43 (25.60-30.40)	27.37 (22.70-34.70)	1670.00 (1450.00-2000.00)	68.67 (6.00-452.00)
KoD-2	11.11 (8.33-16.67)	7.12 (3.33-13.33)	29.50 (27.20-31.90)	25.92 (20.30-29.80)	1247.00 (965.00-1416.00)	99.33 (6.00-650.00)
KoD-3	10.00 (6.67-16.67)	10.47 (3.33-20.00)	28.77 (24.90-31.00)	24.69 (18.40-30.40)	771.67 (535.00-1000.00)	390.00 (3.00-3400.00)
KoD-4	11.67 (5.00-23.33)	9.31 (3.33-23.33)	29.43 (25.40-31.90)	26.95 (20.00-31.70)	702.00 (626.00-740.00)	631.44 (3.00-3580.00)
KoD-5	14.45 (6.67-30.00)	7.27 (3.33-13.33)	29.07 (25.60-31.40)	26.45 (20.00-31.60)	435.00 (155.00-820.00)	492.55 (0.00-4350.0)
KoD-6	8.89 (8.33-10.00)	11.68 (5.00-31.67)	29.23 (25.80-31.40)	26.73 (19.80-32.80)	273.33 (160.00-500.00)	445.78 (0.00-3900.00)
KoD-7	14.16 (10.00-19.16)	15.74 (5.00-36.67)	28.83 (25.00-31.50)	27.13 (21.80-31.20)	159.00 (100.00-210.00)	165.44 (0.00-1416.00)
KoD-8	22.22 (6.67-30.00)	13.99 (3.33-35.00)	29.27 (25.80-31.00)	26.17 (19.70-31.40)	77.00 (52.00-107.00)	86.22 (0.00-708.00)
KoD-9	7.78 (3.33-10.00)	7.18 (3.33-12.67)	29.03 (25.30-31.30)	27.34 (21.80-31.90)	101.00 (68.00-124.00)	61.89 (3.00-500.00)
S-1	5.28 (3.33-7.51)	6.35 (3.33-13.00)	34.53 (33.20-36.10)	27.30 20.60-32.00)	2454.00 (1252.00-3700.00)	62.67 (20.00-208.00)
S-2	5.68 (3.33-8.72)	8.14 (2.50-13.33)	33.53 (32.30-35.30)	26.12 (20.50-30.60)	2330.33 (1116.00-3540.00)	88.33 (9.00-374.00)

Table A.3: Mean and ranges of physical parameters at 18 sampling stations

Sampling Stations	Total Solids (mgL^{-1})		Total Dissolved Solids (mgL^{-1})		Total Suspended Solids (mgL^{-1})	
	UR n = 3	R n = 9	UR n = 3	R n = 9	UR n = 3	R n = 9
AR-1†	94.00 (68.00-109.00)	107.89 (68.00-231.00)	53.33 (40.00-60.00)	42.22 (20.00-70.00)	40.67 (8.00-69.00)	65.67 (8.00-201.00)
AR-2†	89.33 (70.00-99.00)	241.55 (62.00-1315.00)	50.00 (40.00-60.00)	48.89 (20.00-70.00)	39.33 (10.00-59.00)	192.67 (2.00-1265.00)
KoU-1†	71.33 (40.00-106.00)	83.40 (21.40-301.00)	16.67 (10.00-20.00)	14.44 (10.00-20.00)	54.67 (30.00-86.00)	68.95 (1.40-281.00)
KoU-2†	76.00 (32.00-103.00)	74.17 (16.70-242.00)	20.00 (20.00-20.00)	15.55 (10.00-20.00)	56.00 (12.00-83.00)	58.61 (6.70-222.00)
KoU-3†	153.67 (30.00-312.00)	87.83 (42.00-202.00)	20.00 (20.00-20.00)	15.55 (10.00-20.00)	133.67 (10.00-292.00)	72.28 (22.00-182.00)
KoU-4†	51.00 (26.00-91.00)	85.32 (36.70-251.00)	26.67 (20.00-30.00)	16.67 (10.00-20.00)	24.33 (6.00-61.00)	68.65 (16.70-231.00)
KoD	6720.00 (283.00-9989.00)	159.54 (41.80-406.00)	23.33 (20.00-30.00)	17.78 (10.00-30.00)	6696.67 (263.00-9969.00)	141.77 (11.80-386.00)
KoD-1	7705.33 (270.00-15244.00)	536.89 (54.00-3844.00)	26.67 (20.00-30.00)	22.22 (10.00-50.00)	7678.67 (250.00-15214.00)	514.67 (34.00-3794.00)
KoD-2	3029.33 (307.00-7591.00)	321.33 (45.00-1793.00)	30.00 (30.0-30.00)	23.33 (20.00-30.00)	2999.33 (277.00-7561.00)	298.00 (25.00-1763.00)
KoD-3	72.67 (51.00-97.00)	1882.89 (33.00-14651.00)	53.33 (50.00-60.00)	31.11 (20.00-40.00)	19.33 (1.00-37.00)	1851.78 (3.00-14631.00)
KoD-4	76.67 (73.00-80.00)	1626.11 (47.00-12676.00)	46.67 (40.0-50.00)	37.78 (30.00-50.00)	30.00 (27.00-33.00)	1590.33 (7.00-12646.00)
KoD-5	80.67 (57.00-95.00)	1373.44 (48.00-10702.00)	43.33 (30.00-50.00)	43.33 (30.00-60.00)	37.33 (7.00-65.00)	1330.11 (1.00-10662.00)
KoD-6	100.67 (81.00-122.00)	1584.55 (53.00-12486.00)	60.00 (40.00-80.00)	48.89 (40.00-60.00)	40.67 (1.00-82.00)	1535.67 (3.00-12426.00)
KoD-7	75.67 (50.00-93.00)	1200.11 (50.00-8878.00)	50.00 (30.00-70.00)	50.00 (30.00-60.00)	25.67 (14.00-43.00)	1150.11 (0.00-8848.00)
KoD-8	226.67 (88.00-471.00)	1219.00 (70.00-7803.00)	56.67 (40.00-70.00)	55.56 (30.00-70.00)	170.00 (28.00-431.00)	1163.44 (10.00-7773.00)
KoD-9	207.33 (90.00-315.00)	839.89 (72.00-5520.00)	76.67 (40.00-100.00)	56.67 (40.00-70.00)	130.67 (0.00-275.00)	783.22 (12.00-5480.00)
S-1	17243.33 (196.00-42200.00)	191.38 (52.80-369.00)	26.67 (20.00-30.00)	22.22 (10.00-40.00)	17261.67 (176.00-42170.00)	169.15 (42.80-349.00)
S-2	9402.33 (137.00-18779.00)	227.57 (29.00-510.90)	26.67 (20.00-30.00)	20.00 (10.00-30.00)	9375.67 (117.00-18749.00)	207.57 (19.00-490.00)

† marked sampling stations UR and R refers the period March'95 to May'95 and June'95 to Feb'96 respectively

Table A.4: Mean and ranges of chemical parameters at 18 sampling stations

Sampling Stations	pH		Dissolved Oxygen (mgL^{-1})		Total Hardness (mgL^{-1})	
	UR n = 3	R n = 9	UR n = 3	R n = 9	UR n = 3	R n = 9
AR-1†	7.42 (7.40-7.45)	7.60 (6.00-8.80)	6.17 (5.10-7.60)	10.15 (8.10-12.60)	31.00 (19.00-46.00)	46.78 (27.00-76.00)
AR-2†	7.33 (6.90-7.70)	7.11 (6.25-8.30)	6.80 (5.40-9.00)	6.62 (8.70-12.00)	33.00 (15.00-52.00)	50.78 (12.00-80.00)
KoU-1†	6.73 (6.60-6.80)	6.69 (6.00-7.40)	6.17 (5.10-7.80)	8.81 (6.09-9.70)	27.33 (12.00-40.00)	20.00 (11.00-28.00)
KoU-2†	6.80 (6.70-6.90)	6.69 (6.00-7.60)	6.50 (5.60-8.10)	8.88 (6.09-10.10)	28.33 (13.00-42.00)	18.55 (11.00-25.00)
KoU-3†	9.93 (6.80-7.10)	6.73 (6.25-7.40)	6.33 (5.40-7.80)	8.75 (2.03-10.50)	29.00 (15.00-42.00)	16.50 (8.50-22.00)
KoU-4†	7.17 (7.10-7.20)	6.67 (6.00-7.20)	7.03 (5.40-9.70)	9.55 (6.09-13.00)	29.67 (15.00-42.00)	22.22 (15.00-38.00)
KoD	7.60 (7.50-7.70)	6.95 (6.00-8.00)	3.77 (2.80-5.60)	8.83 (2.84-10.50)	66.33 (19.00-120.00)	20.89 (17.00-27.00)
KoD-1	7.60 (7.40-7.80)	7.19 (6.25-8.00)	3.52 (2.18-6.00)	8.29 (6.50-10.50)	53.67 (24.00-70.00)	25.33 (22.00-28.00)
KoD-2	7.30 (7.10-7.60)	7.72 (6.25-8.80)	2.97 (2.18-4.50)	8.39 (5.80-9.74)	54.00 (25.00-70.00)	30.00 (24.00-38.00)
KoD-3	7.37 (7.20-7.60)	7.23 (6.50-7.90)	3.16 (2.80-3.70)	9.52 (6.70-11.20)	63.67 (23.00-88.00)	34.33 (21.00-58.00)
KoD-4	7.37 (7.20-7.50)	7.71 (6.50-8.80)	3.70 (3.00-4.40)	9.02 (6.30-10.10)	65.67 (25.00-92.00)	37.89 (23.00-65.00)
KoD-5	7.45 (7.20-7.65)	7.74 (6.25-8.50)	3.80 (2.90-4.60)	10.15 (7.31-12.60)	69.33 (28.00-97.00)	41.89 (25.00-72.00)
KoD-6	7.45 (7.40-7.50)	7.63 (6.50-8.60)	5.07 (3.30-7.80)	10.22 (7.72-12.60)	82.33 (38.00-112.00)	37.67 (25.00-62.00)
KoD-7	7.62 (7.55-7.70)	7.48 (6.25-8.10)	5.07 (3.90-6.70)	10.10 (8.93-13.00)	88.67 (32.00-127.00)	47.44 (28.00-64.00)
KoD-8	7.73 (7.60-7.90)	7.79 (6.25-9.00)	4.93 (3.60-6.40)	9.95 (8.12-13.00)	94.67 (34.00-143.00)	42.44 (13.00-70.00)
KoD-9	7.58 (7.30-7.80)	7.73 (6.50-8.50)	5.00 (3.70-6.70)	9.88 (7.51-12.60)	101.33 (32.00-150.00)	50.89 (34.00-68.00)
S-1	7.60 7.50-7.80)	7.03 (6.00-7.70)	3.73 (2.70-5.80)	10.05 (6.30-11.20)	24.33 (19.00-46.00)	24.11 (16.00-34.00)
S-2	7.57 7.50-7.60)	7.01 (6.25-7.60)	4.47 (2.90-7.60)	9.62 (7.60-10.50)	25.00 (15.00-52.00)	23.11 (16.00-32.00)

Table A.5: Mean and ranges of chemical parameters at 18 sampling stations

Sampling Stations	Phosphate (mgL^{-1})		Silica (mgL^{-1})		Chloride (mgL^{-1})	
	UR n = 3	R n = 9	UR n = 3	R n = 9	UR n = 3	R n = 9
AR-1†	5.53 (5.10-6.00)	3.41 (1.84-4.44)	11.57 (10.00-13.00)	12.21 (8.20-18.00)	3.90 (1.00-6.20)	1.69 (0.00-4.50)
AR-2†	5.66 (5.10-6.14)	3.67 (2.56-5.12)	11.07 (10.00-12.20)	11.67 (5.80-16.00)	2.87 (1.90-3.90)	2.48 (0.00-4.80)
KoU-1†	8.57 (6.30-10.00)	3.25 (2.28-6.00)	8.77 (6.40-11.70)	8.31 (7.00-10.00)	2.07 (1.00-3.30)	1.20 (0.20-2.80)
KoU-2†	8.18 (6.14-9.40)	3.18 (2.11-5.70)	9.23 (6.40-11.70)	7.80 (6.40-9.60)	1.57 (0.80-2.80)	0.71 (0.00-2.30)
KoU-3†	7.53 (5.70-8.80)	2.99 (1.84-5.30)	9.33 (7.00-11.00)	8.11 (5.80-10.00)	2.47 (1.00-3.90)	0.79 (0.40-1.90)
KoU-4†	5.60 (5.10-6.00)	2.80 (1.26-4.20)	10.30 (8.20-11.70)	8.59 (5.00-11.70)	5.67 (1.00-9.00)	2.03 (1.00-6.00)
KoD	5.27 (4.80-5.70)	2.91 (1.85-4.05)	10.90 (5.80-13.90)	9.37 (2.90-13.00)	2.00 (0.20-3.70)	1.08 (0.00-3.30)
KoD-1	8.25 (5.65-10.85)	3.42 (1.80-4.70)	17.93 (13.00-22.80)	9.82 (7.50-11.70)	3.60 (0.80-8.10)	0.74 (0.20-3.00)
KoD-2	8.37 (5.50-11.10)	3.54 (1.75-5.10)	11.00 (4.50-15.50)	9.63 (7.50-12.20)	1.77 (0.80-2.80)	0.81 (0.20-3.70)
KoD-3	7.98 (6.14-9.20)	3.21 (1.75-4.44)	9.57 (3.50-13.00)	10.50 (7.50-(14.70)	1.63 (0.00-2.80)	1.09 (0.00-4.10)
KoD-4	8.57 (3.72-12.00)	3.43 (1.65-4.60)	10.90 (7.50-13.00)	11.92 (8.20-18.00)	1.20 (0.00-2.10)	1.35 (0.00-4.10)
KoD-5	10.76 (6.52-14.35)	3.62 (1.60-4.82)	12.47 (6.40-18.00)	11.84 (8.20-17.00)	1.80 (1.00-2.50)	1.85 (0.00-4.30)
KoD-6	11.78 (7.18-15.35)	3.66 (2.06-5.70)	14.23 (7.50-20.50)	11.64 (1.40-16.60)	2.83 (2.10-4.10)	1.40 (0.00-4.10)
KoD-7	12.72 (8.50-15.75)	3.09 (1.89-5.12)	18.07 (7.60-23.80)	11.89 (10.00-15.50)	1.77 (0.00-3.00)	1.93 (0.00-3.70)
KoD-8	14.00 (9.20-17.95)	3.24 (1.95-4.12)	22.23 (11.70-28.00)	11.57 (6.40-18.10)	2.13 (0.60-3.30)	1.59 (0.00-5.00)
KoD-9	15.40 (10.20-20.25)	3.83 (2.00-5.10)	18.53 (9.00-23.80)	12.20 (6.40-16.00)	2.63 (1.10-3.50)	2.30 (1.10-4.30)
S-1	9.20 (6.00-12.00)	3.69 (1.17-11.00)	11.47 (7.50-13.90)	10.50 (7.00-14.70)	0.67 (0.40-1.00)	0.79 0.20-2.70)
S-2	8.43 (4.50-11.40)	3.14 (1.89-6.00)	10.10 (6.40-12.20)	9.41 (1.90-13.40)	0.60 (0.40-0.80)	0.47 (0.00-1.00)

† marked zones UR and R refers the period March'95 to May'95 and June'95 to Feb'96 respectively

Table A.6: Mean and ranges of chemical parameters at 18 sampling stations

Sampling Stations	Nitrate (mgL^{-1})		Nitrite (mgL^{-1})		Sulphate (mgL^{-1})	
	UR n = 3	R n = 9	UR n = 3	R n = 9	UR n = 3	R n = 9
AR-1†	0.26 (0.22-0.31)	0.34 (0.28-0.53)	0.15 (0.14-0.17)	0.005 (0.00-0.01)	3.67 (2.00-6.00)	1.44 (0.00-3.00)
AR-2†	0.48 (0.30-0.64)	0.45 (0.30-0.55)	0.18 (0.17-0.20)	0.007 (0.00-0.02)	3.33 (3.00-4.00)	1.22 (0.00-3.00)
KoU-1†	0.0067 (0.00-0.01)	0.0089 (0.0-0.02)	0.00	0.00	0.00	0.00
KoU-2†	0.0067 (0.00-0.01)	0.0078 (0.00-0.02)	0.00	0.00	0.33 (0.00-1.00)	0.00
KoU-3†	0.52 (0.46-0.60)	0.36 (0.01-0.47)	0.24 (0.22-0.27)	0.043 (0.02-0.21)	0.67 (0.00-1.00)	0.44 (0.00-2.00)
KoU-4†	0.52 (0.46-0.62)	0.26 (0.00-0.36)	0.26 (0.24-0.28)	0.04 (0.00-0.34)	1.33 (0.00-3.00)	0.44 (0.00-1.00)
KoD	0.35 (0.31-0.38)	0.25 (0.00-0.33)	0.20 (0.19-0.22)	0.028 (0.00-0.21)	0.00	0.55 (0.00-2.00)
KoD-1	0.29 (0.27-0.33)	0.25 (0.00-0.29)	0.16 (0.14-0.19)	0.03 (0.01-0.18)	0.00	0.33 (0.00-2.00)
KoD-2	0.26 (0.18-0.31)	0.24 (0.00-0.29)	0.15 (0.14-0.17)	0.019 (0.00-0.17)	0.00	0.22 (0.00-1.00)
KoD-3	0.23 (0.16-0.26)	0.16 (0.14-0.18)	0.14 (0.13-0.16)	0.0048 (0.00-0.01)	0.00	0.78 (0.00-2.00)
KoD-4	0.23 (0.17-0.26)	0.21 (0.18-0.29)	0.17 (0.15-0.19)	0.0027 (0.00-0.01)	0.00	0.22 (0.00-1.00)
KoD-5	0.22 (0.15-0.27)	0.20 (0.17-0.22)	0.20 (0.17-0.22)	0.00	0.00	0.44 (0.00-2.00)
KoD-6	0.25 (0.19-0.30)	0.27 (0.18-0.29)	0.22 (0.18-0.24)	0.00	3.33 (0.00-6.00)	0.11 (0.00-1.00)
KoD-7	0.30 (0.26-0.34)	0.14 (0.02-0.20)	0.23 (0.20-0.26)	0.0014	0.00	0.33 (0.00-1.00)
KoD-8	0.35 (0.33-0.37)	0.42 (0.18-0.47)	0.25 (0.21-0.28)	0.0058 (0.00-0.01)	0.00	0.55 (0.00-2.00)
KoD-9	0.33 (0.32-0.34)	0.33 (0.30-0.36)	0.00	0.00	0.00	0.44 (0.00-2.00)
S-1	0.95 (0.75-1.12)	0.13 (0.00-0.73)	0.34 (0.30-0.39)	0.04 (0.00-0.32)	0.00	1.89 (0.00-4.00)
S-2	0.01 (0.00-0.02)	0.0055 (0.00-0.02)	0.00	0.00	0.00	0.78 (0.00-4.00)

† marked zones UR and R refers the period March'95 to May'95 and June'95 to Feb'96 respectively

Table A.7: **ANOVA of different physico-chemical parameters of water of four river zones**

a. Physical Parameters

Source of Variation	df	Mean Sum of Square					
		Flow	Temp	Turb	TS	TDS	TSS
Zone	3	172.68	84.82*	7121137.2*	201227781*	6969.99*	201619627*
Periods	1	24.90	362.14*	13143364*	316965372*	1037.04*	315819751*
Zone x Periods	3	23.58	39.42*	6131630.1*	215097928*	20.61	215138924*
Error	208	76.62	11.82	480957.96	11732596	206.38	11740044

* indicates significance of difference at $p < 0.05$

b. Chemical Parameters

Source of Variations	df	Mean Sum of Square								
		pH	DO	Thard	Phos	Silica	Chlo	Nitrate	Nitrite	Sulphate
Zone	3	4.35*	15.41*	11154.59*	39.39*	146.36*	14.26*	0.12*	0.0032	25.86*
Periods	1	1.02	463.69*	1563.72*	589.24*	45.16	23.88*	0.45*	0.57*	2.12
Zone x Periods	3	0.46	20.85*	5091.92*	35.84*	29.17	3.87	0.20*	0.0077	9.88*
Error	208	0.35	2.36	351.81	4.00	12.19	1.86	0.026	0.0041	0.89

* indicates significance of difference at $p < 0.05$

Appendix – B

Table B.1: ANOVA for Concentration factor of heavy metals for selected species between affected and unaffected area

Source of Variation	df	Mean Sum of Square				
		Fe	Mn	Pb	Cu	Zn
Area	1	0.0002*	0.0028	0.47	0.013*	1.00*
Species	4	0.00005*	0.008*	0.32	0.005	0.07
Area x Species	4	0.00004*	0.001	0.43*	0.0062	0.14
Error	26	0.000006	0.0015	0.13	0.003	0.17

* indicates significance of difference at $p < 0.05$

Table B.2: ANOVA for heavy metal in elephant dung

Source of Variation	df	Sum of Mean Square				
		Fe	Mn	Cu	Zn	Pb
Between Groups	3	526067031*	75975.86*	119.75*	1095.94*	855.94
Error	41	124518877	7311.60	34.39	179.11	505.80

* indicates significance of difference at $p < 0.05$

Appendix - C

Table C.1: Mean and ranges of heavy metals in the river sediments at different distance

River Distance (in km)	Heavy Metals (ppm)				
	Fe	Mn	Cu	Zn	Pb
1.0*	172117.7 (169707.6 – 174516.6)	1058.61 (916.5 – 1199.7)	67.1 (66.9 – 67.2)	63.0 (61.1 – 64.9)	31.2 (30.7 – 31.6)
2.0*	412369.9 (412291.1 – 412442.2)	566.22 (513.7 – 618.5)	80.8 (79.86 – 81.74)	44.8 (43.8 – 45.8)	28.4 (27.7 – 29.1)
4.1*	329636.2 (324962.6 – 334365.9)	847.02 (731.91 – 960.7)	48.0 (47.5 – 48.5)	38.4 (37.9 – 38.9)	15.3 (15.0 – 15.6)
7.8*	265810.3 (261259.9 – 270429.8)	898.74 (672.11 – 1121.8)	78.9 (78.7 – 79.0)	47.6 (46.9 – 48.3)	23.6 (23.1 – 24.1)
8.3	340897.7 (329475.0 – 352270.3)	893.01 (750.0 – 1035.4)	80.1 (79.1 – 81.4)	50.0 (49.2 – 50.8)	21.1 (20.4 – 21.8)
24.9	637417.9 (635858.8 – 638946.5)	480.28 (412.4 – 546.9)	22.3 (20.9 – 23.6)	20.4 (19.5 – 21.3)	9.3 (8.6 – 10.0)
25.9	588972.2 (588017.6 – 589844.4)	463.58 (308.7 – 618.5)	22.4 (21.9 – 22.8)	20.9 (20.2 – 21.6)	8.0 (7.5 – 8.5)
38.9	568937.3 (564458.7 – 573321.9)	382.15 (308.1 – 455.8)	20.7 (18.9 – 22.5)	22.0 (20.8 – 23.2)	7.4 (6.8 – 7.9)
42.6	486239.6 (484577.2 – 487162.3)	2494.94 (497.9 – 6415.5)	28.2 (27.8 – 28.5)	24.1 (23.3 – 24.9)	8.0 (7.2 – 8.8)
54.6	333338.0 (328028.4 – 338547.8)	583.98 (443.5 – 723.6)	39.2 (38.3 – 40.1)	34.0 (33.7 – 34.3)	11.9 (11.7 – 12.0)
58.7	243040.8 (242941.7 – 243215.7)	1644.07 (1477.9 – 1810.2)	59.9 (59.4 – 60.4)	55.3 (54.9 – 55.7)	16.7 (15.9 – 17.4)
80.0	215353.0 (210548.1 – 220129.3)	654.45 (495.83 – 812.2)	50.6 (49.9 – 51.3)	58.3 (57.7 – 58.9)	14.9 (13.5 – 16.3)

* indicates river distance in upstream sector

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Effect of mine discharge on the pattern of riverine habitat use of elephants *Elephas maximus* and other mammals in Singhbhum forests, Bihar, India

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*The aim of this paper is to assess the influence of water quality both on the occurrence of, and utilization by, elephants (*Elephas maximus*) in a riverine habitat. Mining operations and other anthropogenic changes to natural river systems have caused degradation of the ecosystem for elephants. A decline in their numbers has been seen throughout the Singhbhum Forests, India due to fragmentation and loss of habitat. The need to preserve and restore the habitat of the elephant is accepted, but until the factors that influence their distribution are known and understood, suitable management plans cannot be implemented. The study area was the catchment of the river Koina where waste discharge from an iron ore mine and processing plant impact upon water quality. The study period from April 1995 to March 1996 looked at sections of the river where unregulated mine discharge was made, and where regulation through tailing ponds controlled total suspended solids (TSS) output from the mine waste water to the river system. Various physico-chemical parameters recorded at seven sampling stations were quantified. Principal Component Analysis (PCA) segregated the key parameters in determining the discharge levels of both regulated and unregulated discharge at various sites. The main contrasts between regulated and unregulated sites were turbidity and TSS, which were higher in unregulated reaches of the rivers. Patterns of elephant and other mammal use of a river valley in Bihar, India, were recorded using dung dispersion to estimate the distribution and occupancy of elephants. Dung dispersion was employed as a surrogate for habitat use, in an attempt to identify the factors that influence the distribution and occupancy of elephants. Riverine woodlands are seen to be very important for elephants in the summer because they provide shady dense forest and water, needed primarily for behavioural thermoregulation to avoid heat stress during the daytime. The increase in riverine habitat use by elephants throughout the catchment of regulated river sections in 1996 identified the special value of this habitat during summer for such mammals. The regulated river sectors showed an increase of 300% use by elephants, and 600% by other mammals over the unregulated mine discharge situation ($P<0{\cdot}001$). While habitat use remained unchanged ($P>0{\cdot}05$), throughout the study period in the control stations. These findings suggest that river-water quality has a significant influence on mammal use of the riverine habitat. Results suggest the need to regulate mine discharge and restore the ecosystem health by maintaining waste levels below the TSS and turbidity levels of 200 mg l^{-1} and 60 NTU, respectively.*

Keywords: elephant habitat, iron-ore mining, pollution, physico-chemical parameters, heavy metals, TSS, turbidity.

Introduction

In the metal mining industry, mineral processing is a prime source of waste generation in the form of slime (Prugger, 1992) and slurry (Sen, 1988; Ahmad *et al.*, 1994a; Gupta *et al.*, 1994). Environmental pollution occurs when these wastes are not properly managed so that they find their way into the natural watercourse (Down and Stocks, 1977; Ahmad *et al.*, 1994b). The dispersal and deposition of these wastes along a river results in several morphological changes including braiding, silting and widening of the river channel system (Ahmad *et al.*, 1994b; Nagarajan *et al.*, 1994; Pentreath, 1994) and modification of the physico-chemical properties of the river

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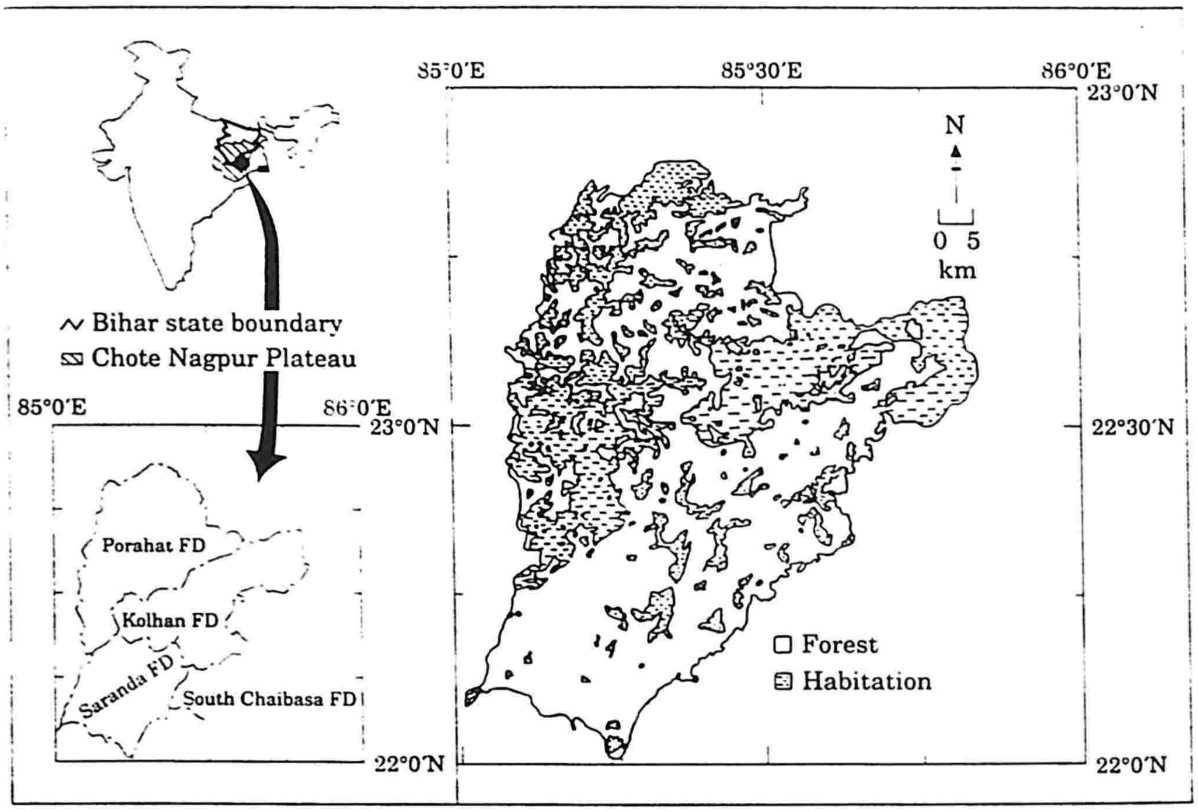

Figure 1. The Singhbhum elephant habitat showing forest and non-forest land use in three forest division

water (Pentreath, 1994; Ahmad *et al.*, 1994b; Gupta *et al.*, 1994; Muthreja and Paithankar, 1994). This in turn affects the life forms within the aquatic ecosystem (Davis, 1976; Hocutt *et al.*, 1978; Hellawell, 1988) and those that are dependent upon it (Heath *et al.*, 1992).

The description and quantification of sub-lethal pollutants in ecosystems, and their effect on individuals and populations, are major thrusts for the ecological assessment of pollution-induced alterations in habitats (Hellawell, 1988; Nriagu, 1988). Exposure to pollutants, even in low concentrations, can elicit changed behavioural responses (Sheehan, 1984) as has been documented in several invertebrates (Wentsel *et al.*, 1977; Saliba and Vella, 1977) and lower vertebrates (Sprague, 1971). However, in the case of higher vertebrate groups such documentation is lacking. It is believed that the most immediate behavioural response to increased pollution by higher vertebrate groups is the avoidance of the contaminated habitat.

In the State of Bihar, India the three Forest Divisions—Saranda, Kolhan and Porhat of the Singhbhum forests constitute a major habitat for elephants; representing 59% (3300 km^2) of the area available to elephants, and containing 58% of the total population of elephants in the State, approximately 500 i number (Anon, 1996). These forest areas ar experiencing a variety of anthropogeni changes at the present time which are a potentially disruptive to elephant occupatio of the area. The Singhbhum forests are sul ject to various forms of management ir cluding changed land use, fragmentation ar degradation, habitat replacement due to con mercial forestry, illegal felling and the loc annual tribal hunt, which is destructive wild ungulates but not to elephants (Chov dhury *et al.*, 1985; Shahi and Chowdhur 1986). In addition the forests are attractir mining activities which constitute one of tl major current threats, particularly in S randa Forest Division (Figures 1 and 2).

Mine waste is released as a result of iro ore extraction and on-site processing of t ore. The uncontrolled production of tailin through wet-circuit processing of ore by E riburu (KBR) mines is the major source pollution of the river Koina, a major perenn source of running water in the Saranda F est Division (Figure 2). The high colourati of river water, as a result of mine waste, a the consequent reduction in water-qual values of the Koina catchment, are a prese concern for both people and wildlife in t area. Since, the start of the present stu

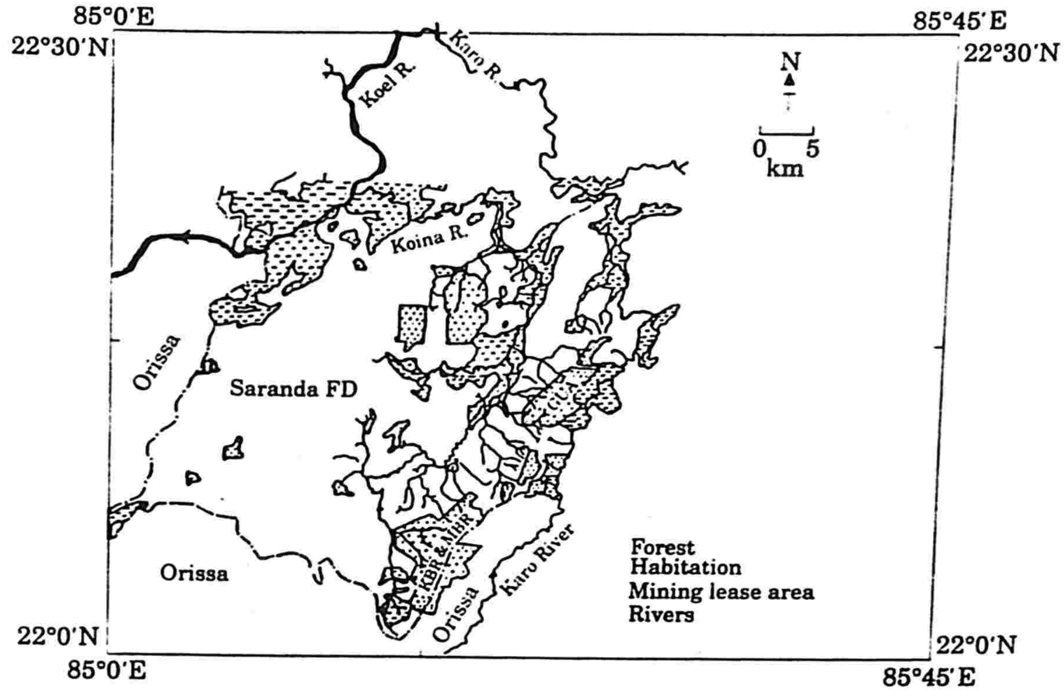

Figure 2. Location of the mining sites and major drainage (Koina) in Saranda FD.

in July 1994, the mine discharge remained above the permissible threshold level of Total Solids (2200 mg l^{-1}) prescribed by the Central Pollution Control Board (CPCB) of India. Regulation of mine discharge by the KBR mine authority was observed from June 1995 onwards. This control was further regulated due to public concern and media attention regarding both river pollution and the high colouration of the Koina River (special correspondent, *The Telegraph* dated 2nd February 1996 and later through United News of India in other dailies).

Elephants are attracted to dense shady deciduous woodland habitats, particularly during the periods of high temperature and low rainfall in the summer months. In addition, the river water is important for the elephants to assist them in thermoregulation in periods of high temperature. At other times of the year, when precipitation is higher, there are other sources of available water, but during the dry summer it is reduced to the permanent streams, which also support the dense shady forest vegetation. Such conditions occur during the summer months in the study area along the main flowing river courses and their tributaries. The 70-km length of the river Koina with a catchment area of 300 km^2 is therefore very important for elephants during the dry season. The spatial and temporal movement of elephants in these habitats during summer months are governed by the presence of this dense shady vegetation (Kumar, 1995) and water (Western, 1975; Leuthold, 1977; Easa, 1988). The importance of such riverine habitats and their increased use during the dry season, have been reported on the basis of studies undertaken on Asian Elephants (Sukumar, 1989) and African Elephants (Buss, 1961; Williamson, 1975; Leuthold, 1977; Allaway, 1979).

The aim and objectives of this study were to quantify the different physico-chemical variables of the Koina River water and to compare the factors influencing the riverine range utilization by elephants and other mammals, made up mostly of domestic livestock belonging to local residents, during periods of 'regulated' and 'unregulated' mine discharge. An understanding of these contrasts, could provide better information to help strengthen elephant conservation through habitat management for an elephant reserve identified under 'Project Elephant', launched in 1993 by the Ministry of Environment and Forests, Government of India. River channel morphology was not considered in this study due to the lack of baseline data. However, its influence may be important for the use of the river by elephants because they use pools within river channels.

Study area

The Singhbhum forests (Figure 1) are found in the Chotanagpur plateau province of the Deccan Peninsular Biogeographic Zone (Rodgers and Panwar, 1988). The moist and dry deciduous forests dominated by *Sal* (*Shorea robusta*) occuring in three forest divisions—Saranda, Kolhan and Porhat form the major elephant habitat on the southern portion of Bihar Province. Geomorphologically the hilly upland tract with valleys and steep mountains has its physical continuity with the forests of the Orissa Province on the southern side and in the north it links up with the small Dalma wildlife sanctuary.

The area has been classified into major vegetation types (Champion and Seth, 1968) under the headings: northern moist peninsular *sal*, dry peninsular *sal*, moist mixed deciduous, dry mixed deciduous, tropical evergreen and semi-evergreen and dry deciduous scrub forests.

The area receives an average annual rainfall of 1820 mm, and temperature varies from 6·5°C minimum during winter to 44·0°C in summer. The only perennial natural water source in this area is the river Koina, which originates in the hills of Saranda and meanders 70 km through the forests. The catchment of the river Koina, which is approximately 300 km^2 in extent, is an important elephant habitat during the summer months (March to May) because it provides their only natural source of water along with the shady vegetated habitat and hitherto relatively low human disturbance. On the eastern side, a perennial river, the Karo, flows; most of its course is outside the Saranda Reserve Forest and passes through human settlements.

Mining in the study area

The Singhbhum region is well-known for its large reserves of haematite iron ore. The estimated reserves in the Singhbhum forests represent approximately 25% of the total known reserves of India. Mining began in the early 1900s and while it does not cover an extensive area within the Saranda Forest Division, it coincides with those areas used by elephants. In its early days, at the beginning of the twentieth century, the impact of mining on the habitat was limited because it was largely unmechanized and the extraction capacity was low. Large-scale mechanized extraction of iron ore started in about 1921 and the activities had few environmental safeguards. A 30 year lease was granted to the National Mineral Development Corporation in the early 1960s. In 1968 this was transferred to the Steel Authority of India Limited (SAIL), for the two major mechanized mines, Kiriburu (KBR) and Megahatuburu (MBR) (Figure 2).

At present, there are 12 operational mines in the Saranda Forest Division which all occur within the elephant habitat. The extraction and processing of ore in this region is a major concern due to environmental pollution and associated habitat degradation. A similar situation exists in the adjoining areas due to several other mineral extraction activities for copper, uranium, talc, manganese, kynite and barite.

The operative mines occupy a lease area of 81 km^2, out of which 17 km^2 have been opened up for iron ore extraction. Most of the iron ore mines despatch their products without processing on-site. Only during the rains when runoff brings sediments into the natural drainage courses, does pollution result from these activities. The three major iron ore mines—KBR, MBR and Gua (Figure 2) process their ore on-site. These occupy 42·9 km^2 of total mining lease area. At present only 30% of the lease area of above three major mines has been opened up for mining. Dry circuit processing largely causes air pollution which is beyond the scope of this study. The process is carried out all year at Gua mine. However, at MBR dry circuit processing is carried out for most of the year, but in the rainy season, wet circuit processing is also practised. Waste disposal through dry circuit processing from the MBR mine causes some pollution of the river Koina during the dry summer season. However, during the rainy season the runoff increases the total load of solids in the river, leading to high colouration. At this time the widespread availability of water allows elephants to use the habitat more extensively rather than being restricted to the zone nearest to the river, so that polluted areas can potentially be avoided.

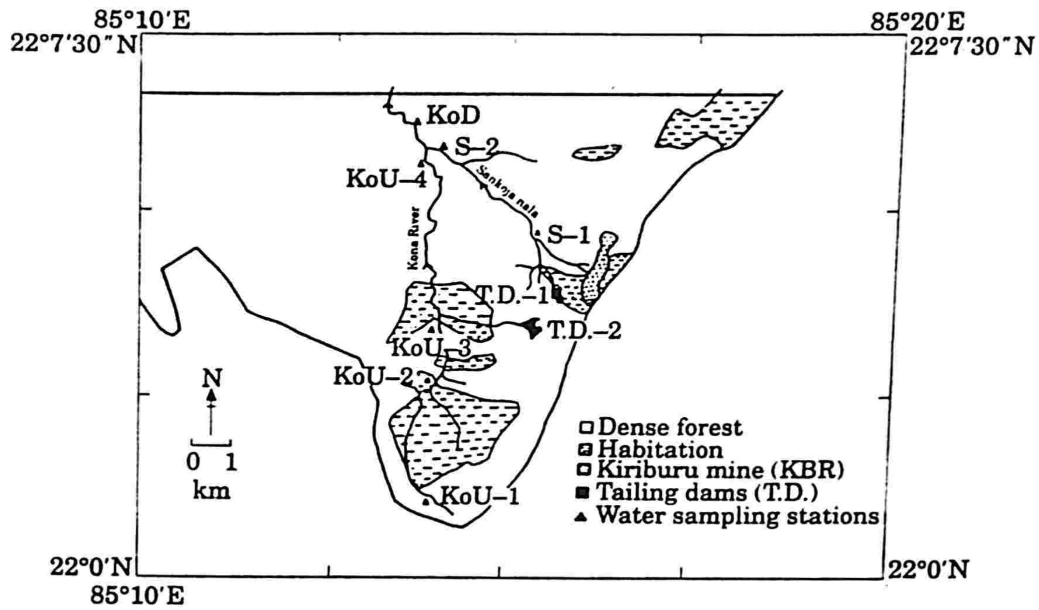

Figure 3. Layout of the sampling stations along the river Koina and Sankoja *nala*.

The KBR mine undertakes wet circuit ore processing exclusively throughout the year using a water-spraying technique. In this process about 1900 $m^3 day^{-1}$ of waste water are released, containing 2491 tonnes of effluent known as 'slime'. This consists of inferior quality iron fines with particle size less than 150 μm. Usually the slime generated is recoverable, through a settling process, while the excess water with unrecovered waste is allowed to spill out for further settling in a tailing dam. Until recently, the KBR mine authorities did not observe the discharge norms set by the CPCB, and allowed all the waste to pass directly into the Sankoja *nala* without passing through a tailing dam. This caused major problems of water pollution in river Koina (Figure 3). The non-functioning of the thickener unit in wet-circuit ore processing along with the lack of dredging of sediment by the company caused the tailing dams (TD-1 and TD-2) to fill with waste, thus reducing their effectiveness at holding back the slime, which then entered the main river course. The impact of the waste discharge was visible due to the high colouration of the Koina River water, and the deposition of fine dust which further contributed to the bed-load component. The colouration was reduced after control on mine discharge when strict regulation was imposed from January 1996.

Methodology

Elephant habitat mapping

Elephant habitat and mining areas were delineated using Survey of India 1:50 000 toposheet maps and Indian Remote Sensing Satellite (IRS-LISS II) False Colour Composite (FCC). Major land use and land cover categories were classified by visual interpretation and ground validation. The GRASS GIS was used to develop a comprehensive map of the area (Figures 1 and 2). The major land cover classes identified and mapped are: *Sal* forests (1881·21 km^2; 46·42%), Mixed forests (240·22 km^2; 5·93%), *Sal* associated with bamboo (1·13 km^2; 0·03%), Mixed forests associated with bamboo (53·96 km^2; 1·33%), Bamboo (12·11 km^2; 0·30%), Plantations (2·26 km^2; 0·06%), Scrub forests (61·71 km^2; 1·52%), Coppice (257·12 km^2; 6·34%), Barren land (8·59 km^2, 0·22%), Water bodies (51·12 km^2; 1·26%) and Habitation (1482·94 km^2; 36·59%). The land use categories delimited are: forests (61·44%), habitation and agricultural land (36·56%) and mining (2·00%). The habitat map with overlaid drainage features was used to locate seven sampling stations for regular monitoring of physico-chemical parameters of river water.

Chemical analysis of river water

For detecting and quantifying heavy metals in fines (crushed ore) and silt (river sediments), samples were taken from five different sites, and digested with mixed acids to facilitate chemical analysis using an Atomic Absorption Spectrophotometer (Allen, 1989).

For determining the physico-chemical variables affecting water quality of the river Koina, water samples were collected from seven sampling stations from April 1995 to March 1996 as shown in Figure 3, according to the guidelines provided by Trivedy and Goel (1986). Four sampling stations (KoU-1 to KoU-4) were located upstream in the Koina River; two further sampling stations (S-1 and S-2) were located in Sankoja *nala*, and one additional station (KoD) downstream in the Koina. The physico-chemical parameters for water quality, namely temperature (Temp), pH, total dissolved solids (TDS) were quantified through the Probe Method and turbidity (Turb) by the Absorption Method at the sampling sites following the methods suggested in APHA (1992). The total solid (TS) was quantified through the Evaporation Method and total suspended solids (TSS) by the calculation method (Trivedy and Goel, 1986). The Volumetric Method (APHA, 1992) was used to estimate total hardness (THard). Total phosphate (Phos) as ortho (reactive), poly and organic and silica were estimated through Ascorbic Acid and Molybdosilicate Methods, respectively, as suggested in APHA (1992).

From April to June 1996 two variables TSS and turbidity were measured at seven sampling stations (Figure 3) because they were identified as key parameters through Principle Component Analysis (PCA).

Habitat utilization by elephants

A 2 m belt transact on both the sides of three river segments, Koina upstream (5 km), Koina downstream (0·5 km) and Sankoja *nala* (4 km) were surveyed in mid May 1995 and 1996 for the presence of accumulated dung of elephants and other mammals. Our experimental design on 50 elephant dung piles revealed a mean decay rate of $0{\cdot}0151 \pm 0{\cdot}0002$ per day in the study area up to a stage of broken or flat masses of elephan dung. In two consecutive years 1995 ar 1996, dung counts of elephants were take only up to this stage of broken or flat ma to distinguish and avoid any inconsistenc The observed dung count per km was taken an index of habitat utilization for compariso between two summer seasons (March to Ma of 1995 and 1996.

Data analysis

PCA was used to examine the variations the physical and chemical properties of th Koina River water, by taking cases (N=8 between April 1995 and March 1996. Th one analysis identified the key paramete that determine whether or not a river polluted. An F-test (Haynes, 1982) was us to compare the significant differences b tween the same river segments between su mer (March/May) 1995 and 1996 for TSS a turbidity. A Chi-square test (Haynes, 198 also was performed to compare differenc between the presence of dung km^{-1} as index for habitat use patterns by elephan and other mammals in the same river se ments between summer (March/May) 19 and 1996.

Results

Climatic conditions

The total annual rainfall was 1455 mm 1996 as recorded at the nearby Kiriburu M eorological Station compared with 1585 n in 1995. Thus the area was wetter and t river levels higher in 1995 than 1996.

Detection of heavy metals in ore

Table 1 shows the concentrations of 10 hea metals in fines and silts sampled dur study. Out of these, five metals (Mn, Pb, Fe and Cu) were found at detectable lev whereas five other elements (Cd, Co, Cr, and Ni) were found below the detection li of the AAS.

Table 1. Physico-chemical properties of water in three river sectors in polluted (April 1995 to June 1995) and unpolluted (July 1995 to March 1996) situations

	Koina upstream	Sankoja *nala*		Koina downstream	
Parameters	Reference zone N=48	Polluted N=6	Unpolluted N=18	Polluted N=3	Unpolluted N=9
TSS[a]	65·26±61·47	13296·00±14384·49	188·36±139·32	6696·67±4549·51	141·77±116·99
TS[a]	84·01±68·68	13322·83±14387·53	209·47±140·13	6720·00±4551·83	159·54±117·73
Turb.[b]	21·23±21·60	2392·17± 996·67	74·28±89·54	2290·00±1008·60	55·67±47·18
Phos.[a]	4·16±2·32	8·82±2·72	3·41±2·10	5·27±0·37	2·91±0·76
Silica[a]	8·44±1·84	10·78±2·81	9·98±3·12	10·90±3·62	9·37±2·86
Temp.[c]	24·74±2·84	34·03±1·35	26·82±1·25	29·37±1·17	24·00±2·78
TDS[a]	16·87±5·46	26·67±4·71	21·11±8·75	23·33±4·71	17·78±6·20
Thard.[a]	21·63±8·51	24·67±9·69	23·61±4·89	66·33±41·47	20·89±3·18
PH	6·75±0·34	7·58±0·11	7·02±0·46	7·60±0·08	6·96±0·54

[a] = mg l^{-1}
[b] = NTU
[c] = °C.

Table 2. Summary of the Principal Component Analysis (PCA) for water-quality parameters of the Koin
River. Cases (N = 84). Kaiser-Meyer-Olkin measure of sampling adequacy = 0·72386

	Factor 1	Factor 2
Eigen Value	4·60357	1·34484
Variance		
Percentage variance	51·2	13·7
Cumulative variance	51·2	64·9
TSS	0·95161	0·19041
TS	0·95136	0·19155
Turb.	0·86038	0·35309
Phos.	0·50384	0·49362
Silica	0·11699	0·80784
Temp.	0·33810	0·76621
TDS	0·13697	0·75001
Thard.	0·29760	0·53636
pH	0·35958	0·37180

Table 3. Dung km^{-1} in three river segments for summer 1995 and 1996

		(Season)		Chi-square test	
River segment	Species	Summer 1995	Summer 1996	Value	Probabilit
Koina upstream (5 km)	Elephant	10	15	1·00	$P>0·05$
	Livestock	20	24	0·36	$P>0·05$
Koina downstream (0·5 km)	Elephant	45	98	19·64	$P<0·001$
	Livestock	50	207	95·91	$P<0·001$
Sankoja *nala* (4 Km)	Elephant	16	47	15·23	$P<0·001$
	Livestock	8	48	28·57	$P<0·001$

Physico-chemical properties of river water

Various physico-chemical parameters of the Koina River water in three river segments during their polluted (April 1995 to June 1995) and unpolluted (July 1995 to March 1996) situations are presented in Table 2. Principle Component Analysis extracted two factors; the results are summarized in Table 3. Factor 1 constituted mainly physical parameters (accounting for 51·2% variance). However, phosphate was also been found as an associated variable in this Factor. In contrast to the Factor 1, Factor 2 was associated with mainly chemical parameters; it accounted for 13·7% of the total variance, including temperature as an associated variable. Scatter plots show a clear demarcation between the polluted and unpolluted regimes of river se
ments along the axis of Factor 1 (Figure 4

Figure 5 and Figure 6 show the TSS a
turbidity load of Sankoja *nala*, which broug
the mine discharge into the Koina River sy
tem at various months. It can be seen fr
Figure 5 that the TSS level in Sankoja *na*
was elevated (133 times above the prescrib
limit of Central Pollution Control Boa
CPCB), during the more polluted peri
1995. The level of turbidity during the sa
period, remained high and showed the sa
trend as of TSS (Figure 6).

Table 4 summarizes the results of turbid
and TSS load in the three river sectors. T
F-test revealed that there was a signific
decrease in the level of turbidity and TSS
Koina downstream and Sankoja *nala* dur
the summer of 1996 as compared to summ

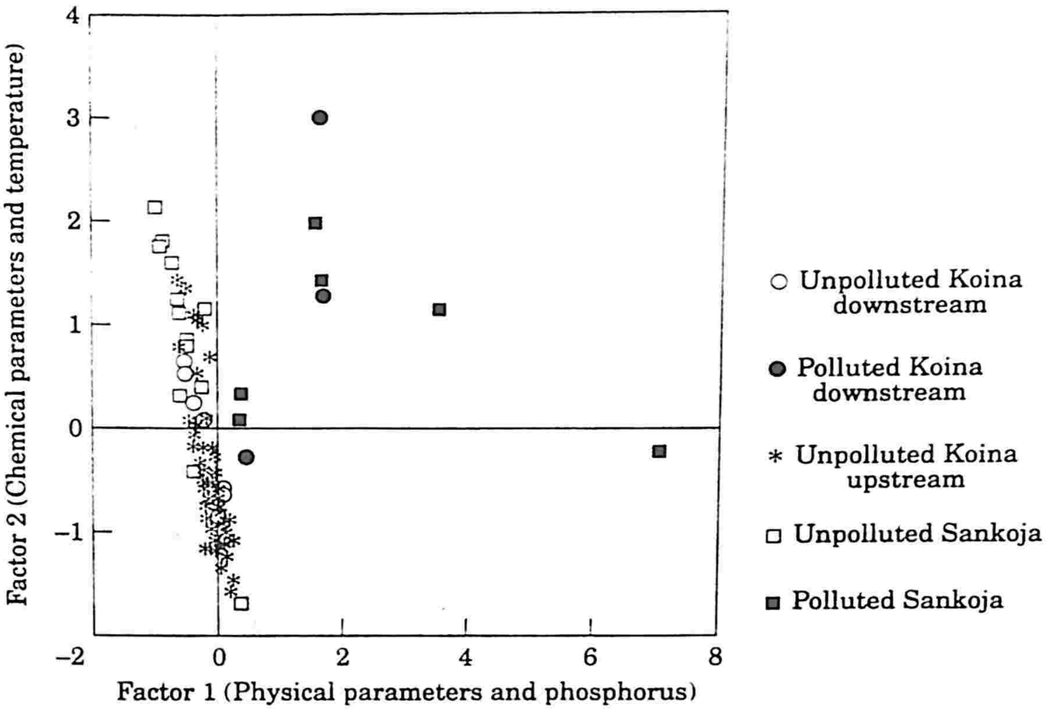

Figure 4. Scatter plot of the two Factors of Principle Component Analysis showing separation of polluted and unpolluted conditions of river sectors.

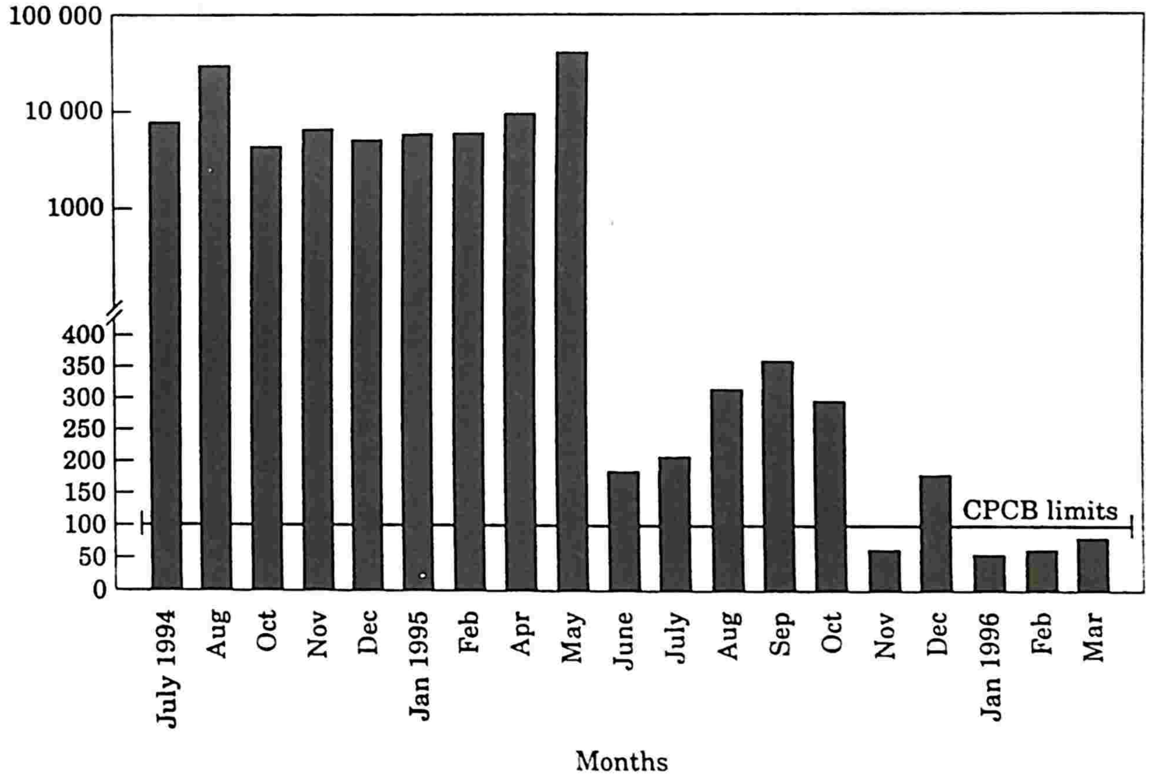

Figure 5. Levels of Total Suspended Solids (mg l^{-1}) in Sankoja *nala* due to mine discharge from July 1994 to March 1996.

1995. However, no significant difference in TSS and turbidity levels were observed in the Koina upstream sector, above the discharge points from the mine. Hence, this sector serves as a reference point against which comparisons can be made.

Fodder quality

The growth of riverine vegetation and the resulting quality of the fodder along the river Konia are influenced by climatic factors, especially rainfall. During the summer months

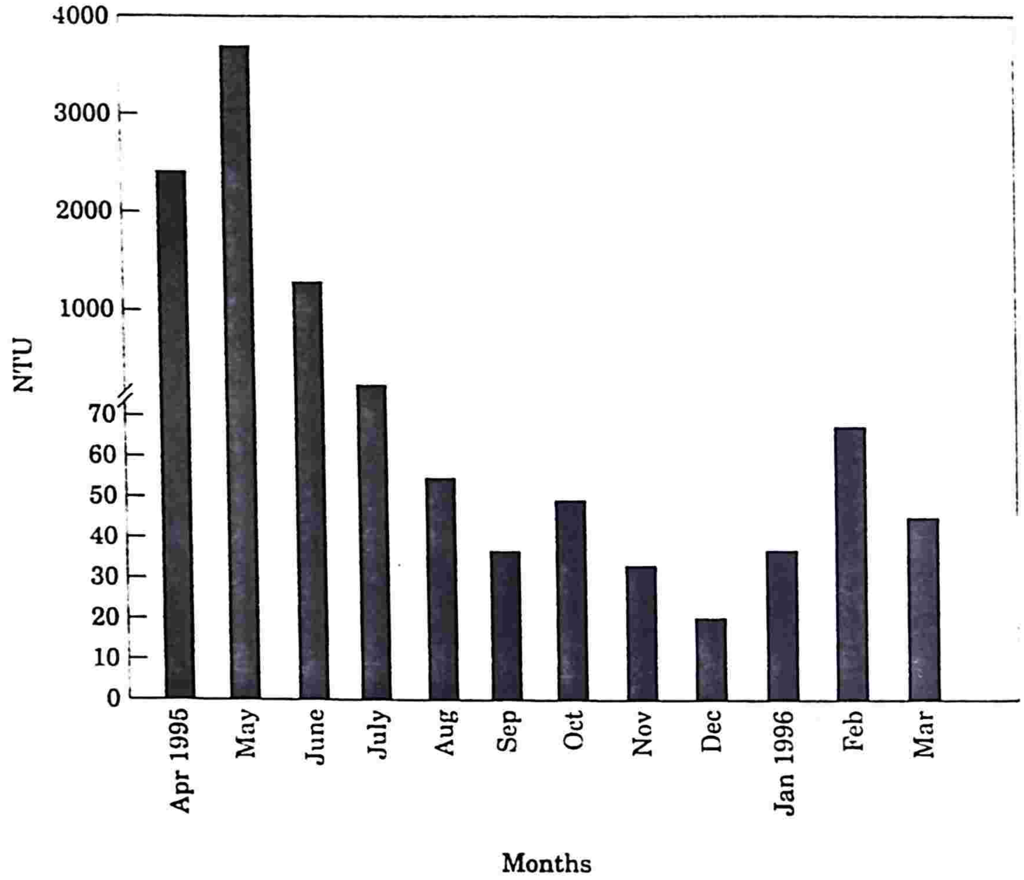

Figure 6. Levels of turbidity (NTU) in Sankoja *nala* due to mine discharge from April 1995 to March 19

Table 4. Detection of heavy metals (ppm) in fines and silts

Elements	Fine	Silt
Mn	61·40	62·40
Zn	38·80	45·80
Pb	251·80	241·00
Fe	$334{\cdot}90 \times 10^4$	$348{\cdot}66 \times 10^4$
Cu	12·80	26·20
Cd	*	*
CO	*	*
Ni	*	*
As	*	*
Cr	*	*

* Below the detection limit of AAS.

the rainfall is low but any that occurs is usually in sudden localized storms of short duration, which are difficult to quantify for the whole area. On an annual basis the rainfall recorded in the area was 130 mm higher in 1995 compared with 1996, and in seasonal terms, during the summer months (March to May) it was 23·32 mm in 1995 against 5·31 mm in 1996. The higher use of the riverine habitat in 1996 (Table 5) occurred spite of lower summer rainfall. The elephar primarily require the shade offered by t vegetation, though it does serve as fodc also. However, as long as the forest cover sufficient to offer the shady habitat it w also offer adequate food for the elephants

Elephant habitat use

Table 5 shows the results for dung encoun rate (dung km^{-1}) for elephants and livestc for three river sectors in summer (Mai to May) 1995 and 1996. These data w analysed using the Chi-square test, a showed a significant increase in habitat during summer 1996 over summer 1995, the two downstream river sectors (Sank *nala* and downstream Koina). The dung position in the case of the Koina River stream sector (Table 5) showed a sm increase in 1996, however, it was not s nificant (P>0·05). Thus it may be conclu that any possibility of fodder quality a quantity improvement in 1995 due to

Table 5. Levels of turbidity (NTU) and TSS (mg l^{-1}) in three river segments of the summers of 1995 and 1996

River segment	Parameter	(Seasons) Summer 1995	Summer 1996	F-Test Value	Probability
Koina upstream	Turb.	03–33 N=11 8·72±10·03 S^2=100·61	09–37 N=12 20·16±10·30 S^2=106·15	1·055	*P*>0·05
	TSS	06–99 N=11 46·72±35·55 S^2=1263·81	9·2–76·40 N=12 30·87±22·43 S^2=503·30	2·510	*P*<0·05
Koina downstream	Turb.	1070–3540 N=3 2290±1235·27 $S^2=1·52\times10^6$	26–60 N=3 42±17·08 S^2=292·00	5225·68	*P*<0·001
	TSS	263–9969 N=3 6696·66±5571·99 $S^2=3·10\times10^7$	10·60–208·60 N=3 118·43±100·17 $S^2=10·03\times10^3$	3093·85	*P*<0·001
Sankoja *nala*	Turb.	1093–3540 N=6 2392·16±1091·79 $S^2=1·19\times10^6$	26–107 N=6 55·66±33·88 $S^2=11·47\times10^2$	1038·46	*P*<0·001
	TSS	117–42170 N=6 13296±157574·16 $S^2=2·48\times10^8$	77·20–456·20 N=6 196·51±160·53 $S^2=25·77\times10^3$	9634·59	*P*<0·001

higher rainfall, has not been sufficient to influence the use of the area by the elephants.

Anthropogenic factors

The mine discharge was regulated during 1996 as compared with 1995 which was unregulated (Table 4 and Table 5), with a resulting improvement in water quality. Less sediment was allowed to enter the river system in 1996, both TSS and turbidity were lower and the colouration of the water was less.

Other human activity is increasing and resulting pressure is occurring in the area. This is a factor that would have occurred in all the river sections of the study period. This disturbance factor is considered to be important to elephants, and may have caused a reduced occurrence of elephants if considered on its own. However since it was even over the study area, it is not significant for the purposes of this study and this disturbance factor was offset by other factors in the drainage basin which caused a rise in the elephant occupancy.

Analysis of results

The observations have shown that the increased occurrence of elephants in the area in 1996 coincided with the lower rainfall. It is possible to discount most of the other influences on elephant occurrence because the changes were uniform over the study area. These include rainfall, and therefore vegetation quantity and quality, and human use of the area, which though it is increasing has not changed significantly over the study period. Therefore, the change in the riverine habitat use by elephants must be due to other factors.

The input of the heavy metals such as Lead, Zinc, Manganese and Copper as the result of mine discharge into the aquatic and terrestrial ecosystem have occurred, but, their uptake and distribution into the plant and animal tissue is yet to be established. Working on Asian elephants, Jayasekera and Kuruwita (1996) reported elevated lead concentration in the blood plasma of domesticated compared with free ranging elephants. They related this elevated level to water contamination through engine exhausts by burning fossil fuel as a source of lead pollution. Zimbabwe Wildlife sources (Anon, 1993) reported an increased concentration of lead in water, forage and soil causing flaccid trunk paralysis in African elephants, resulting in death due to inadequate feeding. It is further reported that Lake Kariba, one of the Zimbabwe's biggest tourist attractions was impacted by fishing weights, petrol, batteries, discarded oil filters and engine exhausts which are all sources of lead pollution. All these sources of environmental pollutants can impact adversely on elephants. In the study area, no recorded elephant deaths or reduction in numbers has yet been correlated with heavy metal poisoning, and the increased occupancy of elephants in 1996 over 1995 indicate some other influence.

The literature for elephants suggest that maintenance of water quality in aquatic ecosystems is an essential component because of its overall ecological benefits. In the present study, the modification of physico-chemical properties of the Konia River water occurred due to the solids in waste water from the iron-ore mine. The near neutral level of pH prevented the solids from becoming dissolved, and they therefore remained mostly in suspended form causing high turbidity in river water. Furthermore, phosphate becomes proportionately associated with solids (dissolved and suspended) in fresh-water systems in the form of ortho (reactive) phosphorus (Wetzel and Likens, 1991), and therefore is represented in the Factor 1 of PCA (Table 3).

A comparison of Tables 4 and 5 clearly indicates that the excessive turbidity and TSS during the uncontrolled discharge regime coincides with a reduction in the riverine habitat use pattern by the elephants and other mammals during the summer 1995. While the lower annual rainfall (1455 mm) in 1996, as compared to 1995 (1585 mm), might not have brought any pronounced changes in the riverine habitat structure, the animal response is marked. It is thought that the increased use of the riverine habitat wa due to the improved water quality followin regulated mine discharge. An increase in ri erine habitat use of two to three times b elephants and four to six times by other liv stock was observed when turbidity and TS levels were reduced by 42–55 times an 56–67 times, respectively, during summe 1996 and summer 1995. Graphical repr sentation of these are shown in Figure 7 f the downstream section of the Koina Rive and Sankoja *nala*.

Kurt (1971) reported the low use of shallo water holes compared to the deeper ones b the elephants during summer months. H reports that shallow water holes are co taminated because of heavy churning b water buffaloes, rendering them unfit f elephant use. Similar findings from S Lanka have shown the avoidance of su contaminated water holes by elephant Eisenberg *et al.* (1990). Churning is a mec anism which leads to an increase in the leve of turbidity and TSS of small stagnated wat bodies. This situation is similar to the riv contamination through heavy mine dischar which results in high sediment loads a corresponds to avoidance of the riveri habitat by elephants.

Conclusions

This study suggests that the unregulat mine discharge is potentially damaging t river system, and can reduce its habitat v ues for wildlife. Decreased use of the Koi downstream and Sankoja *nala* riverine h itats by elephants during the dry spell summer 1995 is a surprising result, given t higher precipitation in that year. Informati available from African studies reveal that t dry season home ranges of elephant co only about 10% area of wet season, and a based around the permanent water sour (Owen-Smith, 1988). This indicates t water quality is important to elephants. S nificant increase in use of the above t riverine habitats by elephants, two to th times during the dry spell of summer 1 attracts management attention to maint water quality of the river Koina. The dry y also experienced regulation of mine was and so the water quality was higher both

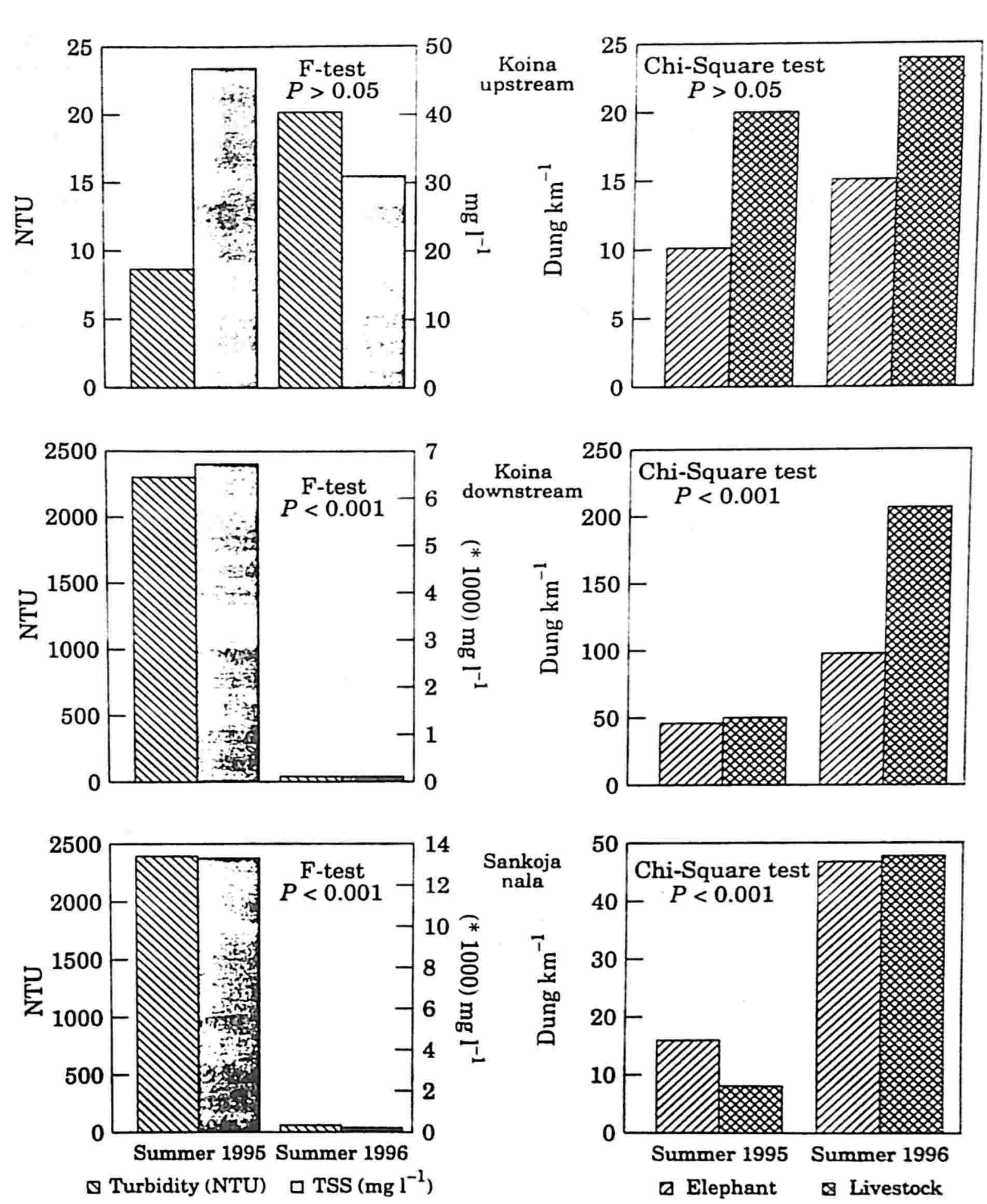

Figure 7. Showing effect of turbidity (NTU) and TSS (mg l^{-1}) on the riverine habitat use by elephants and other mammals in three river segments—Koina upstream, Koina downstream and Sankoja *nala* during Summer 1995 and Summer 1996.

terms of sediment loads and pollution levels.

It is concluded that the turbidity and TSS levels in the mine discharge should not be allowed to exceed the mean values of 60 NTU and 200 mg l^{-1}, respectively, before allowing it to mix with the Koina River water (Table 4; mean turbidity and TSS values for Sankoja *nala* in column 4). Turbidity and TSS above these mean values in the discharges affect the water quality for low use of the habitat. The CPCB guidelines recommend the waste discharge limit 100 mg l^{-1} for TSS and do not prescribe any limit for turbidity. However, it emphasizes reduction of colouration as low as possible in waste water. Controlling the turbidity and TSS level as suggested above will eventually help to restore and maintain the aquatic and terrestrial ecosystems for the benefit of elephant conservation. Furthermore, this will also help 12 000 tribal people who at present are solely dependent on this perennial water source for domestic consumption and irrigation.

The present study showed turbidity and TSS are the two key parameters for monitoring water-quality impacted through iron ore mine discharge. Therefore, regular monitoring of these parameters should form an integral part for evaluating the Koina River system by the Bihar State Pollution Control Board (BSPCB) according to the guidelines of the CPCB. To deal with pollution offences and breaching, the surface water quality standard enactment's—Water (Prevention and Control of Pollution) Act, 1974 and 1977; Air (Prevention & Control of Pollution) Act, 1981 and Environmental (Protection) Act, 1986 are available. Ameliorative waste management and treatment of waste water should also be taken up. As for the Forests (Conservation) Act, 1980, cost benefit analysis report along with proper Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) should be drawn up by those siting iron-ore industries. These preventive and ameliorative measures will ensure the restoration of elephant habitat quality in Singhbhum forests. Such measures are important given the present mining regime that is planned to continue for another 40 years at present extraction levels.

It is expected that future human use of the study area will increase. Local people already use the river water for irrigation and the riverine habitat for grazing, and some areas have been cleared for agriculture. It is important that the management plans for the reserve prevent loss of elephant habitat, but also take account of such activities that are outside the reserve but which may impact upon the reserve's habitat, such as water extraction for agriculture.

Further work needs to be done to assess the impacts of the various activities that may in some way undermine the quality and extent of the habitat under consideration. Other factors for consideration include: assessments of the minimum habitat extent and fodder quality necessary to support the elephant population; minimum levels of river flow needed for both vegetation preservation and for the maintenance of the river channel habitat with the perennial pools and flow regime required by elephants. Such information and knowledge will allow a fully integrated management plan to be drawn up within which further mining activities and use of the area by the local population can occur along with the preservation of the elephant habitats. It is important that such investigations are now made so that the necessary management strategies are established before further expansion of human activities takes place, so that they can b implemented with maximum effectiveness.

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