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RESEARCH ARTICLE

STATUS OF HIGH VERTEBRATE FAUNA AND THEIR HABITATS IN POTENTIAL LIMESTONE MINING AREAS OFALECH HILLS OFGUJARAT, INDIA

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Abstract

Unsustainable mining is one of the key development threats to the biodiversity. Alech hill in west-central Saurashtra region has substantial limestone deposits with long history of limestone and sandstone extraction. The Barda Wildlife Sanctuary adjacent to this area has been frontrunners for second home of Asiatic lions. A rapid field study was carried out in excavated mine sites (core area)and adjacent area up to 10 km as buffer. Flora,fauna and habitat characteristics were sampled on circular plots and belt transects (n=145). Total 85, 12, 42 and 14 species of plants, reptiles, birds and mammals were recorded. Invasive exotic weeds such as *Prosopis juliflora* and *Lantana camara* are most common shrub plant species across the area and seems to have replaced native floral assemblage. Mostfaunal species found were hardy and common while important native wildlife species such as wolf and blackbuck have become rare. It seems thatNilgai and Wild pig are slowly replacing native sympatric species. Environment friendly mining followed by ecological restoration as well as judicious use of geological resources may provide the solution to arrest degradation of the precious natural resources in potential mining areas.

Introduction:-

The miliolite limestone is one of the important major mineral deposits in Saurashtra peninsula with more than 11200 million tons of reserve (Lele, 1973);the area is also unique for biodiversity values, composition and known for globally important wildlife species such as Asiatic lions and Indian wild ass.There are enumerable mining and quarrying leases for limestone or sandstone across the region. It has also been found that relationships between mining and biodiversity are complex and interact with several threatening processes at different ecological scales (Sonter et al.2018). To safeguard the interests of biodiversity and environment there are strict legislation and provision for obtaining environmental clearances from the state as well as central authorities. Despite these legal provisions to safeguard natural ecosystem settings, it is observed that biodiversity values in and around mining areas has been dwindling in long run.

The status of higher vertebrate fauna is often used as an indicator of ecological health of a larger landscape (Rehmanet al. 2021). The current study covered the slight to moderately undulating terrains of the west central Saurashtra region covering part of Porbandar, Rajkot and Jamnagardistricts. These hills and hillocks form the part of 'Barda' and 'Alech' hills which are rich in miliolite limestone deposits. Oldest records of limestone and sandstone extraction as building blocks or bricks dates back to prehistoric times in various places in Gujarat and India

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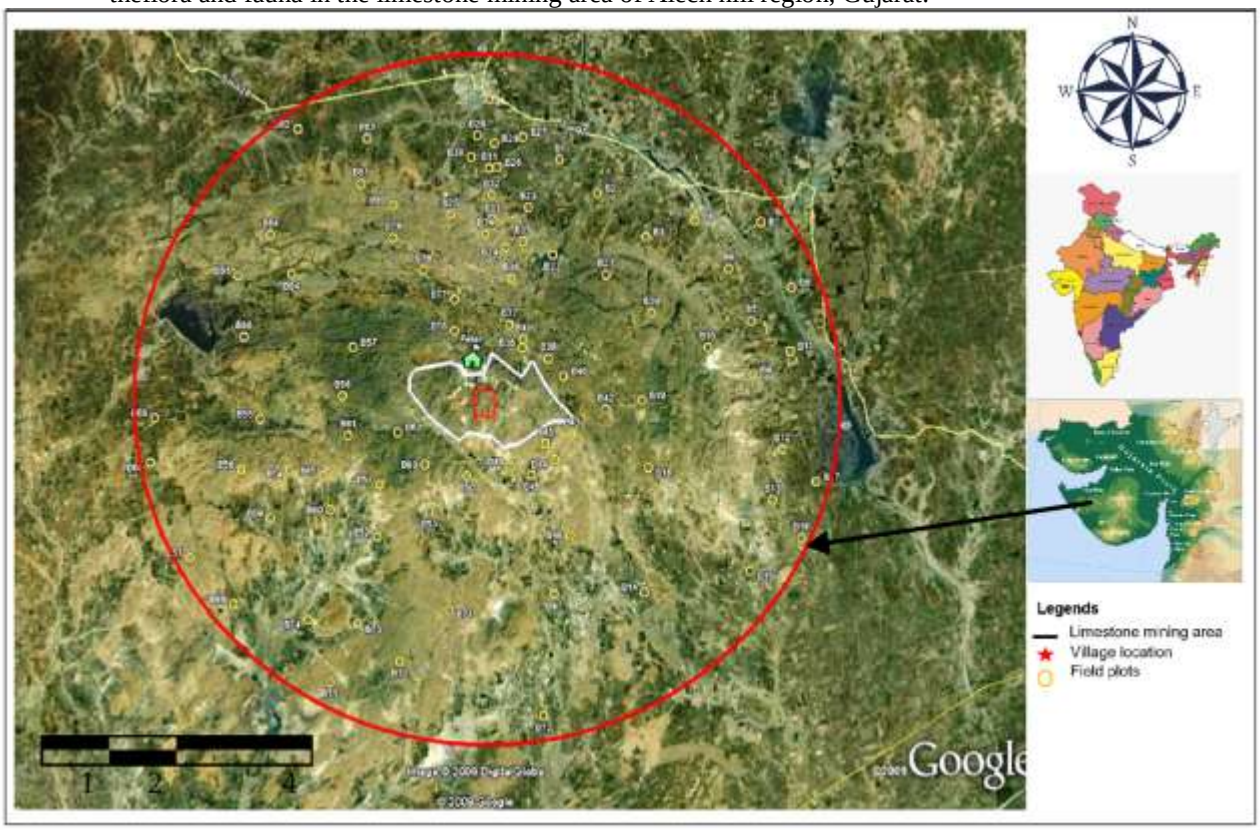
(Solomon & Bond, 1992). In modern times increasing mining related development and access to better extraction, processing and transport technologies and strategies worldwide, pressure on untouched mineral resources in remote and difficult areas of this hill range is building up. As recent publications (Ashraf et al 1995; Meena & Kumar, 2012; Jhala et al. 2019) and intentions of the state government (Jha & Gadekar, 2012) to provide lions a second home in this region signifies the conservation importance of the landscape. Therefore, keeping these prospects in mind, an effort was made to evaluate the status of the key wildlife species and the health of their surrounding habitats.

The 10 km^2 area within 'Alech hills' near Patan village of Jam jodhpurTaulka in Jamnagardistrict has been historically famous for the limestone and nowadays it is one of the key sources of raw material for cement and soda ash production. The study aimed to comprehend the impact of long-term mining activities on the surrounding biodiversity components.

Study area

Alech hill range with highest elevation of 181 meter, is situated in the central highland of Saurashtra peninsula of Gujarat, India.

Figure 1:- Map showing the study area with sampling locations and intensive search trails for the assessment of theflora and fauna in the limestone mining area of Alech hill region, Gujarat.



It covers the parts of Jam Jodhpur, Upleta and Kutiyana taluka of Jamanagar, Rajkot and Porbandar districts, respectively. The vegetation of the area has been classified as 6B-Northern Tropical Thron Forests (Champion & Seth, 1968) and the biogeography of the area classifies as zone -4 of semi-arid biogeographic zone (Rodgers et al. 2000). The grey limestone is found and traditionally extracted from this region as building blocks or bricks. The area experiences cooler winter (10-24 ^{0}C) from November to February followed by hotter summer (24 -42 ^{0}C) during March to June. Several rainy spells are brought about by south-western monsoon between June and October with average 23 rainy days. The study area composed of grassy scrubland on undulating terrain flanked by agricultural landscape. There are several seasonal streams, village ponds and irrigation tanks which dries up by mid-summer in

average rainfall year. Because of extensive agropastoral practices, a substantial number of dairy animals exert grazing pressure in the study area.

Methods:-

The study was conducted during vegetation growing season i.e., during August and September months to better capture the diversity of flora and fauna in the area.

Following a rapid reconnaissance survey of the landscape, the area under mining and excavated mines as well as immediate neighbourhood was considered as the core area and the area beyond core zone but within 10 km radius of core was considered the buffer zone.The study area was divided into seven habitat classes based on broad ecological parameters which were 1) Barren land 2) Grassland 3) Agriculture land 4) Open scrubland 5) Dense scrubland 6) Thorn Forest 7) Wetlands.The Google earth imageries were used to quantify the contribution of each of the broad habitat types using QGIS 1.0.

Sampling vegetation

For vegetation parameters, circular plots with 15.0 m radius (core zone, n=59 & buffer zone n=86) were randomly sampled to study trees; for shrub and herbaceous vegetation10m and 1m nested circular plots were sampled (Magurran, 1988),respectively.Consideration of tree, shrub and herb was based on their height from ground level. A plant of less than 0.5 m was considered herb while plant from 0.5 m to 2.0 m height and less than 10 cm girth at base was considered shrub. Whereas, tall plant with more than 10 cm girth at base and more than 1.5 m height was categorized as tree. All vegetation in the plot was identified using reference guide for plant/vegetation study (Shah, 1978). Percentage ground cover by herbaceous vegetation was quantified into five equal range classes (0-100%) by ocular estimation using Releve's method (Muller-Dombois& Ellenberg, 1974).

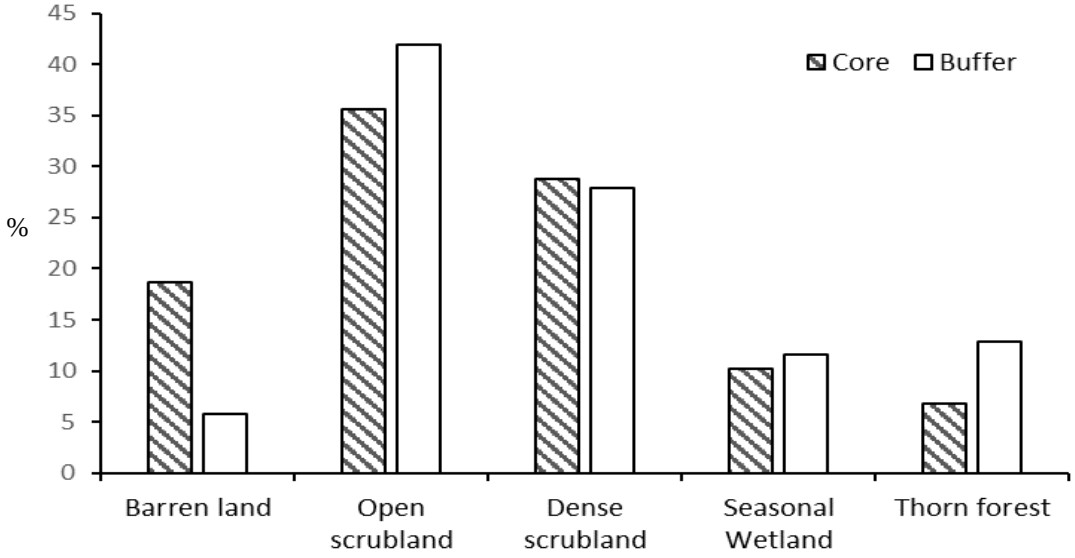
Sampling fauna

Status of vertebrate fauna of higher taxa is often used as indicator of ecological health of an area (Burkhard et al. 2008). To assess the presence and abundance through sightings and indirect evidences of reptilesand mammals, a total of 59 & 86 quadrates (30 m × 2 m) were sampled in core and buffer zones, respectively (Figure-1). The quadrate sampling sites intersected the vegetation sampling plots. Indirect evidences of these faunal species include pugmarks, hoof marks, droppings, scrap marks, burrows, dens, bones etc. Since, wild mammalian presence was too scanty in the area, five intensive searches were made on foot trails in most probable sites for wildlife presence (range- 2.73 to7.18 km) looking for opportunistic sighting or indirect evidence of any rare, shy or illusive species. Percent frequency of occurrences and encounter rates for all wild animals assessed on sampling plots as well as intensive searches were computed for core and buffer zones. *Ad libitum* sightings of birds during routine field visits were aided by the intensive search on foot trails.

Results:-

Open scrubland with sparse and stunted scrub species such as *Acacia sps*, *Cassia auriculata*, *Ziziphus mauritiana* dominated the landscape followed by dense scrubland predominantly occupied by *Prosopis juliflora*(Figure-2).

Figure 2:- Habitat composition within 10 km radius of potential limestone mining area in Alech hills, Gujarat.



Thornforest occupying gentle undulating terrain was third major habitat. Since, core area had been subjected to limestone excavation for very long period, barren land was a sizable habitat, especially in core area. In this semi-arid region surface water is scarce and therefore proportion of wetland habitat is little. Grasslands are restricted to 13 small patches which are largely protected by forest department. Apart from natural habitats a large tract of flat land had long been converted into agriculture land.

Floral assessment

There were 85 floral species (23 in core zone) found in the area which also includes cultivated and ornamental species as well. It includes 33, 23 and 29 species of tree, shrub and herbs, respectively (Table-1a). The ground cover by herbaceous species was >38% overall in core and buffer zones. Common and abundant herbaceous species were*Cassia tora*, *Aristida adscensions*, *Cynodondactylon*, and*Apludamutica*. Richness diversity and evenness of herbaceous species was overall poor(Table-2).

Table 1a:- List of plant species reported in the limestone mining area of Alech hill region, Gujarat.

	HERBS		**SHRUB**		
1	*Aristida adscensionis*	1	*Aegelmarmelos +*	6	*Butea monosperma*
2	*Barleriapriontis*	2	*Balanites aegyptica*	7	*Ficus amplissima +*
3	*Blepharismaderaspatensis*	3	*Calotropis procera*	8	*Ficus benghalensis +*
4	*Cassia tora*	4	*Capparis decidua*	9	*Ficus religiosa +*
5	*Cynodondactylon*	5	*Commiphorawightii +*	10	*Ficus silla*
6	*Cyperus nutans*	6	*Datura metel +*	11	*Prosopis cineraria +*
7	*Dichanthiumannulatum*	7	*Dichrostachys cinerea*	12	*Salvadora persica*
8	*Echinochloacolonum*	8	*Lantana camara*	13	*Tamarindus indica +*
9	*Eclipta alba*	9	*Ocimumgratissismum*	14	*Wrightia tinctoria*
10	*Eragrostispoaeoides*	10	*Prosopis juliflora*	15	*Cassia fistula*
11	*Heteropogoncontorius +*	11	*Ziziphus nummularia*	16	*Syzygiumcumini*
12	*Imperata cylindrica*	12	*Capparis sepiaria +*	17	*Syzygiumrubicundum +*
13	*Ischaemumpilosum*	13	*Ethritialaevis*	18	*Xeromphisuliginosa +*
14	*Panicum sp.+*	14	*Grewia hirsuta*	19	*Catharanthus pusillus +*
15	*Paspalidiumsp*	15	*Premnaherbacea +*	20	*Melia azaderachta +*
16	*Borreria stricta*	16	*Xanthium strumarium **	21	*Casuarina equistifolia +*
17	*Pupalialappacea*	17	*Holarrhenaantidysenterica*	22	*Cocos nucifrea +*
18	*Tribulus terrestris +*	18	*Thevetia peruviana*	23	*Cordia monoica +*
19	*Sidacodata*	19	*Neriyam indicum +*	24	*Delonixelata*

20	*Vernoiaanthelmintica* +	20	*Bougainvillea spectabilis* +	25	*Eucalyptus hybrid* +
21	*Peristrophebicalyculata*	21	*Hibiscus sp* +	26	*Mangifera indica* +
22	*Ischaemumpilosum* +	22	*Punica granatum*+	27	*Moringa oleifera* +
23	*Cassia auriculata*	23	*Musa sapienta* +	28	*Murrayakoenigii* +
24	*Pennisetum typhoides* +		**TREE**	29	*Peltaforumsp* +
25	*Sorghum bicolor* +	1	*Acacia leucophloea*	30	*Pithecellobium dulce* +
26	*Zea mays* +	2	*Acacia nilotica*	31	*Pongamia pinnata*
27	*Triticum sp* +	3	*Acacia senegal* +	32	*Psidium guajava* +
28	*Gossypium sp* +	4	*Ailanthus excelsa* +	33	*Terminalia catappa* +
29	*Arachis sp*+	5	*Azadirachta indica*		

+ Plant species absent in core area;

* Plant species found only in core area and absent in buffer area.

Table 1b:- List of animal species reported in the limestone mining area of Alech hill region, Gujarat.

	REPTILES		
1	Indian Cobra (*Naja naja*) +	23	Black Drongo (*Dicrurusadsimilis*) +
2	Saw scaled viper (*Echiscarinatus*) +	24	Rosy Starling (*Stumus roseus*) +
3	Common krait (*Bangarus caeruleus*) +	25	House Crow (*Corvus splendens*)
4	Rat snake (*Ptyasmucosus*)	26	Red-vented Bulbul (*Pycnonotuscafer*)
5	Common sand boa (*Eryx conicus*) +	27	Common Babbler (*Turdoidescaudatus*) +
6	Red sand boa (*Eryx johni*) +	28	Indian Robin (*Saxicoloidesfulicata*)
7	Common wolf snake (*Lycodonaulicus*)	29	Purple Sunbird (*Nectarinia asiatica*)
8	Garden lizard (*Calotes versicolor*)	30	House Sparrow (*Passer domesticus*) +
9	Fan-throated lizard (*Sittanaponticeriana*)	31	Indian Silverbill (*Lonchuramalabarica*) +
10	Small tailed agama (*Agama minor*)	32	Grey-breasted Prinia (*Priniahodgsonii*) +
11	Jordons snake-eye (*Ophiopsjordoni*)	33	Common Myna (*Acridotheres tristis*) +
12	Brook's Geeko (*Hemidactylus brooki*) +	34	Red-rumpedSwallow (*Hirundodaurica*) +
		35	Black Francolin (*Francolinusfrancolinus*) +
	BIRDS	36	Black Ibis (*Pseudibispapillosa*)
1	Indian Pond Heron (*Ardeolagrayii*) +	37	Brahminy Kite (*Haliasturindus*)
2	Cattle Egret (*Bubulcus ibis*)	38	Tailorbird (*Orthotomussutorius*) +
3	Painted Stork (*Mycteria leucocephala*) +	39	Eurasian Thick-knee (*Burhinusoedicnemus*)
4	Black-shouldered Kite (*Elanus caeruleus*)	40	Green Sandpiper (*Tringaochropus*) +
5	Black Kite (*Milvus migrans*) +	41	Rose ringed parakeet (*Psittaculakrameri*)
6	Shikra (*Accipiter badius*) +	42	Common hawk cuckoo (*Hierococcyxvarius*) +
7	Grey Francolin (*Falco pondicerianus*)		
8	Indian Peafowl (*Pavo cristatus*) +		**MAMMALS**
9	Black-winged Stilt (*Himantopus himantopus*) +	1	Jungle cat (*Felis chaus*) +
10	Red-wattled Lapwing (*Vanellus indicus*) +	2	Indian fox (*Vulpes bengalensis*) +
11	Yellow-wattled Lapwing (*Vanellusmalabaicus*)	3	Jackal (*Canis aureus*)
12	Eurasian Curlew (*Numenius arquata*)	4	Nilgai (*Boselaphustragocamelus*)
13	Painted Sandgrouse (*Pterocles indicus*) +	5	Striped hyena (*Hyaena hyaena*) +
14	Rock Pigeon (*Columba livia*) +	6	Wild pig (*Sus scrofa*)
15	Eurasian Collared Dove (*Streptopeliadecaocto*) +	7	Five striped palm squirrel (*Funambuluspennantii*)
16	Red Collared Dove (*Streptopeliatranquebarica*)	8	Grey mongoose (*Herpestesedwardsii*)
17	Laughing Dove (*Streptopelia senegalensis*) +	9	Porcupine (*Histrix indica*)
18	Green Bee-eater (*Meropsorientalis*) +	10	Indian hare (*Lepus nigricollis*)
19	Singing Bush Lark (*Mirafracantillans*) +	11	House shrew (*Suncus murinus*)
20	Crested Lark (*Galerida cristata*) +	12	Indian pipistrelle (*Pipistrellus coromandra*) +
21	Ashy-crowned Sparrow-Lark (*Eremopterix grisea*) +	13	Indian flying fox (*Pteropus giganteus*) +
22	Southern Grey Shrike (*Lanius excubitor*)	14	House rat (*Rattus rattus*)

+ Animal species absent in core area;

* Animal species found only in core and absent in buffer area.

The shrub vegetation was less diverse and more even across the study area composed mainly by two exotic species viz. *Lantana camara* and *Prosopis juliflora*. Shrub density was similar across the study area (buffer zone-110.4 ± 6.1 ha^{-1}, core zone-109.5 ±8.2 ha^{-1}). The tree species richness and density were overall poor. Among tree species *Acacia nilotica*and*Acacia leucophloea*were common species followed by *Acaciasenegal* and *Buteamonosperma*.

Table-2: Comparative account of density, diversity, richness, evenness and dominance of different vegetation strata in the limestone mining area of Alech hill region, Gujarat.

	Herb		**Shrub**		**Tree**	
Mean (SE)	**Core**	**Buffer**	**Core**	**Buffer**	**Core**	**Buffer**
Density/cover	**38.91** (2.48)	**40.49** (2.19)	**109.46** (8.24)	**110.40** (6.13)	**12.76** (1.27)	**39.66** (2.62)
Shannon Diversity Index	**1.00** (0.07)	**0.79** (0.04)	**0.83** (0.06)	**0.66** (0.05)	**0.16** (0.05)	**0.27** (0.05)
Margalef's Diversity Index	**0.24** (0.03)	**0.18** (0.01)	**0.73** (0.05)	**0.52** (0.04)	**0.18** (0.05)	**0.31** (0.06)
Simpson's Diversity Index	**0.45** (0.03)	**0.39** (0.02)	**0.50** (0.03)	**0.41** (0.03)	**0.12** (0.02)	**0.18** (0.03)
Evenness	**0.91** (0.01)	**0.95** (0.01)	**0.90** (0.01)	**0.93** (0.01)	**0.98** (0.01)	**0.98** (0.01)
Simpson's Dominance	**0.55** (0.03)	**0.61** (0.02)	**0.50** (0.03)	**0.59** (0.03)	**0.86** (0.03)	**0.82** (0.03)
Richness	**2.36** (0.21)	**1.99** (0.07)	**2.78** (0.18)	**2.30** (0.11)	**1.22** (0.06)	**1.42** (0.08)

Faunal assessment

Among higher vertebrate species, reptiles were 12 (6 in core area), birds were 42 (15 in core area) and mammals were 14 (9 in core area) (Table-1b). Lizards and snakes found in the area are common to the landscape. Indian star tortoise, Common krait, Common sand boa andRed sand boa could not be seen directly during the field work but their presence was confirmed by local people.Among birds, most bird species are common to human dominated landscape. Among mammals, nilgai and wild pigs were common in the area while black buck herds were found in the buffer zone. Two species of flying mammals i.e., Indian pipistrel and Indian flying fox were found in the buffer zone. Pugmarks and hauling of hyena and golden jackal, respectively confirmed their presence in buffer zone. According to local anecdotes, Indian wolf is present but no authentic direct or indirect evidence found during this study. During intensive search attempts most common mammalian species was the wild pig with highest encounter rate (0.86 per km in core and 1.1 per km in buffer zone), followed by nilgai (0.69 per km in core area and 0.81 per km in buffer area)

Discussion:-

Mining is considered as a destructive developmental activity globally, where environmentseems to suffer largely at the cost of short-term economic gains.It is an unfortunate coincident that in most regions of the earth, the underground geological resources are superimposed by biological resources (Butt et al. 2013; Harfoot et al. 2013; Murguia et al. 2013); and therefore, the extraction of minerals lead to widespread concern for environmental degradation, and adverse impact on biodiversity i.e., forests and wildlife (Lambin et al. 2013).Here too, the floral assessment suggests that extensive and intensive anthropogenic pressure, which includes mining and related activities, led to the replacement of native scrub species such as *Acacia*sps by an exotic and invasive scrub i.e.,*Prosopis juliflora*.Since, the area is home to the large number of goats, sheep and cattle which in turn leaves signs of heavy trampling and grazing on herbaceous cover. The health of ground vegetation seems further deteriorated by the settling of mining dust and movement of transport vehicles. The poor richness of the floral species in the core area compared to surrounding landscape could be attributed to the long-term impact of the mining operations in the area. In most natural landscapes the species richness of the ground cover is more than the shrub layer followed by the tree cover (Bhattarai &Vetaas, 2003). However, the trend here is otherwise (Table-2). Among observed species of flora most are either common and hardy species or ornamental/cultivated species that tolerated wider disturbance regime or supported by human care (see the list of flora). The resultant oversimplified and degraded ecosystemcan be attributed to the increased anthropogenic pressure(Li et al. 2010).

Most reptile species are fossorial in habit and therefore the assessment of reptiles and their diversity holds special significance for any study focusing on mining related impacts (Sasaki et al. 2016). All the reported reptilian species are common and have occurrences throughout Gujarat state in forested and non-forested landscapes (Daniel, 2002).Mining and related activities have significant impact on the reptilian fauna and same is evident in this study with poor presence of reptiles across the study area (Gibson et al. 2000; Mayani-Paráset al., 2019).

Among higher vertebrates, birds are greatly sensitive to anthropogenic disturbances (Rehman et al. 2021) and therefore, most birds recorded during this study are common and generally common in human dominated landscape of Saurashtra. Majority of the wild mammalian species recorded in the area are common throughout semiarid, non-forested and non-protected landscapes of Saurashtra region. This region has long been inhabited and used extensively and intensively for agropastoral practices and also for stone and sand mining(Adye, 1914). The extensive and intensive abuse of the land resources might have eroded the diversity of the fragile mammalian assemblages and hardy species such as nilgai and wildpig might have replaced them over a period of time (Li et al. 2010). Poor presence of wild herbivores like blackbuck and relatively high anthropogenic pressure could be some of the attribution to the rare reports of Indian wolf and other small carnivores in the area(Jhala& Giles Jr., 1991).

Conclusion:-

The present study indicates that long term anthropogenic pressure, especially mining could possibly alter the structure and composition of the natural assemblages of flora and fauna. It seems pertinent that extensive mining operations for a very long period in the area has altered the structure and composition of the natural habitatsof many wildlife species in this landscape. Whereas in patches with ongoing intensive mining operations it directly interferes with the presence of even common and hardy animals and plants. Due to fractured ecosystem structure with loss of key natural components in such intensive mining sites, invasive exotic species are rapidly proliferating to take over remaining small patches of natural vegetations.

Careful and environmentally responsible mining operations accompanied by ecological restoration, judicious use of geological resources, with search for eco-friendly substitutes and alternatives provide the answer to our worries and concerns for the wildlife. Some of the measures to arrest the further degradation of the biotic resources includes careful planning of mining operations, sensitization of mine workers, habitat restoration and rewilding programs and waterhole management for wildlife.

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