Opportunities for investment in the societal values provided by Sanjay Gandhi National Park, India

Supplementary material

The information in this Supplementary Material is substantially drawn from an unpublished study conducted jointly by Sanjay Gandhi National Park and Wildlife and We Protection Foundation (2019), Mumbai, supported also by Current Science (1997).

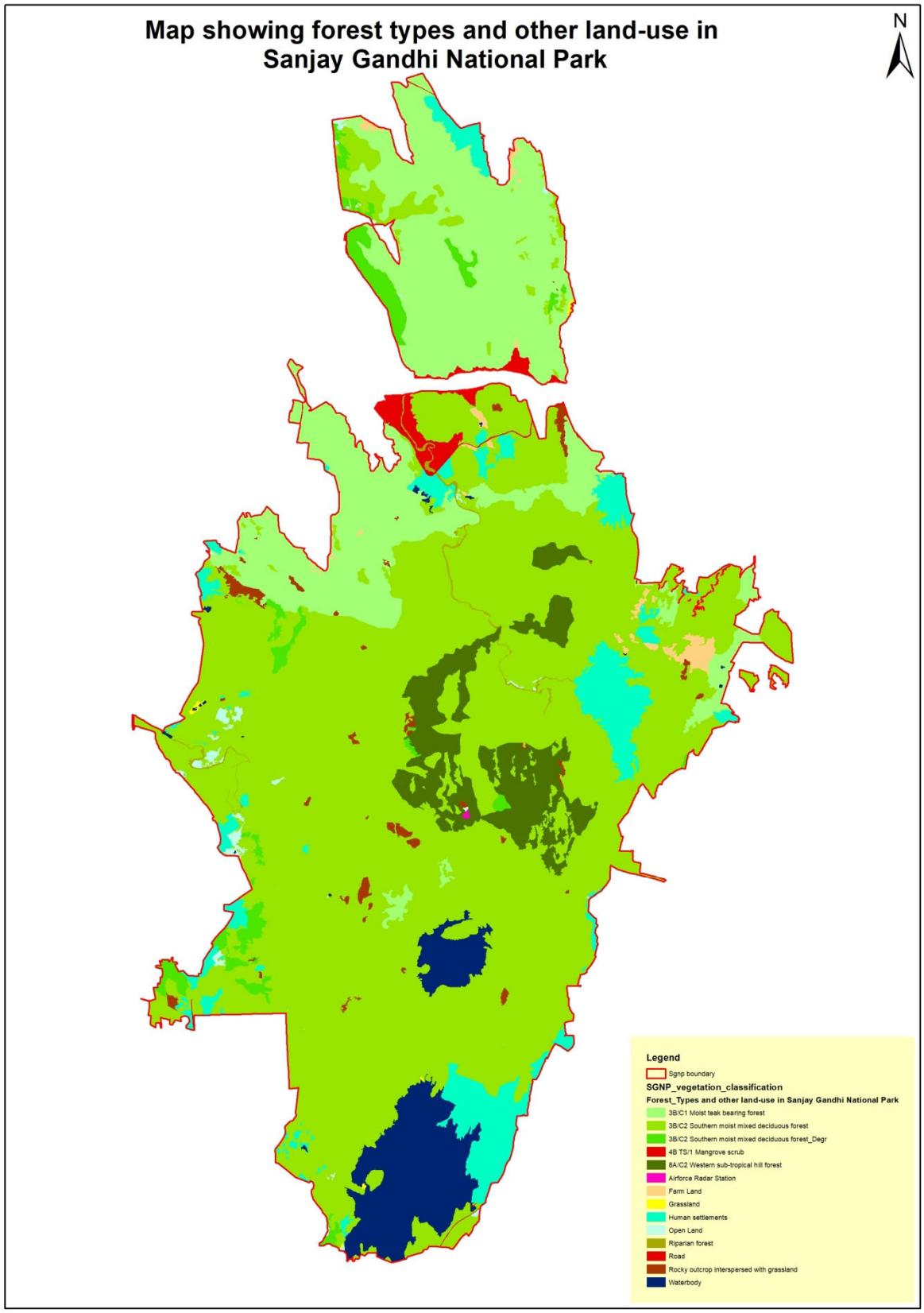
S1. Principal ecosystem types in SGNP

Field survey and review of secondary literature undertaken to identify the ecosystems in Sanjay Gandhi National Park has revealed that there are following types of major ecosystems in the Park.

1. 3B/C1 Moist teak-bearing forests
2. 3 B/C2 Southern moist mixed deciduous forest
3. 4B/TS1 Mangrove scrubs (coastal margin)
4. 8 A/C2 Western sub-tropical hill forests
5. Degraded forest
6. Plantations
7. Wetland and marshes (lake catchments) / large water bodies
8. Streams
9. Riparian areas – fringing forest adjacent to streams and rivers
10. Creeks
11. Rocky expanses and outcrops interspersed with grassy patches
12. Grasslands
13. Agriculture
14. Human settlements (encroachments)
15. Human settlements (enclaved in the forests)

The listed ecosystems were identified and mapped using Arc GIS software (Figure S1). The map depicts the location of the principal ecosystems in the National Park, though some could not be depicted as the area they covered was too small.

Figure S1: Map of Sanjay Gandhi National Park depicting location of various identified ecosystems


Map showing forest types and other land-use in
Sanjay Gandhi National Park
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Forest_Types and other land-use in Sanjay Gandhi National Park
3B/C1 Moist teak bearing forest
3B/C2 Southern moist mixed deciduous forest
3B/C2 Southern moist mixed deciduous forest_Degr
4B TS/1 Mangrove scrub
8A/C2 Western sub-tropical hill forest
Airforce Radar Station
Farm Land
Grassland
Human settlements
Open Land
Riparian forest
Road
Rocky outcrop interspersed with grassland
Waterbody

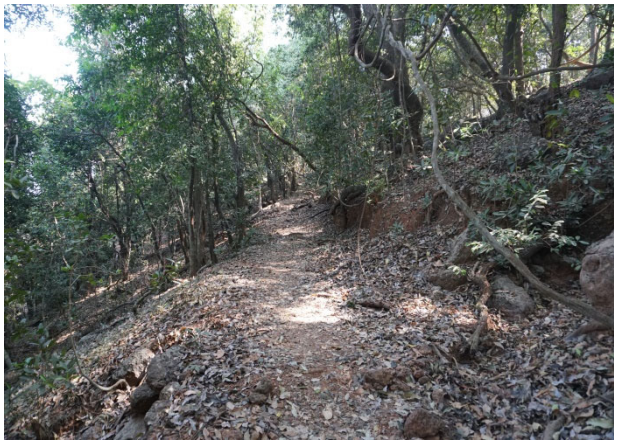
S1.1. 3B/C1 Moist teak-bearing forests

Moist teak-bearing forests occur in 3-5 % of the area of SGNP. These forests exist on relatively richer soil condition in the Park. The density of the standing crop of trees generally ranges from 0.4 to 0.7 (where 1.0 is 100% coverage). The moist teak-bearing forests are mostly concentrated in Yeur and Ghodbander rounds of the Park. Previously, Nagla block had substantial areas under teak forest, but teak has subsequently been almost wiped by illicit cutting from this area.

Important tree species of this forest type include *Tectona grandis, Garuga pinnata* , *Lannea grandis, Schleichera oleosa* , *Mimusops hexandra* , *Mangifera indica, Adina cordifolia*, *Pterocarpus marsupium*, *Bombax malabaricum and Syzygium cumini*

Important shrubs in moist teak-bearing forests include *Carissa carandus*, *Helicteres isora*, *Adhatoda vasica* and *Thespesia lampas*. Climbers associated with the forest include *Abrus precatorius*, *Climatis triloba* and *Zizyphus rugosa*. Bamboo species found in the forests include *Dendrocalamus strictus* and *Bambusa arundinacea*. Important grass species found here include *Cynodon dactylon, Dicanthium anulatum, Coix gigantea, Eragrostis spp.* and *Panicum glabrum*.

Figure S2: Moist teak-bearing forests in SGNP



S1.2. 3 B/C2 Southern moist mixed deciduous forest

Southern moist mixed deciduous forests are occur profusely in SGNP. Teak is also occasionally found in low proportions in this forest type. The density of this forest type varies from 0.4 to 0.7 (where 1.0 represents 100% cover). Clumps of *Dendrocalamus strictus* and *Bambusa arundinacea* are found in the area. This forest type covers major parts of SGNP on deep, loamy soils that are generally rich in humus content. Semi-evergreen species found in this forest type are *Mangifera indica*, *Ixora* spp., *Bixa orellana*, *Schleichera oleosa* and *Saraca asoca*, though *Saraca* is mostly localised along nullah (seasonal drainage line) courses in Kanheri, Chena and Krishnagiri Upvan forests.

Figure S3: Southern moist mixed deciduous forest in SGNP

S1.3. 4B/TS1 Mangrove scrubs

Maharashtra has a coastline extending for approximately 720 km (NIO, 1998) indented by numerous river mouths, creeks, small bays, headlands and cliffs. Vasai creek is one of the 37 stations that were surveyed by NIO for the floral and faunal diversity. Vasai creek is the longest creeks in Maharashtra, at a length of 41 km. However only 23% area (approximately 2000 ha) has mangrove coverage (NIO, 1998). This creek passes through Sanjay Gandhi National Park, separating the main part of the Park from the northern Nagla Block (see Figure 1 in the main body of this paper). The extent of mangrove forests included within the boundaries of this area is not precisely known. The mangrove *Avicennia marina* is the dominant vegetation but it has stunted growth. *Bruguiers gymnorhiza* and *Lumnizera racemosa* have almost completely vanished from the estuaries of Vasai Creek, while species like *Sonneratia alba, Rhizophora apiculata, Axrosticham sureum* are absent from this region. Marine Algae found in Vasai creek include *Entromorpha clathrate*.

Figure S4:Mangrove vegetation around Chene and Nagla area of SGNP

S1.4. 8 A/C2 Western sub-tropical hill forests

Western sub-tropical hill forests are restricted to remnant patches of natural forests at higher elevations, though some occur on low lying hills (Current Science, 1997). Western sub-tropical hill forests have density around 0.6, comprising semi-evergreen forest with many evergreen species present. Bamboo is typically absent. Floristic diversity includes climbers, orchids and ferns. *Mangifera indica* (Mango), *Pongamia pinnata* (Karanj), *Garcinia indicia* (Kokam), *Syzygium cuminii* (Jambul), *Calophyllum inophyllum* (Undi), *Sideroxylon tomentosum* (Kate-Kumbal), *Ixora* spp. (Lokhandi), *Murraya paniculata* (Pandari). *Garcinia indicia* is found at the highest peak in Kanheri Forests.

Figure S5: Western sub-tropical hill forests at Gaimukh and Yeur hills in SGNP

S1.5 Degraded forest

There are patches of degraded forest mainly near human habitation. Degradation is mainly due to the extreme pressure that these areas are being subjected to due to anthropogenic activities.

Figure S6: Degraded forest seen in SGNP near human habitations

S1.6. Plantation

Some plantations have been taken up in the past in Yeur and Nagla forests. In the period between 1981-82 and 1991-92, an area of over 500 ha had been converted into successful plantations of fruit and fodder species. *Glyricidia* has been extensively planted on the western side of the area. Also, exotic species including *Leucaena leucocephala* and *Acacia auriculiformis* have been planted in the past, some still persisting.

S1.7. Wetland and marshes (lake catchments) / large water bodies

Two major water impoundments, Tulsi and Vihar Lakes, occur within SGNP. Both are used to supply water to Mumbai and Thane cities. Though these two lakes are geographically situated within the National Park, the the Park authorities manage the lake catchments, the water bodes themselves are under the jurisdiction of the Municipal Corporation of Greater Mumbai (MCGM: also known as Brihanmumbai Municipal

Corporation, or BMC) which is responsible for supplying water to Mumbai. These two lakes and their surrounding forests constitute a prime habitat for the wildlife of SGNP.

Vihar Lake, situated at the extreme south of the Park, has a water surface area of about 731.492 ha. The catchment of Vihar Lake is roughly 851.488 ha though, currently, only 366 ha of the catchment is under the management of the National Park division. The basin of the lake, and the rest of the catchment, are under the control of the MCGM/BMC.

The Catchment of Tulsi Lake is about 745.25 ha. The Lake's water surface area is 130.918 ha, under the management of the MCGM/BMC, though the catchment is managed by National Park authorities. The quantity of water supplied by the reservoir is about 8,000,000 gallons (over 36 million litres) per day. The wilderness of the surrounding catchment area keeps the water free from risks of intensive contamination, representing a substantial ecosystem service benefit.

Figure S7: The Tulsi and Vihar Lakes in SGNP

S1.8. Streams

In addition to the rain-fed Tulsi and Vihar Lakes, the Dahisar River, Revat nullah and numerous forest streams run from SGNP serving as water sources for the city.

The Dahisar River originates from Tulsi Lake and flows through the forest of Magathane village, joining Manori Creek to the north-west of Dahisar village before discharging to the Arabian Sea. The catchment area of Dahisar River extends for over 2,000 ha. Numerous small nullahs join the Dahisar River during its course through the Park. Very few perennial water springs or waterholes are seen in the beds of the Dahisar River and its tributaries.

The Revat nullah originates in Avaghada Hill, flowing northwards through the reserved forests of Yeur village and then through the reserved forests of Chena village, ultimately

joining Vasai Creek (the Ulhas River). Revat nullah is also locally known as Laxmi River, while near its origin it is known as Vagbacha khonda. The catchment area of Revat nullah extends to over 2,226 ha. However, the nullah is not perennial. At a number of locations, the bed of the nullah could be developed as perennial waterholes.

Figure S8: Streams seen during monsoon in SGNP


S1.9. Riparian areas

Riparian areas are ecosystems adjacent to a river or waterway that, in an undisturbed state, provide habitat for wildlife and help improve water quality. Riparian areas are usually transitional zones between wetland and upland areas, generally comprising grasses, shrubs, trees or a mix of vegetation types influenced by local landscape. A number of small rivulets occur in the Park, all with riparian areas rich in biodiversity.

Figure S9: Riparian areas seen along the streams in SGNP


S1.10. Creeks

Vasai Creek flows in east-to-west direction, dividing SGNP unequally into northern and the southern blocks. Vasai Creek is one of 37 stations at which floral and faunal diversity were surveyed by India's National Institute of Oceanography (NIO). Vasai Creek is the longest creek in the greater Mumbai area with a length of 41km. 23% of the area of the Vasai Creek (approximately 2,000 hectares) is covered by mangroves (NIO, 1998). Where the Creek passes through SGNP, it has mangrove patches along its banks. *Avicenna marina* is the dominant plant, *Bruguiera gymnorhiza* and *Lumnitzera racemosa* have almost vanished from the estuaries of Vasai Creek, while species like *Sonneratia alba*, *Rhizophora apiculate* and *Acrosticham sureum* are absent from this region. Marine algae found in Vasai creeks include *Enteromorpha clathrata* and *Claloglossal epureurii* (SGNP, 2012).

S1.11. Rocky expanses and outcrops interspersed with grassy patches

Dry rocky surface on the top of hills, vegetated with sparse forest but mainly by shrubs, can be seen at higher elevations in the Park. During the monsoon, ephemeral plants including various grasses proliferate but dry out soon after the monsoon. Vegetation in these areas is sparse. Rocky outcrops can be seen around Kanheri Caves.

Figure S10: Rocky expanses seen around Kanheri caves in SGNP

S1.12. Grasslands

Grasslands seen in the Park cannot be classified as actual grasslands. Rather, they are openings in the forest that have developed into patches of grass. Some grassland development was undertaken by the Park management, with the view of providing forage for herbivores.

Figure S11:Open areas that have turned in grassy patches are common in disturbed forest areas in SGNP

S1.13. Farmlands

There are some farmlands especially around the Yeur range. The villagers living in the vicinity for the park have fields where they practise agriculture. These agricultural activities are usually on the periphery of the forested patches.

S1.14. Human settlements (encroachments)

The total area encroached throughout the Park is 255 ha. These encroachments are at the fringe of the forest. The interaction between different elements of the forest and human habitation has led to the formation of a different type of degraded ecosystem.

S1.15. Human settlements (enclaved in the forests)

There are a number of hamlets in the park that are inhabited mostly by tribal people. Due to the activities of these people, the ecosystem of the nearby forest has changed due to influence of the elements associated with human presence.

S2. Biological values of the SGNP forming a basis for beneficial ecosystem services

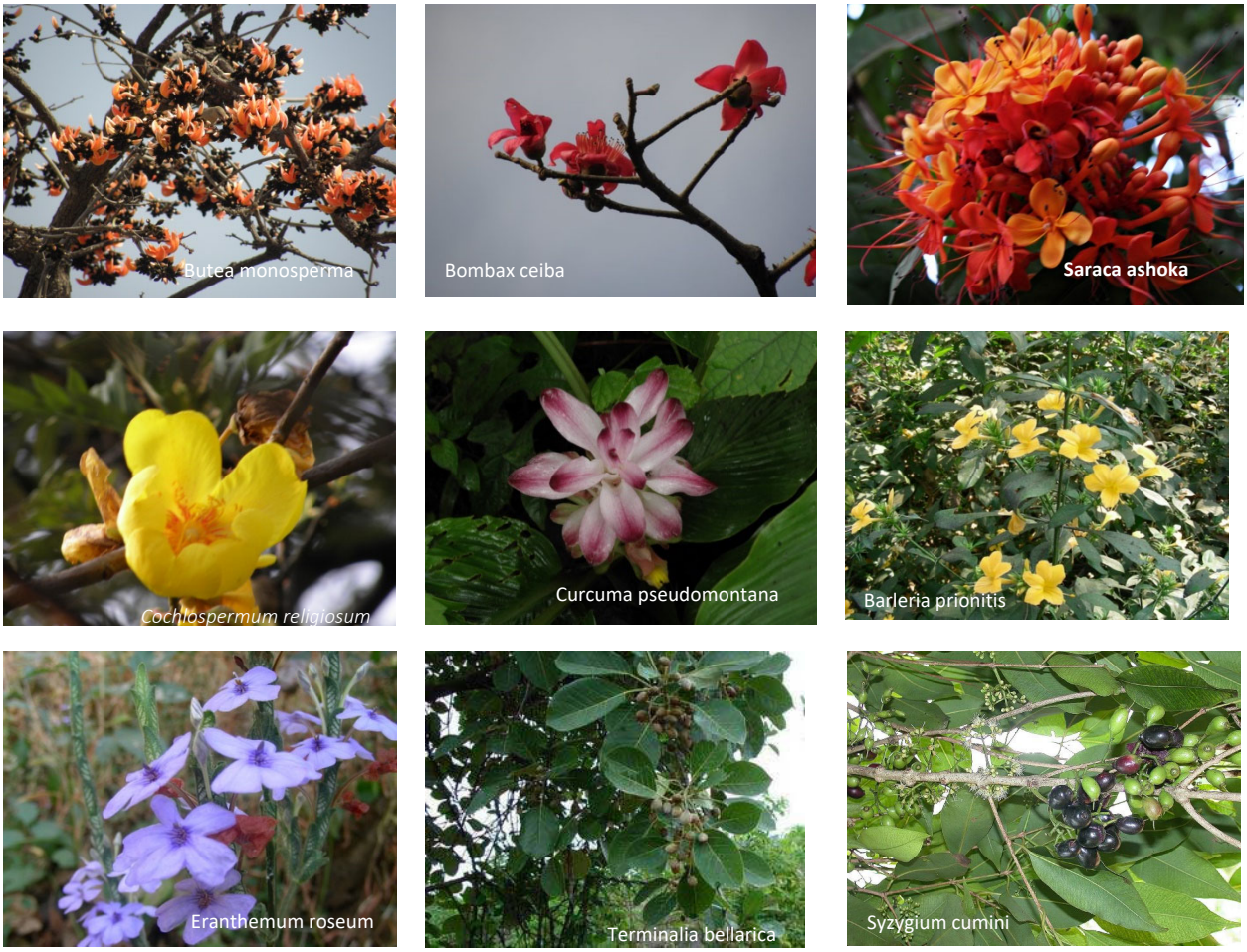
S2.1 Flora

The vegetation of this area ranges from littoral forests to western sub-tropical hill forests. Large numbers of vertebrate and invertebrate species belonging to various classes and orders are indicators of immense biological diversity of this area. The Botanical Survey of India (BSI) published records of the flora of Sanjay Gandhi National Park. The BSI lists 151 Angiospermic families spanning 581 genera, 1,078 species and 31 infraspecific taxa from the park. Some of the dominant families are Poaceae, Fabaceae, Cyperaceae and Acanthaceae (Pradhan, 2005). *Chlorophytum borivilianum* is a rare herb recorded from the park and is listed as endemic to the National Park. The herb is also reported to now be endangered and vulnerable due to over-collection. *Ceropegia vincifolia,* an annual climber that is also found in the Park, is also reported to b have become endangered due to over-collection (Kehimkar, 2000). A botanical survey at disturbed and undisturbed areas of the park categorized 84 different species of trees belonging to 28 families. 17 species of shrubs belonging 8 families were also found, along with 37 species of herbs from 19 families, 20 species of climbers belonging to 11 families, 3 species of bamboos from one family, 1 species of epiphyte, 1 parasitic species, and 4 species from one family of palms.

Of the recorded 84 species of trees, at least 81 of them are known to have exploitable values as food, commercial, medicinal or religious resources. From the trees recorded, flowers of *Nyctanthes arbor-tristis, Cochlospermum religiosum*, *Michelia champaca, Mitragyna parvifolia* and *Mammea suriga* are known to be used as religious offerings. *Ixora brachiata* and *Aegle marmelos* possess both religious and medicinal values. 6 of the 84 tree species are endangered, vulnerable, rare or endemic to the region. These include *Garcinia indica*, *Atalantia racemosa*, *Flacourtia montana*, *Syzygium cumini*, *Ixora brachiata* and *Miliusa tomentosa*. Of the total recorded species of trees, 40% possess medicinal value, including as examples *Miliusa tomentosa, Terminalia chebula*, *Bauhinia racemosa* and *Syzygium cumini*. 13% of the recorded tree species are

economically important, many also serving as food sources with high monetary returns, including as examples *Anacardium occidentale, Mangifera indica, Annona reticulate, Annona squamosa* and *Tamarindus indica*. *Tectona grandis*, *Acacia chundra*, *Acacia catechu, Pterospermum canescens*, *Manilkara hexandra*, *Gardenia latifolia*, *Peltophorum pterocarpum*, *Diospyros melanoxylon, Wrightia tinctoria Samanea saman, Terminalia elliptica Macaranga peltata*, *Melia dubia* and *Mitragyna parvifolia* are known for their timber. Apart from the trees known to produce commercial timber and fuel wood, species including *Bombax ceiba* and *Cochlospermum religiosum* are known for the cotton obtained from their fruit, used for filling economically priced pillows, quilts, sofas, etc. Parts of *Butea monosperma* are used for timber, resin, fodder, medicine and dye (Joshi, 2016).

Figure S12: A variety of plant species found in SGNP



Number plant of conservation importance occur in SGNP. *Saraca ashoka* (Sita ashok) is a rare and endemic tree species of the National Park. A sizeable patch of *Saraca ashoka* spanning nearly 75 ha, popularly known as 'Ashok Van' (or 'Ashok forest'), occurs near Kanheri Caves. Sita ashok flowers from March to May. Subsequently langur, other monkeys and other herbivores eat the seed pods.

Garcinia indica (Kokam) is an evergreen tree species seen mostly at higher elevations. Its fruits are eaten by langur and other monkeys and some birds. The fruits are also of medicinal value, used as an antidote for stomach upset.

Two species of white orchids, identified as species of *Platanthera* and *Habernaria*, are found at the highest peaks in SGNP where they flower in the month of September.

S2.2 Fauna

Studies have revealed that the Park is very rich in fauna. 30 species of Pisces, 7 species of Amphibia, 23 species of Reptilia, 64 species of Aves and 48 species of Mammalia have been observed and recorded (Yazdani *et al*., 1992). More than 150 species of butterflies have also been recorded in the Park. At least 21 individual leopards have been identified within the park's boundaries. Dominant fauna include:

- Mammals: 48 species of mammals were observed in the Park. The fauna is typical of the Sahyadri region with a predominance of spotted deer, leopard, etc. A good variety of bat species have been observed. These bats inhabit only a few (2-3) caves out of about a hundred caves in Kanheri. Bonnet and Rhesus Macaque monkeys both inhabit the Park. A large number of domestic dogs have been seen near the MAFCO factory area where they behave almost like wild dogs, starting to hunt and attack wildlife in packs (Yazdani *et al*., 1992). Other mammal species present in SGNP are Indian hare, barking deer, porcupine, Asian palm civet, mouse deer, grey langur, Indian flying fox and sambar deer.

Figure S13: Spotted Deer occur commonly at Sanjay Gandhi National Park

- The bird fauna of the Park is rich and diverse with species composition typical of the Konkan region (Yazdani *et al*., 1992). Bird seen in the Park include species of kingfisher, woodpecker, drongo, sun bird, hornbill, bulbul, swift, egret and heron as well as the white-bellied sea eagle, paradise flycatcher, trogon, blue flycatcher, jungle owlets, golden oriole, minivet species, magpie and peacock.

- Spider species encountered in SGNP include giant wood spiders, signature spiders and black wood spider.

- 30 fish species (both freshwater and marine) were recorded from the Park. The principal freshwater habitats are Tulsi and Vibar Lakes, the Dahisar River and Rewat Nullah. Numerous small tributaries join these rivers during their course through the Park. As the rivers are of a short length, indigenous fish fauna includes small-sized varieties of *Puntius,* Rasbora, *Garra,* etc. A hill stream cyprinid, *Parapsilorhynchus tentaculatus* was found in seasonal streams flowing

down the Kanheri caves from an altitude of about 486msl. In summer, these fish are seen in water-filled stone cisterns along the caves (Yazdani *et al*., 1992).

- Most of the common species of amphibian occurring elsewhere in India are represented in SGNP. *Rana breviceps,* the Indian burrowing frog, is found in the Kanheri Caves area during early monsoon months. The common tree frog, *Polypedates maculatus,* is also commonly seen during the monsoon (Yazdani *et al*., 1992).

- The prominent feature of the reptilian fauna of the Park is the occurrence of marsh crocodile (*Orocodilus palustris*) in Tulsi Lake. Indian python and cobra are also found in the forested areas of the Park (Yazdani *et al*., 1992). Some other reptilian species found in the Park include monitor lizards, Russell's viper, bamboo pit viper and Ceylonese cat snakes.

Faunal Species of conservation importance include:

- Leopard (*Panthera pardus*);
- Sambar (*Cervus unicolor*);
- Brown fish owl (*Bubo zeylonensis*);
- Mottled wood owl (*Strix ocellata*);
- Blue mormone (*Papilio_polymnestor*), the State Butterfly of Maharashtra; and
- Atlas moth (*Attacus atlas*).

S3. Geological values of the SGNP forming a basis for beneficial ecosystem services

SGNP is characterised by steep, rocky forests, the physical structure and topography of the landscape forming characteristic features but also contributing to a range of ecosystem services. Cultural values of geodiversity are seen in the formation and continuing value of the Kanheri Caves, and also the use of rocky outcrops for hiking and other informal recreational activities.

S4. Additional environmental values of the SGNP forming a basis for beneficial ecosystem services

This area acts as a carbon sink for the surrounding megacity, and it is also known as the 'green lung' for Mumbai and Thane. The ecosystems of SGNP absorb and filter high levels of pollution, much of it released from the exhausts of vehicles and emissions from industries in the surrounding urban areas. SGNP thereby maintains the ecological balance of the city.

SGNP also helps to conserve endangered flora and fauna, cools the atmosphere and provides fresh air, and protects the catchments of Tulsi and Vihar Lakes that are important source of water supply for the metropolis. F orests and the topography of SGNP also regulate temperature, encourage cloud formation, promote precipitation and help to recharge groundwater.

S5. Archaeological value of the SGNP

Kanheri Caves, located within the park, were built by Buddhist monks and are said to date from the 1st century BC to the 9th century AD. The Kanheri Caves site is looked after by the Archaeological Survey of India. The caves are arranged in several viharas or monasteries, solitary cells for hermits, lecture halls and temples. Most of the 109 caves chiselled into the volcanic rock are simple. Small chambers are known as 'Vihars', whereas the larger and deeper chambers are known as 'Chaityas'. Outside the caves are small tanks for water, separate for each cell, and couches carved out of rock that may have served as places for monks to recline on. The caves are said to have been occupied by a well-organized Buddhist establishment of monks on an ancient trade route connecting a number of Indian sea ports.

Figure S14: The Archaeological Caves at Kanheri

S6. Recreational and educational values:

In a city which has turned into a dense 'concrete jungle', SGNP plays an important role in terms of 'citizen to open spaces ratio' and as an alternative green cover present in the city limits. The unique location of the SGNP Protected Area renders it a paradise amidst thickly populated surroundings. The Park is used for formal education and research. Large numbers of visitors also come to the Park every year, enjoying the surroundings as well as receiving wildlife conservation messages.

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