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Using morphometric and analytical techniques to characterize elephant ivory

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Abstract

There is a need to characterize Asian elephant ivory and compare with African ivory for controlling illegal trade and implementation of national and international laws. In this paper, we characterize ivory of Asian and African elephants using Schreger angle measurements, elemental analysis {X-ray fluorescence (XRF), inductively coupled plasma-atomic emission spectroscopy (ICP-AES), and inductively coupled plasma-mass spectroscopy (ICP-MS)} and isotopic analysis.

We recorded Schreger angle characteristics of elephant ivory at three different zones in ivory samples of African ($n = 12$) and Asian ($n = 28$) elephants. The Schreger angle ranged from 32° to 145° and 30° to 153° in Asian and African ivory, respectively.

Elemental analysis (for Asian and African ivory) by XRF, ICP-AES and ICP-MS provided preliminary data. We attempted to ascertain source of origin of Asian elephant ivory similarly as in African ivory based on isotopes of carbon, nitrogen and strontium. We determined isotopic ratios of carbon ($n = 31$) and nitrogen ($n = 31$) corresponding to diet and rainfall, respectively. Reference ivory samples from five areas within India were analyzed using collagen and powder sample and the latter was found more suitable for forensic analysis. During our preliminary analysis, the range of δ^{13}C values (-13.6 ± 0.15‰ and -25.6 ± 0.15‰) and δ^{15}N values (10.2 ± 0.15‰ and 3.5 ± 0.15‰) were noted.
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Keywords: Elephant ivory; Schreger angle; Morphometry; Inductively coupled plasma analysis–MS; Isotopic analysis; X-ray fluorescence

1. Introduction

India being one of the 12 identified mega-biodiversity nations has 8% of the world's biodiversity with 60% of the world's tigers, 50% of Asian elephants, 70% of Asian rhinos and harbours the only population of Asiatic lion in the wild [1]. Illegal trade in wildlife and its products is a major threat and concern for conservation of endangered species throughout the world. Major illegal wildlife trade exists in skin, ivory, horn, antler, bone, live animals, feathers, nails, claws and pod. The illegal wildlife trade has been estimated to be worth US$ 5 billion which in economic terms ranked second after the drugs [1].

Over the years, poaching of megavertebrate species has depleted their numbers. In India, 75 mammal species out of 129 mammals listed in various Schedule categories under Wildlife (Protection) Act 1972 are under threat from illegal trade, of which 25 mammal species are included under the endangered categories of Schedule I and II.

Ivory being one of the highly priced article is illegally traded and the estimated annual world demand for ivory during the 1980s was 500–700 tonnes [2]. The African elephant (*Loxodonta africana*) was initially placed in Appendix II of CITES and its ivory was permitted for trade in the global market this was justified because of its large population and the considerable volumes of ivory generated from the presence of tusks in both males and females. However, was the Asian elephant (*Elephas maximus*) was listed in Appendix I of CITES and in Schedule I of the *Indian Wildlife* (*Protection*) *Act* 1972

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due to its endangered status. In spite of such legal protection, ivory from Asian elephant has always been found in the illegal trade. This is a major cause of concern for the conservation of the Asian elephant as large number of elephants were being poached every year [3].

The ban on trade in African elephant ivory in 1989 by CITES was a reaction to the significant decline in its populations from poaching [3]. However, the ban was relaxed for three African countries namely Botswana, Namibia and Zimbabwe in 1997 to permit a one-time sale of 60 tons of ivory [4]. The continued poaching of elephants in India [3] is a clear indication that illegal ivory trade is still in existence from Asian sources. This is probably because Asian ivory is more valuable than African [3]. Due to the demand for Asian ivory, widespread poaching has skewed the sex ratio in several populations [5]. The adult male to female ratio of the Nilgiri elephant population in India shifted from 1:5 in 1981 to 1:15 in 1998 [5] and further to about 1:25 by 2005 [6].

Ivory of African and Asian elephants is indistinguishable, particularly in the processed form, and thus it is almost impossible to trace the origin of tusks [7]. Enforcement of wildlife protection laws is often hampered by lack of proper methods to identify the species as well as source of the ivory [8]. Therefore, the present study aims to characterizing elephant ivory using different techniques to help enforcement agencies in getting rapid and reliable identification of seized materials and presentation of evidence in courts on the origin of such material.

Morphometry has been used extensively to differentiate species. Schreger angle of ivory is one of the important morphometric characters to be used for differentiation [9]. Elemental analysis could potentially help in distinguishing Asian from African ivory. Isotopic analyses is also useful in determining the source of origin and hence, has important role in forensics [9]. Isotopes have been successfully used to determine the source of African ivory [10]. For instance, carbon, nitrogen and strontium isotopes provide information on feeding habits, water stress and geology, respectively.

2. Materials and methods

Ivory reference samples of Asian and African elephants were used for analysis by different morphological and analytical techniques (Table 1).

Table 1
Different techniques used in characterizing Asian and African ivory

Techniques applied	Asian ivory	African ivory
Schreger angle	28	12
X-ray fluorescence (XRF)	5	5
Inductively coupled plasma-AES	5	3
Inductively coupled plasma-MS	3	3
Isotopic study	31	–

3. Morphometric technique

The Schreger angle pattern is a characteristic structural feature of the dentine portion of elephant tusk (Fig. 1). These are sets of intersecting lines radiating in spiral fashion from the axis of the tusk [9]. The angles are formed when dentinal tubules, produced by odontoblasts move towards the tusk axis during dentine deposition [11]. The Schreger angle are either centripetal or centrifugal. The Schreger angle technique has been used by in USA and by CITES to distinguish tusks of African ivory and mammoth to prevent illegal trade. Schreger angle measurements have widely been used to distinguish ivory of different species [9,12,13].

Schreger angles were examined on polished transverse section of tusks. For getting the best Schreger angle photographs, xeroxing and scanning of sample were tried. Scanning gave the best visibility of angles. A 10–20 angles were measured manually or by using software [14], at three different regions (central, middle and periphery) of Asian elephant ivory ($n = 28$) and African elephant ivory ($n = 12$).

4. Analytical techniques

4.1. X-ray fluorescence

X-ray fluorescence is an non destructive technique for elemental analysis. The X-ray spectrum reveals a number of characteristic peaks. The energy of the peaks leads to identification of the elements present in the sample (qualitative analysis) and intensity provides the relevant elemental concentration.

Five Asian and five African ivories were used for this analysis. Cross-section of ivory samples were cut and polished. Small pieces of 35–40 mm diameter and less than 10 mm thickness were directly used for analysis. Samples were desiccated overnight and analyzed under X-ray spectrometer (Siemens SRS 3000). X-ray fluorescence technique is a dry technique which gives intensity of various elements present.

4.2. Inductively coupled plasma-atomic emission spectrometry (ICP-AES)

ICP-AES is a powerful analytical tool for determinative elemental analysis. Detection limit is around 1 ppm. Three to five samples of Asian and African ivory were analyzed. Powder samples were digested by six treatments of 15 ml mixture of hydrofluoric acid (HF) and perchloric acid ($HClO_4$) each. Followed by two treatments of Perchloric acid and after adding 15 ml 10% HCl to the dried sample it was heated. This solution was made-up to 100 ml by adding distilled water. Prepared solution was analyzed through ICP-AES (Jobin Yvon JY 70 plus) spectrometer. Instrumental concentrations of various elements were transformed into parts per million using standard formula.

4.3. Inductively coupled plasma mass spectrometry (ICP-MS)

Inductively coupled plasma mass spectrometry is one of the advanced techniques to know the elemental details of the

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