- The facilities should be kept away from aviculture centres like a poultry farm because of the threat of disease transmission. The centres shall also be established away from human settlements.
- From the available information *Gyps* vultures are relatively easy to house, keep and maintain in captivity, provided we have the desired facilities and observe proper management techniques.
- Before bringing the birds into captivity, it is important to meet the following criteria: the breeding enclosures/rescue centres to be naturalistic and keeper-friendly; Individuals involved with the project to have expertise in vulture husbandry, nutrition and health protocols of the species in captivity; To develop and initiate collection and breeding plans in order to ensure maintenance of genetic variability in captivity, and to enhance representation of genetic variability; To identify aspects on individual, social and reproductive behaviour and reproductive physiology which are critically important in maintaining captive populations; To liaise with experts in exchange of technical knowledge; To assess the habitats for restocking (if any) from captive bred populations; To prepare a manual on the maintenance and husbandry of the species in captivity; To develop standardization of enclosure/technique with regard to maintenance of the species in captivity.

However, I also foresee a few hurdles in initiating a captive breeding programme for the vultures:

- The existing population of vultures in captivity (zoos) taken together cannot constitute the ideal founder population required for the breeding programme, as many may be old, juveniles or sick.
- The vultures cannot be sexed from their phenotypic characters. They need to be captured for such identification. Due to capture stress there can be significant mortality among the birds.
- The *in-situ* population in many areas has drastically reduced. Capture from these sites for the breeding programme can make the species locally extinct.

In my opinion, the government should invest more resources in preservation of the species in *in-situ* condition, especially in our National Parks and Sanctuaries and stop the use of Diclofenac in the country. It may be noted that as Indians are getting more civilized in the cities and using more modern equipments for disposal of solid wastes including carcasses, the habitats of vultures have vanished and there is no point in thinking of reviving the city population of vultures through captive breeding. Similar condition is also seen in rural India. Our motto therefore should be to preserve the isolated wild population of vultures wherever it exists *in situ* itself rather taking them into captivity as it may further result in extinction.

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BRIJ KISHOR GUPTA

C-280, Beta-I,
Greater Noida 201 308, India
e-mail: brijkishor68@yahoo.com

Tsunami of 26 December 2004 and related tectonic setting

A large tsunami triggered due to an earthquake offshore Sumatra at 7:58:53 AM local time on 26 December 2004 created havoc in several countries of the Indian Ocean, primarily Indonesia, Thailand, Malaysia, Andaman–Nicobar (India), East Coast of India, Sri Lanka, Somalia, Madagascar and several small islands in this area. It caused maximum loss in terms of affected area, leaving millions of people homeless. More than 200,000 human lives are reported to have been lost and millions have been injured; thousands are reported missing. It has affected the citizens of more than 50 countries including tourists from developed countries. The loss of property is so large that even UN officials hesitate to make an estimate and suggest that it may take decades to normalize the situation in the affected regions. The details of this earthquake are as follows: magnitude = 9.0, focal depth = 30 km, epicenter = 3.32°N and 95.85°E offshore Sumatra with nearest town of Banda Aceh about 250 km NNW in northern part of Sumatra (Figure 1)[1]. The main shock was followed by several aftershocks, which were primarily confined to the Burma micro plate extending towards Andaman–Nicobar islands north of the epicentral area. The study of the main shock and the immediate aftershocks suggests that approximately 1200 km of plate boundary slipped along a mega thrust with about 15 m of displacement on the fault plane, which resulted in this seismic activity[1]. Subsequently the magnitude is modified to 9.3 and focal depth to 15 km with much larger slip area covering the entire stretch of Burma micro plate which makes it the second largest recorded earthquake during the last 100 years[2].

The loss owing to this tsunami on such a large scale appears to be due to unpreparedness in the countries bordering the Indian Ocean against tsunami waves and socio-economic conditions of the people living along the coasts of these countries. The lack of preparedness has been primarily attributed to absence of tsunami in the Indian Ocean. However according to records in the last 60–65 years, at least three large tsunamis have hit the Indian coasts related to earthquakes in the Andaman sea in 1941, offshore Karachi in 1945 and the present one. The principle of recurring period may be applied to earthquakes but not to tsunami. The tsunamis occurring in 1941 and 1945 suggest that they can strike even at close interval specially because they are likely to originate from an earthquake along the plate boundaries in the Arabian Sea, the Indian Ocean and the Bay of Bengal or any other activity such as landslides or volcanic eruption at the bottom of these oceans. The second one offshore Karachi in 1945 resulted into a wave front of almost the same magnitude as the present earthquake (11–11.5 m) along the coasts of Gujarat, India. Probably the biggest tsunami was also reported from the Indian Ocean related to the Karkatoa volcanic explosion in 1883. This one was so big that it caused about 40 m high waves along the coasts of Indonesia and some of the islands vanished under sea. It affected the entire Indian Ocean and Pacific Ocean and even affected the environment in these regions for days and weeks[3]. With such activities happening in the Indian Ocean, unpreparedness of countries around the Indian Ocean cannot be logically explained. As tsunami affects several countries at a time there ought to be an international effort through international organizations like UN, etc. as it is being done in case of eradication of AIDS, polio, etc.

The region offshore Andaman–Nicobar–Sumatra–Java is an active subduction zone and is well known for high seismicity. Here the Indian plate subducts under the Burma micro plate and the Sunda plate with clockwise rotation in NE direction with a speed of 6 mm/year causing an oblique convergence[1]. It results into high stress generation, which is released as earthquakes from time to time. The tectonics in epicentral area of the 26 December 2004 earthquake is further complicated as it is located at the junction of four plates, viz. Indian, Australian, Burma and Sunda (Figure 1). North of the Sunda plate lies the Eurasian plate and their junction represents a continent–continent boundary (Figure 1), which makes the transmission of stress towards north difficult. In the epicentral zone of the present earthquake stress build up is further increased due to presence of a large number of ridges and fractures in the deformation zone, which are subducting under the Sunda plate along with the Indian plate. The boundary between the Indian plate and the Australian plate is a diffused zone (between dashed red lines in Figure 1) and is part of the Central Indian Ocean Deformation Zone. The central continuous red line between dashed red lines (Figure 1) showing boundary between the Indian plate and the Australian plate lies approximately in the central part of deformation zone. The deformation zone is characterized by large earthquakes, east-west trending folds, thrusts, faults and fractures in sediments[4]. It also shows high heat flow indicating recent subsurface tectonic activities in this section[5].

Another important aspect of tectonics in this region is the presence of thick sediments from the Himalayan rivers draining into the Bay of Bengal along coasts of Bangladesh, which almost covers a triangular zone starting from south of Dhaka extending up to southern diffused boundary of the Indian plate and the Australian plate (dashed black lines in Figure 1) with almost 2400 tons/sqkm/year of sediments[6]. Because of thickness of large sedimentary rocks (8–10 km), crustal thickness in the Bay of Bengal is unusually large (24–25 km) compared to typical oceanic crust[7]. The coincidence of southern limit of sediment spread (black dashed line in Figure 1) and southern limit of CIDZ (dashed red line) suggests the importance of sediments in this region. The Islands of Andaman–Nicobar–Sumatra–Java show relatively curvilinear gravity highs relative to adjoining gravity lows in ocean following the trends of islands both in free air (Figure 2)[8] and Bouguer anomaly[7] with both fields showing a good correlation, suggesting under compensation and unstable situation. It is interesting to note that other ridges of the Indian Ocean such as the Ninety East Ridge, the Laccadive Ridge, etc. which are relatively older and do not represent plate boundaries, show an opposite correlation between free air and Bouguer anomaly; the former showing gravity highs while the latter gravity lows, which suggest some form of isostatic compensation and stable situation. The epicentre of the present earthquake lies within the linear gravity low in free air anomaly (Figure 2) representing the Sunda trench which is the southward extension of Andaman trench where the main and aftershocks are located (Figure 1). These trenches also depict similar linear gravity low in Bouguer anomaly[7] showing good correlation with free air anomaly which is typical to present-day active subduction zones.

Such large earthquakes associated with mega thrusts at ocean bottom cause vertical displacement of large water mass, which subsequently tries to come to equilibrium and triggers tsunami. As tsunamis are generated at the bottom of the sea, they are large wavelength waves in the open sea, travelling with speed of 700–800 km/h

Figure 1. Tectonic setting of North East Indian Ocean and epicentres of earthquake of 26 December 2004 and its aftershocks in the week following main shock[1]. The area between two red-dashed lines in the Indian Ocean is part of the Central Indian Ocean Deformation Zone (CIDZ). Superposed on it is the sedimentary zone in the Bay of Bengal and south of it due to rivers draining into the Bay of Bengal shown by black dashed lines triangle starting from south of Dhaka[6]. The southernmost boundary of sediment cover almost coincides with southern boundary of CIDZ marked by black and red dashed lines respectively.

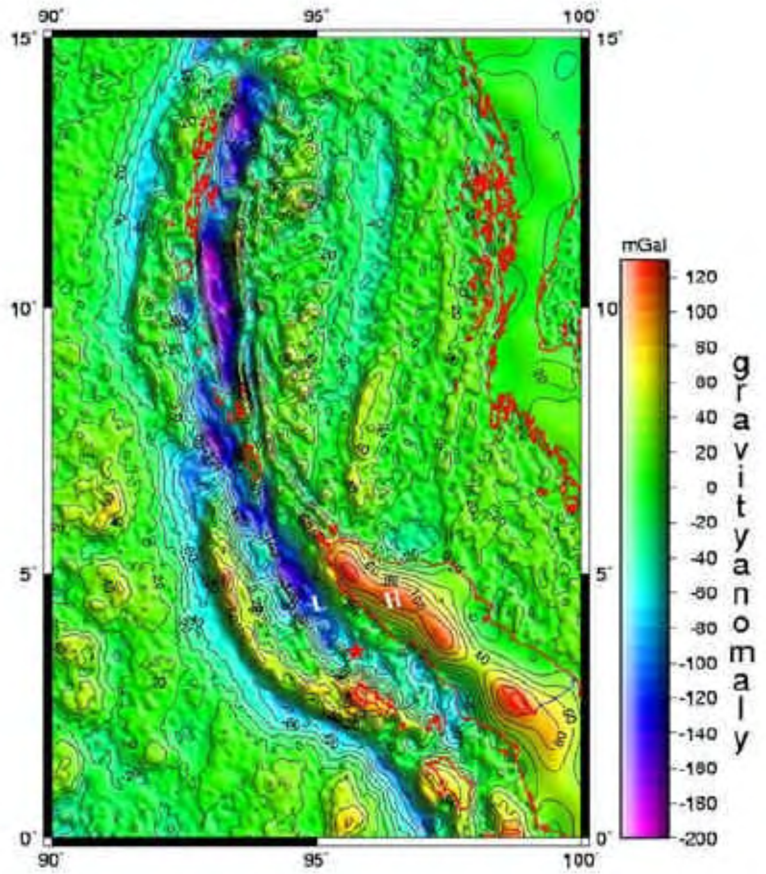

Figure 2. Free air anomaly map of eastern part of the Bay of Bengal and adjoining Indian Ocean prepared from global 2-minute data[8] with epicentre of the present earthquake marked as star superimposed on it. Linear gravity lows (L) and highs (H) represent Sunda trench and related volcanic islands respectively.

with minimum loss of energy. However, when they encounter shallow sea along coast, their kinetic energy is converted to potential energy and they grow in height up to tens of meters, causing large-scale devastation.

The most important feature of the present tsunami was its widespread effect towards west which struck as far as coasts of Somalia, east Africa while its effect towards the east is limited and did not affect the west coast of Australia. It can be attributed to the near perpendicular direction in which the affected countries are located, with regard to the subduction front and rupture zone[9]. In fact, the present earthquake consists of three events occurring within seconds of each other. The primary slip offshore Sumatra is followed by two other slips towards the north of it[10]. The modelled tsunami suggests maximum amplitude of waves north of the actual epicentre[11]. The maximum amplitude of modelled tsunami[11] north of the epicentre of the main shock indicates that amplitude of primary tsunami might have been enforced due to some secondary tsunami due to northern slips or due to landslides in the sedimentary section of the Central Indian Deformation Zone. Sediments over basement rocks in the ocean behave like a plate of large wavelength and in case its natural frequency matches with that of tsunami, the amplitude of waves will increase significantly causing a large scale destruction as it happens in case of large buildings on continent. The height of waves at the coast will also depend on bathymetry near the coast along continental shelf. The east coast of Sri Lanka is almost perpendicular to line of rupture in the epicentral zone of the present earthquake and therefore the tsunami has caused maximum damage in this section. The 200 m bathymetry of the continental shelf offshore east coast of Sri Lanka extends to Cuddalore–Nagapattinam sector along east coast of India, which might have channelized these waves to cause maximum damage also in this part. It is, therefore, essential to incorporate the direction of coastlines with respect to known oceanic subduction zones and bathymetry including that of continental shelf and its extent in the models to predict the amplitude of tsunami waves.

The role of an earthquake on 23 December 2004 north of Macquarie Island of magnitude 8.1 at plate boundary between the Indo-Australian plate and Pacific plate south of New Zealand, in triggering the present earthquake and thereby tsunami should be investigated. This is important specially because epicenters of both the earthquakes lie on the same plate and both are caused by convergence in NE direction. Such paired earthquakes, one triggering the other have been reported in some cases[12].

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D. C. MISHRA*
R. P. RAJASEKHAR

National Geophysical Research Institute, Hyderabad 500 007, India
**For correspondence.*
e-mail: dcm_ngri@yahoo.co.in