# Earthquake Prediction through Animal Behavior: A Review

Neeti Bhargava[1], V. K. Katiyar[2], M. L. Sharma[3], P. Pradhan[1]
[1]*Department of Mathematics, G.K.V., Haridwar*
[2]*Department of Mathematics, IIT Roorkee*
[3]*Department of Earthquake Engineering, IIT Roorkee*

**Abstract**

This paper presents a review of the work done in earthquake prediction using abnormal animal behavior. The earthquake prediction can be done using the abnormal behavior of animals preceding earthquake occurrence in seismically active region because of their relatively more capability than humans of perceiving certain kind of geophysical stimuli which may precede earthquake. The international work specially carried out in China, Japan, USA has been summarized. Further, the data requirement for the earthquake prediction in the Indian context has been discussed.

**Keywords:** *Earthquake, unusual animal behavior, seismic waves at low frequency, Sound of seismic waves, ground electric field, animal physiology*

## 1. Introduction

Earthquakes are one of the most destructive of natural hazards and to reduce the risk, it is necessary to predict where and when a future large earthquake may occur. Earthquake prediction means the accurate forecasting of the place, size and time of an impending earthquake (Agarwal, 1991). Solutions have been searched in past using earthquake precursors, particularly in China, Japan, and USA by conducting multi parametric regional studies. Many countries have been working on integrated national earthquake prediction research programs (Wyss, 1975; UNESCO, 1984). An endeavor has been made in the present study to review the work done in the earthquake prediction with respect to the abnormal animal behavior before an earthquake. The present paper consists of basic information of earthquake prediction, its research components being carried out in China, Japan and America with comments on its feasibility in Indian context.

## 2. Earthquake prediction

Earthquake prediction is done in three different time frames assigned by scientist as long term, intermediate and short-term predictions (Scholz, 2002). Long term predictions are of very limited use for public safety and by this type of prediction forecasts of earthquake occurrences have not been very accurate. Intermediate prediction consists of prediction for few weeks to few years, and again would not be of great practical usefulness. Short term prediction is specific information of the time and location of an earthquake given within days, weeks, or months and therefore would be more useful for any kind of public safety and evacuation. It is this prediction for which scientific community is trying to use the abnormal behavior of animals.

It has been observed that earthquakes are generally, but not necessarily, preceded by some signals mainly divided into geophysical precursors and others which also contains

the unusual animal behavior. While lot of research work has been carried out for the geophysical precursors, animal behavior has not been explored to its full capacity for use in earthquake prediction. The following sections review the abnormal animal behavior observed for earthquake prediction.

## 3. Animal behavior and earthquake prediction research

The earthquake prediction can be done using the abnormal behavior of animals preceding earthquake occurrence, because animals are much more capable than humans of perceiving certain kind of geophysical stimuli which may precede earthquake. The main research has been carried out in China, Japan and America.

Chinese began to study systematically on the unusual animal's behavior, and the Haicheng earthquake of magnitude 7.3, on 4 February 1975 was predicted successfully as early as in mid December of 1974. The most unusual circumstance of animal's behavior was that of snakes that came out of hibernation and froze on the surface of the earth and also a group of rats appeared. These events were succeeded by the swarm of earth of earthquakes at the end of December 1974. In first three days in Feb the unusual behavior of the larger animals such as cows, horses, dogs and pigs was reported. Chinese have established an operational network in different counties. In 1968 first experimental station for earthquake making use of biological observation established in Hsingtai province. Other similar stations were set up in 1971 in Aksu, Sinkiang province, where earthquake were expected to occur. Whenever unusual event occur and are reported by numerous observers, these are evaluated as a way of predicting earthquakes. In August 1971 the State Seismological Bureau of China started to collect reports of unusual animal behavior for earthquake prediction purposes. Four years later, based on observations of unusual animal behavior and geophysical measurements, they successfully evacuated Haicheng city several hours before an earthquake (M7.3) on February 4, 1975. This earthquake caused considerable damage to existing structures and cultivated lands, and the successful evacuation was thought to have saved more than 100,000 lives. There were also reports of unusual animal behavior before the Tangshan Earthquake (M8.2) in 1976, but no warning was issued. There were 240,000 casualties (George, 2007).

In Japan, unusual behavior of catfish before the 1855 Edo earthquake was reported. Many fish jumping in a pond just one day before the great Kanto earthquake occurred was reported (Musha, 1957). (Hatai and Abe, 1932) investigated the response of catfish to the earthquake first time. According to (Buskirk et al., 1981 and Ikea et al., 1997) aquatic animals are more sensitive to electric signals than other animals. Some of them have special electro-sensory systems which are used to acquire information for orientation and communication with each other (Lissman, 1958; Knudsen, 1975; Buskirk et al., 1981). These systems may be perturbed by electric field before earthquakes.

(Ikeya et al., 1996) investigated the ground electric field effects on behavior of Albino rats, Mongolian gerbils (sand rats), hair-footed Djungarian hamsters, guinea pigs, and red sparrows. To determine seismic anomalous animal behavior prior to a major earthquake due to seismic electric signals, an experiment on these animals was organised. The animals were kept in a cage with a wet conductive floor and electrodes. When Voltage between (0.01 to 50) Volt was applied to the electrodes separated by 25 to 30 cm on the floor of cages, between which wet tissue papers with resistivity of 20 KΩ were placed.

The film was recorded and it was noticed that initially these animals started grooming, nervous looking and field avoidance behaviors, and finally as the ground electric field increased from 1 to 1000 V/m they started running in panic, jumping, tumbling, crying, standing up, biting wires, flying up and some time their behavior could not be judged.
(Ikeya et. al., 1998) established a laboratory by applying a pulsed electric field on silkworms, earthworms, lungworms, mollusc, Japanese minnows, tropical fish, guppies and fresh water loachcs and observed as seismic anomalous animal behavior (SAABs) as electrophysiological responses to the stimuli of seismic electric signals (SES). It was observed that these animals became aligned perpendicularly to the field direction since their skeletal muscle had a higher resistivity perpendicular to the field direction then parallel to it. Mollusc (Venerodia tapes japonica, and Corbicula japonica) showed responses after applying single electric pulse of 0.5 ms. They quickly closed their open shell, when electric field of intensity as low as 50 V/m, even for a single pulse with the width of 5 **ms** they show same effect. To correlate such type of voltages an electromagnetic model of a fault based on piezoelectricity effect was proposed, in which dipole charges, $+q$ are generated due to the change of seismic stress, σ (t).The field intensity and seismic current density at fault zone, were calculated. The mathematical model showed,

$$d\,q/d\,t = -\alpha\,(d\,\sigma/d\,t) - q/\epsilon\,p \qquad (1)$$

Where α = charge generation constant like piezoelectric coefficient, Є = dielectric constant and ρ = resistivity of bedrock granite. A fault having a length 2a and a displacement or rupture time τ, during which the stress is changed, gives pulsed dipolar charge surface densities, +q(t, x) and –q(t, x+2a), or an apparent electric dipole moment of

$$p(t) = 2aQ(t) = 2aAq(t) = \alpha M_0 \left[ \varepsilon\rho / (\tau - \varepsilon\rho) \right] \left( e^{-t/r} - e^{-t/\varepsilon\rho} \right) \qquad (2)$$

Where, $M_0$ = Earthquake moment, D = Fault displacement, and the stress drop, D' = Initial velocity and Δσ = Stress drop, then

$$\tau = D/D' = \left( \Delta\sigma/\sigma_0 \right) \left( \alpha/\beta \right). \qquad (3)$$

Field intensity F = q/Є, and seismic current density at a fault zone, J= F/ρ, using ρ' of water as to give J = 0.1 ~ 1 A/m$^2$ sufficient to cause animal anomalous behavior experimentally. The ultra low frequency (ULF) waves near field, generated by charges, P (t) give Seismic electric signals (SES) reciprocally proportional to the distance R. And hence an equation of pulsed seismic electric signal derived theoretically, which is a wave packet of electromagnetic waves and should be measured using digital storage oscilloscope at fault zones for early warning.
According to (Ikeya et al., 2000) unusual animal behavior during the compression of rocks was observed together with the blood analysis. These EM pulses may be used as early warning to reduce the accompanying the disaster though the exact time of earthquakes would still be difficult to predict. Animal behavior similar to those induced by pulsed electric field and EM exposures and so by lighting in nature could be a useful

warning to lay citizens in earthquake prone areas even admitting the difficulties of deterministic earthquake prediction using these EM signals.

(Ustundag et al., 2005) proposed a multi layer capacitor model of the Earth's upper crust to explain the behavior of measurement patterns acquired from network of the earthquake forecast project. This model indicates that change of dielectric features due to structural changes, such as liquid dilatency, requires a change in the electric field at the surface. Amount of variation is locally independent from the area. Similarly the patterns between the model based simulations using approximate parameters and the real data based patterns beside the relatively high correlation between the anomalies and the earthquakes gives hope for the progress of earthquake forecast in future. It is possible to modify equivalent circuit model of the multi-layer capacitor approach with some additional parameters.

It has been shown by laboratory experiments that long animals such as snake tends to stay vertical to the electric fields in order to decrease the potential difference on its body.

(Bleier and Freund, 2005) claimed that a network of passive sensors (magnetometers) can be used in EP by using the transient change in earth's magnetic field prior to imminent earthquakes. California earthquakes could have been predicted sometime before, if the region were covered by a network of 200-300 ground-based magnetometers (Sevgi, 2006). Ground-based sensors can be used to monitor changes in the low-frequency magnetic field as well as to measure changes in the conductivity of air at the earth's surface. Moreover, noise levels at extremely low frequency (ELF)—below 300 Hz can be monitored using satellites, observe the earthquake related infrared light, even use existing GPS system to detect changes in the total electron content of the ionosphere that occur days, even weeks before the earthquakes.

Numerous observations also exist of animals displaying panic in the few seconds prior to the onset of strong ground shaking in American case.(Tributsch, 1982) lists many such examples, including dogs barking, nervous cats jumping out of windows, birds screaming, rats running out of their holes, bees swarming, etc. Such behavior immediately prior to an earthquake is not difficult to explain, as seismic P waves travel faster through the crust than the associated S waves by roughly 2–4 km/ sec. If organisms are sensitive enough to detect vibrations accompanying the arrival of P waves, that sense could provide enough of a warning to trigger a death-avoiding response immediately prior to the arrival of the more damaging S waves.

Animals that live tens of kilometers from the epicenter have several seconds after detection of the P wave to escape the effects of the energetic S waves (Pease and Orourke, 1997).

(Kirschvink, 2000) suggests the tilt, hygroreception (humidity), electric, and magnetic sensory systems in animals could be linked in to a seismic escape behavioral system. Several testable predictions of this analysis are discussed, and it is recommended that additional magnetic, electrical, tilt, and hygro-sensors be incorporated into dense monitoring networks in seismically active region. The analysis presented here implies that if there are occasional precursors to earthquakes that animals could detect, behavioral patterns could evolve to minimize associated mortality.

(Heaton et al., 1995) suggested that controlled shake table experiments could be done on laboratory populations of burrowing animals from seismically active zones; also some of California's endemic kangaroo rats would establish a baseline of animal behavior for

comparison with reactions of other stimuli. To determine geophysical and geochemical signals, a variety of field based experiments could be done on the same species, and the expatiation model outlined here would predict some similarity in evoked behavioral response between shaking and other stimuli linked to seismic escape activity.

The recognition that changes in groundwater level might sometimes provide clues to an impending earthquake suggests that associated changes in local humidity might be detected by animals.

The process of humidity reception in animals is known as hygroreception. Spiders and insects possess hygro-sensensitive sensilla that consist of specialized receptor cells with hygroscopic hair-like structures that detect humidity and/or temperature fluctuations (Sayeed and Benzer, 1996; Tichy and Loftus, 1996).

According to (Vanderwall, 1993) vertebrates appear to detect humidity through their olfactory system and some controlled laboratory experiments have shown that desert rodents are able to detect seed caches buried in dry sand based variations. Therefore animal detection of impending earthquakes through hygroreception might be possible in arid environment, but it is difficult in rainy areas like Japan which have uniformly high levels of humidity both in the soil and in the air. It is also difficult to understand that how pattern of a pre seismic humidity change would differ from that generated by an impending storm.

On other hand, (Tributsch , 1982) observed that some of the behaviors displayed by animals before earthquake resemble their prestorm behavior.

In terrestrial animals, electrical sensitivity is rather low compared to marine or freshwater animals due to the high resistivity of air. High voltages are perceived through the secondary effects of shock and/or the electrostatic action on feathers or hairs. In contrast, aquatic animals such as sharks, rays, and some fish often have exquisite electrical sensitivity due to specialized organs used both for communication and prey location (Bullock, 1982).

In the elasmobranch fish (sharks and rays), a specialized receptor system in the ampullae of Lorenzini has, in fact, reached the thermal noise limit with the ability to perceive nanovolt changes in electrical fields (Kalmijn, 1974).

(Tributsch, 1982) suggests an electrical link to anomalous behavior in fish and other aquatic animals before earthquakes. Similarly, nocturnal animals would have no difficulty detecting earthquake lights by simple visual signals. If some of these signals happen prior to significant seismic events, expatiation could link them to a pre-existing escape response.

## 4. Earthquake prediction research: - indian context

While lot of research has been carried out in China, Japan, America, very little efforts have been made in India in the area of earthquake prediction. Very few of the unpublished reports sometime shows some abnormal animal behavior which has not been studied scientifically. Looking at the future prospects of the abnormal animal behavior in earthquake prediction and the high seismicity faced by most of the regions in India, this science require much more attention than given in the past. The data on geophysical precursors has not been acquired in the past systematically. Recently, Department of Science and Technology has developed multi parametric geophysical Observation at

various places in India. The animal behavior has not been reported from any of the Indian studies.

## 5. Conclusions

Earthquake prediction is a social imperative and there is need to carry out research with respect to abnormal animal behavior. The review has shown encouraging results of using abnormal animal behavior before an earthquake for prediction in many countries and it requires its due attention in Indian context.

## Reference


1. Agarwal, P.N., "Engineering Seismology", Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi,170, 1991.
2. Bullock, T. H., "Electroreception", Annu. Rev. Neurosci. 5, 121–170., 1982.
3. Bleier, T. and Freund F., "Earthquake Alarm", IEEE Spectrum,Vol. 42, No.12 (INT), pp. 17-21, Dec 2005.
4. Buskirk, R. E., Frohlich K., Litham G.V., "Unusual Animal Behavior Before Earthquakes: A Review of Possible Sensory Mechanisms", Rev. Geophy. Space Phy. 19, pp. 247-270 1981.
5. George, P.C., "Can animal Predict Earthquake", Tsunami Pages of George P.C www.dr.georgepc.com, 2007.
6. Hatai, S. and Abe, N. "The Responses of the Catfish, Parasilurus ascotus, to Earthquake", Proc. Imperial Acad. Japan, 8, pp. 374-378, 1932.
7. Heaton, T. H., Hall, J. F., Wald, D. J.and Halling, M. W., "Response of highrise and base-isolated buildings to a hypothetical M(w) 7.0 blind thrust earthquake", Science 267, 206– 211, 1995.
8. Ikeya, M., Furuta, H., Kajiwara, N. and Anzai H., "Ground Electric FieldEffects on Rats and Sparrows: Seismic Anomalous Animal Behaviors (SAABs)", Jap. J. Appl. Phys., Vol.35, pp. 4587-4594, part 1, N0. 8, August 1996.
9. Ikeya, M, Takaki, S, and Matsumoto, H., "Pulsed charge model of a fault behavior producing seismic electric signal", J Circuit Systems and Computers, 7(3): t 53-164,1997.
10. Ikeya, M., Matsumoto, H., and Huang, Q.H., "Alignment silkworms as seismic animal anomalous behavior (SAAB) and electromagnetic model of a fault: a theory and

laboratory experiment", ACTASEISMOLOGICA SINICA, Vol. 11, No.3, 365-374, May 1998.
11. Ikeya, M., Yamanaka, C., Mattsuda, T., Sasaoka, H. , Ochiai, H., Huang, Q., Ohtani, N., Komuranani, T., Ohta, M., Ohna, Y., and Nagakawa T., "Electromagnetic Pulses Generated by Compression of Granitic Rocks and Animal Behavior" , Union of Geological Sciences, Vol. 23, No. 4, pp. 262-265, December 2000.
12.Kalmijn, A. J., "The detection of electric fields from inanimate and animate sources other than electric organs", in Handbook of Sensory Physiology, Vol. 9, A. Fessard (Editor), Springer-Verlag, Berlin, New York, 147–200.,1974.
13. Kirschvink, J. L., "Earthquake Prediction by Animals: Evolution and Sensory Perception", Bulletin of the Seismological Society of America, 90, 2, pp. 312-323, 2000.
14. Knudsen, E. L., "Spatial aspects of electric fields generated by weakly electric fish", J. Comp. Physiol., 99, 103–118, 1975.
15. Lissman, H. W., "On the function and evolution of electric organs in fish", J. Exp. Biol., 35, 456–486, 1958.
16. Musha, K., "Jishin Namazu (Earthquake and catfish). Toyotosho", Tokyo, 208 pp 1957.
17. Pease, J. W., and T. D., Orourke "Seismic response of liquefaction sites", J. Geotech. Geoenviron. Eng. 123, 37–45, 1997.
18. Sayeed, O., and Benzer, S., "Behavioral-genetics of thermosensation and hygrosensation in drosophila", Proc. Natl. Acad. Sci. USA 93, 6079–6084, 1996.
19. Scholz, H. C., "The mechanics of Earthquakes and faulting", Cambridge Press, 2nd Edition, 2002.
20. Sevgi, L., "Earthquake Early Warnings: Prediction or Guesswork", IEEE R8Newsletter, Vol. 9, No.1, pp. 11, Mar 2006.
21. Tributsch, H., "When the Snakes Awake: Animals and Earthquake Prediction", MIT Press, Cambridge, Massachusetts, 248 pp. 1982.
22. Tichy, H. and Loftus, R., Hygroreceptors in insects and a spider humidity transduction models, Naturwissenschaften 83, 255-263, 1996.
23. Ustundag, B., Kalenderli, O.and Eyidogan, H., "Multilayer Capacitor Model of the Earth's Upper Crust", Turk J Elec Engin, Vol.13, No. 1, pp. 163-174, 2005.
24. UNESCO, "Proceedings of the International Symposium on Earthquake Prediction", terra Scientific Publishing Company, Tokyo, Japan, April 2-6, 1979, 1984.
25. Vanderwall, S. B., Seed water-content and the vernerability of buried seeds to foraging rodents, Am. Midland Naturalist 129, 272–281. 1993.