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Earthquakes, Animals and Man

CHAPTER III—ANIMAL RESPONSE TO EARTHQUAKES

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Eerie, Anomalous Phenomena

A child discovers that when he holds an empty tumbler to his ear, a sound is produced as if from nowhere and he is bewildered. An echo is an equally bewildering phenomenon to one who first hears it. The anomalous fires in coal mines are an enigma to a common man. Franklin's discovery of static electricity through the string of his kite must have been an eerie experience. Magnetism, is an equally eerie experience for an untrained mind. So are the ubiquitous telluric currents in the earth. Electricity and magnetism are intricately related, yet their effects on a casual observer are often eerie or anomalous, depending upon his familiarity with natural phenomena. These phenomena are created by peculiar situations. No external energy is utilised whether in the hissing sound in the tumbler, or in static electricity in the atmosphere, or in telluric currents or in echoes.

For every expression of energy such as heat, sound, light, electricity, magnetism etc., some energy input is necessary. Any energy can change its form depending upon the situation. A volume of water falling on a turbine generates electricity, the form of energy is changed from potential to electrical. Many more examples might be given.

In the case of earthquakes the energy is derived from internal stress. This stress causes movement of enormous masses of land, the plates. The excess energy remaining after what has been expanded for the land disturbance, is released on the surface. In what form it will be expressed depends upon the situation. Therefore, even though the source of this energy reaching the surface is known, yet the consequent phenomena often present an enigma incomprehensible to the common man. The reaction of animals to all these phenomena is awe, astonishment, fear.

It should be no surprise, therefore, if the animal world sometimes reacts to these anomalous physical and physico-chemical phenomena through its sixth sense. Equally strange is the reaction of human beings. You see a tiger suddenly and the situation creates fright and horripilation on your body. This is just as eerie even if we do not know the casual relation, and simply call it eerie, anomalous, etc.

Miracle Memory Metals

Science is unravelling many of nature's mysteries. A recent study, for instance, shows that some plastics after being deliberately deformed resume their original shape when they are melted and allowed to cool again. This phenomena is called 'plastic memory'.

The inorganic world is not usually known to possess or exhibit faculties that are peculiar to the biosphere. Yet some alloys of metals such as Nitinol exhibit a faculty of 'memory' which has so far been considered an attribute of higher animal life alone.

A wire of a specific metal or alloy like Nitinol is given a shape—Say, of a dog—at a certain range of temperature, allowed to cool, and then deformed beyond recognition. When the temperature is raised again to the same point, the wire reverts to the former dog shape. The metal retains the memory of that shape and attains it again!

This is not all. Professor Honma of Tohoku University, Japan and his research team prepared a toy spider out of this wonder alloy, marmen. At room temperature the spider spread its eight legs horizontally. When dipped in water at 70°C, it tucked its legs beneath its body curling into a ball. Removed from the hot water, the spider gradually spread its legs out once again. When the same spider was cooled to-10°C it curled into a ball, but this time wrapping its legs above its head! (Science Today, August 1983). This can be repeated several times.

This is no fiction but scientific fact, established by experimentation. Memory in a metal appears indeed a miracle, not only to the common man but to many trained scientists.

There are many miracles in our world, where exact explanation of science has not fully established as yet. Some animal behaviour is of this category; it defies explanation but remains a fact.

The physical, physiological and psychological phenomena in the animal world are astounding. To almost every phenomenon the sensitivity of animals is far beyond the range of human sensitivity. Some faculties of animals are even beyond the range of some of our modern sensitive instrumentation. The migration of animals and birds is still bewildering, and unbelievable for man. Bats can separate a particular signal from 1000 signals, displaying an ability far beyond human or even instrumental capabilities.

These reactions and faculties of insects, birds, and animals defy our comprehension. Yet there is nothing supernatural about them. The behaviour of the animal world is strictly governed by the laws of physics, chemistry, biology, physiology and psychology and their natural habitat and environment.

Zoologists and animal behaviourists have studied the responses of animals to various physical and chemical stimuli in the laboratory. There has not been much study on the free range and among wild animals. Kraemer, Smith and Levine, have given an excellent resume of animal behaviour and responses in the context of earthquakes, in the USGS Conference I (1976).

Table 9 contains a classification of animal behaviour in detail. Observations relate to the behaviour of Chimpanzees, as an example.

Table 9 *Classification of animal behaviours*

A. *Don't know*
   1. cannot see chimp
   2. see, but cannot classify
   3. chimp visible, not locomoting, not idle, but cannot see behaviour

B. *Idle*
   1. standing
   2. lying
   3. sitting
   4. clinging above ground
   5. general infant activity
   6. fixate

C. *Solicit for grooming*

D. *Scratching*

E. *Self-grooming*

F. *Grooming other*

G. *Mutual grooming*

H. *Lone travel*

I. *Group travel*
   1. tandem walk
   2. buddy walk
   3. waltz
   4. carrying another — dorsal
   5. carrying another — ventral

J. *Object investigation or manipulation*
   1. sniff
   2. dab, poke or pick with fingers
   3. peer
   4. handle
   5. throw
   6. drag/carry
   7. tool use

K. *Lone play*
   1. swinging/dangling/climbing
   2. tumbling/headstands
   3. gamboling/playwalk
   4. pirouette
   5. jumping
   6. slapping
   7. stamping
   8. flailing of arms and/or legs
   9. object play

L. *Attack (contact, hair out)*
   1. biting
   2. stamping
   3. slapping
   4. dragging
   5. grasping/grabbing
   6. shove/push

M. *Display/Threat (no contact, hair out)*
   1. tantrum
   2. throwing
   3. dragging
   4. stamping
   5. slapping
   6. charging
   7. bipedal
   8. branch-waving
   9. rocking
   10. head-nodding
   11. arm-threat
   12. head-jerk
   13. hand-clapping

Table 9 (Contd.)

N. Social play
1. biting
2. dragging
3. grasping/grabbing
4. stamping
5. slapping
6. tickling
7. pursue (play chase)
8. avoid/flee (play chase)
9. object play
10. branch-waving
11. hand-clapping
12. bipedal
13. head-shake
14. rocking
15. head-nodding

O. Unclear cues: Attack, Display/Threat, Play
1. biting
2. stamping
3. slapping
4. dragging
5. grasping/grabbing
6. shove/push
7. throwing
8. charging
9. bipedal
10. branch-waving
11. rocking
12. head-nodding
13. head-jerk
14. hand-clapping
15. chase
16. object
17. head-shake

P. Touching (placing a hand on another chimp)

Q. Reassurance
1. half embrace
2. full embrace — ventral/ventral
3. full embrace — ventral/dorsal
4. kiss
5. extend hand and/or touch
6. hunch over
7. finger in mouth
8. hand holding

R. Submission
1. bending away
2. bobbing
3. crouching
4. touching
5. presenting

S. Begging
1. hand to mouth
2. mouth to mouth
3. mouth to hand
4. hand to hand
5. peering

T. Oral activity
1. eating
2. coprophagy
3. object investigation

U. Drinking

V. Interfering with copulation

W. Sexual behaviour
1. presenting (females)
2. courtship display (males)
3. inspection
4. masturbation
5. rump-bumping

X. Mounting
1. with intromission
2. without intromission

XX. Being mounted
1. with intromission
2. without intromission

Y. Being carried (infant only)
1. dorsal
2. ventral
3. dangling

Z. Suckling

AA. Nest building

BB. Gathering

CC. Avoiding/Fleeing

DD. Urination/Defecation

Source: After Kraemer, Smith and Levine, USGS Conference. I. An Animal Behaviour Model, 1976

List of Animals Involved

The list of animals which have been watched all over the globe and found to have indicated the possibility of on-coming tremors, is a large one. A list of these animals, prepared from a number of references, is given in table 10.

Table 10 *List of animals known to have indicated on-coming earthquakes*

Ants	Eels	Porcupines
Bats	Fish (many kinds)	Quails
Bees	Foxes	Rabbits
Birds (various)	Frogs	Racoons
Bobcats	Geese	Rats
Buffaloes	Goats	Sardines
Canaries	Guinea pigs	Sea lions
Catfish	Hamsters	Sea urchins
Cats	Horses	Seals
Cattle	Isopods	Sheep
Chameleons	Jackals	Shrimps
Chickens (Fowls)	Leaches	Snakes
Chimpanzees	Loaches	Snails
Chinchillas	Lions	Sparrows
Chipmunks	Mackerels	Spiders
Cockatiels	Mice	Storks
Cockroaches	Monkeys	Squirrels
Cods	Mules	Swans
Coyotes	Newts	Tigers
Crabs	Ospreys	Trepanes
Crickets	Oysters	Trout
Crows	Pandas	Tuna
Deer	Parakeets	Turtles
Dogs	Parrots	Walruses
Dolphins	Pigs	Whales
Donkeys	Pigeons	Wolves
Doves	Peafowls	Worms
Ducks	Pheasants	Yaks

Compiled from several references on the subject

Scientific Studies Relating to Earthquakes

Until 1949 it was presumed that the world around us is no more than what we perceive by our five senses of touch, smell, sight, taste and hearing. That year saw some fundamental discoveries about animal behaviour. These, included the bat's astounding ability to 'see' in the dark and to change its course just before encountering an obstacle. The sonic waves generated by its mouth are reflected back in a split second, enabling the bat to change its course swiftly before it dashes against the obstacle. The speed at which the bat flies is so great that if it did not deflect its course in good time it could very well dash itself to death. The dog's ability to distinguish different smells, and retain them in its memory for a phenomenally long time, is equally astonishing.

Those animals which hibernate go into deep slumber from which on a suitable day they wake up and immediately resume normal life. If a human being were to remain in suspended animation like the hibernating animals even for a few days, it would take months of physiotherapy to get back into his normal life rhythm. The uncanny sense of migrating birds, who sail in the air for thousands of kilometres without navigational aids, is still not clearly understood. A mother bat in her cave, which she shares with hundreds of others, looks for her own offspring and finds it even among hundreds of similar young ones, in a way which is yet beyond our comprehension. The biological clock of animals, birds and fishes is nothing short of a miracle. Innumerable instances like these force us to conclude that the world we know through our senses is only a part of the world that exists around us.

Modern advances in science, with its vast array of instrumentation, including the computer, have not yet enabled us to unravel the mysteries of the animal world. If it were possible to devise an instrument which could replace the dog in its capabilities of following a scent, we should no longer depend upon dogs to track a criminal or detect narcotics or bombs in civil aircraft.

The folklore of several countries tells of animal behaviour as indicator of on-coming earthquakes. The earliest reference to the discovery of a relation between unusual animal behaviour and earthquakes was found in Italy, as early as 1887. By interrogating people and collecting data on pre-warnings of earthquakes, much information was collected. The Ligurian (1982, earthquake of February 1887 was investigated through a questionnaire considering animal behaviour as a possible precursor. People from distant villages, and particularly the educated and literate, were approached for their reactions in the matter. The consensus did indicate that in some cases there was a definite spacio-temporal relation between animal behaviour and the earthquake.

One of the points that emerged was that the conditions leading to earthquakes are so strange and unusual that animals show the common startle reaction by instinct. In most cases these animals had no previous experience of this kind and hence there was no possibility of conditioned reflex. The minute physical or chemical phenomena that precede earthquakes are perceived by the animals through their normal senses and through some undefinable sixth sense. Depending upon the provocation or the severity of the physical precursor, animals react to the unusual and unexpected phenomena like shaking of the ground, unusual sounds, smells, lights, etc. Sheer fright drives animals to behave in their own peculiar way.

In 1966, China decided to start a major national effort, according to Peter Verney, in involving the masses in earthquake prediction. The national slogan was "Rather a thousand days with no earthquake than one day with no precaution". It was a national appeal for 'war against earthquakes'.

Large groups of people were involved in watching earthquake precursors, including the rise and fall of water levels and emanation of radon in wells and rivers and on the sea coast. What could be done by instrumentation was being done by scientists and laboratory personnel. The main thrust of this movement was directed towards observing animals that could, by their unusual behaviour, give some clue to an on-coming earthquake. Some 300,000 amateur earthquake watchers were enlisted. They watched domestic animals in particular but also wild animals in free range and in zoos. The outcome, it is reported, was spectacular and a number of earthquakes were thus predicted.

In the early stages there were some inadvertant false alarms. Soon the watchers were trained and the spirit of search permeated a larger proportion of the population. Today, mass participation and study of earthquakes helps to form the fabric of China's attempts at prediction. The Haicheng earthquake of 1975 is claimed to have been predicted by animal behaviour. However, it must be mentioned here that in the case of Haicheng many common physical precursors also showed a rise of tempo towards an earthquake. The abnormal animal behaviour precipitated the prediction.

In course of time China collected a colossal body of information, which was later computerised and processed, the results being verified in laboratories and studied by physicists, chemists and biologists. The Chinese contributed several papers at various conferences, both within their country and abroad.

Western scientists were stirred by the results of the Chinese experiments and started to verify them for themselves. Among these studies should be mentioned those by the U.S. Geological Survey, Ruth Buskirk and her associates at the University of Texas at Austin, the State University of California, and the Earthquake Research Institute, University of Tokyo, Japan.

The Stanford Research Institute in Menlo Park, California, has established a network of animal observers along the San Andreas Fault. 'A few hundred selected collaborators are in touch with a central office', according to Tributsch (1982), about 70 animal species are being watched as a part of 'Project Earthquake Watch.'

Biological Premonitors of Earthquakes, a study by the Otis et al. (1981) records that Project Earthquake Watch has established a prima facie case for pursuing this study 'to determine the degree to which unusual changes in animal behaviour may precede earthquakes'. It is observed further, 'several earthquakes have been successfully predicted on the basis of such reports, along with other geophysical data, and thousands of lives have been saved. In China, volunteer farmers, ranchers, breeders, pet owners and others, who are around animals a great deal of the time, form a net work of people who report any unusual animal behaviour.'

The above information forms a part of the notice inviting volunteer observers for Project Earthquake Watch.

'If such a system of amateur groups of animal watchers could be introduced in all earthquake prone regions of western countries' says Tributsch (1982), 'we could reasonably expect that valuable information about controversial earthquake signs could be collected considerably faster than now. Besides that, these groups could, as they do in China, spread vital information among the people about safety measures to be taken in case of earthquakes.'

Two noteworthy conferences were held in 1976 and 1980 by the U.S. Geological Survey, which were attended by several Chinese, Japanese and western scientists. The results are published in two volumes (1976, 1979). By now, hundreds of independent papers have been published detailing one aspect or another of animal behaviour as precursor of earthquakes. The same hypothesis, which met with scorn and raised eyebrows in earlier days, is now being treated with respect, especially against the background of our inability to predict with certainty on the basis of physical and chemical parameters alone. This raises hopes that in densely populated urban areas, as well as in rural areas, many more lives may be saved.

Most earlier text-books, including the writings of Rikitake (1982), mentioned animal behaviour as the last of all precursors to be considered as elements for prediction. The references, which were rather casual, did not win any support from scientists. The main emphasis was, as it still is, on the geophysical precursors.

The list of presursors of earthquakes given on page 565 is indeed a long one, pertaining to several fields covered by modern science. Seismic, geodetic, electric, electromagnetic fields, vibration, and the emanation of gases and odours all belong to the realm of physics. However, all these affect animals and plants in one way or another. The heaving of groundwater and changes in the level of lakes, seas and oceans, affect aquatic life directly. Sudden changes in weather likewise tell upon all living beings, which naturally react according to their specific anatomy, physiology, psychology and behavioural patterns.

Our seismologists are involved in the study of the physical aspects of earthquakes, their fore-shocks and their after-shocks, fore-shocks being the physicists' main source for prediction. Animal behaviourists are similarly engaged in their own way in studying animal responses to various stimuli and in observing their individual and social behaviour, the effects on their reproductive systems, their family habits, and their interaction with others, of their own or different species. However, partly due to the lack of interest in other branches, and partly because the social implications of prediction, namely the saving of human life, are probably not given the priority they deserve. The gulf persists between the two sciences, the physical and the biological. Signs of closer cooperation have only recently appeared. The effort is still half-hearted and marked by an apparent mistrust of the subject rather than the appreciation of the success attained or the potential it holds for the future.

Premonition of earthquakes by animals does not normally appeal to most peoples reason, perhaps because the subject is not very popular so far and not many wish to delve into it. Even geophysicists display a general apathy, few of them realising that animal premonition is also based upon physical stimuli. Animal behaviour is the natural reaction to physical stimuli without any awareness of the law of cause and effect. Consequently, animals can react to the physical precursors of on-coming earthquakes spontaneously and precisely.

It is seldom realised that a few human lives saved are worth all the expenditure and efforts involved in educating the animal watchers.

Animal Reactions

Different kinds of animals react to external physical stimuli, each in its own characteristic and typical fashion. Most domestic animals, when excited, make unusual noises and behave abnormally, such as breaking tethers and running away wildly, or biting each other and even inanimate objects. Birds leave their accustomed trees and perches and refuse to return, animals in zoos go out of control, fish migrate or jump out of water, snakes and other burrowing animals leave their hide-outs and come out into the open even in winter, thus facing the risk of freezing to death; rats run helter-skelter, unmindful of well-known dangers, sometimes becoming so confused that they can be caught by hand easily.

The period of warning varies from a few hours to two or three months (see tables 11 to 13). Some fish are known to have indicated excitement one to two months in advance. Chickens, dogs, pigs and other domestic animals are known to have given warning 8 to 10 days in advance, rats have done this from a few days to a month beforehand. Quite a large number of animals show unmistakable signs a day or a few hours before the event.

The reaction of animals depends upon the nature and severity of the physical precursors, such as foreshocks. There is nothing occult or supernatural about this behaviour.

There are many stimuli to which animals respond, such as touch, vibration, light, sound, infra-sound and odour; also electrical, electromagnetic, magnetic and microwave radiations, air and hydrostatic pressure, ionisation, changes in temperature and gravity, etc. Just as different species will respond differently, the individuals of the same species may perhaps respond differently according to their age, sex and any previous experience of similar situations.

Birds are sensitive to electric, magnetic and electromagnetic changes; to ionisation, anomalous lights and sounds, ultrasonic sounds, vibrations through the trunks and branches of the trees on which they are roosting and sudden weather changes, all caused by physical precursors. Most animals are sensitive to vibrations, sounds and ultra-sounds, smells, and vertical and lateral displacements of the ground under their feet. Fishes are perhaps the most sensitive to electrical, magnetic and electromagnetic stimuli as well as to vibrations, sounds, anomalous sounds and anomalous lights. Snakes as well as rats and other rodents, are sensitive to vibrations, smells, earth sounds, and changes in air temperature and pressure.

Sixth Sense of Animals

Apart from these known and demonstrable aptitudes, the animal world exhibits yet another faculty which can be best characterised as a sixth sense. Homing pigeons exhibit uncanny powers of returning to their starting point, no matter how many twists and turns they have taken in their flight. Migrating birds cross thousands of miles and alight at the same spot, usually lakes, every year at precisely the same time of year. Wild animals leave one country and migrate to another, say from Tanzania to Kenya and back, precisely at the same time annually. This migration is a spectacular phenomenon. Their disciplined movement, four or five abreast, is a unique sight. Tourists come from all over the world and are able to watch this migration during precisely the same time of the year, to within a week.

Magnetotactic bacteria are found orientating themselves to the same magnetic direction in spite of all possible disturbances (Blakemore 1982).

Young ones of cows and buffaloes run to their respective mothers, and only after recognition does the mother entertain the calf. Fishes migrate upstream for several miles, for annual spawning; salmon are particularly known for this. There are innumerable instances that flabbergast us. A mother bat can recognise the voice of her off-spring. Birds and big insects recognise their food and go straight for it. The bats' ability to steer clear of obstacles in their flight is well known.

These are outstanding phenomena beyond the comprehension of human beings. Some of these faculties are not detected or explained by modern instruments. Man is unable to copy these faculties in spite of the tremendous scientific and technological progress he has achieved.

The most typical response of the animal world is fear, fear of the unknown and of unexpected changes in their normal surroundings. The startle response, which is spontaneous and uniform in almost all animals, is expressed in different ways. Some animals produce sounds peculiar to their own species, but much more intense and shrill than usual. Domestic animals like cows, horses and sheep tear loose from their tethers, refuse to enter barns, and run for higher elevations. Some, such as pigs, bite each other, or bite off each other's tails, or other animals coming in the way of their flight. Some, such as dogs, dig in the ground or adopt unusual and sometimes belligerent postures. Fishes migrate from their usual habitat, jump out of water, bite each other, or bite aquatic plants. Birds may shun trees and stay on the ground for unduly long periods, or migrate to distant places. Even the mating habits of some animals are reported to change under the threat of an earthquake. Alertness is the principal part of the defensive mechanism of the animal world. A wild animal has no second chance, its first mistake is usually its last.

Animal Behaviour

Tables 11, 12 and 13 show a few earthquakes with observations of animal behaviour.

In a very comprehensive report on 'Unusual Animal Behaviour before Earthquake, A review of possible sensory mechanism', Ruth Buskirk et al. (1981) have dealt with the subject of anomalous animal behavior through intricate laboratory studies and subjecting the animals to different known stimuli.

"....... our major conclusion is that some animals are much more capable than humans of perceiving certain kinds of geophysical stimuli which may precede earthquakes. These geophysical stimuli are seismic or acoustic waves at low frequency (below 50 Hz), electric field changes and olfactory stimuli. Some birds and fishes are more sensitive than humans to sounds with frequencies below 40 Hz; many animals are exceptionally good at perceiving low frequency vibrations through their skin; certain fish are sensitive to electric field changes as small as 10^{-5} V/M and some laboratory mammals also respond to significantly weaker fields, than humans. For these electric and acoustic stimuli the reported levels of geophysical precursors are within the reported perceptible range of some animals which show unusual behaviour prior to earthquakes. Stimuli caused by the release of gases from small cracks may well be perceived by some animals before earthquakes. Recent research has confirmed the remarkable olfactory sensitivity of some animal species, but no quantitative comparison with geochemical precursors can be made yet."

The geophysical stimuli of low frequency (below 50 Hz) electric field changes affect several animals to a marked degree. Some birds and fishes are more sensitive to electric impulses than human beings at frequencies below 40 Hz. Some react to electric changes through their skins and bodily parts peculiar to their species.

As a consequence of physical changes prior to earthquakes, some gases emanate from the sub-surface. These gases are peculiar to the underlying rocks and the nature of their movements. Friction, as along faults, causes gas to issue from great depths. These gases are perceived by some animals along with the numerous fore-shocks.

Laboratory experiments have confirmed that some animals have an uncanny sense of smell. The dog's sense of smell is well known and is made use of by man in tracking criminals and the clandestine 'underworld' movement of narcotics. Some dogs are now trained to recognise the characteristic smells of bombs and explosives. More astounding than that, is their ability to distinguish individual constituents in a mixture of gases, to memorise them, and to track any one of them as directed by their master. One well-known problem that man is faced with, is how to separate an individual signal from amongst a group of similar sounds. Many animals are adept in this regard, much beyond the range of man, and the instruments he has designed, for this purpose. These faculties of animals have been qualitatively examined and studied, but there seems to be no way as yet to quantify their faculties or determine the exact manner in which they operate. The different smells that emanate from small cracks are recognised, far beyond human capacity, burrowing animals, by reptiles and fishes, and even by birds under certain circumstances.

Some animals react to micro-changes in the magnetic field surrounding them, changes caused by many physical precursors, to which some animals are particularly sensitive. Such changes in the magnetic field are comparatively rare, and can seldom be detected by instrumentation even in sensitive areas. The attenuation in these changes may be considerable, but the sensitivity of burrowing animals, of fishes and birds is so great that even the slightest magnetic micro-changes are enough to scare them and make them behave anomalously. Mention has already been made of the magnetic bacteria which align themselves, or move, only in one magnetic direction in spite of efforts to disturb them (Blakemore 1982).

Table 11 *Some examples of animal anomalies observed before some earthquakes, in China*

No.	Earthquake	Time observed	Place observed	Description	References
1.	July 1917 Daguan quake M = 6.5	One month before	Daguan River	Fish floated to surface, jumped to shore.	(1)
2.	July 1969 Bohai quake M = 7.4	2 hours before	Tientsin Zoo	Tiger depressed; pandas held their heads and screamed; loaches, leeches, and turtles restless; yak did not eat and rolled over; swans stayed away from water.	(2), (4) & (9)
3.	May 1970 Tangshan quake M = 4.9	May 24	Tangshan	Cattle refused to enter barns or to eat grass.	(2)
4.	Dec. 1971 Yangtze quake M = 4.75	?	?	Chinese cabbage, Shepherd's purse, Potato vines, bloomed.	(4)
5.	Feb., 1975 Haicheng quake M = 7.3	Late Nov. 1974	?	Some apricot trees bloomed.	(4)
		Middle Dec. 1974	Tantung (Dantong)	Rats agitated and were easily caught.	(6)
		1.5 months before	?	Snakes came out of hibernation.	(4), (5) & (6)
		2 days before	Panjan district	Small pigs bit each other.	(4)
		1–2 days before	?	Pigs did not eat, climbed walls.	(4)
		1 day before	Yingkou county	Cows fought and dug ground.	(4)
		8 hours before	Anshan	Deer ran away	(4)
		20 minutes before	Dantong	Turtle jumped out of water and cried.	(4)
		Shortly before	Dantong	A hen flew to tree top	(4)
		?	Five feeding farm	Chickens flew blindly, geese panicked.	(5)

Limitations of Sampling

While subjecting animal behaviour to scrutiny in the laboratory, cognizance is taken of the fact that the laboratory environment is isolated and almost free from the other influences that obtain in the free outdoor world in which these animals live. And to that extent the laboratory tests will not mirror the full facts, including the normal background conditions, and may not give a complete and final answer. In the laboratory while studying the effects of natural sound due to physical precursors, other conditions such as electrical fields, magnetic fields, gases and ionisation are not simulated. The conjoined effect of several stimuli cannot be fully reproduced in the laboratory, and to that extent the restricted conditions of laboratory experiments are likely to differ from the free behaviour of animals in their natural habitat.

At best we can take only a small 'sample', that is, a few individuals of the species. That sample may not include the most sensitive animals in the flock. In migrating birds, for instance, one member leads the flock. He is not 'voted' democratically. He just takes the lead and the rest of the flock follow in a far more disciplined way than human beings do. This group behaviour, and that too mainly in flight, can never be tested in the laboratory. Some animals seem to be amenable to laboratory tests, such as rats and rabbits. But larger animals, and in particular wild animals or shy animals, when isolated from the group will not behave normally or naturally. Therefore, we are not

Table 12 *Some examples of animal anomalies observed before some earthquakes, in Japan*

No.	Earthquake	Time observed	Place observed	Description	References
1	2	3	4	5	6
1.	Nov., 1855 Edo (now Tokyo) quake M = 6.9		Downtown Tokyo	Many crabs crawled onto land.	(2)
		2–3 months before	Downtown Tokyo	Sparrows did not return to their usual tree that year.	(1)
		10 days before	Chiba pref.	A chicken would not enter its coop and stayed on a house beam.	(1)
		3 days before	Chiba pref.	Cows left noisily; grass snails came out of their burrows.	(1)
		shortly before	Downtown Tokyo	Eels excited and could not be caught as usual by an experienced fisherman; catfish were caught instead.	(2)
2.	Oct., 1891 Nobi quake M = 7.9		Atsuta coast, Aichi pref.	Sillages were not caught by local fishermen.	(2)
			Oyama	Rats were excited, crows left the forests, and sparrows left their nests.	(1)
		Several days before	Aichi pref.	Winged ants dispersed	(1)
		3 or 4 days before	Aichi pref.	Many mudfish came out of dry rice fields. Several wells became muddy or their water levels reduced.	(2)
		1 day before	Gifu pref. several hundred metres from fault	Wild cats cried.	(1)
		1 day before	Konomi, Aichi pref.	Pigeons disappeared from their nesting site.	(1)
		1 day before	Nagoya (30–40 km south of the epicentral area)	A restaurant called Rathouse had rats which ran around in the daytime; but in the evening preceding the quake, they gradually disappeared. Family members talked about it as a disaster precursor.	(1)
3.	June 1896 Sanriku quake M = 7.1			Rats were unusually quiet. Sea urchins appeared.	(1)
				Sea snakes went up the river.	(2)
		about 3 months before	Iwate pref.	Eels were caught in spring; Laver grew on beach.	(2)
		about 3 months before	Tokai area	Spatial pattern of tuna catch was unusual.	(2)
		a couple of days before	Miyako	Trepangs disappeared.	(1)
		same day	Iwate pref.	Trout ascended rivers.	(2)

Table 12 *(Contd.)*

1	2	3	4	5	6
		6 hours before	Akita pref.	Sky changed its colour to red with clouds lowered. Temperature increased from 77°F in the morning to 82°F in the afternoon. Crows and other birds left trees.	(1)
		20 minutes before	Akita pref.	Birds cried for 20 minutes.	(1)
4.	Sep., 1923 Kanto quake M = 7.9		Sea adjacent to Tokyo	Larger size mackerels were caught instead of horse-mackerels.	(2)
			Coast of Sagami Bay, Kanagawa pref.	Poor fish catch, especially of yellow tails. Bonitors and tuna did not appear as usual.	(2)
			Chiba pref.	Eels disappeared.	(2)
			Saitama pref.	Catfish appeared and bred tremendously.	(2)
		about 3 months before	Offshore Kinkazan	Mackerel-pikes were caught in off-season.	(2)
		about 3 months before	Tamanaka lake Kamata	Catch of crustaceans increased; lake water appeared muddy.	(2)
		about 1 month before	Tokyo	Eels and chars appeared.	(2)
		about 1 month before	Kawasaki	Many catfish reappeared.	(2)
		1 week before	Kamakura	Shrimps and gobies appeared.	(2)
		? days before	Downtown Tokyo	Catfish splashed in a wash-tub.	(2)
		5 or 6 days before	Yokohama	fish died; water muddy.	(2)
		several days before	Hayama coast	A deepsea fish (Nemichthys avocetta) found floating on the surface.	(2)
		1-2 days before	Yokohama	Large numbers of crabs crawled on beach.	(2)
		1 day before	at the mouth of Yokohama Bay	Large school of sardines appeared.	(2)
		1 day before	Downtown Tokyo	Catfish splashed noisily in a restaurant pond.	(2)
		1 day before	Yokohama City	Gray mullets came to surface.	(2)
		1 day before	Arakawa River	Sweetfish caught in off-season.	(2)
		1 day before	Coast clost to Manazura	Good fish catch of breams, basses and gray mullets; their sizes were larger than usual.	(2)
		1 day before	Tokyo Bay	Unusually poor fish catch; calm water.	(2)

Table 12 *(Contd.)*

1	2	3	4	5	6
		1 day before	Kamata, Tokyo	Good catch of crustacians in a pond.	(2)
		? hour before	Rivers at Yokohama	A large number of fish died in agony.	(3)
		several hours before	Tokyo Bay	Bonitos appeared in large quantity unusually close to shore.	(2)
		several hours before	Sagami Bay (?)	Fishermen observed many deepsea fish of the cod family floating dead at the surface. Fearing a disaster, they returned to land.	(2)
5.	March 1933 Sanriku quake M = 8.5	1932	Funakoshi Iwate pref.	Crabs were not caught that year.	(1)
		Sep.-Dec. 1932	Shizugawa Bay Miyagi pref.	Large school of sardines appeared; might be due to some ocean current effects.	(2)
		about 1 month before	an elementary school, Iwate pref.	Rats disappeared and did not gnaw rice cakes.	(1)
		1 month before	Futamata village Miyagi pref.	Rats became unusually quiet.	(1)
		15–16 days before	Unosumai Iwate pref.	An unusual species of crab was caught.	(1)
		1 week before	Funakoshi Elementary school Iwate Pref.	Rats disappeared.	(1)
		2–3 days before	Kamaishi Iwate pref.	Rats and cats were unusually quiet	(1)
		"	Ishinomaki Harbour	Sardines caught there had mud in their stomachs.	(2)
		2–3 days before	Futamata village Miyagi pref.	Pheasants flew down from a mountain and cried a little more frequently than usual. It was not clear whether they came to feed or to find a mate. No crying sounds were heard after the quake.	(1)
		1 day before	Hachinohe	Sea gulls left their usual habitat in Kabura Island.	(1)
			adjacent sea of Misaki Kanagawa pref.	Benthonic diatoms instead of planktonic diatoms were found in sardines.	(2)
		Several hours before	Ofunato Iwate pref.	A duck stayed away from its usual sleeping place.	(1)
		3 hours before	an elementary school, Iwate pref.	A rat appeared in an unusual place.	(1)
		before and after	Tate Village Aomori pref.	Dace were hard to catch before, but were easily caught after the quake.	(2)

Table 13 *Some examples of animal anomalies observed before some earthquakes in Western Countries*

No.	Earthquake	Time observed	Place observed	Description	References
1.	1805 Neopolitan quake	?	Naples, Italy	Oxen and cows bellowed. Sheep and goats bleeted and tried to break out of their pens. Dogs howled terribly. Geese and fowl made noise. Horses were greatly agitated. Cats tried to hide and their hair bristled. Rabbits and moles left their holes. Birds rose, as if scared. Fish left the sea bottom. Ants and reptiles emerged from holes. Locusts entered streets; Winged ants entered houses. Sparrows not seen nor heard for a week prior to the earthquake.	(1)
2.	Feb. 1835 Concepcion quake.	1 hour 40 minutes before.	Concepcion, Chile	Flocks of sea birds flew inland.	(3) & (4)
		?	Talacahano, Chile	All dogs escaped from city.	(4)
3.	Feb., 1887 Liguria quake	Preceding night	Liguria, Itlay	Dogs barked and howled; horses panicked	(12)
		Several minutes before	Liguria, Italy	Fowl escaped from pens. Peacock cried. Carriage horses stopped and refused to proceed. Parrot beat wings violently.	(12)
4.	May, 1976 Friuli quake M = 6.7	2–3 hours before	NE Italy	Deer formed flocks; cats left houses; none left in village.	(12)
			„	Mice and rats left hiding places; a fowl refused to roost.	(12)

*The column "Time observed" is the time observed relative to the occurrence of the main shock tabulated under the "Earthquake" column.

** Reference cited in Table :
(1) Anon (1881), (2) Lawson (1908), (3) Von Hentig (1923), (4) Milne (1939), (5) Fischer (1960), (6) Adams (1964), (7) Engle (1966), (8) Lane (1965), (9) Anderson (1973), (10) Dewy & Mandino (1973), (11) Werner (1974), (12) Tributsch (1976).

Source: Lee, Ando and Kautz., U.S.G.S. Conference I, 1976, pp. 23–43.

likely to get the final analysis of animal behaviour from mere laboratory studies of single individuals. However, we shall have to be content with establishing how a few individuals of the species will generally beh°ve in the laboratory experiments, and extrapolate those findings to the free range or to the rest of the species. The migration of animals from one country to another in search of food, is a well-known phenomenon in Africa. Zebras, wielderbeast, wild buffaloes and several other wild animals, migrate in an orderly manner, guided by their biological clock which determines the exact time, almost precise to a day of a year when all individuals of the species are urged from within to follow this annual ritual. The communication is in their own peculiar or specific language which—at least with our present knowledge of animal behaviour—our laboratories cannot fathom or simulate.

However, although today's laboratory studies can tackle only a limited number of species, and subject them to limited tests isolated from the factors of the natural environment, serious studies are in progress in many countries on this aspect of animal behaviour, and there is good hope that fruitful results may be achieved.

Period and Distance of Reaction before Earthquakes

Several studies have been made listing how long before the real event, the animals show their reaction (table 14).

The sensitivity of animals can be judged from the distance away from the epicentre at which they start to react (table 15).

The general conclusion drawn by Buskirk and others is that:

(1) Most of the animals prone to this behaviour react within the epicentral areas. They react up to two days before the earthquake. The common animals in this category are dogs, horses and chickens. Horses and pheasants responded 5 to 10 days before the earthquakes.

A majority of animals react only a few hours before the earthquake.

(2) Animals perceive the P waves which are faster and less intense, while humans perceive the S waves which are slower but stronger.

(3) On all counts, whether it be the long distance from the epicentre or the longer interval of time before the quake, such animals as fish and rats are sensitive in a variety of ways and do exihibit anomalous behaviour.

Table 14 *How early animals react*

Peiod before	Animals
Less than one hour	— Horses, chickens, rats, dogs, cattle and some fish.
1–4 hours	— Dogs, rats, horses, deer, chickens, cats, eels, snakes, cows.
6–12 hours	— Chickens, dogs, cats, fish, frogs.
1 day	— Cows, rats, fishes, chickens, cats.
a few days	— Rats, fish, eels, horses, snakes, chickens.
a few weeks	— Fish, pigeons, snakes, rats.

(After R Buskirk et al. 1981)

Table 15 *Reaction by Distance from epicentres*

Epicentral area	Animals known to react
20–50 km	— Chickens, pigeons, flying birds, dogs, fish, frogs, rats, goats, eels.
70–100 km	— Horses, chickens, frogs, deer, cats, goats, snakes.
150–200 km	— Horses, pigeons, fishes, birds, rats, flying birds, eels.

(After R Buskirk et al. 1981)

These conclusions must be read against the background that not all earthquakes are similar. In fact no two earthquakes are exactly alike. The micro-seismic shock waves, having the smallest amplitude and lowest frequency, also vary widely amongst themselves. And some animals are more sensitive to them than others. Again, the time gaps between successive fore-shocks are unequal.

Just as the aptitude of each species differs from that of others, so does the aptitude of one individual differ from that of his fellows, so that not all members of the same species will necessarily react with equal speed or equal intensity in all cases. There is no possibility that every member of the same species will react in a similar fashion. While a few members react violently, others fail to show any perceptible effect. The difference may be attributed, in part at least, to the age group, the sex or the physical condition of the individuals concerned.

If we compare differences in human behaviour we shall notice a wide range of variation. If somebody from outside the earth were to observe human behaviour he would not find it any less divergent than the behaviour of any one species subjected to the stimulus of earthquake precursors.

One more point needs careful consideration. If in any area the fore-shocks are too frequent, the animals become somewhat used to them and fail to show the startle reaction which is what animals are known to show under similar circumstances. Take a fish from an area like the Java Trench, which is visited by earthquakes every few hours. This fish will be conditioned to frequent shocks and may grow immune to them. This is one of the plausible explanations why animal behaviour led to a final successful prediction in Haicheng whereas in Tanshan, hardly 400 km away, and within a time span of only 1½ years, the earthquake was not anticipated. This may well be because the animals behaved in much the same way in both cases but the human observers at Tanshan failed to read the same warning in the same animal behaviour.

The question of animal behaviour as a precursor has many facets, all leading to the necessity of our spreading the knowledge of anomalous animal behaviour, and the reasonable deductions to be drawn from that behaviour as widely as possible.

Responses of Animals to Different Stimuli

Sounds and Vibrations

Sounds, ultra-sounds, and physical micro-displacements of rocks on the surface form the background of most earthquakes. What appears to a man to be a calm and quiet atmosphere is actually a din of noises varying in quality, tone, pitch, and intensity. Detection of these through auditory sensors is necessary for most animals for protection, communication, searching for food and finding mates. Against this background, the crepitation caused by micro-fracturing of rocks, in even the smallest of microseisms, is noticed by some animals.

Earth sounds are all-pervading. We do not know the exact causes of many of them. The frequencies of some are known to be below 100 Hz. Earthquakes produce some noises of even lower frequencies, nearing 1 Hz. Some animals can distinguish between the higher and the lower ranges, and react to the lower frequency in spite of the presence of other frequencies and noises. Different animals have varying thresholds of these noises. Codfish and pigeons can single out frequencies close to 1 Hz, whereas human beings can detect only those between 50 to 10,000 Hz. Several other animals—in particular, fish other than cod—are among the earliest to react to this precursor. Several rodents are observed to run out of hiding in sheer fright.

Human beings, in comparison with most animals, have a narrow or limited range of sound perception. According to Monagan (1981) we notice sounds of 1000 to 4000 cycles per second (cps). We are insensitive to sound beyond 20,000 cps and below the thousand range. Some animals like dogs, cats, foxes, hear up to 60,000 cps. Rats, mice, bats, whales and dolphins can emit, and also detect, sounds of 100,000 cps and even below 1000 cps. Bats in search of prey, by creating lower range noises, can close their inner ear and concentrate on such low ranges only.

Infra-sounds below 100 cps are beyond the reach of the most sensitive human ears. In a study Melvin Kreithen of Carnegie University discovered that homing pigeons can detect sounds as low as three cycles per minute thereby alerting themselves to even an approaching but still distant storm. Cod and other fish perform the same miracle under water.

Dog as Forewarner of Earthquakes

The dog, known for his susceptibility to several physical precursors, is pre-eminent in this field. However, man is not inclined to take dogs seriously because they behave in an almost similar manner, for other reasons also. And it is sometimes difficult to differentiate such behaviour from behaviour provoked by an earthquake. According to Buskirk (1981) dogs are mentioned more often than any other species in the behavioural reports. This may be because dogs are more sensitive than other species to many earthquake precursors occurring at the same time, or simply because they are more easily observed by human beings. Some pet dogs are watched as intimately as a member of the family, and any odd behaviour seldom escapes attention.

Dogs are reported to have responded in numerous incidents of earthquakes, from 1 to 24 hours before the main shock.

Acoustic Precursors

Even the slightest movement in the rocks can generate acoustics or micro-sounds. Invariably even the earliest of micro-seismic movements create peculiar sounds. Instruments can record between 40 and 70 Hz. Some animals can detect these early fore-shocks and react to the unusual noises. The effects of depth of focus and distance from the epicentre, are very significant. Invariably distance attenuates signals. Yet some animals do recognise these fore-shocks. Almost all earthquakes of M 4 and above have fore-shocks which generate microsounds detectable by animals.

It is relevant here to repeat that there are not more than about 4000 precision seismographs in the whole world, which means that many fore-shocks, in innumerable areas of the globe, go undetected by modern instrumentation. According to Buskirk et al. (1981) it is quite possible that many fore-shocks which stimulate unusual animal behaviour, are not detected by seismographs. The conventional seismographs are not very sensitive to frequencies below 10 Hz and the micro-earthquakes of much higher frequencies. Besides, although some seismographs can detect earthquakes as low as M 1.5, yet several earthquakes up to M 4 have gone undetected. It is therefore no surprise that animals, which are ubiquitous, detect the micro-earthquakes whereas the instrumentation, inadequate in number as it is, sometimes does not record sounds with frequencies below 50 Hz and above 10,000 Hz. The human range of audibility is similarly restricted.

The infra-sounds of frequencies below 50 Hz apparently agitate and even frighten a wide range of animals. Pigeons are susceptible to frequencies lower than 10 Hz, and in some cases they have been affected by frequency of 1 Hz. The homing power of pigeons is linked to this hearing acumen in addition to others such as orienting on the basis of ambient magnetism.

The threshold sensitivity data on fishes indicate that they can sense earthquake-generated pressures. Fishes are reported to have responded to quakes of Richter scale 2 magnitude and are probably the most sensitive to sound waves in the low frequency range, being endowed with several sensory organs for detection of sounds beyond the sensitivity range of land animals. The aquatic environment is conducive to the quick propagation of sound waves and there is comparatively little or no attenuation due to higher density. The inner ears, the air-filled swim bladder, and the lateral line system, are the unique features which make fishes supremely sensitive to shock and sound waves, far more than many other animals which are known to respond to geophysical micro-scale percursors. Fishes can distinguish between the phase of the waves, their rarefaction and compression, which most other animals cannot do. In addition, fishes seem to have perfected the direction-finding mechanism which enables them to move in the direction of the source of the stimulus or away from it, depending upon whether they are attracted by the sound (as in a mating call) or are scared away from it (as in the case of predators or earthquake precursors). Not only can they differentiate meaningful signals from mere noise, but they react differently according to the nature of a signal and their evaluation of it.

Even though man is the apex of creation, he is surpassed in sense perception by many animals. In fact in every organ of sense perception man is not the pacesetter.

While ears are a specialised device for detecting sound and evaluating its nature, the wide range of musical notes and their inter-relation, as in high-class music, is a matter calling for elaborate training and study. Besides the ear, man can also perceive vibrations through other parts of the body. The touch of a foreign body anywhere on the human body is promptly detected, largely through the skin. Even the blowing of air on any part of the body is at once recognised if the senses of the person are alert. These capabilities can be enhanced by training; for instance, a blind man after practice can read a playing card through touch which perhaps a sighted man cannot think of doing.

The vibration frequencies of many animals, including man, have been studied by a number of animal behaviourists and biophysicists. Sensitivity to vibrations is perhaps highest in cockroaches, who are followed by snakes, humans, fish and monkeys, in that order. Animals have an advantage in that they are constantly in direct contact with the ground whereas humans are separated from the ground in various ways. Shoes seriously hamper human sensitivity to ground vibrations and a man may not detect or feel an earthquake of M 1 or 2 or even 3. Here again, the degree of sensitivity varies widely. Concentration, or the directing of attention to external stimuli, is less in humans than in animals. The latter are perpetually on the alert against dangers, whereas a man may be so deeply engrossed in thinking of other matters as not to perceive the stimuli. Animals have few or no distractions and therefore are more sensitive to vibrations or other stimuli. The skin, hair, and soles of the feet communicate vibrations to an animal's body far more effectively than these features do for a human being.

Buskirk, Frohlich and Latham of the University of Texas (1979) have conducted laboratory studies on various animals such as rats, pigeons and codfish, and on human beings and tabulated the responses to sound of various frequency changes. They refer to works of several other scientists who have conducted similar experiments on animals, of frequency change of sources of earth noise, with hearing thresholds of pigeons, codfish, rats and human beings. Figure 7 shows sound frequencies against sound pressure level.

Their conclusion is that several animals investigated by the authors and reported in the Conference (No. XI)—1979 pigeons, kangaroo-rats and codfish—have much keener hearing than human beings, in the sound range of 25 to 50 Hz. These species have also been cited as showing unusual behaviour before earthquakes.

Animals like snakes, the larger part of whose bodies are in contact with the earth, are at an advantage since they have a relatively large area to collect signals from, and are sensitive to frequencies of 100 Hz and below. With animals, the distinction between hearing and the perceiving of vibrations through touch is very small, because their feet and clawpads are spread out and hence better adapted for catching vibrations. Insects are by nature sensitive to vibrations of amplitudes less than 10^{-8}m, and in the frequency range of 500 to 5000 Hz.

Olfactory Sensitivities of Animals

The sense of smell is well developed in almost all the animal world, being employed mainly in the search for food, tracing the opposite sex, anticipating the approach of a predator or a prey or protecting young ones and home territory. The degree to which this sense is

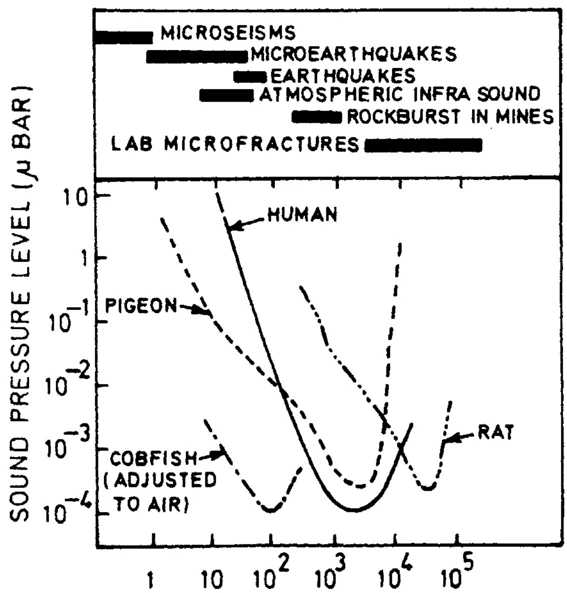

Figure 7 Sensitivities of animals to Sound—thresholds of animals
Source: Buskirk, Frohlicks and Latham *'Animal behaviour prior to earthquakes'*, Conference XI, U.S.G.S., 1979

developed varies in different animals. The shape, size, construction and tuning of the olfactory organs differ from one species to another. Some insects perceive smell through a proboscis in the head, others through other parts of the body. Snakes perceive smell through the tip of their forked tongues.

The olfactory sensitivity of animals is used by man in several ways. The favourite French and Italian delicacy truffles, a well known fungus, is explored with the help of animals. Truffles are found 10 to 13 cm below the ground. They give rise to a peculiar scent which is easily detected by pigs, dogs, goats and bear cubs. (Encyclo. of Mushrooms p. 98). Pigs have the keenest sense for hunting Truffles and can do so from 30 to 50 metres away. However, the pigs are themselves fond of truffles and dig for them and eat them. Therefore dogs are preferred for the purpose.

A female silkworm moth produces less than a millionth of a gram of sex attractant, which is carried by wind in all directions. Male silk-worm moths have nearly 25,000 receptors and are known to trace only a few of these particles over a kilometre and to find the female without fail.

Diffusion of gas in the atmosphere is a phenomenon that stimulates the animal world exposed to the atmosphere. Burrowing animals and forms of aquatic life are less often subjected to gaseous emanations unless the gases emanate from the rocks below their hide-outs. In marine earthquakes, the sea creatures are affected by gases in some cases; but in many others, the gases seem to get dissolved in the water, and therefore exert no effect on marine life.

The sensitivity of animals is sometimes amazing. For instance, dogs are perhaps 10,000 times more sensitive to smell than many other animals. Some animals recognise sex in the same species by smell alone from distances as large as a few kilometres. Mice can recognise their own species from some 15 to 20 known ones, by smell alone. Some birds (e.g. petrels) can locate their nests by the odour. Snakes, through their vomerobasal system, can smell minute amounts of odorants and thus recognise prey or predators in the vicinity. In areas where the rocks contain minerals or elements like sulphur, any disturbance by an earthquake may give rise to strong effusion of smells.

Moulton (1979), writing on the influence of odour, gives long lists of animals which are sensitive to minute traces of odour such as bears, catfish, cattle, deer, dogs, eels, frogs, horses, pigs, pigeons, rabbits, snakes, tortoises and wolves.

There are innumerable instances of emanation of gases before earthquakes, sulphurous odours are known to have been responsible for scaring a large number of animals in the above list, driving them away from their normal habitat. Moulton quotes Gold (1980), who examined reports from many countries of more than a hundred earthquakes occurring over, during the last 300 years, and who reported that the one gas predominating over others, in these quakes, is sulphur dioxide. A dog has an olfactory organ, considerably smaller than that of a deer or a horse, and yet may detect some odorants in concentrations 100 to 1000 times lower than can be detected by human beings.

Methane, and similar hydrocarbons and radon are also associated with gases emanating before earthquakes. Gases, which are released by microfractures from cracks within the rock, also cause flames, lights, highly obnoxious smells, hissing sounds, fountains, bubbles in water, etc. And all these manifestations of earthquakes affect animals in their own ways.

Olfactory Sensitivities of Different Species

Sensitivities of some animals are given in table 16.

Most birds have a well-developed olfactory sensitivity, for instance —

Chicken	pentane	18.1 ppm
Chicken	hexane	2.3 ppm
Pigeon	heptane	0.44 ppm

Mammals like chimpanzees and other primates are sensitive to gaseous emanations of extreme dilution. Chimpanzees grow restless a day before an earthquake. About 80% of the instances of anomalous animal behaviour in Japan relate to fish.

Table 16 *Absolute olfactory sensitivity of some animals*

Animals	Odorant	Range of vapour saturation
Human beings	Pentyl acetate	$10^{-5} - 10^{-5.5}$
Dogs	,,	$10^{-6.5} - 10^{-7}$
Dogs (threshold)	,,	$10^{-8} - 10^{-9}$
Rabbits	,,	$10^{-4.5} - 10^{-5}$
Rats	,,	$10^{-5} - 10^{-5.5}$
Pigeons	,,	10^{-4}
Tortoises	,,	$10^{-5} - 10^{-5.5}$
Dogs (Vapour saturation, 1000 times more sensitive than humans)		$10^{-8} - 10^{-9}$
Catfish (bottom dwelling)	Amino acids	$10^{-9} - 10^{-12}$
Tiger salamander	Benzaldehyde	$10^{-5.5}$

(Source: Moulton (1979))

In conclusion, Moulton (1979) thinks that sulphurous odorants take the lead in gaseous emanation before an earthquake, to be followed by radioactive gases such as radon and helium. The animals listed in table 16 are sure to respond to the stimulation of gases however dilute they may be. To each of the stimuli at least one animal in the list will respond and thus indicate the on-coming earthquake. It is necessary to observe the behaviour of all animals and draw our own conclusions.

Detection of Industrial Gas Leaks

The high sensitivity of some animals to physical and chemical stimuli, especially through their olfactory ability, can be an asset to human society if we shed our indifference to animal behaviour. We can utilise the acumen of these animals to our benefit.

The leakage of gas at Bhopal is now known all over the world. Whatever the reasons for the leak, it was obviously not noticed till it was too late. Probably the persons in charge of the tank of lethal liquid or gas storage could not detect any leakage earlier, because the threshold of human beings is too high as compared with that of certain animals.

The early history of the mining industry mentions birds like canaries being taken down the pits. If lethal gases were present, in excess of the birds' tolerance limits, the birds died of gas poisoning, which served as a danger signal to the miners, who thereupon ran for safety. Canaries are 15 times more sensitive than human beings to these gases. Rats were also taken down in the mines; as soon as they heard the infrasounds of cracking in the roof or the walls of the mines, the rats ran helter skelter giving a warning to the miners.

Some insects, such as bees, abandon their hives on sensing dangerous gases. It is possible that if animals of the right sensitivities are kept in the vicinity of gas tanks liable to leak, they will be the earliest to detect the presence of gases and give warning through their peculiar behaviour. It is conceivable further, that by careful study we could select the appropriate animals for announcing gas leaks earlier than man or even some instruments can do.

If the gas is heavier than air, it will tend to remain near the ground and snakes, rodents, tortoises, rabbits and frogs will be affected sooner than others. If, on the otherhand, the gas is lighter than air, then dogs and some birds, including pigeons may announce its presence and thus avert a catastrophe. If the gas leak is in water catfish and other fishes will respond in their own peculiar way.

Since the Bhopal tragedy, gas leaks are being detected in many parts of India and some other places in the world, from industrial establishments which are obliged to store lethal and dangerous gases. It seems logical to consider the use of selected animals for detecting gases in good time to avoid the danger of deaths and disabilities.

Earth's Electrical Phenomena

The earth has its own electric field which, at sea level, amounts to 100 to 300 volts/m. As we go higher in altitude we do not get as wide a field. In fair weather the diurnal variations of the vertical field have been measured as ranging from 100 to 2000 v/m. According to Ruth Buskirk local electrical storms produce as much as 10^3 v/m. The maximum recorded is about 10^4 v/m. Telluric currents, which are ubiquitous, change their intensity, amplitude and direction frequently. During an earthquake or during storms, these changes are intensified several times. The telluric currents change intensity to more than 4 times the normal in a day. During the Haicheng earthquake (M 7.3) in 1975 the fluctuation was very severe. However, the pre-earthquake changes are caused by several other consideration also, such as the electrochemical potential across the electrodes. It is difficult to determine accurately the magnitude of the changes before earthquakes of magnitude 7 or more. Electrical changes can be due to several other causes, such as spontaneous ionisation.

When the sub-surface rocks fracture under tension from below, the friction causes generation of currents which are communicated to the surface. Their access to the surface will be facilitated or retarded according to the conductivity and other characters of the intervening rocks.

Electric eels, as also some other fish, have a specialised organ which either generates electricity or detects the currents, judges the direction of their source, and communicates the danger to others.

The passage of an electric current is swifter in water, less swift in rocks and still less in the air. Consequently, terrestrial animals are comparatively less sensitive to electrical changes than aquatic animals, requiring four times the magnitude of electric changes that aquatic animals require to be affected. Hence, the startle reaction in land animals through this electrical stimulus is less spectacular than in the aquatic animals.

The reaction of the animal world to these currents depends upon biological make-up, peculiarities of environment, group behaviour and state of health.

Writing on electrical field changes in a paper read at USGS Conference XI (1980) Ruth Buskirk et al. describe fish and other aquatic animals subjected to DC electric field changes. Their results are incorporated in a diagram (figure 8).

Sharks and electric fishes are sensitive to 10^{-6} volts/cm whereas rats are sensitive to only about 10^2 volts/cm.

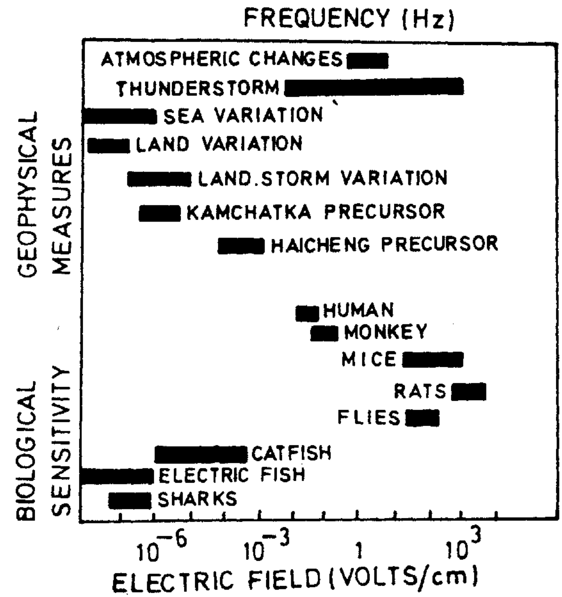

Figure 8 Sensitivities of animals to Electrical Field Changes—thresholds of animals
Source: Buskirk, Frohlicks and Latham *'Animal behaviour prior to earthquakes'*, Conference XI, U.S.G.S., 1979

These effects are broadly physiological, nervous or psychological. The behavioural changes are sudden and contrast with normal behaviour shown when animals are at rest, or are not agitated by any external stimuli such as sexual excitement or fright induced by a predator, or concentration on their prey. Against this background the electric field changes exercise a somewhat smaller effect. But the most conspicuous reactions are exhibited by animals which normally adopt a peaceful stance. Field changes as low as 10^{-5} v/m, according to Ruth Buskirk et al., cause a variety of physiological and chemical responses in land animals including mammals.

The Fisheries Experimental Station in Tokyo, reports "Tributsch (1982) started a systematic watch of catfish, which have played a big role in Japan's earthquake prediction". Shojiro Nakamura discovered that the 10 catfish, observed between December 1977 and July 1978 announced 17 out of 20 earthquakes by their unnatural behaviour. Before a severe earthquake in January 1978, which claimed many victims and destroyed several houses, the catfish circled the basin as many as 60 times a night, whereas normally they would tour only 5 or 6 times.

Flying birds are easily affected by ionisation or electrical discharges, such as occur during storms.

Piezo-electricity

The mineral quartz which is present in many rocks, when in crystalline form and subjected to stress in one crystallographic axis, generates electricity called piezo-electricity. Quite apart from the friction caused by the movement of rocks, a slow steady unidirectional stress causes generation of electric fields. According to Tributsch (1982), this stress is one of the most potent sources of electric fields and field changes in the context of earthquakes. Piezo-electricity generated in the micro-crystalline quartz rock is, according to the Soviet geophysicist Parkhomenko, less than in a single well-develpeq quartz crystal. Therefore coarse-grained and porphyritic rocks generate more electric fields. Some other minerals besides quartz, such as tourmaline, also generate piezo-electricity. If these grains are aligned in the direction of the internal stress caused by dilatance or cracking in an earthquake, the effect is significant for the animal world.

This effect also causes air-borne ions before earthquakes. Since stress is a gradual process, emanation of ions proceeds almost continuously before an earthquake. In areas where an earthquake is building up, this phenomenon is manifest much beforehand. The all-pervading telluric currents in the subsurface react with these ions and either neutralise the piezo-electric effects or accentuate the phenomena to a magnitude which stimulates animals to show sudden and violent reactions. Potential changes of 30–300 millivolts were found to have been generated in the Kamchatka earthquake (Tributsch 1982) several hours or even day before the quake. The Haicheng earthquake also exhibited this phenomenon as a precursor. Humbolt observed that a little before an earthquake, his electrometer showed sudden deflection of the leaves without any known provocation in the room. This was soon confirmed by the earthquake that followed within some hours. Dogs, cats, sheep and human beings were restless and some became excited in excess of normal behaviour. The Chinese scientists at the Geological Institute at Beijing (Peking) report that there was an obviously strong change In the electric field of the earth before the Haicheng earthquake. 'This leads us to the conclusion that a great difference in potential ionised the air, which is in itself an important earthquake precursor and perhaps one of the most important causes of anomalies.' (Tributsch 1982).

Changes in the density of air ions, according to Tributsch (1982), cause strange behaviour in animals, which is in some respects similar to their behaviour during storms. To that extent it may be difficult to distinguish whether the unusual behaviour is due to the approach of a storm or of an earthquake. However, storms do not occur as unexpectedly as earthquakes do, and hence there are greater possibilities that the above unusual behaviour is the precursor of an earthquake. An experienced observer can distinguish between the two. Tributsch vouches that charged aerosol particles are more abundant prior to earthquakes. Radon emanation, according to Yost (USGS, open file report 80–453, 1980), would increase the total ions present in the background electrical field over several days or weeks before an earthquake. This could also be caused by change in the groundwater level or piezo-electric effect.

Animal reactions directly attributable to the electric field changes, or changes in the concentration of aerosol particles, are many and varied. Chickens fly wildly, pigs, as stated earlier, start biting each other and even bite off each other's tails. Experiments have proved, according to Bach (1981), that with antistatic treatment to the chicken-houses or pig-styes, this external stimulus can be suppresed. The threshold of concentration is about 300 to 2500 ions per cubic centimetre with a concentration of positive ions. Excess of positive ions stimulates rats to hyper-activity as shown by agitation, aggression or excessive sexual emotion. Excess of negative ions produce similar effects on other animals. In any case it is established that concentration of ions affects animals almost invariably and in a variety of ways. In mammals an excess of positive ions increases irritability and sudden changes in normal behaviour such as disoriented physical agitation. Negative ions reverse these changes. Similar effects on the brain were also observed in rats by Diamond et al. (1977).

Response to an electric field among terrestrial animals is far less than among aquatic life. Dogs are not sensitive to electric field changes though they are the harbingers of earthquakes with regard to other physical changes preceding earthquakes. According to Buskirk, mice living in a constant 60 Hz electric field of 800–1200 v/m, show increased nocturnal activity. An electric field of 10 v/m, with frequency range of about 7 Hz, affects the brain and impairs the time perception of squirrels, monkeys etc. Low frequency electric fields of about 2–4 v/m affect human reactions. Monkeys are affected by fields of frequency of about 7 Hz. According to Tributsch (1982) earthquake fogs and earthquake lightning can produce strange activity in animals especially in mental cases, due to the presence of charged particles.

Finally, Buskirk feels that 'ions are still a positive candidate to explain unusual animal behaviour prior to earthquakes. However, with geophysical and biological data available at present, it is not yet possible to make a quantitative interpretation of these phenomena'.

Magnetic Field Changes

The Earth's geomagnetic fields indicate 60.000 gammas at the poles and 30,000 gammas at the equator. During magnetic storms this intensity steps up considerably. Also during a storm sudden changes in the magnetic field are caused by atmospherics, especially by lightning. Animals living on the ground, in the water and in the air can detect minute changes brought about in the fields to which they are accustomed. Any change in this intensity affects animals in different ways and they express it by unusual behaviour.

Unlike the air-ion phenomena, magnetism can be easily demonstrated by a simple bar magnet or by observing a magnetic needle which points to the north. The Earth's magnetic field is easily understood, its changes are not easy to understand. For instance, fluctuations in the magnetic fields due to solar disturbances are complicated. As mentioned on page 554, the polarity of the earth changes frequently (geologically speaking) due to solar disturbances. the changes produced by earthquakes can be measured only by observations from at least two or more different stations situated far apart. Magnetic changes are also caused by nuclear blasts, reservoir filling or movements of large rock masses. Earthquakes vary immensely in their form and character. Consequently the effects they produce are equally varied. The changes in the magnetic fields produced by earthquakes vary to a large extent.

'....The Earth's magnetic field is approximately 0.5 Gauss whereas the short term fluctuations due to solar disturbances have been measured at 40, 300 and 700 γ at different sites, ($1\ \gamma = 10^{-5}$ G). Secular changes over a period of about one year are about 1–4 γ depending on the locality. Some of the precursors measured befors 1960, according to Rikitake, have been as large as 900 γ (Buskirk et al. 1981). More recent observations taken with a proton precession magnetometer have been as low as 20 γ. Smith and Johnson (1976) have observed a clear change of 1–2 γ, measured prior to a magnitude 5.2 earthquake. In short, the magnetic precursors can vary from 1–2 γ to some 900 γ. The anomaly can last from a week to some months. A tectono-magnetic effect observed before an earthquake near Hollister, California in November 1974 showed the magnetic change as low as 1 to 2 γ'.

To such small changes in the magnetic field, barely detectable even with the help of a highly stable proton precession magnetometer, some animals unmistakably react. The earliest victims are the homing pigeons and other birds which migrate long distances largely through their ability to align themselves to a set magnetic direction which they are used to. Thus gulls, migrating birds, homing birds, bees and some fishes do react to changes smaller than 10 γ. Higher magnetic anomalies disturb their course to a large extent.

Homing pigeons, according to David Managan (1981), can be thrown off their course of flight by as small a change as 30 γ. If a pigeon is to reach its destination it has to detect not only this minute change but also its trend, and do a mid course correction during its flight. Many birds arc Master Mariners or have super-sensitive in-built magnetic compasses. The global migratory birds cross thousands of miles non-stop and arrive at a pre-set landing on a patch of land, the size of a football field which is infinitely small by comparison with the thousands of kilometres covered by them in their flight. That their tiny wings can carry them incredibly long distances, mastering the art of manouvering in mid-air, is a miracle. This annual exercise by the whole community, is still an enigma and may well continue to be so for years to come. This superhuman instinct and behaviour is not noticed by many people. Is it any wonder then that these master performers can detect the minutest changes in the ground and the air caused by micro-earthquakes?

Once again, quoting several other authors, Buskirk et al. (1979) have reported on the responses of several animals subjected to magnetic field changes. In a diagramatic sketch they have summarised these responses as shown in figure 9.

Buskirk et al. feel that the animals sense magnetic field changes as small as 10 gamma (10^{-4} Gauss). This is well below the level of precursory changes reported before several earthquakes. Artificial reversal of field and increase in field strength by an order of magnitude above the earth's fields, can be sensed by many species of vertebrates.

Pigeons are not alone in this field. Honeybees and seagulls exhibit the same capabilities. Magnetic changes of 10–30 gammas, recorded prior to recent quakes in Turkey, Japan and China, caused a tremendous uproar and disjointed behaviour among birds, and mass flights of bees.

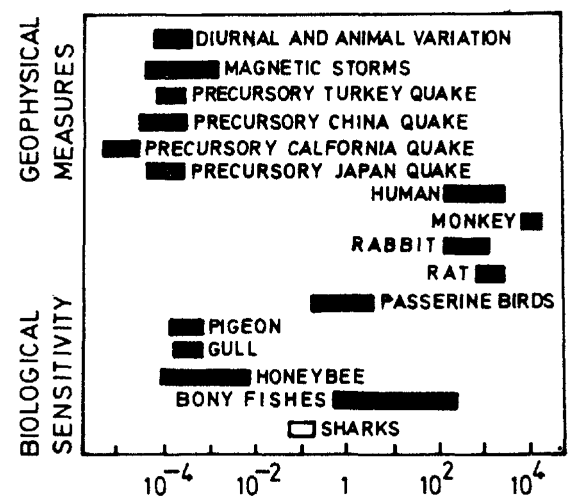

Figure 9 Sensitivities of animals to Magnetic Field Changes—thresholds of animals
Source: Buskirk, Frohlicks and Latham *'Animal behaviour prior to earthquakes'*, Conference XI, U.S.G.S., 1979

Some animals are affected not only by change in magnetic field but even by a reversal of the magnetic poles. According to Buskirk et al. flagellate bacteria of marine sediments, and some worms, are similarly affected and are prompted to change their course. Migratory birds are sure victims of these magnetic effects. Sharks and other marine life respond equally to the minute changes in the ambient magnetic fields.

Mammals require much larger static field changes than fish requires before being affected. Laboratory experiments give different results because it is not known which of the normal sense organs recognises magnetic variation. The magnetic field does not seem to affect animals through the senses of sight, touch, taste, odour, hearing and the electric field changes which affect the nervous system. Their reactions can be judged as being due to magnetic changes whenever other geophysical precursors were not in evidence.

Even bacteria are sensitive to magnetic field. Blakemore (1982) while reporting the recent discovery (1982) of magnetotactic bacteria, writes 'they swarm in the same geographic direction even when the microscope was turned around, moved to another location or covered with a pasteboard box. The bacteria were magnetically responsive. When a bar magnet was brought near the microscope, hundreds of swimming cells instantly turned and rushed away from the end of the magnet'. This would be a new field to watch before an earthquake.

Piezo-magnetism

Some recent research in magnetism indicates that, like piezo-electricity, piezo-magnetism is also generated in the crust by stresses that occur before earthquakes. The minerals responsible for this phenomenon are magnetite, ilmenite, pyrrhotite and sometimes hematite. Piezo-magnetism explains how variations in the magnetic field are generated in the region where earthquakes are building up. These variations are recognised as precursors of earthquakes as mentioned on page 554.

These reactions of animals naturally intensify as the earthquake approaches. While it is possible that similar reactions are exhibited before other natural hazards, yet after some study of animal behaviour, we can distinguish between behaviour induced by an approaching earthquake and that induced by change of weather or other natural hazards.

The major conclusions of Buskirk et al. are that broadly four types of geophysical precursors commonly agitate animals, namely (1) low frequency sounds, (2) ground vibrations, (3) dc electric field changes, and (4) odour. These are amplified below:

(1) & (2) Seismic waves in frequency range of 10–50 Hz; sound pressure variations and

ground vibrations in this frequency range are poorly recorded by conventional seismographs and are below the threshold of human perception.

(3) Electric field changes of which only scattered data are so far available.

(4) The release of gases; gases other than radon and helium, are not reported in high earthquake activity.

Tributsch highlights the influence of electric, magnetic and electromagnetic precursors which affect animals in a variety of ways, generating reactions like depression, fatigue, general debility and deliberately avoiding their usual company. These reactions become obvious to an observer after some practice. Some workers have observed that smell is a fairly common precursor as many rocks contain elements like sulphur, phosphorus etc. which give rise to peculiar smells.

Summary of Geophysical Precursors and Animal Responses

One can do no better than reproduce two more tables prepared by Ruth Buskirk et al. and read at the International Geological Conference No. XI organised by the U.S. Geological Survey in 1980 (tables 17 and 18).

Animals in the Service of Man

In fine, the animal world is alive to all physical stimuli around them. Animals obey their own reflexes and act in the manner they think fit, to save their lives when threatened by unusual phenomena. Their startle reaction followed by flight from the scene, is all we see.

It is for us to study their typical reactions to stimuli that sometimes even modern sophisticated instrumentation cannot detect. One example in which normal behaviour contrasts with abnormal, is the already mentioned case of pigs, which, as a result of the specific stimulus from an on-coming earthquake, get confused and disoriented, and even bite off each others' tails! There is also the example of the fish which jumps out of water even though, instinct tells him, that such a step is suicide for him. Several other examples are quoted. We can make use of this peculiar behaviour to sense that an earthquake may be coming in perhaps a week or so, as was noticed in the Haicheng earthquake of 1975 in China.

Man has to observe the animal worla around him in its own natural environment. The closer our rapport with the animal world, the better we can notice and interpret the signals they give about an earthquake. Animals do not behave in the way they do, out of consideration for our benefit; it is for us to take advantage of the warning they give.

Animals of the same species may behave differently in two different parts of the world, or in two different earthquakes in the same region; this is understandable because the precursors released by different earthquakes may be dissimilar and hence give rise to dissimilar behaviour.

In the Haicheng earthquake in China in February 1975, spectacular animal behaviour appears to have been noticed as reported by Lee, Ando and Kautz of the U.S.G.S. (29).

Some apricot trees blooned, rats were agitated and were easily caught, snakes came out of fybernation, small pigs bit each other, pigs did not eat and climbed the walls, cows fought and dug the ground, dear ran away, turtles jumped out of water and cried, a hen flew to tree-top, chickens flew blindly and geese panicked (see page 592).

It must be noted that Haicheng was recognised as an earthquake prone area and the geophysical parameters were being watched with special care. However, the peculiar animal behaviour which started indications as early as two months before the earthquake appears to have precipitated the prediction. It is reported that several thousand lives were saved by timely warning. In Tangshan, however, the animal behaviour apparently did not impress the people. Possibly the signature of the Tangshan earthquake was different and therefore the physical precursors were also different from those in Haicheng. It is conceivable that the animals did not react as spectacularly as in the case of Haicheng.

Tables 11, 12 and 13 are not sacrosanct. Each country or region, with its specific many-splendoured animal world, will behave differently in the face of the same or similar physical precursors. Each can eventually make its own list of observations to be handed down to posterity. Knowledge grows in each generation and becomes a legacy for the next. Earthquakes happen once in a life-time. Only intelligent and faithful records can guide and save posterity.

There is scope for improving our knowledge and understanding of abnormal animal behaviours, as a precursor of earthquakes, provided we keep an open mind and are willing to pursue unconventional strategies for the good of Mankind.

Table 17 *Geophysical Precursors and Biological Sensitivities (For each type of geophysical precursor at the left, the availability and amplitude of geophysical measures are evaluated relative to the sensitivity of animals)*

Type of earth-quake precursor	Geophysical Data		Biological Sensitivities	
	Field data availa-ble?	Clear precursors sometimes recorded?	Appro-priate level? (1)	Responses widespread among species? (2)
Electric field change	Yes	Yes	Yes	Yes (3)
Low frequency sound	Yes	Yes	Yes	Yes (3)
Ground vibrations	Yes	Yes	Yes	Yes
Odor	Yes (4)	Yes (4)	Yes (6)	Yes (6)
Magnetic field change	Yes	No (5)	Yes	Yes (3)
High frequency sound	Yes	No	Yes	Yes
Microwave radiation	No		?	
Air ion changes	No		?	
Ground water change	Yes	Yes	?	
Gravity change	Yes	Yes	No	
Ground tilt	Yes	Yes	No	

(1) Some animals respond to changes at the level of the geophysical precursors or on the level of ambient noise.
(2) For stimuli at the appropriate level, laboratory studies have documented response to this type of stimulus in at least four major animal groups (phyla of invertebrates, classes of vertebrates).
(3) The trend of recent studies indicates widespread phenomena.
(4) Quantitative data available only for Radon.
(5) Some precursors have been found, but single-to-noise ratios are low.
(6) No evidence is yet available proving that animals are sensitive to geochemical precursors, but olfactory sensory cells are triggered by extremely small quantities of some odorants.
Source: A review of Possible Sensory Mechanisms by Ruth Buskirk et al., Animal Behaviour Prior to Earthquakes, U.S.G.S. Conference XI, 1980

Table 18 *Physical precursors and animal reaction (Unusual behaviour prior to earthquakes has been reported for the animal species listed on the left. For each of the possible precursors below, the table indicates the results of experiments on the sensitivity of each species)*

Animals	Electric field change	Magnetic field change	Low frequency sound	High frequency sound	Ground vibra-tions	Odor
Catfish	+	+	+	−	+	+
Codfish			+	−		
Snakes			−	−	+	+
Pigeons		+	+	−	+	?
Rats	+		−	+	+	+
Dogs	+		−	+		+
Cats			−	+	+	

Source: A review of Possible Sensory Mechanisms by Ruth Buskirk et al., Animal Behaviour Prior to Earthquakes, U.S.G.S. Conference XI, 1980
\+ = animal has greater sensitivity than humans
− = animal has less sensitivity or no better than humans
? = conflicting information
blank = information not available

CHAPTER IV — WHAT CAN WE DO?

Peoples' Response to Earthquake Prediction

Here are two imaginary public annoucements—both made in May 1986:

(1) "An earthquake is likely to strike Northeastern region of India in about 1996."

(2) "An earthquake of M 7 will strike, on 15th July 1986, the city of Megalopolis."

What will be the reactions of the people concerned in the two cases?

In the first case, the prediction is so imprecise and vague in time, space, magnitude and probability that the people will be unlikely to take any notice of it, particularly if the area is thinly populated. In the second case, there will be some panic especially because it is in an urban area and the number of people involved will be substantial. A period of about one month is normally adequate for making arrangements for evacuation, or for shifting to camps outside the predicted ambit of the region likely to be affected. Even so, in urban areas some panic is unavoidable.

The response of the people will also depend upon the credibility of the source of prediction. Even in the second case above, involving an imminent prediction, the degree of people's faith in the prediction is most important. If the prediction is made by the Government, or any reputable scientific organization charged by the Government with this specific responsibility, it will acquire greater credibility than the unofficial prediction of some individual scientist, or of an astrologer.

The whole subject of prediction has now been carefully considered by several scientific and Governmental organizations and a number of publications have appeared on it. Many Governments have established their own organizations for scrutinising such predictions, which are announced only when the Governments feel satisfied.

Although a few earthquake predictions have proved roughly correct, yet on the whole the science of prediction is, as stated on pages 580-581, yet to attain maturity. In Rikitake's (1976) own words '..... Judging from the rapid development of earthquake prediction study in recent years ..... it would not be in the remote future that a realistic warning based on scientific observations of a hazardous earthquake will become possible, at least over areas such as parts of the U.S.A., Japan and so on, where intensive work of monitoring earthquake precursors is in progress'. This was written in 1976. Despite spectacular progress in instrumentation and the study of seismology, very little improvement seems to have been attained in the matter of precision and reliability in prediction. To this we must add the possibility that even the officially recognised prediction can go wrong as indicated on page 579.

The media, newspapers, radio, television (and even loose gossip) always play roles which are not only important but sometimes decisive. Most of these media are looking for sensation, obviously to boost their sales or increase their popularity, even though they write ostensibly in the name of public safety and out of concern for saving the society from damage and destruction. The unscrupulous element in the society has a selfish role to play. If the prediction is backed by some official organization, the scare is even greater. Prices of land and buildings crash, encouraging the gullible to part with their estates and lands which the more shrewd pick up at rock-bottom prices. More complications are likely to be created by unsocial elements; insurance tariffs go up and so on.

Against this background the public's response will be mixed at any time. Its initial reaction may be one of hesitation, while in areas which have been subjected to small, inocuous tremors for long periods, the people may not be stirred at all. Further, there will be less panic if the predicted quake is of some marginal magnitude—say, 4 to below—which is considered as not so dangerous. It is therefore increasingly realised that in any society, organised training and education are essential.

Intermediate Term Prediction

The city of Los Angeles and the Southern California Earthquake Preparedness Project (SCEPP) offer the following suggestions for the Intermediate Term Prediction:

Magnitude	—	Magnitude is of sufficient intensity to cause significant property damage and other related results (within and contiguous to the city).
Location	—	Impact is anticipated to be within or contiguous to the city.
Time	—	The event is anticipated to occur with a time frame of six to eighteen months.
Probability	—	The event is ascribed a moderate to high probability.
Ground Motion	—	Predicted ground motion may be variable within the affected area. It is dependent on several factors such as epicenter, magnitude, geological cosideration.

The SCEPP **50** has also proposed uniform terms of expressing earthquake potential, prediction and probability as follows:

Suggested Terms for Expressing Earthquake Potential, Prediction and Probability

A. Long Term Earthquake Potential	—	No specific time window. Can refer to decades, centuries or millennia.
B. Earthquake Prediction	—	Any specific time window shorter than a few decades.
1. Long-Term Prediction a. Forecast b. Watch.	—	Few years to a few decades
2. Intermediate-Term Prediction	—	Few weeks to a few years
(no subdivisions suggested at present)		
3. Short-Term Prediction	—	Up to a few weeks
a. Alert	—	Three days to a few weeks
b. Imminent Alert	—	Up to 3 days

Source: Table No. 2 (SCEPP **50**, 1983)

In one of the detailed studies made at the U.S. National Academy of Sciences by a panel consisting of seismologists, sociologists and members of other faculties concerned, the subject to earthquake prediction and public policy was discussed in depth. This study has been quoted widely. Rikitake reports at length in his book 'Earthquake Forecasting and Warning' (1982).

Amongst the recommendations systematically outlined, serious attention is solicited to the saving of life, minimum dislocation of social life and loss of property, and steps for mitigation of the hazard. The responsibilities of Governments and public and private agencies are also discussed. The book also covers the aspects of the legal provisions under the U.S. Disaster Relief Act of 1974 which provides for relief to the most needy first. The author stresses that the publication of predictions should be left to scientists rather than to politicians, and that for this purpose a group of scientists should be nominated by the Government well ahead of the emergency. An agency should be appointed specifically for relief and rehabilitation work well in advance of the anticipated event.

The book also recommends that a prediction be issued in such a manner that the public will understand its implications, that a co-operative responses will be obtained from all persons likely to be affected, the assistance of all Government organizations will be secured, and public institutions and private individuals will work in close co-operation.

Public Response to Prediction

The Southern California Earthquake Preparedness Project (SCEPP) also studied the Earthquake Prediction Response in October 1983. Their report directs attention to the liabilities for action taken or not taken by local Governments in response to a prediction. It comprises examination and evaluation of the prediction warning and the decision-making mechanisms. It highlights the responsibilities of both the Federal and the local Governments and the relevant committees set up by them for the purpose.

In 1974 the Co-ordinating Committee for Earthquake Prediction in Japan attempted to assess popular reaction to the prediction of an earthquake of M 5–6 near Kawasaki. The object of the investigation was to ascertain how the citizens received, understood, responded and evaluated the annoucement of the Committee. There was no mention of the probability rating but it was indicated that the earthquake might occur in a year or two. The study covered the degree of intelligent and emotional responses, sources of information, evaluation of the information, general attitude and proposed action. Some of the results as reported by Kisslinger and Suzuki in 'Earthquake Precursors' are reproduced below to illustrate the reaction and response of the people.

(1) *Size of earthquake (expectation):*

Intensity 5	—	21.5%
Intensity 6	—	31.8%
Intensity 7	—	24.9% (stronger than announcement)
Intensity>5	—	6.2% (weaker than announcement)

The percentage of citizens who responded with the higher intensity was four times larger than that of those who thought the intensity was to be weaker than that announced.

(2) *Time of occurrence of earthquake (expectation):*

Within one year or two	—	32.7%
Earlier than that	—	42.0%
Later than that	—	10.1%

The results show that the imminence of the disaster was exaggerated by the citizens.

(3) *Uneasiness (Did you feel particular uneasiness about the prediction?)*

Yes	—	64.8%
Not particularly	—	12.8%
No	—	21.4%

(4) *Source of Information (Q—From which media did you learn of the prediction?)*

Newspaper	—	83%
Television	—	73%
Public information	—	37%
Others	—	10–20%

The primary media source for male subjects is printed matter whereas for women it is radio and television.

(5) *Source of false rumours:*

Gossip	—	75%
Newspaper	—	24%
Television	—	20%

In general women are more easily influenced by rumours than men. Subscribers of local newspapers were more easily influenced. People with less formal education were more likely to be influenced by rumours. Some people are inclined to depend more on the rumours than on the information issued by official sources.

(6) *Evaluation of earthquake occurrence (expectation):*

Will occur	—	20%
Will not occur	—	20%
Undecided	—	60%

Women are more likely to believe the occurrence than men. Strangely, those who lived closer to the predicted epicentre were less likely to believe that the earthquake would occur.

In conclusion, Kisslinger and Suzuki think that the first reaction is one of fear and confusion. People living near the predicted epicentre showed mainly emotional responses whereas people living in distant areas tended to show a dispassionate response.

The basic elements in prediction, namely size of epicentral area, intensity, probability of occurrence, intermediate or immediate nature of prediction, and other factors such as the reputation of the source, scientific basis, consensus of scientists, Government's opinion, economic impact and anticipated severity of damage, etc. are important if the people are expected to react rationally.

The statistics (1) to (6) given above are true of a particular community in a country like Japan, where earthquakes are of fairly frequent occurrence; most Japanese people have experienced earthquakes at sometime. The general preparedness of that country is greater than that of countries which experience earthquakes less often or not at all.

In areas which are not prone to earthquakes, the element of scare and consequent panic is greater. The Governmental preparedness is also material. If the social services and utilities, the police, emergency transport and other essential services are not organised beforehand, or the public is unaware of them, the panic is greater and hence the consequences are more severe.

Political Significance of Prediction

In a very comprehensive book on 'Forecasting Earthquakes', (Srivastava 1983) outlines various aspects of prediction on the society such as political consequences, economic implications, evaluation of future earthquake damage, etc. Referring to the political consequences of prediction he points out that the prediction made by any individual will immediately be discussed in the parliament and the Government may be compelled to announce their proposed action in the matter. Quite often Governments are embarrassed for various reasons. If the prediction is announced in consultation with the Government, officialdom will have to take all precautions to mitigate the damage by adopting measures of hazard prevention, such as are known elsewhere in the world.

Governments are obliged to set up organizations of geo-scientists, seismologists, engineers of various relevant disciplines, and social institutions who are apprised of the latest information available in the country. Since the predictions are apt to be based on partial information and liable to more interpretations than one, Governments are often in a quandary as to whether to recognise the prediction officially or not. The example of the Office of Foreign Disaster

Assistance (OFDA) on page 579 is a case in point. No organization, whether sponsored by the Government or the public, can be infallible in this game of earthquake prediction. In urban areas, if the prediction is precise in time, space, magnitude and probability, it has, as of today, an even chance of going wrong. All that the Government can do is to screen the predictions with the utmost care and be prepared to meet the hazard to ensure the least possible damage to life and property.

The role of governments has been considered by many authorities. California is constantly threatened with the possibility of an earthquake. The Department of Mines and Geology has considered this matter carefully. Oakeshott, formerly Chief of the Department, writing in 'Volcanoes and Earthquakes' on "What can Governments do "emphasises that the role of Government operates in two ways: enacting suitable legislation and taking administrative steps to mitigate the risk. The sequence of steps is: (i) to recognise the nature and severity of the problem, (ii) to devise solutions and make preparations for meeting the problem, and (iii) to plan long-range recovery action. Oakeshott states further that improved building codes to ensure better earthquake-resistant designs, and reinforcement or demolition of poorly built structures, will go a long way in mitigating the risk.

Economic Aspects of Earthquake Hazard

Depending upon the severity of the ground motion, the density of population, and the amount of development of the society, the damage will naturally vary from earthquake to earthquake and from area to area; hence the evaluation of the loss, both in terms of deaths, injuries, and damage to buildings and industries, will require careful assessment which often cannot be completed until long after the event.

In a very detailed study by the United Nations in their Disaster Prevention and Mitigation (UN 1979) the effects of hazards in particular earthquakes are divided into three categories:

(1) Direct effect on the property and income of persons, business enterprises and communities affected.

(2) Indirect effects resulting from reduction in family income and decline in production.

(3) Secondary effects which may appear some time later, such as epidemics, inflation, increase in income disparities, isolation of farming areas.

The economic damage will comprise:

(i) Capital losses such as destruction of housing, factories, means of communication (bridges, roads, railways), schools, hospitals, electricity networks, sanitation systems, etc.

(ii) Production losses resulting in reduction in income, destruction of crops, livestock, etc.

Nature of Earthquake Damage

The nature of the damage that can occur as a reuslt of any earthquake may well be imagined. Everything based upon the stability of the earth is rudely disturbed. If the tilt or displacement of the ground disrupts the equilibrium, structures will fall; Gravity excuses nobody. Therefore, the maximum damage is noticed in the case of buildings. If these are not designed to withstand any substantial ground movement, they will fall. Tall buildings and roofs are the first casualties. In the wake of their collapse, most damage is done to those who are at home; many will be hit by falling debris or become trapped inside the collapsed material. Persons trapped under the debris, shouting pathetically for help constitute a truly gruesome sight. Sometimes steel beams have to be cut before the victims can be rescued alive. The recent Mexico City earthquake gives some idea of the horror.

Essential services such as water-mains, drainage systems, and electrical transmission lines are also seriously disturbed. Broken water-mains cause flooding of the area and leave no water for drinking or for fire-fighting. The sparking of high tension over-head electric cables cause fires, setting ablaze whatever combustible material is in the vicinity. Disrupted drainage lines spread noxious fluids and give rise to the diseases and epidemics, which invariably follow earthquakes.

Faults become activated and accentuate displacement of the ground, producing gaping fissures in which human beings and animals are known to have been engulfed. Telephone and telegraph poles fall down and the services go out of order; communications are seriously hampered or altogether stopped. Railway lines are twisted out of alignment and rail communication to and from the affected area is broken off. In some cases the only access to the affected area is by helicopter.

Large dams in the vicinity may be affected, and in some cases may even burst and cause floods.

On the coast, huge waves called tsunamis lash the shore and bring down houses and other structures and dislocate fishing and navigation.

In the Makran Coast earthquake of 26th November 1945, four new islands had come up through the buckling of the sea-floor. The islands were roughly circular in shape, 100 to 200 metres in diameter and rose to some 10 to 20 metres above the sea level. Some hydrocarbon gas issued from the cracks and fissures. Such islands are a rare phenomenon. They were composed of loose sand and clay and were being eroded fast due to waves and tides. Samples of rocks and gas were collected by the author.

There is no limit to what may happen during an earthquake; anything that can fall, will fall. There is a chain reaction, with one calamity leading directly to another. Along with miraculous escapes from death, like two one-day old babies in recent Mexico City earthquake, there have been no less miraculous hits from totally unexpected sources.

In earthquake-prone areas several precautions are usually taken at the Government level through the utilities and service departments. Do's and don'ts are made known to the public and the builders alike. Buildings are designed to withstand anticipated ground movement. Vulnerable structures and wanton additions are banned. With such preparedness the damage will be commensurately less. Normal urban planning should cover preparedness against earthquakes.

There are very few countries in the world which are thoroughly prepared in all respects. Many houses are over-age, built without any thought or consideration of earthquakes. The fire-fighting services are kept ready but often the fire engines cannot reach the scene of a conflagration on account of roads being broken or blocked by fallen trees, buildings and other structures.

Even California, China and Japan, have some areas which are not fully prepared to withstand the calamity without suffering. It is well-nigh impossible to immunise any area completely from earthquake casualties and damage. All that can be done is to minimise the danger and loss.

In spite of all the precautions that can be thought of and made, the final defender is man himself, through his rational behaviour and composure. And it is here that some special efforts are necessary.

Role of the Public

The role of the public, quite apart from the responsibilities of the Government, is poignantly highlighted in a study by the United Nations, Disaster Prevention and Mitigation (1979) as follows:

1. People will probably panic when faced with threat or danger.
2. If threatened individuals do not run they will become disorganised, hysterical and, at best, uncertain and erratic.
3. Others are immobilised by the crisis and will be dazed and traumatised.
4. Local organisations will not perform effectively in handling emergency tasks.
5. Personal and social disorganisation provides conditions for anti-social behaviour such as looting.
6. Community morale becomes very low.

The human resource, which is by far the most valuable and effective asset in an earthquake disaster, must be organised. Discipline and rational behaviour have to be implanted in a society before the unhappy event is expected to occur.

Finally the study warns, "let not months and years of freedom from earthquake disaster lull you into complacency. Lives depend upon the people and facilities".

A Drill to Minimise Losses

Earthquakes are by and large unpredictable. They will strike some part or the other of the globe and kill thousands of people and render millions homeless. Civilizations built up over centuries are destroyed in a moment of time. Table 4 on page 563 gives the frequency of earthquakes and their possible magnitude. At least one earthquake of M 8 and above will strike somewhere on the globe. There will be over a thousand quakes of M 5–6 killing people and destroying cities. The smaller ones of M 2–3 will amount to some 300,000 on the globe, not serious but scaring all the same. What then can be done?

Attempts at defusing earthquakes have not succeeded so far. All that we now know is that some areas are more prone to earthquakes than others. Even though we may not know the precise location or time, yet the people see the sword hanging over their heads, as in California.

Ground movements cause houses and structures to collapse, killing people under the debris. It is now recognised, more than ever before, that all civil structures should be built to withstand most probable earthquake shocks so that the buildings will not collapse. There is considerable research in progress on these lines in all countries. Earthquake proof structures are now in vogue in all developed parts of the world. Even then, California has perhaps more than 100,000 unreinforced brick buildings built in 1930s. These bulidings are prone to earthquake hazard, according to joint committee on seismic safety (Mileti 1985). If this is the condition in the U.S. the Third World lives in millions of houses and dwellings with rickety walls and roofs, waiting to fall down, with the slightest of ground shake.

We cannot be ready overnight; we must plan meticulously. Geologists, seismologists, planners, architects, engineers, builders, developers and owners should all remember the earthquake hazard. There should be adequate official inspection of materials used in construction with due regard to the earthquake zoning of the region. Building codes must be revised as often as necessary and strictly followed. Unsafe buildings must be reinforced or demolished.

Even in the best parts of the Developed Countries, only a small proportion of the houses can today be expected to withstand earthquakes up to M 6 to 7. Therefore in most parts of the world house collapses in an earthquake are a foregone conclusion.

Safety Measures

Engineers, seismologists and sociologists in most countries have given thought to the question of what people can do to help themselves and reduce losses. The International symposium on Creation of Awareness about Earthquake Hazards and Mitigation of Seismic Risks, held in Roorkee, in November 1984, dealt with this matter in depth. Some guidelines have been thought of as to what people can do before, during and after earthquakes to minimise losses. There is a good deal that single individuals, and groups of people, can do to mitigate the severity of earthquakes. A very brief summary of a drill as to what to do or not to do is given below.

This drill will depend upon so many factors as one can imagine. What shape the damage will take will depend upon the area, development, communication etc. the society had attained. For instance in high-rise buildings, lifts or elevators are the first to be affected and then the only way to safety is through the staircases which too are vulnerable. Even if the stairs are intact it may take considerable time to get all the residents down, to safety.

Therefore these suggestions will have to be modified according to local conditions.

What to do BEFORE an Earthquake

It is safest to remain out of doors immediately before the onset of the earthquake, if this moment can be anticipated. One should leave the house and stay out in the open or in temporary camps till the scare is over. In short if you take proper precautions chances are that you will not be hurt.

(a) Keep cool, panic causes heavy injuries.
(b) Secure all top heavy objects like furniture, storage cabinets, fridges etc. to the walls.
(c) Keep supplies of food, water, clothings (warm if in winter), torches or candles, emergency medicines, radios, helmets, first-aid kit, blankets, ready with you. Use plastic bottles in preference to glass bottles for carrying water or other liquids.
(d) Keep all combustibles and explosives at a safe distance.
(e) Turn off gas, electric stoves, water etc.
(f) Educate all members of the family as to what to do in such emergencies.
(g) Avoid the risk of an epidemic which usually follows earthquakes, by using safe water and clean food.
(h) Evacuate old delapidated buildings as they are sure to tumble first.

What to do DURING the Earthquake

There is a drill proposed as to what to do during the earthquake. Since earthquakes last for only a few seconds to a couple of minutes, the earthquake can be all around you before you are aware of it.

(a) Do not panic. The ground movement is frightening to all.
(b) If you are in a building stand in a strong doorway or get under a table, desk or bed, avoid standing just outside the main door or near the outside walls. This is usually an unsafe place. Watch for falling objects.
(c) Do not rush outside without making sure you are going to be safer there.
(d) If you are out of a building when earthquake strikes, stay out. If you are in an automobile stop at the nearest safe place, away from buildings or trees.
(e) Watch for falling plaster, bricks, ceiling fixtures and other loose objects.
(f) Do not use gas stove, candles or matches unless you are sure there is no combustible gas around.
(g) Avoid escalators, even stair-cases may be crowded by escapers. Take your turn.

What to do AFTER the Earthquake

After the earthquake is over, there will be tremendous rush of rescue work. Those who have escaped injuries will be trying to rescue persons who have been trapped. If you are one of the trapped, wait patiently for your turn; remain calm, conserve your energy; if possible tap with a metal piece so that your call will reach rescuers.

(a) Look for the injured in your family or neighbour's families because you know where they were and probably still are. Render assistance as you can, until medical aid arrives.
(b) Check your electric, gas, water and sewerage connections. They may have gone hay-wire and damaged beyond immediate repair. You will have to live without them for some time.
(c) Check for fires and fire hazards, and secure fire extinguishers. Do not strike match sticks unless you are sure that there is no gas leak around.
(d) Watch for instructions from the Government Rescue Authorities on radio or by other means, regarding likely aftershocks, and the manner in which the relief will be rushed to you.
(e) Keep away from hanging portions of buildings or overhanging cliffs, as they may fall due to aftershocks which do continue for some time.

The object of these hints is to encourage people to react rationally in this natural calamity. It is wellnigh impossible to provide a complete guide as to what should be or should not be done, in this connection. Much will depend upon the nature of damage in any particular calamity and the education imparted by the Government, if any.

The Government, Semi-Government and the voluntary agencies from the country and abroad, rush rescue by providing emergency requirements to the affected people. Patience and composure are the two virtues which come in handy for the affected people.

Earthquake Education

"If only you had told us what to do in such a situation, many of us could have been saved!"

These were the words of children who had survived the roof-collapse of a school, in which several of the children died, as a result of an earthquake. They were replying to press reporters who had asked them about the catastrophe.

That reply set thousands of citizens thinking about the serious lapse on the part of the seniors. It was obvious that if the children had been introduced to the modern disciplines of saving life and property, some deaths at least could have been avoided.

We teach our children first-aid, fire fighting, traffic codes, and now even the intricasies of sex. But we seldom think of educating children—or even grown-ups, for that matter—about the intricacies of earthquakes! Some officials and even Governments evade the issue on the ground that any attempt to teach children or adults about earthquakes may be misinterpreted as a warning of an impending earthquake; and this, they feel, may create panic. This stand is untenable in as much as by teaching first-aid or traffic codes, we do not invite accidents, by teaching fire-fighting we are not inviting fires, demonstrating the use of life-jackets in an aircraft does not invite a crash. However, in the United States there has been a movement for over ten years now, for teaching all children about earthquakes. Many schools teach their students regularly. The response from parents to this education has been very favourable, even insistant.

The Department of Sociolgy at the University of California, Los Angeles, found that the public very definitely wants to be educated about the kinds of problems and hazards they can expect before, during and after a damaging earthquake.

M.P. MacCabe of the U.S.G.S., California (EI Bull. 1980) reports that the Natural Hazards Research and Application Information Centre, at the University of Colorado, Boulder, serves as a clearing house of hazard-related subjects; it also publishes a newsletter and joins Government agencies in sponsoring workshops for all concerned in mitigating natural hazards, mainly earthquakes.

The Earthquake Eduactional Institute at San Francisco State University was established in 1978, under the patronage of the National Science Foundation, to develop earthquake-related curricula for use in elementary and secondary schools. It was hoped that such education will better prepare the pupils at these schools to meet the hazards of earthquakes. According to Raymond Sullivan et al. (1980), by about 1982, 140 elementary and secondary school teachers and administrators had enrolled in the programme.

The Southern California Earthquake Preparedness Project (SCEPP) issued 'Guidelines for School Earthquake Safety Planning, in December, 1982.

In the melee that follows an earthquake, parents search frantically for their children and often fail to find them for a long time. The book therefore recommends what precautions a school can take so that parents find their children easily after the catastrophe.

The public, no less than the bureaucrats, the Government and the Ministers, hold more misconceptions about earthquakes than about any other hazard. Governmental organizations wake up and get into action only after the earthquake strikes. They seldom take the public into confidence, and yet they expect all and sundry to respond to post-earthquake rescue work in a disciplined manner! The result naturally is utter confusion even at the governmental level. At one earthquake, away from the capital, the bureaucrat in charge of the region is reported to have left the distressed area and rushed to the capital, to get instructions from headquarters! What he got was a well-deserved reprimand that 'he should have known for himself'.

Earthquake precautions courses in the U.S. are intended for all officers, teachers, police, voluntary agencies and public alike. The secondary school programme includes reading material for the use of children, illustrations, cartoons, picturess, puzzles, cassettes, etc. for the elementary schools, the information begins with the interior of the earth and the crust, how and why it breaks, and proceeds to instructions upon what to do before, during and after an earthquake. There are also games such as 'Quake Estate' (played like Monopoly), 'Quake-0' (a question and answer game based on 'Bingo'), 'Shakes and Hazards' (played like 'Snakes and Ladders'). Children are also introduced to 'Tremor Tales'. They prepare elementary water compasses, and use wax paper and iron fillings to demonstrate earth's magnetism.

All this is done without giving the students any sense of alarm. The children are made to feel that, should this earthquake unhappily visit their area, they have a positive role to play. This role may consist of escorting family members to safety or rescuing family pets. In the absence of such training, children are apt to confront elders as in the opening paragraph of this section.

It has been observed that during an earthquake children naturally become disorganised, and to suggest a positive role for them to play, will help to stablise them so that instead of becoming a liability to parents and elders, they will lend a useful hand for relief work. The size of their physical contribution is not important, the important considerations are their stability and composure.

In a project 'Quake Safe', the U.S. Geological Survey, the American Red Cross and the Office of the Emergency Services participated. Within less than a year 7,000 Girl Guides were involved in the project. Children taught their friends, parents and families. Even six- and seven-year-olds could help the family to prepare for an earthquake which may not happen for years. Margaret Masdeo and her husband are the spirit behind this yeoman service. The couple have issued a number of publications meant for teachers and children, with illustrations that will attract children and tempt them to study.

Animal Behaviour for Children

We do not have to rear animals or train them. In fact, animals which have developed a conditioned reflex will not be useful as precursors of earthquakes. We have to spread this knowledge amongst the would-be observers who, after some training, will be able to predict earthquakes for themselves. This will be true especially in the rural areas, where both animals and observers are found in large numbers. If in spite of the anomalous animal behaviour the earthquake fails to appear, the result would be a source of relief because a threatened calamity has been averted.

On the other hand, in urban areas animals are relatively rare. If on the basis of physical parameters an organisation were to announce a prediction for an urban area panic may prevail in the interim period, which may cause unnecessary dislocation of normal life and result, in extreme cases, in deaths due to panic and irrational behaviour.

Animal behaviour as a precursor, which is the main theme of this book, will at once interest children and enable them to serve as excellent observers of different animals who may give hints about an impending earthquake. This opportunity would be missed, without the imparting of this general knowledge to the children. It has also been stressed that even with our geophysical parameters and instruments we cannot predict as dependably as some animals can. In order that not a single opportunity to save lives should be missed, no part of the efforts and expenditure involved in this educational programme should be grudged.

It may be argued that although all this education may be necessary for the patently earthquake-prone areas like California, there is no justification for scaring others who are not on the earthquake hit list and who may never see an earthquake in their life-time. This book has sought to emphasise that even in the marked earthquake-prone areas this aspect of education is treated with indifference. It must be remembered that what is learnt in childhood may come in handy after, say, 50 years, when the quake may strike.

Besides, the Intra-plate areas, as has been stressed at page 560, are also susceptible to earthquakes, and severe ones at that. Here also the education and the general knowledge of precautions to be taken would be useful. This knowledge is essential for all and at all times, as strictly speaking, no part of the earth is truly immune to earthquake.

Finally, which inhabitant of a 'safe' area can be sure that he or she will never be called upon to live or serve in an earthquake-prone area?

Education regarding earthquakes is a very vital matter. The greater the ignorance of the society in this respect, the greater will be the dependence upon luck and unscientific methods. When the earthquake unhappily strikes, the society is disorganied and people behave in an irrational manner. The efforts of the Government and the rescue organisations will prove ineffective for lack of orderliness among the people.

In some places earthquakes occur rarely. If education is not imparted today the next visit of an earthquake will catch the people napping. There is no time to lose. It is necessary to involve as many people as possible, irrespective of where they are located, much before next earthquake strikes.

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