ABNORMAL ANIMAL BEHAVIOR AND THE PREDICTION OF EARTHQUAKES

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ABSTRACT

Earthquake prediction in the Western world has been accepted only since the 1960's, and has relied almost exclusively on instrumental measurements. Observations of abnormal animal behavior before earthquakes date back to antiquity, and come from all over the world, but have been largely ignored by scientists, who have regarded them as unscientific folklore. When China reported the prediction of a major earthquake in 1975, using observations of abnormal animal behavior as part of their data as well as geophysical and geochemical precursors, interest in the serious study of precursory animal behavior was renewed in the Western world. The U.S. Geological Survey sponsored two conferences on Abnormal Animal Behavior Prior to Earthquakes in 1976 and 1979. These conferences brought together biologists and biophysicists with geophysicists and seismologists. The conferences presented results of systematic laboratory investigations of the sensory capabilities of animals mentioned in reports, in order to identify the particular geophysical precursors which may be responsible for causing abnormal behavior. It is hoped that precursory animal behavior may eventually be better understood, to the point that it may one day be used as a reliable seismic precursor.

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Introduction

The prediction of earthquakes is a relatively new branch of seismology. Just two decades ago, earthquake prediction was not even considered to be serious science; rather, it was left to astrologers, mystics, and religious zealots (Press & Siever, 1978). The emergence of earthquake prediction as a truly scientific discipline has taken place as a result of a program of fundamental observations begun in the late 1960's and supplemented in 1973 and 1976. The research effort has from its inception in the United States consisted both of attempts to develop a systematic catalog of precursory phenomena through field measurements and a program of fundamental studies of the physical basis for the occurrence and nature of earthquakes and of the pre-earthquake failure process (Raleigh, 1980).

Earthquake premonition by animals, while having a long history and persistence in literature, does not seem to fit into the rational world of science, and as a phenomenon, it has the added disadvantage in that it cannot be examined at will. Skepticism of anomalous animal behavior before earthquakes by many scientists in the Western world is largely based upon this unfavorable image, as any scientist interested in studying this problem risks not only his professional reputation, but also any chance of getting research funds (Tributsch, 1982). Beginning

in the mid-1970's, however, the perspective of the possible connection between animals and earthquakes began to change, when it was revealed that in 1975, China successfully predicted a major earthquake, using observations of abnormal animal behavior, as well as geophysical and geochemical precursors. The entire population of Haicheng, a large city, was evacuated before a magnitude 7.3 earthquake struck, saving thousands of lives. This imminent prediction was the first prediction of a major earthquake in recorded history. U.S. seismological teams visiting China were impressed by China's methods and accomplishments in earthquake prediction, although the Chinese admitted some failures among their successes, and much more study still needs to be done. In 1976, the U.S. Geological Survey sponsored a conference on "Abnormal Animal Behavior Prior to Earthquakes", held in Menlo Park, California. This conference discussed and reviewed accounts of unusual animal behavior and the various geophysical precursors which might stimulate the animals. In 1979, a second U.S.G.S. conference was held at the University of Texas in Galveston. This conference introduced experimental data on the effects of earthquake-related geophysical and geochemical phenomena on animals, under controlled conditions. A survey, summary, and analysis of the literature concerning abnormal animal behavior before earthquakes, and its possible usefulness in predicting future earthquakes, is the focus of this paper.

ABNORMAL ANIMAL BEHAVIOR AND THE PREDICTION OF EARTHQUAKES

Earthquake prediction: Not seriously considered in the Western scientific world until the 1960's; relies almost exclusively on instrumental measurements.

Earthquake precursors: Observable geophysical and geochemical changes which precede an earthquake.

Folklore of abnormal animal behavior: Date back several thousand years, from many parts of the world; observations made primarily by laymen and non-scientists - thus, reliability and accuracy is suspect.

Pivotal historical event: World's first prediction of a major earthquake took place in China in 1975 using abnormal animal behavior as well as geophysical data; a town of 90,000 inhabitants (Haicheng) was evacuated before a magnitude 7.3 earthquake struck; very few lives were lost. This prediction aroused interest in studying abnormal animal behavior in the Western world.

Biological precursors: If abnormal animal behavior before earthquakes can be understood and is a reliable prediction method, it may be called a biological precursor.

Analysis of the data: Should consider the following questions...

1. How reliable is the data?
2. Can non-seismic noise factors be eliminated from the data set?
3. What is the "normal" behavior of the animals when no earthquake is imminent?
4. Can a particular geophysical/geochemical change be shown to cause the observed behavior in animals?
5. How many individual animals within a population tend to be more sensitive to pre-earthquake stimuli?
6. What are the sensory thresholds (limits of detection by the senses) of the animals to different stimuli?

Summary of folklore accounts:

Earliest accounts date back 3000 years, imperial Chinese records contain 50 million words; difficult to interpret.

Observations made by farmers and peasants - usually farm animals and housepets are mentioned.

Chinese scientists have identified 58 species of wild and domestic animals as having reliable anomalous reactions before earthquakes.

Most dramatic reports:

1. Hibernating snakes leaving their burrows during the winter, one month before the 1975 Haicheng (M = 7.3) earthquake; froze to death.

2. Fish leaping from the water into the air, sometimes onto land. (China)

3. Deep sea fish swimming near the surface waters (caught by Japanese fishermen).

SYSTEMATIC STUDY OF THE PHENOMENA: Only feasible for recent earthquakes.

1. Retrospective studies: Interviews of people who experienced an earthquake and observed unusual animal behavior before the event; attempt to identify statistical patterns in the behavior.

2. Laboratory simulations: Controlled experiments to investigate the sensory thresholds of animals; attempt to isolate the particular geophysical/geochemical changes which might cause their unusual behavior.

Types of Geophysical Phenomena Tested on Animals:

1. Sound with an intensity and frequency outside the range of human perception

2. variations in local magnetic or electric fields

3. ground vibrations or foreshocks

4. changes in groundwater level

5. electromagnetic waves

6. release of gases usually trapped beneath earth's surface

Precursors unlikely to be detected by animals:

ground tilt

velocity variations in P-waves/S-waves

electrical resistivity changes

gravity anomalies

Summary of Chinese Data by Academia Sinica:

1. Most animals in the seismic area become increasingly restless, and a number of them fall into a state of anxiety.

2. These features may appear from a few minutes to as long as ten days before the earthquake, but usually the precursor time is within 24 hours of the quake.

3. These phenomena appear to have a non-random and non-uniform regional distribution, occurring mostly in particular belts of the seismic area and in certain regions. These places correlate to some degree with the strike of active faults, as well as with the bends, branches or terminal points of faults. It appears that they tend to be in the epicentral area or high-intensity zones of the impending earthquake.

4. These remarkable changes in animal behavior generally precede a destructive earthquake of magnitude 5 or greater.

5. Although there is great variety in the cases of unusual behavior, generally speaking, this behavior falls in to the category of increased restlessness - being startled, extremely nervous, and panicky, as if the animals were on the brink of meeting their natural enemies. A small number of animals may become depressed or apathetic.

6. Macroscopic (detectable without instrumentation) changes in animal behavior constitute only one of many precursors of earthquakes. So far as the time of occurrence is concerned, it can be used as a means of extremely short-term forecasting. Combined with data from other disciplines, animal observations may be of some value in making an overall judgment.

7. Anomalous animal behavior has also been noticed during the earthquake, as well as before.

8. The number of animals of any given species that behave abnormally prior to earthquakes is not necessarily a high proportion of the total population (usually, only a fraction of a given species shows unusual behavior). Some show no anomalous behavior; on the other hand, some anomalous animal behavior may not be followed by an earthquake. Furthermore, it must be noted that much of the data were collected after the earthquakes had occurred.

9. The unusual behavior is not necessarily related only to earthquakes. Non-seismological factors can sometimes cause similar behavior. Although such interfering factors have been investigated, it is almost impossible to eliminate them completely.

TABLE 2. ABNORMAL ANIMAL BEHAVIOR PRIOR TO EARTHQUAKES AND OTHER CONTEXTS IN WHICH SIMILAR BEHAVIOR HAS BEEN OBSERVED

ANIMAL	BEHAVIOR REPORTED BEFORE EARTHQUAKE	BEHAVIOR REPORTED IN OTHER CONTEXT
Cats	constant hiding, refusal to go outside	psychogenic shock
Chickens	flying to high perches, crowding together, hysteria	sudden darkness, loud explosion
Dogs	barking	territorial response, response to strangers
Dogs	following owner constantly from room to room	overdependent pet
Fish	jumping out of water	quick turns during swimming, twilight hunting
Fish	change of depth in water	artificial pressure changes, injured swim bladder
Mice	behave as if drunken, convulsions	audiogenic seizure caused by noise of 4-80 kHz, 90-130 db
Mussels	move to higher attachment site on seashore	rising water before hurricane
Pigs	biting each others' tails	overcrowded conditions
Rats	vigilance, jumpiness, vertical leaping	alarm response to ground predators
Rats	crouchlike gesture, muscle contractions	acoustic startle response

(From Buskirk et al., 1981)

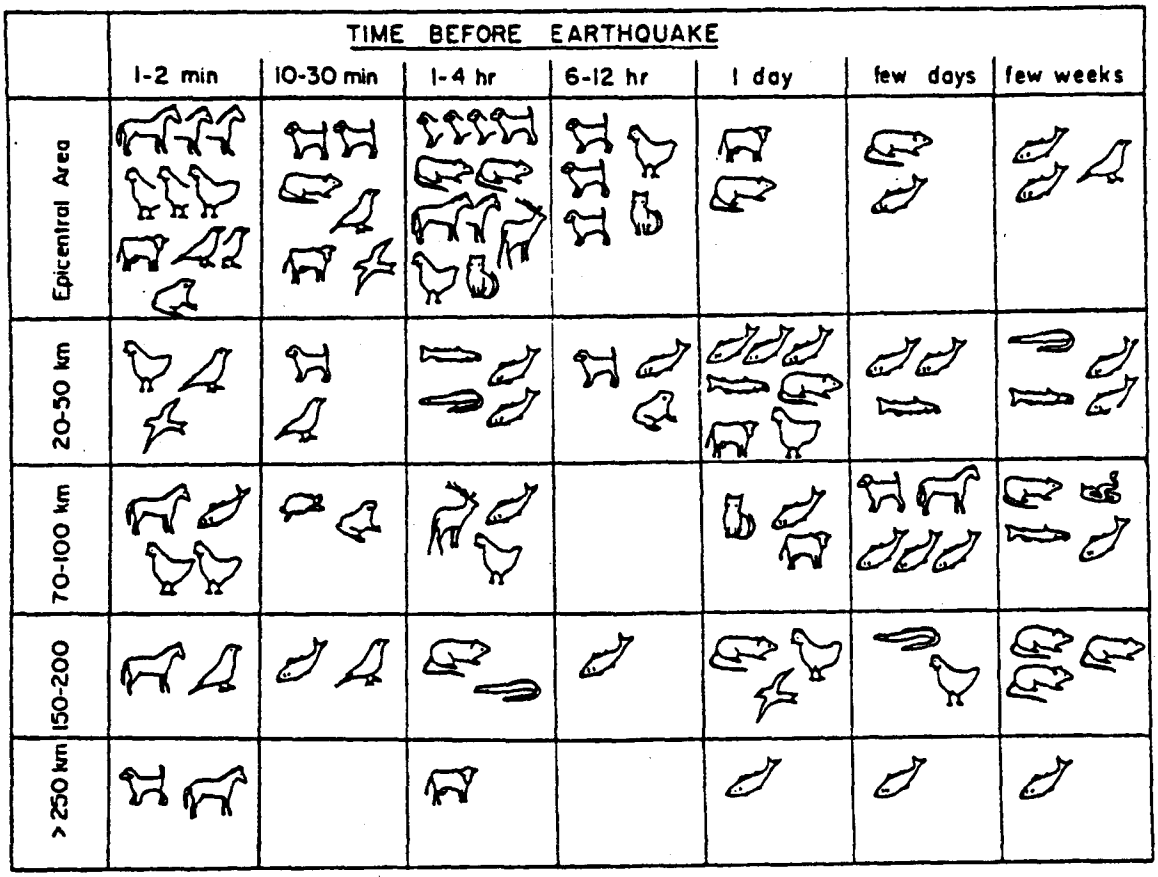

Fig. 12. Distribution of animal behavior according to the distance from the epicenter and the time before the main shock of 36 different earthquakes in Europe, Asia, North America, and South America. Symbols indicate reports on the following animals: catfish, eels, other fish, frogs, snakes, turtles, sea birds, chickens, other birds, dogs, cats, deer, horses, cows, rats, and mice. Data are non-systematic and collected from many sources. (From Buskirk et al., 1981)

SOUND & VIBRATIONS

Range of human hearing: 20 - 20,000 Hz

Sensitivity not uniform: Humans hear best in the mid-range (100 Hz to 10,000 Hz); vibrations below 20 Hz are felt rather than heard.

Low-frequency sound: Birds (pigeons, owls) much more sensitive than humans; fish, even more so, since water transmits these sounds more efficiently than air. Low-frequency sound is highly energetic (which produces long wavelengths), travels great distances without appreciable attenuation in a radiating (non-directional) pattern. Foreshocks and seismic waves typically in the 0.1 - 10 Hz range.

Mid-range frequency sound: Most mammals not much more sensitive than humans. Rock fracturing emits sounds up to 3000 Hz.

High-frequency sound: Mice and rats hear and "speak" upwards to 80,000 Hz. High-frequency sound is low-energy, highly directional, easily attenuated by obstacles. Rocks under extreme stress produce ultrasound (100,000 - 1,000,000 Hz) when fine hairline cracks appear, just before fracturing.

CONCLUSION: Low-frequency sound below 50 Hz (infrasound) is best candidate for explaining anomalous behavior far from the epicenter, and behavior of fish.

ELECTROMAGNETIC PHENOMENA

1. ELECTRIC FIELD CHANGES: Most sensitive animals are aquatic, especially "electric" fish (stingrays, electric catfish), sharks, catfish, eels. Land animals are about 4 orders of magnitude less sensitive to electric field changes.

   Disadvantages: Variations also occur due to rainfall, electrical and magnetic storms. Land animals relatively insensitive.

2. MAGNETIC FIELD CHANGES: Birds (pigeons, gulls) and honeybees are most sensitive animals.

   Disadvantages: Variations due to normal (non-seismic) factors are only 30 gammas; those due to earthquakes are usually only 20 gammas. Such changes are barely within the detection ranges of even the most sensitive animals.

3. ELECTROMAGNETIC RADIATION: Overexposure to microwaves can cause sickness in humans; can throw migrating birds off course (due to powerful radar antenna).

   Disadvantages: Poorly documented phenomena, no mechanisms yet proposed.

4. AIR IONS: Charged airborne particles (aeorsols), especially small, positively-charged ions, can produce significant physiological deterioration (studied in laboratory animals and humans - increase in body levels of serotonin).

   Accounts for: burrowing animals fleeing from underground burrows, animals fleeing any enclosed structures (where electrostatic charge density is high), birds flying continuously and refusing to land.

   Disadvantages: Not enough data collected to make quantitative interpretation; increased air ion levels before earthquakes, and mechanisms not definitely established.

PHENOMENA RELATED TO OPENING OR CLOSING OF SMALL CRACKS IN ROCKS

5. GROUNDWATER LEVEL CHANGES: irregular water levels, artesian flow, muddy wells, and oily wells have been observed before many historic earthquakes.

   May account for: behavior of underground or burrowing animals (change of water table floods their burrows).

   Disadvantages: Non-seismic factors due to seasonal changes and rainfall occur very often.

6. RELEASE OF UNDERGROUND GASES: radon, sulfides, ozone, methane, etc. have been cited. Nearly all animals have a better sense of smell than humans.

   Radon: Gas most often measured for precursory changes in levels. However, radon is inert, and animals probably cannot detect it.

   Odorous gases: May explain the anecdotal accounts of animals seeming to react to strange smells before earthquakes.

   Disadvantages: Most data available account only for radon; measurements of other gases released is needed.

FURTHER RESEARCH

1. Acoustic waves and vibrations in the frequency range 10 - 50 Hz: More measurements of animal behavior to sound both in air and under water are needed.
2. Electric field changes and air ion monitoring: More measurements of electric fields are needed to compare terrestrial and aquatic environments. Monitoring equipment for changes in air ion levels should also be set up.
3. Earthquake gases other than radon: Radon is the most often measured gas before earthquakes; however, radon is chemically inert, and animals probably are insensitive to it. Methane, ozone, and sulfur compounds are likely candidates for further monitoring of gases released prior to earthquakes.
4. Olfactory thresholds for odors: Most of the data on animal sensitivities to natural odorants are not quantitative. Quantitative data are necessary to test the effects of gaseous geochemical precursors on animals.
5. Responses of common domestic animals: Dogs, cows, horses, and chickens are the animals most commonly mentioned in the anecdotes. Surprisingly, there have been few or no controlled studies of the sensitivities of these animals to low-frequency sound, vibrations, electric fields (with the exception of dogs), and odorous gases (Buskirk et al., 1981).

CONSENSUS OF MOST WESTERN RESEARCHERS:

"There is, as yet, no conclusive scientific evidence for believing that abnormal animal behavior is in any way related to the occurence of earthquakes. There is, however, general agreement among scientists that a great many of the anecdotal accounts are entirely plausible in light of what is known about animal sensory capabilities and the level of many seismic precursors."

Existing Western techniques have the following limitations:

1. Earthquakes cannot be predicted where there are no instruments.
2. Instrumental surveillance of all possible seismic areas is too expensive.
3. Instruments cannot tell or estimate when an earthquake will occur.

Conclusions of world reknowned geophysicist, T. Rikitake (1982):

"While not all of the legends may be true, it is important for scientists to look into things which might contain some truth, without being biased. From a statistical analysis of all available data, such behavior may sometimes be used as an extremely short-term seismic precursor."