

To what extent can animals aid earthquake prediction?



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ABSTRACT

Earthquakes are very hard to predict. Even when Scientists believe an earthquake is likely, it is still hard to comprehend what the probability implies and what precautions should be taken. In this article, it is considered how valuable animal behavior can be for earthquake prediction. Since we cannot accurately predict earthquakes, how do we test the hypothesis that other species can heed warning signs currently unknown to technology?

Introduction

It is reported that around 500,000 detectable earthquakes occur every year, with an estimated 100,000 of those felt by humans without apparatuses and 100 causing damage to the affected area.^[1] Though not all of these 100 cause significant damage to human life and economic well-being, in recent years, we have seen many catastrophic events such as in 2011, with the Christchurch earthquake and the Japanese tsunami. This surely raises the question: Why, in such a technologically advanced world, are we still so vulnerable to geological hazards? Is it not time that we were able to accurately forecast these events with enough warning to save human lives? As we are currently unable to successfully forecast earthquakes, there has been an interest in the folklore surrounding earthquakes to hopefully discover whether in this case, literary documentation is able to triumph over science.

Iain Stewart, a geosciences professor at Plymouth University and a well-known television presenter,

suggested in a discussion that unusual animal behavior is “very much the dark side of earthquake science” and that although there is not much information “in the main seismology literature... there are nuggets.” This report aims to find such “nuggets” of information and to explore whether there is biological or geophysical reasoning behind this unusual animal behavior.^[2]

The 1975 Haicheng Earthquake

When discussing unusual animal behavior before an earthquake, it is impossible to avoid the 1975 Haicheng earthquake. This event has since been widely branded as the earthquake that was successfully predicted by animals. The earthquake, measuring 7.5 on the Richter scale, struck on February 4; however, thanks to officials evacuating the area several hours before the event, it is thought that hundreds of lives were saved. At the time of the earthquake, the Cultural Revolution was still heavily underway in China, and thus external scientists were not granted entry into the country^[3] until months after the event. The Chinese

people had been ordered to look out for unusual animal behavior, and from this came wide reports of snakes coming out of hibernation and freezing on the earth's surface.^[4]

Although the thought of successful earthquake prediction aroused interest in the Western world, reports since suggest that it was purely political propaganda to encourage support from the Chinese people. Personal communication with Lucile Jones, a USGS seismologist who went to China in 1980 to research the Haicheng earthquake, confirmed this idea:

"It was clear that the signal was politically motivated – the scientists were ordered to 'learn from the people' and the peasants were ordered to find animal anomalies and so they found them. The biggest signal in the data was the spike every Saturday afternoon after the Saturday morning commune meeting when the peasants were exhorted to find the anomalies."^[5]

In addition to this criticism, the prediction is frequently criticized by the large number of foreshocks that occurred before the main earthquake, as many geologists argue it was these that alerted officials, rather than the animal behavior.^[6]

Reports of Unusual Animal Behavior

Helmut Tributsch is considered the world's leading scientist when it comes to animals in earthquake prediction, and his book *When the Snakes Awake* is a list of 78 reports of unusual animal behavior before earthquakes. As the list was compiled in 1982, there have been further numerous reports. Moreover, Chinese scientists have identified 58 species of wild and domestic animals that are thought to have "reliable anomalous reactions before earthquakes."^[7]

A particularly strange report of unusual behavior is that of toad migration preceding an earthquake. Before the Sichuan earthquake of 2008, tens of thousands of toads are reported to have left Mianyang, a city close to the earthquake's epicenter.^[8] Many people reported this behavior; it has since been described as an "earthquake omen." However, it has since been suggested by local experts that their migration was due to the depleting oxygen source in a nearby river, which would account for the effects on different groups of toads from surrounding villages.^[9] Alternatively Andy Michael, a USGS seismologist,

claimed that this was actually an annual toad migration reported to occur the same time every year.^[10] Either way, this documentation of unusual animal behavior before an earthquake seemed to be a false alarm.

However, a similar occurrence was seen before the 2009 earthquake in L'Aquila in Italy. Biologist Rachel Grant was completing a 29-day study of toad behavior in Italy around the time the earthquake struck. She documented that 5 days before the earthquake, the number of male toads fell by 96%, and 3 days before the earthquake, the number of breeding pairs unexpectedly dropped to zero.^[11] As the documentation was part of a study unrelated to seismology, it is thought to be one of the most reliable documentations of unusual animal behavior in recent years. It has so far remained unexplained, but due to the mass of press surrounding the scientists who were on trial for "manslaughter" for the same earthquake, it has perhaps lacked the deserved media and scientific attention.

Though the majority of the evidence is anecdotal, it seems more than just coincidental that the reports are so widespread in aerial distribution and timescale. A frequent criticism of the documentations of unusual animal behavior comes from the difficulty in establishing a universal definition of "unusual." Richard Walker, a Royal Society University research fellow from Oxford University, posed the question in an email discussion of "how many times animals behave in a way that we would describe as 'abnormal' but which isn't followed by an earthquake, and so is forgotten about."^[12] This idea seems a constant topic of debate within the scientific field.

Unusual Animal Behavior Immediately Before an Earthquake

The most frequently proposed reasoning behind unusual animal behavior before an earthquake is the occurrence of foreshocks, as seen when examining the case study of Haicheng. As there is currently no way to distinguish foreshocks from smaller earthquakes, it is thought that animals react to the shaking of the ground, rather than to any more complicated geophysical precursors.

There is a general consensus within seismological circles that the reason for this is that animals have the ability to detect P (primary) waves before

humans detect the slower S (secondary) waves. An earthquake causes both S and P waves, but seismic P waves travel approximately 2–4 km/s faster than the S waves that cause the ground to shake,^[13] and are therefore detectable by humans without instruments.

The Changes in Electric and Magnetic Fields and Their Effect on Animal Behavior

Before an earthquake, it is thought that electrical pulses in the earth increase the “telluric current.” This is thought to create an electric field, which sparks a magnetic field, thus the effects of them cannot be examined independently. The earth’s electric field naturally varies up to around 10^{-5} V/m, and before an earthquake, the electric field is thought to fluctuate by around 6×10^{-5} . Though this is six times the usual amount, it is approximately the same level of variation that occurs during a normal thunderstorm, and thus cannot reliably be deduced as a geophysical earthquake precursor.

Changes in the magnetic fields on the other hand are thought to have a large impact on animals that use magnetic fields to orientate themselves, such as homing pigeons. In a conversation with former USGS seismologist Jim Berkland, it was mentioned that “homing pigeons were being lost” during stronger Californian earthquakes.^[14] It seems that migrating birds show deviations from their usual course due to local geomagnetic anomalies. In a lecture given by Friedemann Freund, he showed a disruption of the circadian rhythm of rats that occurred at the same time as a spike in the magnetic field before the 2008 Sichuan earthquake.^[15] Though both of these examples seem to suggest an animal reaction to geomagnetic anomalies, they are still only considered as “anecdotal,” so do not pertain to be reliable enough. The opposing argument is presented by Tong, who claims, “the variations due to normal (non-seismic) factors are only 30 gammas; those due to earthquakes are usually only 20 gammas.”^[7] This therefore suggests that an animal would not be able to distinguish between a change in the magnetic field caused by impending seismic activity and a normal magnetic field variation.

Scientific Viability through the Theory of Increased Ionization

The possible precursors presented so far seem to be dubious in their reliability when examined in direct relation to the stimulation of unusual animal behavior. This theory has, for a long time, seemed inexplicable. However, a paper written in 2011 that mainly focused on ground water chemistry changes before major earthquakes may offer us a solution.^[16] Grant *et al.* propose a theory of increased ionization, an idea that was also mentioned in Tributsch’s *When the Snakes Awake* but at that time required more research to be considered a serious possibility. This research has since been done, and Grant *et al.* appear to put forward a convincing argument.

When rocks are put under pressure, it is thought that an electric current is generated within the rock. The theory stems from the principles of the piezoelectric effect and has been furthered by Grant *et al.*^[16] who put forward the idea that a reaction occurs between the silicon bonds of the rock and oxygen and forms what is called a “positive hole” in the rock. This hole can then move away from the initial site of strain, spreading the stress into the unstressed rock. This means that the original stressed rock becomes negatively charged as it has lost the charge to the originally unstressed rock, which gains a positive charge. This effectively turns the rock into a battery by creating a flow of electric potential. Not only does the electric charge create an electric current beneath the earth’s surface, but if it is strong enough (i.e., in more major earthquakes), it is thought that it can also generate microscopic electric fields that are able to ionize the air surrounding the rock.

Positive ions in the air are also thought to cause serotonin levels to increase, both in humans and animals, and thus would give reason to unusual animal behavior.^[16] It is thought that an increase in serotonin levels in animals leads to irritable behavior, and also has the ability to cause physiological deterioration^[17] which may explain the unusual animal behavior before earthquakes.

Though the idea of increased ionization seems the most likely as of yet, discussions with Alexander Densmore, the Deputy Director of the Institute of Hazard, Risk and Resilience at Durham University, suggested, “just because something is possible, doesn’t mean that it is definite” (personal correspondence, 2012).^[18] There are still flaws in this line of thinking, for example, the argument that the electrical conductivity of the ground means that the electric field would not be suggested at the

magnitude required to ionize the air. Though this theory is without doubt the most promising, Iain Stewart's claim that this is "dark side of earthquake science" still rings true.

Critical Response from Academics

The theory of animals in earthquake science is frequently criticized by the variability in the animal's responses from reactions of agitation to panic to excitement. Cynics often argue that if one dog reacts unusually before an earthquake, surely all dogs should react the same way before all earthquakes.^[10] However, this line of reasoning seems to have a fairly simple answer in that there is huge variability within a species. In addition to this, Tributsch's list of 78 incidences of unusual animal behavior preceding an earthquake^[19] includes around 85 different species,^[20] which makes it unsurprising that one particular geophysical signal could be responsible for the reactions of so many different species. In addition to this, we have to take account of the variability within a species, which may lead to varying responses even to the same geophysical signal. In discussions with John Rollins, a professor from the University of Southern California, it was also made evident that the geophysical variability between earthquakes could easily be responsible for the variability in animals' responses. He put forward the idea that "different faults have different failure strengths," so their ability to surpass an animal's stress threshold would be different for each earthquake that occurs.^[21] This reasoning also shows how difficult coherent research would be into this field, as there are so many independent variables.

Another criticism of the usefulness of animals in earthquake forecasting often lies with the flaws in the people involved in the data collection. For example, the data are often collected after the event, which has led some critics to argue a theory of "confirmation bias."^[10] This means that an owner of a domestic animal will notice unusual behavior, but only link it to the earthquake after they have felt the shaking or heard news reports of the earthquake, and thus the information is unreliable. Such an idea was supported by Dr. Max Wyss, the Director of the World Agency of Planetary Monitoring and Earthquake Risk Reduction, who claims, "human beings have a tendency to believe anything that catches their fancy."^[22]

Primary research was conducted as part of this report, whereby an interview with 42 academics

from the fields of geology and seismology was conducted; in the majority of whom are experts in the fields of seismology. Table 1 shows just some of the responses in these interviews:

Figures 1 and 2 show the extent to which the idea of animals in earthquake prediction is ridiculed within academic circles. An almost unsurprisingly high percentage of the academics asked believe that animals present absolutely no chance of improvement in earthquake prediction. The email sent to the academics asked only for two yes/no answers; however, a large majority of the people responded with more comprehensive answers. Of the 31 more detailed replies, 58% blamed their cynicism on the "anecdotal" nature of the current evidence, making it unreliable. Conversations with Friedemann Freund, a senior NASA researcher, introduced an opposing viewpoint:

"Many mainstream seismologists use the word 'anecdotal' to call into question something which THEY don't understand. They conveniently forget that every discovery in the natural sciences begins with 'anecdotal' observations. Just think of shooting stars. In the past people had to wait endless hours through the nights to see them. Once it was understood that they are debris particles in comet trails, which the Earth intersects at certain times of the year, the chances of seeing them and even seeing fireballs became much better... it all boils down to understanding."^[25]

Freund presents an interesting idea that is mirrored by Tributsch (p. 11), that "few seismologists had the courage to take the evidence seriously."^[20] This therefore presents the idea that the problems lie with the current world of science. Tributsch even goes so far as to suggest that the cynicism of the science world may have dissuaded many people from passing on their experiences of earthquake

Table 1: Descriptions used to directly describe the use of animals in earthquake prediction

Description	Source
"Magical thinking at its worst"	Email correspondence with Lucile Jones, 2012 ^[5]
"Just voodoo"	Email correspondence with Thorne Lay, 2012 ^[23]
"Something of a distraction... a complete diversion from finding (a method of earthquake prediction)"	Email correspondence with Richard Phillips, 2012 ^[24]
Part of "the pseudo-science realm"	Email correspondence with Iain Stewart, 2012 ^[2]
"Nonsense"	Email correspondence with Max Wyss, 2012 ^[22]
"Unscientific folklore"	Tong, 1988 ^[7]

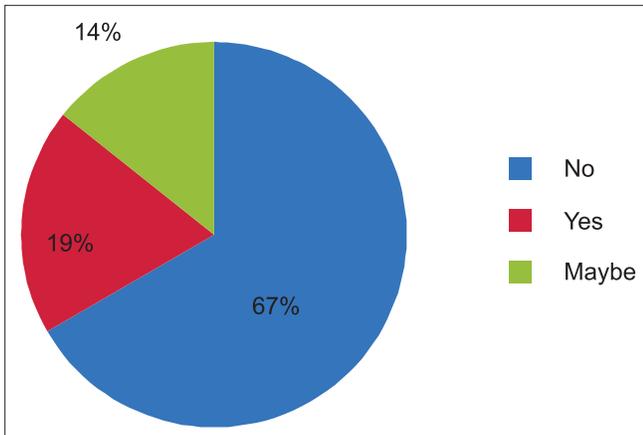


Figure 1: Answers to the question 'Do you think examining animal behaviour has the potential to seriously impact earthquake prediction?'

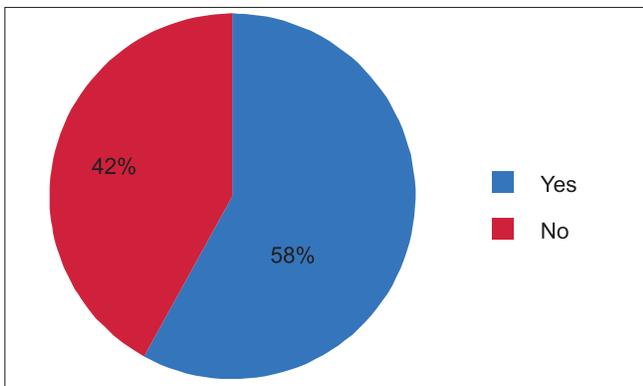


Figure 2: A graph to show the percentage of academics asked who mentioned the idea of 'anecdotal evidence' in their responses

precursors, for fear of being ridiculed, a fear which is shown in Table 1 to have fair foundations.

Tributsch (p. 213) argues, “scientific progress seems able to offer us everything except the knowledge that takes centuries to acquire,”^[19] which brings into question the future of the idea of animals in earthquake science. It is necessary for us to establish whether the cynicism comes from fear of researching something currently considered as “nonsense,” or whether the cynicism really is because the idea is just not scientifically plausible.

The Future of the Use of Animal Behavior in Earthquake Prediction

Susan Hough, another well-known author in earthquake science, claims, “earthquake prediction represents an ongoing collision between science and society.”^[6] It seems almost that this collision is taking over from the importance of the research itself.

Hough does, however, pose the question of whether the small-scale approach of villages can in this case triumph over the advances of science. Tributsch^[19] was really the first to make a serious impact in the field of animals in earthquake science, and after his demands for additional research, there seemed to be a boom in interest in the late 70s/early 80s. Fattahi, a geophysics lecturer from Oxford university, claims, “after the failure of all people who work on earthquake prediction, the available funding has declined a lot” (personal correspondence, 2012).^[26]

The current available research makes it clear that more investigation is needed into the various different geological precursors, and particularly into the area of increased ionization. Kirschvink suggested, “it is clearly prohibitively expensive to record continuously a random variety of physical and chemical parameters near all possible earthquake epicenters”^[13] (p. 314). This is an understandable argument as constant monitoring would be required; however, Kirschvink also suggests that the introduction of inexpensive monitors could severely impact our current knowledge. Constant monitoring does propose huge benefits as it would not only pick up unusual activity before an earthquake, but could also provide a baseline for “usual” activity. A constant record would also oppose the argument that we do not get reports of unusual behavior without an earthquake.

There is certainly controversy surrounding the concept of using animals in the forecasting of earthquakes. Though no conclusive research has yet been published, one could argue that there must at least be a possibility for truth in the “folklore,” else the idea would immediately be dismissed on a large scale. An idea further to those discussed in this report is that even if animals do not respond with enough notice to directly impact or enable earthquake prediction, they may at least point us to geophysical precursors that may otherwise have gone unnoticed.

It should be noted that the aforementioned research “boom” in the late 70s was even supported by the USGS, who according to Tong funded two research projects into “Abnormal Animal Behaviour Prior to Earthquakes.”^[7] This suggests that the idea is not as ridiculous as many geologists and seismologists have implied, as it was once seriously considered by the USA’s leading seismological body. Our advances in technology have perhaps made people less open to traditional scientific methods. Tributsch’s view from over 30 years ago still rings true in that more

research is the only way to confirm or rule out the idea of using unusual animal behavior as a reliable method of earthquake prediction. Freund ended his research paper from 2003 with the quotation from philosopher Arthur Schopenhauer:

“All truth passes through three stages. First, it is ridiculed. Second, it is violent[ly] opposed. Third, it is accepted as being self-evident.”^[27] (p. 67)

Based on this, one could say that the prospect of animals in earthquake science has already succumbed to ridicule and violent opposition. If Schopenhauer is to be true, the only stage left is self-evidence.

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