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AN EVALUATION OF THE ANIMAL-BEHAVIOR THEORY For Earthquake Prediction

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INTRODUCTION

The notion that animals can sense earthquakes before they occur may have originated in ancient Greece in 373 B. C. when rats, weasels, snakes, and centipedes were reported to have moved to safety several days before a destructive earthquake (Quammen, 1985). In recent years earthquake prediction based on premonitory behavior in animals has been attempted in China and Japan, but scientists in this country remain skeptical.

Can a scheme for predicting earthquakes be based on animal behavior? This article contains the conclusions of a statistical test of this theory, based on a temporal comparison between 41,717 reports of missing pets and 224 earthquakes in the San Francisco Bay area over the three year period, 1983-1985.

For a dozen years a theory has been advanced in the south San Francisco Bay area that when an extraordinarily large number of dogs and cats are reported in the "Lost and Found" section of the San Jose Mercury News, the probability of an earthquake striking the area increases significantly (Maryanski, 1985; Allstetter, 1986). These earthquake predictions, based on two other criteria as well (Wells, 1985), specify that an earthquake of Richter magnitude between 3.5 to 5.5 will occur within a 70-mile radius of downtown San Jose in a designated time period. A success ratio of 80% over the last 12 years was claimed (Allstetter, 1986). However, seismologists do not accept this method of predicting earthquakes; McNutt and Heaton (1981) refute one of the other two criteria.

The scope of this study is limited to testing the validity of the theory that animal behavior, based on "lost and found" ads in the San Jose Mercury News, can be used to predict earthquakes. In this study the scientific method was used to test this theory in the following manner: (1) the problem is defined, (2) assumptions and constraints are recognized, (3) quantitative data is presented, (4) qualitative observations are made, (5) a statistical analysis is presented, and (6) a conclusion is made based on the data.

PURPOSE

The purpose of this study is to determine whether a positive temporal correlation exists between the quantity of lost and found pets and earthquake events. The method used to evaluate this correlation is straightforward: compare the daily quantities of

lost and found pets reported in the San Jose Mercury News with dates of earthquake events in the San Francisco Bay area over a statistically significant period of time--a three-year period from January 1, 1983 to December 31, 1985.

ASSUMPTIONS AND CONSTRAINTS

The data and constraints used in this article are the same used to determine the original hypothesis (Maryanski, 1985; Allstetter, 1985). The data base consists of the reports of stray pets as reported in the lost and found pet column in the San Jose Mercury News (daily circulation: 500,000). A broad range of seismic events is considered in this study: all those of magnitude 2.5 or larger, within a 70 mile radius of downtown San Jose. Accurate earthquake prediction in an urban area like the south San Francisco Bay can reduce earthquake hazards. The population in this area, including Santa Clara County and contiguous counties to the north (Alameda and San Mateo), was 3,156,900 on July 1, 1984 (AP, 1985).

The animal-behavior theory for predicting earthquakes assumes that pets leave their homes, places normally secure and comforting, in order to escape a disturbance or danger in their surroundings just before an earthquake. In practice the theory is based on the assumption that more pets run away from home at such times than at any other time. The hypothesis states that when quantities of missing pets increase extraordinarily, there is a marked increase in the probability of a forthcoming earthquake (Maryanski, 1985; Allstetter, 1986).

There are reports that turtles, eels, snakes, and catfish display premonitory anomalous behavior before earthquakes (Quammen, 1985). The problem of identifying the actual stimulus of this behavior remains unsolved, although ultrasonic and electromagnetic phenomena are suspected (Simon, 1976). Homing pigeons and geese are now known to navigate by earth's magnetic field using tiny crystals of magnetite incorporated in sense organs in their heads (Cooke, 1984). Magnetotactic bacteria, tuna, and salmon also contain similar magnetite crystals (Kirschvink and others, 1985). The animal-behavior theory tested in this study is based on the postulate that dogs and cats can detect precursory magnetic disturbances from seven to ten days before earthquakes (Allstetter, 1986).

An important qualification for this study is that each pet may be reported lost over a period from two days to two weeks. Therefore, the data on lost pets do not refer to separate animals, but rather to numbers of reports of stray pets.

Furthermore, the newspaper reports of stray pets do not necessarily represent an accurate account of all the stray pets in the San Jose area. Many missing pets are undoubtedly not reported. However, the daily variation of entries in the newspaper columns was the sole criterion used to establish the original animal behavior theory of earthquake prediction. It is assumed in this study that the general trend of quantities of reports of stray pets in the newspaper parallels the true number of stray pets. A lag time probably exists between the actual disappearance of a pet and the time that the owners are sufficiently distressed to run an advertisement in the newspaper. An additional delay is attributable to the response time for publications.

FIGURE 1

Figure 1. Daily reports of earthquakes and missing pets. Total quantities of lost-and-found (L & F) dogs (broken line), cats (solid line), and birds (dots) are shown for each day from January 1 through June 31, 1984. Note the weekly variation of missing dogs, with the minimum reported numbers on Mondays. Earthquake magnitudes and dates are plotted on the same time scale for comparison with missing-pet curves. If the correlation is positive, then peaks in missing-pet curves should correspond with quakes in the same week, plotted directly above.

Correlating the publication date of a missing-pet with a true-time earthquake event clearly involves many unaccountable variables. A pet may detect precursory effects of an earthquake and leave home, but the report of the missing pet may not appear in the newspaper until after the earthquake. So, reports appearing a day or two following an earthquake may be as important as those immediately before. On the other hand, a noisy, destructive earthquake may frighten pets enough to cause them to flee, and may also account for reports of missing pets after a quake. In addition, pets undoubtedly are absent from home for other reasons. Some pets may go into seclusion to give birth; get stolen; or be killed in automobile traffic.

Pet owners must pay $2 or more per day for reports of lost pets in the San Jose Mercury News. Even Good Samaritans reporting lost pets they had found paid for ads in the newspaper. Free ads for Good Samaritans who had found lost pets were run for two consecutive days. These free services were available from January 1, 1983, through June 20, 1984, and from November 13 through December 31, 1985. A possible fluctuation of the number of lost pets that were found by strangers many correlate to the period when there were no free found ads in the newspaper.

QUANTITATIVE EVIDENCE

This study is based on a tabulation of 41,717 daily reports of missing pets in the San Jose Mercury News, and of 224 earthquakes of magnitude 2.5 or larger. Data are too voluminous for reproduction here but are available on request. Table 1 summarizes annual totals. All data on stray pets are from Section 1400 (called Lost and Found Dogs) and Section 1405 (called Other Pets Lost and Found) in the Classified Section of the San Jose Mercury News.

Earthquake dates and magnitudes are from the Branch of Seismology, U. S. Geological Survey, Menlo Park, California. Earthquakes considered in this study have Richter magnitudes of 2.5 and larger and have epicenters located in a 70-mile (113-kilometer) radius of downtown San Jose, 37°20'N --- 121°53'W. Quakes smaller than M 2.5 have been disregarded in this study because they are negligibly perceptible and so numerous that they are insignificant to the study of animal behavior. For example, from April 24th through 26th, 1984, seismographs recorded approximately 300 earthquakes (Ansley, 1984). Only 15 of those quakes registered larger than M 2.5.

QUALITATIVE OBSERVATIONS

The M 6.2 Morgan Hill earthquake of April 24, 1984 and the hundreds of strong aftershocks provide an ideal test for the animal behavior theory of earthquake prediction. The epicenter of the Morgan Hill earthquake is located about 10 miles from downtown San Jose and was considered a major earthquake. It was the fifth

largest since 1850 within 100 km of the San Francisco Bay area (Toppozada, 1984). Most notably, the quake caused the strongest horizontal earthquake acceleration ever measured, at 1.3 g (Shakal and others, 1984). The period from January 1984 to July 1984 covers the time period of the occurrence of the Morgan Hill earthquake and its main aftershocks.

Daily quantities of earthquakes and reports of missing pets during this period are shown in Figure 1. Effects of strong quakes such as the Morgan Hill earthquake extend over large areas and theoretically affect more pets than do small quakes. Consequently, time periods in which strong quakes occur have the best potential for correlating quakes to missing pets.

The weekly variation in Figure 1, with the minimum reports of missing dogs on Mondays, continues throughout the three-year study period from January 1983 through December 1985. This pattern reflects a trend of most reports appearing in mid-week and expiring on Monday.

Plots of weekly totals of missing pets, for the period January 1983 through December 1985, eliminate the variation in daily trends and show net changes (Figure 2). Weekly totals are used for interpretation because they account for lag times between pet disappearances and their reported loss in newspaper ads and because they may show potential premonitory behavior for days prior to an earthquake. Correlation of missing pets with earthquakes is irregular (Figure 2). There are nine peaks in missing-dogs curves that correspond with earthquakes of magnitude 3 or larger. However, there is a total of 62 large quakes during this period, and 16 of them correlate to valleys (Figure 2). Furthermore, the size of the spikes is not proportional to the quantity or magnitudes of quakes.

FIGURE 2

Figure 2. Weekly totals of earthquakes and reports of missing pets. Total quantities of lost-and-found dogs, cats, and birds are plotted for each week from January 1983 through December 1985.

The only annual trend repeated during the three years studied are the weeks numbered 27 and 28 for each year. Those weeks have anomalously high quantities of missing dogs while quantities for missing cats and birds are normal. Since those weeks coincide with the Fourth of July and the week following, do they indicate that dogs hide from fireworks?

There is no apparent trend or correlation between reported cats and birds to quakes. The quantities of reported cats and birds seem too low to be statistically significant.

Four-week totals plotted in Figure 3 are not suitable to provide specific temporal correlation between missing pets and quakes, but they do show that the quantity of quakes does not correspond to peaks in missing-pet curves. Numerous quakes following the Morgan Hill earthquake in April 1984 correspond to normal or below-normal quantities of reported lost-and-found dogs, cats, and other pets. Only the quantity of reported lost-and-found birds increases during that four-week period.

FIGURE 3

Figure 3. Totals in four-week periods of earthquakes and reports of missing pets, January 1983 through December 1985. Figure includes the total numbers of not only lost-and-found (L & F) dogs, cats, birds, and other pets, but also lost dogs (L DOGS) and lost cats (L CATS) as separate quantities.

Quantities of both lost and lost-and-found dogs and cats are plotted on Figure 3. This separation creates pairs of lines that are nearly parallel, signifying a lack of variation of found-pets during the period when the newspaper offered "Free Found Ads" to Good Samaritans who were looking for owners of lost pets.

The only strong positive correlation in Figure 3 falls on the first four-week period in 1984 where there is an apparent correlation between reports of missing dogs, cats, and birds to the occurrence of 13 quakes in that period. The significance of this correlation, however, vanishes with reference to Figure 2. The peaks for missing pets precede the swarm of 13 quakes by two or three weeks.

A comparison of quakes to missing pets on a yearly time-scale is shown in Table 1. There is a peak in the number of earthquakes in 1984; however, only the quantities of missing birds and other pets (mainly rabbits and turtles) have peaks in 1984. The total for cats is lowest in 1984. The number of missing dogs declines steadily over the three year period. The reports of lost dogs and cats do not correlate to annual quantities of earthquakes.

TABLE 1

Table 1. ANNUAL TOTALS OF EARTHQUAKES AND MISSING PETS REPORTED IN CLASSIFIED SECTIONS 1400 AND 1405, *San Jose Mercury News.*

STATISTICAL ANALYSIS

The quantities of lost-and-found dogs is statistically the most important data. Reports of missing dogs are most numerous and thus the best index for tracing trends for lost and found pets. Their numbers are in the hundreds per week, while cats number less than 100 per week, and birds and other pets less than 35 per week. For these reasons only reports of missing dogs are considered in the following analysis.

A statistical analysis for correlating quakes and missing dogs is shown in Figure 4. In each of the three years studied, a total of 18 weeks had no earthquakes and 34 weeks had one or more earthquakes. An ideal correlation (reports of stray pets being most numerous on dates of earthquakes) would place earthquake events in weeks with above-average reports of missing dogs in the upper right region of each graph of Figure 4. In this scenario, an ideal positive correlation would show the weeks without earthquakes plotted in the lower left region of each graph, signifying that the quantity of pets leaving home is lower when earthquakes do not occur. The actual correlation between reports of missing dogs and the occurrence of earthquakes is summarized in the Figure 4 caption.

FIGURE 4

Figure 4. Graphic test for correlating earthquakes with weekly variations of lost-and-found dogs. Weeks with earthquakes are plotted above the abscissa, depicted with symbols of earthquakes in each week (a horizontal line separates weeks in a single column where necessary); weeks without quakes are below. To the right and left of the ordinate are weeks with above- and below-average weekly totals, respectively, at a distance proportional to the relative deviation (RD) of the number of lost and found dogs per week (W) compared to the annual average of lost-and-found dogs per week (A), or the relative deviation equals the reported number of lost-and-found dogs per week minus the annual average of lost-and-found dogs per week (RD = W - A), where A (1983) = 249, A (1984) = 218, A (1985) = 177.

The lack of correlation between earthquake occurrences and lost-and-found dogs is illustrated in Figure 4. The number of weeks of earthquakes with an above-average number of stray dogs is 45 weeks. The number of weeks with earthquakes that have a below-average number of stray dogs is also 45 weeks. A correlation of only 50% was found to exist for these data in the total 156 weeks in the study period (Figure 4). The total number of earthquakes for each of the three years in the study period were then correlated with the number of missing dogs. A similar correlation of 49% was found to exist (Figure 4). A 50% correlation between any two sets of data is considered to be random.

PLATE SUMMARIZING DATA IN FIGURE 4:

The yearly statistical correlation between weekly occurrences of earthquakes and weekly numbers of missing dogs shown in Figure 4 is summarized below.

1983: 11 weeks with quakes in above-average region of missing dogs,

22 weeks with quakes in below-average region of missing dogs.

There is a 33% correlation based on weeks with quakes.

6 weeks without quakes in below-average region of missing dogs,

12 weeks without quakes in above-average region of missing dogs.

There is a 33% correlation based on weeks without quakes.

An average correlation of 33% exists for these two factors.

1984: 15 weeks with quakes in above-average region,

18 weeks with quakes in below-average region.

There is a 45% correlation based on weeks with quakes.

11 weeks without quakes in below-average region,

7 weeks without quakes in above-average region.

There is a 61% correlation based on weeks without quakes.

An average correlation of 53% exists for these two factors.

1985: 19 weeks with quakes in above-average region,

15 weeks with quakes in below-average region.

There is a 56% correlation based on weeks with quakes.

13 weeks without quakes in below-average region,

5 weeks without quakes in above-average region.

There is a 72% correlation based on weeks without quakes.

An average positive correlation of 64% exists for these two factors.

An average correlation of three years is (33% + 53% + 64%) / 3 = 50%.

The total number of earthquakes for each year are correlated with the number of missing dogs. A 49% correlation exists.

1983: 14 earthquakes fall in above-average region of missing dogs,

36 quakes in below-average region.

There is a correlation of 28%.

1984: 62 quakes in above-average region,

42 quakes in below-average region.

There is a correlation of 60%.

1985: 38 quakes in above-average region,

28 quakes in below-average region.

There is a correlation of 59%.

An average correlation for three years (28% + 60% + 59%) / 3 = 49%

The earthquakes were then weighted as to their relative energies and correlated with the number of stray dogs. The correlation was also random. The data show there is no correlation other than random chance that dogs left home prior to earthquakes.

CONCLUSION

This study shows that a significant positive correlation does not exist between the behavior of pets in the San Jose area and the occurrence of earthquakes within the same area over the three year period from January 1983 through December 1985. Based on this random disappearance of pets with respect to earthquakes,•no scheme seems possible to predict earthquakes using newspaper reports of missing pets.

DISCUSSION

This study illustrates how the scientific method tests the validity of new ideas. The data used in the animal-behavior hypothesis of earthquake prediction is not scientifically sound. The same quantitative data, assumptions, and constraints used to establish the hypothesis were used in this study and led to the conclusion that the hypothesis is invalid.

Science is designed to correct itself. New hypotheses must survive the strict test of the scientific method to be accepted. New ideas are greeted with healthy skepticism and rigorous evaluation. If they pass the scientific method of evaluation, then the idea is accepted. If a new concept fails the tests, it must be revised with more accurate and compelling evidence and cautious interpretations. Data that could bring doubt to new ideas must be given. All of the facts, even those that disagree with concepts, must be presented in order to help judge the value of the contribution and to help construct new interpretations.

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REFERENCES

Allstetter, B., 1985, Eighty percent chance of quake to hit next week: Gilroy Dispatch, June 18, p. A3.

Allstetter B., 1986, Hang on --- south county's due for big year of quakes: Gilroy Dispatch, January 30, p. A1.

Ansley, D., 1984, Quake watchers keep tabs on what's shaking in area: San Jose Mercury News, October 9, p. C1.

Associated Press, Sacramento, 1985, Most California counties gain population in '84: San Jose Mercury News, January 15, p. B4.

Cooke, P., 1984, How do birds find where they're going? Science 84, September p. 26.

Kirschvink, J. L., Jones, D. S., and MacFadden, B. J., editors, 1985, Magnetite biomineralization and magnetoreception in organisms: Plenum Publishing Corporation, NY 681 p.

Maryanski, K., 1985, Get out your calendar; Berkland has plotted our quakes for 1985: Gilroy Dispatch, January 3, p. A1.

McNutt, M., and Heaton, T. H., 1981, An evaluation of the seismic-window theory for earthquake prediction: CALIFORNIA GEOLOGY v. 34, no. 1, p. 12-16.

Quammen, D., 1985, Animals and earthquakes: This World, San Francisco Chronicle, April 21, p. 15-16.

Shakal, A., Gay, T. E., Jr. and Sherburne, K., 1984, Morgan Hill earthquake caused record shaking force: CALIFORNIA GEOLOGY v. 37, no. 8, p. 163-164.

Simon, R. B., 1976, Animal behavior and earthquakes: CALIFORNIA GEOLOGY v. 29, no. 9, p. 210-211.

Toppozada, T. R., 1984, Morgan Hill earthquake of April 1984: CALIFORNIA GEOLOGY v. 37, no. 7, p. 146-148.

Wells, J., 1985, Emotional, physical signs may portend earthquakes: San Jose Mercury News, October 15, p. E1.