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Group planarian sudden mortality: Is the threshold around global geomagnetic activity ≥K6?

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Sudden deaths in groups of animals have been observed by field and laboratory biologists. We have measured mortalities in large group-housed planarian during the infrequent periods of very intense geomagnetic activity. In 13 separate episodes over the last 5 y we have observed the sudden death in our laboratory of hundreds of planarian if their density was about 1 worm per cc and the global geomagnetic activity was K≥6 the day before or the day of the observation of the mortality. Such mortality never occurred in other conditions or days. Both estimates of the "magnetic moment" of a planarian in magnetic fields above this threshold of sustained magnetic flux density as well as the magnetic energy within the planarian volume predict values that could affect phenomenon associated with the total numbers of pH-dependent charges within each worm. These conditions could affect the Levin-Burr bioelectrical signals and networks that affect patterning information and sustainability in whole living systems. The establishment of a central reservoir for the report of these transient events might allow Life Scientists to more fully appreciate the impact of these pervasive global stimuli upon dense groups of animals.

Introduction

Sudden increases in global geomagnetic activity are primarily mHz amplitude variations over a range of about 40 to 1000 nano-Tesla (nT).[1] Although the intensities are < 1% of the magnitude of the steady-state earth's magnetic field, the occurrences of these 2 to 5 day transients have been associated with a variety of physiological changes in terrestrial organisms across the phylogenetic continuum.[2-4] Increased mortality, the most extreme consequences, has been reported for a variety of species, including human beings.[5] Some organisms, such as those exhibiting electrical anomalies that produce epileptic seizures, may be particularly vulnerable.[6-7]

Experimental studies, where the applied magnetic fields were patterned to simulate geomagnetic activity in both amplitude and temporal structure, have supported the assumption that the mortality is associated with the magnetic field component rather than correlative stimuli.[8] Recently we[9] found that planarian exposed to a sequence of weak magnetic field patterns designed to simulate "global magnetic storms" produced complete mortality that was "intensity" and "exposure-duration"-dependent. Our other experiments had shown the sensitivity of these worms as indicated by their behavioral responses to opiate concentrations in the femtoMole range that interacted with brief (15 min) exposures to temporally patterned magnetic fields in the 1 micro-Tesla range.[10] The points of interaction were consistent with the different binding capacities of receptor subtypes.[11]

Over the last few years we have observed massive, sudden mortality in densely housed groups of planarian occurring within 24 hr after the onset of geomagnetic storms with maximum intensities of K6 or greater. Our definition of planarian death is when only fragments of whole planarian remain. These occasional events occurred even though we followed a very rigorous housing and feeding protocol. Upon arrival from the supplier planarian were maintained in large groups in spring water with a density of 1 planarian per cc of water. Depending upon the specific experiment the groups could be maintained with higher ratios, i.e., 1 planarian per > *1 cc*. Typically 50 planarians were maintained in *50 cc* while 300 planarians were maintained in *300 cc*. The groups were allowed access to small chunks of beef liver for 3 hrs once every 3 d. The housing water was changed after feeding during which time the planarians in the same groups were placed in temporary containers containing spring water (same worm/water ratio). After thorough rinsing of the home container with spring water the planarian were returned.

Even cursory calculations indicated the forces or energies from these changes could overlap with the "bioelectrical" signals and

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"blueprints" developed by Michael Levin[12] and pursued decades earlier by H. S. Burr.[13] Such occasional episodes of "spontaneous" deaths in groups of planarian occur in many laboratories. We Googled planarian researchers and e-mailed the first 10 laboratories in the list (for North America) that have long histories involved with planarian research. The researchers responded with explanations that ranged from bacterial infections to suspected viral contaminations. We understand there is likely to be multiple etiologies rather than a single precipitant.

Intense Geomagnetic Episodes and Sudden Planarian Death

Our research with planarian has gained momentum over the last decade. Consequently for utility we began to maintain large numbers of brown planarian (*Dugesia tigrina)* in convenient volumes of spring water. They have thrived with minimal mortality. Since we started this procedure over the last 5 y there have been 13 episodes where hundreds of planarian (30 or 40 planarian within one container) were found dead as inferred by fragments of worm relative to intact viable worms. Because of the infrequency of the event and the conspicuous occurrence of unusually intense geomagnetic storms at the same time, we began to keep systematic records of both phenomena. It became evident that population density (about 1 planarian per cc) was a significant variable that contributed to the geomagnetic activity-mortality effect. If the density was less, no mortality occurred. These results are shown in **Table 1**. These were the only mass mortalities we observed during this interval. The percentage values were rounded to the nearest 5 percent. The numbers of worms in the initial stock population were based on the counts from the supplier.

Biophysical Support of Possible Physical Mechanisms

From our perspective as Physical Biologists we have reasoned there should be quantitative bases for this "threshold" derived from known physical mechanisms and geomagnetic/solar values. In general a $\geq$K6 magnetic storm at the latitude of our laboratory displays a maximum $\sim 5\cdot 10^{-7}$ T (500 nT). If we assume the rostral-caudal potential difference across an average planarian of about 1 cm is 10^{-3} V (1 mV), then current can be estimated. (Some sensory cells can respond to shifts in voltages as low as 5 $nV\cdot cm^{-1}$,[14]). Because the planarian are maintained in spring water which contain ions similar in concentration to extracellular fluid, which has a resistance of 2 $\Omega\cdot m$, the current ($V\cdot\Omega^{-1}$) would be about 10^{-3} $A\cdot m^{-1}$ and when applied over 1 cm would be 10^{-5} A.

The average flat, cross-sectional area of planarian in our stocks has been about 2 $\cdot 10^{-4}$ m^2. Consequently the functional "magnetic moment" of this linear animal could be assumed to be $\sim 2\cdot 10^{-9}$ $A\cdot m^2$. When multiplied by an applied magnetic field flux density ($kg\cdot A^{-1}\cdot s^{-2}$) of the peak to peak values for $\geq$K6 geomagnetic disturbances the resulting available energy ($kg\ m^2\cdot s^{-2}$) would be $\sim 10^{-15}$ J. From the perspective of magnetic energy defined by $E=B^2\ (2\mu)^{-1}\ m^3$ where B is the strength of the field shift, μ is the magnetic permeability ($1.26\cdot 10^{-6}$ $N\cdot A^{-2}$) and m^3 is the volume of the worm ($\sim 1.5\cdot 10^{-10}$ m^3), the "magnetic energy" available would be $\sim 3\cdot 10^{-17}$ J. The frequency equivalence, obtained by dividing by Planck's constant ($6.626\cdot 10^{-34}$ J·s) is $4.5\cdot 10^{-18}$ Hz. For an electromagnetic frequency (assuming the velocity of light) the wavelength approaches the width of the cell plasma membrane ($\sim$10 nm). It is also the wavelength of spectral power density[15] of the increase in photon emissions from spring water after exposure for protracted periods in the dark to one of the field patterns that produced the complete planarian mortality.[9]

Critical values also converge with other more classical perspectives. Assuming about 300 worms per 500 cc of spring water (which was a typical density in which the mortality was maximum but only during geomagnetic activity of $\geq$K7) the average distance between each worm would be $1.2\cdot 10^{-2}$ m. Applying the classic electric force equation: $F=qq\ (4\pi\varepsilon_o)^{-1}\cdot r^{-2}$, where q is the unit charge ($1.6\cdot 10^{-19}$ A·s) and ε_0=electric permittivity

Table 1. Dates, percentage (and numbers) of planarian found dead, and geomagnetic indices (K value) for the day before, during, and after the observation. These were the only losses of this magnitude recorded when planarian stocks were being maintained during this 4 y period

			Peak K Index		
Date	**Planarian Loss (% of stock population and equivalent n)**	**Worm to Water Ratio**	**Day Before**	**Day of**	**Day After**
July 17, 2011	100% loss, n = 300	1 to 1, 1 to 2	1	6	2
March 10, 2012	70% los, n = 300	1 to 1	7	5	2
October 10, 2012	70% loss, n = 200	1 to 1	6	3	2
March 10, 2012	100% loss, n = 300	1 to 1, 1 to 2	7	5	3
March 17, 2013	60% loss, n = 220	1 to 1	3	6	3
May 26, 2013	25% loss, n = 75	1 to 1	5	4	2
June 2, 2013	85% loss, n = 250	1 to 1, 1 to 2	6	3	3
February 20, 2014	85% loss, n = 250	1 to 1	6	6	3
June 9, 2014	70% loss, n = 200	1 to 1	6	2	2
September 12, 2014	35% loss, n = 100	1 to 1	4	7	4
January 8, 2015	100% loss, n = 250	1 to 1	7	4	3
March 17, 2015	100% loss, n = 250	1 to 1	3	8	6
May, 14 2015	25% loss, n = 75	1 to 1	6	3	3

($8.85\cdot10^{-12}$ $C^2\cdot N^{-1}\cdot m^{-2}$) the F between any 2 charges, such as protons, would be 10^{-23} N. The addition of the dielectric constant for spring water could change it by a factor of ~10 to 100. Over 10^{-2} m the energy would be 10^{-27} J.

For the total energy to achieve the value of 10^{-15} J as shown above, the number of functional charges in each planarian (especially if they were configured as a bioelectric field[12,14]) should be around 10^{11} to 10^{12}. The typical pH of the spring water in which our planarian are housed, even after not being changed and when the presence of mucous residues is visible, ranges between ~7.2 and 7.4. The concentration of hydronium ions[16] around this pH within the volume of the planarian by calculation is about 10^{11}. That protons act as transmitters for contraction of muscles in *C. elegans*[17] and in vestibular cells[18] with changes of only 0.2 pH units has been established.

Levin[19] has provided evidence that endogenous bioelectrical signals and networks affect patterning information by non-local processes during the development and regeneration of planarian. Particularly strong ambient, shifts in geomagnetic intensity could interact with these patterns. However whatever biophysical variable that is associated with species *density* appear to be the required component for this synergism. Many years ago Milkman[20] published some elegant studies with flies indicating how population density could predispose these invertebrates to "spontaneous" mortality. Interestingly, group or pod animals such as cetaceans in aqueous environments may show a predilection for disorientation and beaching (death) from subtle changes in geomagnetic configurations or geomagnetic "storms".[21]

We appreciate their may be many etiologies for sudden death in groups of high density animals on the planet. For planarian, fish, birds, and rodents there is now evidence that the correlational observations can be confirmed with experimental simulations.[8,9,22-24] The molecular biological changes in planarian in response to brief exposures of power line intensities reported by Goodman et al[25] emphasize the sensitivity of these conditions. Considering the data base and posting sites now available on the WEB, perhaps Biologists have the opportunity to systematically report cases of sudden death of the studied species on a day-to-days basis. Perhaps by viewing these global data we will find that these events are more common than we have assumed.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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