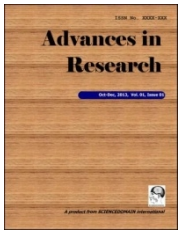


Advances in Research
2(6): 303-319, 2014, Article no. AIR.2014.6.001

SCIENCEDOMAIN *international*
www.sciencedomain.org

Multi-Parametric Monitoring System of Associated Seismic Phenomenology and Unusual Animal Behaviour in Western Piedmont

Giovanna De Liso[1,2,3*], Cristiano Fidani[1,4*] and Andrea Viotto[1]

[1]Seismic Precursors Study Center, Via Servera 16, 10066, Torre Pellice, Italy.
[2]Institute for Higher Education in Art and Music "G. F. Ghedini", Cuneo, Italy.
[3]Voce Pinerolese, P. S. Donato 30, 10064, Pinerolo, Italy.
[4]Central Italy Electromagnetic Network, CIEN, 63900, Fermo, Italy.

Authors' contributions

This work was carried out in collaboration between all authors. The animal behaviour and instrumental observations in SPSC were performed by author GDL which designed the study. Author CF installed the electromagnetic detector, managed the discussion and final manuscript, he performed the statistical analysis of the Radon data. Author AV performed the observations in Luserna San Giovanni. All authors read and approved the final manuscript.

Review Article

Received 31st December 2013
Accepted 8th March 2014
Published 10th April 2014

ABSTRACT

Earthquakes have been seldom associated with reported non-seismic phenomena observed weeks before and after shocks. Non-seismic phenomena are characterized by unusual sounds and light emissions as well as degassing of vast areas near the epicentre with chemical alterations of shallow geosphere (aquifers, soils) and the troposphere. Many animals are sensitive to even the weakest changes in the environment, typically responding with behavioural and physiological changes. Data on animal behaviour, before the moderate and low seismic activity in Western Piedmont, started to be monitored in connection with several physical measurements related to time and the earthquake epicentre distance, evidencing the specific responses of different animals. Several instances of strange animal behaviour were observed, which could causally support the hypotheses that they were induced by the physical presence of gas, electric charges and electromagnetic waves in atmosphere. A multi-parametric monitoring system was created to verify these hypotheses.

**Corresponding author: E-mail: c.fidani@virgilio.it;*

Keywords: Unusual animal behaviour; earthquake early warning; electric monitoring; magnetic monitoring; radon monitoring; sound monitoring.

1. INTRODUCTION

The unusual animal behaviours, often observed before earthquakes in a moderate seismic area in Western Piedmont [1,2] and nearby regions [3,4], Italy, with the observation of anomalies of some physical parameters [5], induced the Authors to create the "Seismic Precursors Study Centre" (SPSC) [6]. The SPSC is placed in de Liso's house (Fig. 1), in Torre Pellice (44°49'235'' N, 7°123'04'' E, Western Piedmont, NW Italy) at 699 m above sea level on Vandalino Mountain. It is not too far from an abandoned iron mine, near a particular "geological sanctuary" on Castelluzzo peak [7] and Bonnet, which are rich in augen-gneiss, of eruptive origin, biotite, ophiolite, zeolite, pechblenda and "Luserna Stone" (gneiss) [7]. It is also near a forest, at a distance of 70 m from the Biglione creek, 600 m from a graphite mine and 12 km far from the talc mines in Prali's area. The recent classification of the seismic risk in this area is 3S, with a moderate seismic activity. It must be remembered that Val Pellice was the theatre of historical earthquakes with great magnitudes, as the famous earthquake of April 2nd 1808, with a magnitude 5.7 Richter [8]. Regarding this earthquake, an interesting report of physicist G. Eandi and of Captain L. Garola about pre-seismic anomalous animal behaviours and weather anomalies was found [1], similar to those which were observed now. Past observations of animal behaviours before, during and after earthquakes, have been reported since the early BC centuries in Italy [4]. There are several modern annotations concerning strange animal behaviours with hundreds of observations not only from Italy [3,4,9], but from other seismic region of the world [10,11], even if very different study approaches to the nature [4] and geological structures were implicated.

From the cinematic point of view, the coexistence of extensional, compressional and transcurrent regimes in various areas of the Alps poses interpretation difficulties [12]. The Alpine belt resulted from the Tertiary convergence between the European and African plates. The Apulian microplate was caught in between the two, leading to the closure of the mid-Jurassic Ligurian Tethys Ocean during Upper Cretaceous–Eocene eras and to subsequent continental collision during the Tertiary [13]. The collision history, characterized by the propagation of the compressive front towards external zones, started in the Palaeogene era with syn-metamorphic structuring of the internal Penninic zones, which consists of a stack of high-temperature to high-pressure metamorphic nappes [14]. The metamorphic internal zones overthrusted the external zones along the Penninic frontal thrust during the Oligocene period [15]. At the Western margin of the Po Plain, where SPSC is located, the ongoing indentation and related anticlockwise rotation, between the Adriatic and European plates, is accommodated by complex fault kinematics [16]. The NW–SE oblique convergence between Adria and Europe seems to be accommodated by NE–SW thrust/transpressive faults in the Western Po Plain subsurface, and by N–S strike-slip faults along the inner border of the Cottian Alps. The seismicity (see Fig. 2a) is considered to be only low to moderate, with typical magnitude range $3 < ML < 5$, while a relatively high level of seismicity is found in the Briançonnais and Piedmontese arcs. In terms of stress field, an orogen-perpendicular orientation of the maximum horizontal compression axis is established along the western periphery of the Alpine chain [17]. Within the Alpine chain, uplifting values obtained both by the analysis of the PS-InSAR and the GPS data [18] are observed along the Pellice and Chisone valley bottoms, where a thick sequence of strongly consolidated Early-Middle Pleistocene lacustrine and fluvio-lacustrine deposits are present, indicating an overall positive velocity trend (see Fig. 2b).

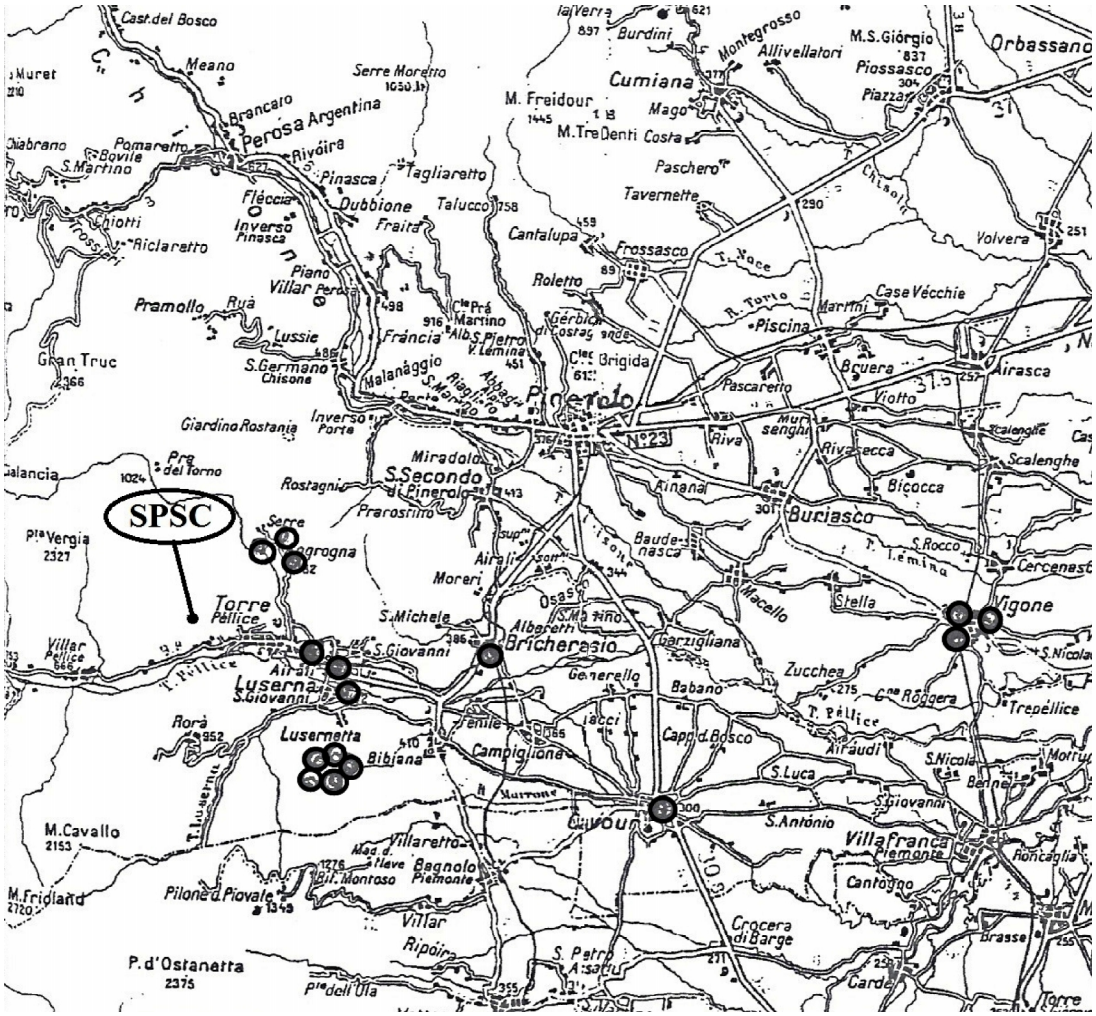


Fig. 1. Map with SPSC location in the territory near Pinerolo; radon measurements in SPSC and in the other locations are inside the black circles

The next Section is dedicated to the methodology of collecting animal observations and the multi-parameter data obtained from instruments. The multidisciplinary informations together with some observation examples are reported in Section 3, with a particular attention to animal behaviour phases. Human health problems are also observed and considered in Section 4, for people safety. The Conclusions summarises preliminary observations occurred in SPSC and the potentialities of this multi-parameter monitoring.

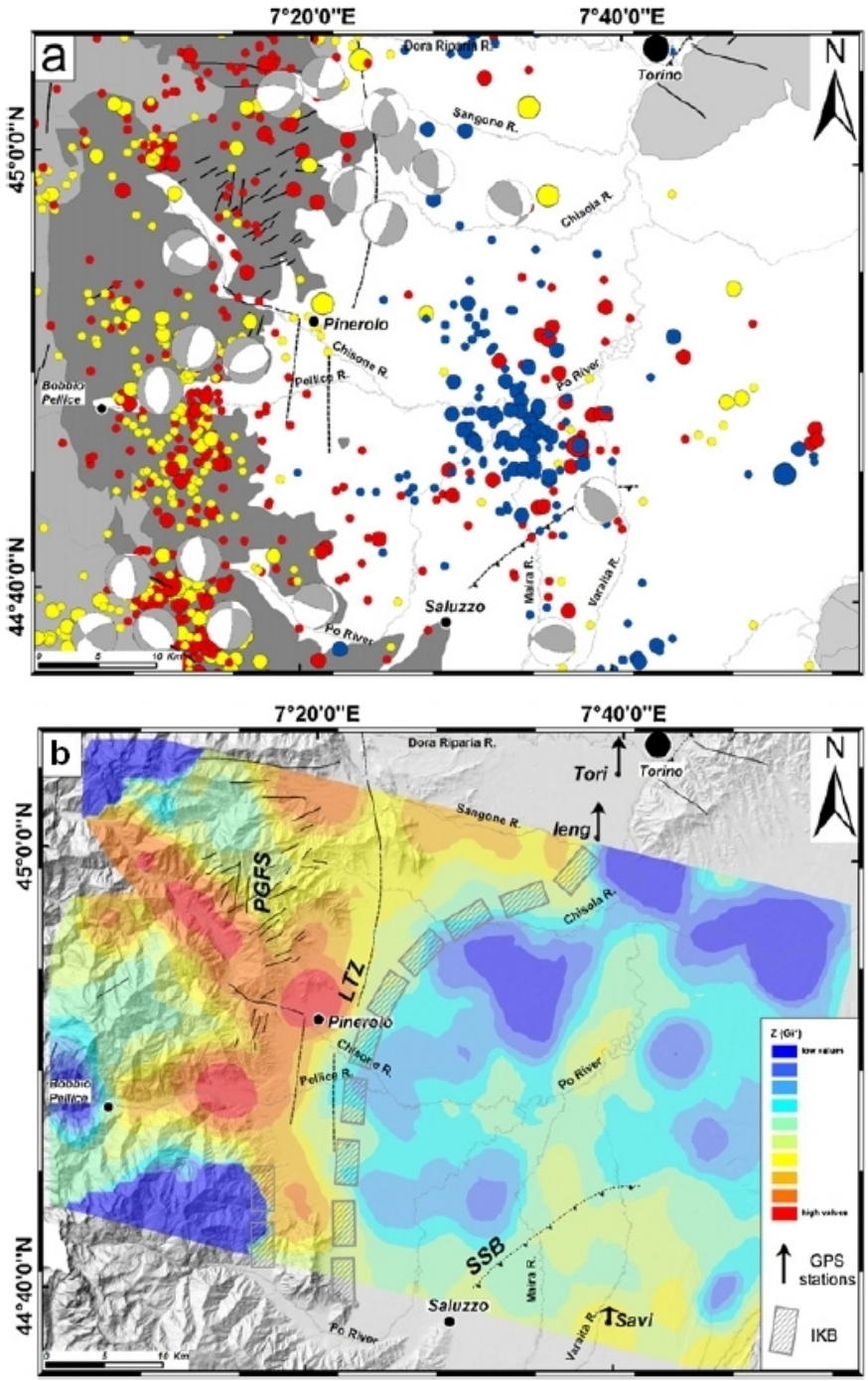


Fig. 2. (a) instrumental seismicity and focal mechanisms around SPSC; (b) Iso-Kinematic Map expressed in high and low values of differential uplift, in red and blue areas, respectively; rectangles filled with grey solid lines show the Iso-Kinematic Boundaries; after Perrone et al. [12]

2. OBSERVATION OF ANIMALS, INSTRUMENTATIONS AND MONITORING

The observation of animal behaviours began in 1991, when it was noted that some unusual recurrences in animal behaviour occurred before earthquakes. The study of animal behaviour was conducted with the following modalities:

1991-2006:

1 dog and 1 Italian wolf in SPSC	Every day: 07-10, 22-24
Cats in SPSC	Every day: 07-09, 23-24
Insects and Arachnids in SPSC	Every day: 06.30'-07

2007-2011:

2 dogs in SPSC	Tuesday and Thursday: 04.30'- 05.30' Other days: 07-10, 22-24
Cats in SPSC	Tuesday and Thursday: 04.30'-05.30' Other days: 07-09, 23-24
Insects and Arachnids in SPSC	Tuesday and Thursday: 05.30'-06 Other days: 06.30'-07

2012-2013:

2 dogs in SPSC	Tuesday and Saturday: 04.30'-05.30' Other days: 07-10, 22-24
Cats in SPSC	Tuesday and Saturday: 04.30'-05.30' Other days: 07-09, 23-24
Insects and Arachnids in SPSC	Tuesday and Saturday: 05,30'-06 Other days: 06.30'-07

1991-2013:

For birds in wild areas near SPSC	Every day: 01-02.30'
For other animals near SPSC	Every day (except the 2 days/week when out for work reasons): irregularly

The particular observations of dead arachnids near some windows in SPSC were made several times a few days after Geiger showed radioactivity values above average. Thus, since 2006, five days a week were observes the arachnids eventually dead in SPSC. Since 2011 these observations were also compared with Radon monitoring.

Behavioural observations of other wild animals that come near SPSC were irregular, and also hearing observations for farm animal were irregular since 1991. It is possible only to hear the vocal language of farm animals, as they are live enclosed in farms or pens not too far from SPSC. All the observations were recorded in a notebook and then compared "a posteriori" with a multiple physical monitoring and with seismic events. They can be resumed in Table 1. Observation results for animal behaviour confirmed the cases reported by Tsuneji Rikitake [19], even if not yet in a similar extended work.

Table 1. Study of animal behaviour

Animals	Observation place	Modality of observation	Observation period	Animal number
Dogs	SPSC	Continuous	1991-2006	1
Italian wolf	SPSC	Continuous	2001-2006	1
Dogs	SPSC	Continuous	2006-2013	2
Cats	SPSC	Continuous	1991-2007	6
Cats	SPSC	Continuous	2008-2013	4
Insects, arachnids	SPSC	Continuous	1991-2013	Numerous
Insects, arachnids	Garden of SPSC	Continuous	1991-2013	Numerous
Dogs	Farms near SPSC	Continuous hearing observations	1991-2013	Numerous, over 30
Little Birds	Wild near SPSC	Continuous	1991-2013	Numerous
Owls, barn-owls	Wild near SPSC	Continuous	1991-2013	Numerous
Crows, rooks	Wild near SPSC	Continuous	1991-2013	Numerous
Magpies	Wild near SPSC	Continuous	1998-2013	Numerous
He/she blackbirds	Wild near SPSC	Continuous	1991-2013	Numerous
Buzzards	Wild near SPSC	Frequently	1999-2013	2
Water snakes	Garden of SPSC	Frequently	1991-2013	3
Vipers	Garden of SPSC	At intervals	1998-2006	2
Salamanders, toads	Garden of SPSC	Frequently	1991-2013	4
Hedgehogs	Garden of SPSC	Frequently	1995-2013	2
Fox	Wild near SPSC	Frequently	1991-2013	2
Wolf	Wild near SPSC	1 time	91	1
Squirrels	Garden of SPSC	Frequently	1991-2013	4
Cows, sheep, goats, cocks, chickens	Farms near SPSC	Continuous hearing observation	1991-2013	Numerous
Donkeys	Farms near SPSC	Continuous hearing observation	1999-2013	2
Limacidae, earth-worms	Farms near SPSC	Continuous hearing observation	1991-2013	Numerous

These observations were supported by a multi-parameter monitoring gradually more complex since 1998 [5,6,20]. Starting in 2000, a daily monitoring for radioactivity and air temperature measurements were undertaken during the night in the forest near SPSC. The air temperature values were recorded from a little rock crack and water temperature measurements were intermittently recorded in Biglione creek near SPSC. Since 2011, a continuous radon monitoring started in the basement of SPSC. Since 2012, irregular radon monitoring started by dosimeters, placed in some places inside and outside (in the garden) of SPSC. Since May 2012, a station of the Central Italy Electromagnetic Network (CIEN, formed by 12 stations whose positions are shown in Fig. 3) [21], together with a ground thermometer and a meteorological station were installed in SPSC. Characteristic ELF electric perturbations were monitored by CIEN in relation to seismic activity, together with VLF and LF signals which were emitted from different VLF and LF global transmitters [22]. Since July 2012, weekly measurements of the water pH were started in the garden near

SPSC and in the Biglione creek. The positions of the instrument in SPSC basement are shown in Fig. 4 and instrumental details are resumed in Table 2.

Fig. 3. The actual geographical positions of the 12 CIEN Stations in Italy

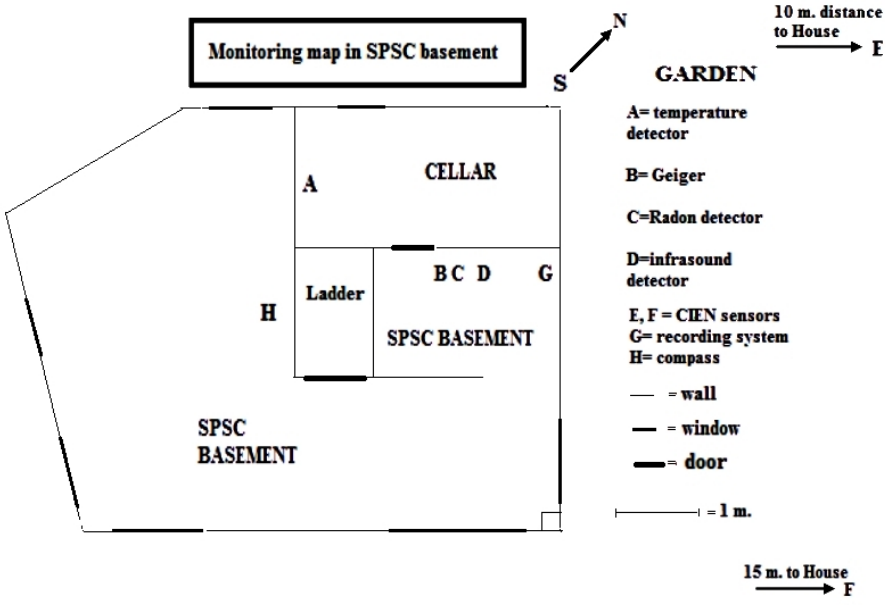


Fig. 4. Spatial disposition of the multi-parametric monitoring devices in SPSC

Table 2. Instruments in SPSC and nearby area

Physical parameter	Instrumentation	Measurement unit and sensitivity	Monitoring modality	Place of monitoring	Period of monitoring
Magnetic induction	1 TreField EM Meter	0-100 μT in logarithmic scale	2 time/day for 1/2 h every time	on gneiss in SPSC and nearby area	1999-2013
Magnetic declination δ	4 compasses "Virginia" 6036VA	sensitivity of ±0.5 °	2 time/day for 1/2 h every time	2 on wood , 2 on iron surfaces in basement	1998-2013
β, γ particles	1 Geiger "Ю нчмер SKM 05";	Scale 0.00-99.99 μS/h; alarm at 0.5 μS/h; data every second	2 time/day for 1/2 h every time	SPSC/garden , on big rock crack	2003-2013
Radon^{222} emission, α particles	1 Radon-meter detector (Geoex, model 1027)	measurements in pC/l	continuous: PC connection	basement, at 0.30 m from the floor, on gneiss	2011-2013
Temperature	1 analogical thermometer	Degrees Celsius (±0.1 °C)	2 time/day at the same hours	in cellar, in Biglione creek	1999-2013
Temperature	1 thermometer TM-917 DICOM	from -100 °C to +132 °C, ±0.1 °C), every 0.4 sec.	continuous: PC connection	In cellar, at a depth of 2 meters in the soil;	2013
Meteorological Station: temperature, pressure/humidity	PCE-FWS 20	Digital measurements respectively in: degrees Celsius, hPa, as a %	2 time/day at the same hours	on the roof of the house	2013
Water pH	Litmus papers	----------	1 time/week	SPSC/garden / Biglione	2012-13
Infra-sounds	Infra-sound detector, model "Infrasonic 200", Aetech,	a continuous monitoring – 5 samples/second , monitoring in Hertz	continuous: PC connection	SPSC, at 1.20 m from the floor and 5 cm from a wall of the basement.	2013
EM signals: ELF, VLF and LF	CIEN antennas	ELF, in the range 4–1000 Hz, VLF and LF, in the range 1–25 kHz and some station from 1 to 50–100 kHz	continuous: PC connection	SPSC garden	2012-2013

In order to obtain a confirmation of physical variations not connected to effects strictly local, and to verify their variations in connection with distance from SPSC, a further set of instruments was installed in Luserna San Giovanni, at about 4 km East of SPSC. The monitoring in Luserna San Giovanni since 2011 was also characterized by a continuous measurement of ground electrical currents [23] and recording of mechanic seismic shocks

[24]. The instruments activated in Luserna San Giovanni are resumed in Table 3. Seismic data were retrieved from the institutional database of Istituto Nazionale of Geofisica e Vulcanologia at http:\\www.ingv.it and ISIDE at http://iside.rm.ingv.it/iside/standard/.

Table 3. Instruments in Luserna S. Giovanni

Physical parameter	Instrument	Measurement unit and sensitivity	Monitoring modality	Place of monitoring	Period of monitoring
Magnetic induction	1 TreField EM Meter	0-100 μT in logarithmic scale	every night with buzzer threshold modulations	on gneiss surface in SPSC and nearby area	2012-2013
β , γ particles	Inspector Alert, International MEDCON Inc	Scale : 0.00-99.99 μS/h; alarm at 0.6 μS/h; data every second	3 time/week	in cellar	2012-2013
Seismic waves	1 gravity-meter with an hanging pendulum [12];	Measurements in mV, data every second	continuous: Pc connection	in cellar	2012-2013
Electric field	self-made	measurements in pV magnified 250000, every 2 seconds, from DC to 50 Hz	continuous: PC connection	Two copper drills, 50 cm long and placed at a depth of 20 cm in the cellar subsoil.	2012-13

3. RESULTS AND DISCUSSION

Here, some reports of observations were summarised to give preliminary results, which can be used to stimulate the discussion descending from the comparison between animal behaviours and physical and chemical measurements.

3.1 Animal Vocal Language Observed Before Earthquakes

The acoustic perception of vocal alarms can regard a large area, it gives concise information and it is easier to notice. The animal vocal alarm is a particular vocal language, which seems aimed at the own species. It is an individual answer to the danger or a co-ordinate answer of the leading animal to the same danger. It can be supposed that the vocal animal alarm is a “thought answer”, which expresses oneself as a dialogue with other animals or with humans. A few hours and sometimes days before seismic events, animal agitation is now well known in scientific literature [25]. It was identified a particular tripartite sequence in the vocal alarms of domestic animals and birds: *phase A*, lasting up also to 2 hours, with shrills and high sounds, from 30 minutes until 10 hours before the earthquake, then, when cries stop

simultaneously, *phase B* follows, with a strange and worrisome silence; finally *phase C*, with animal cries normally 20-40 seconds before the earthquakes, a few times 5-10 seconds before, generally stopping few seconds before the shock.

Obviously, unusual animal behaviours were only taken into account for those species whose normal behaviour was known. The vocal animal alarms beginning up to 10 hours before local earthquakes, sometimes before distant earthquakes if the future magnitude was great, were contemporaneous to the drastic reduction of the variations in intensity and declination of the magnetic field and of radioactivity values. Fig. 5 resumes an interesting relation between the distances of the seismic epicentres to SPSC, the magnitude and the percentage of unusual animal behaviours, in relation to cries from domestic animal and to bird songs, noted before the same seismic event.

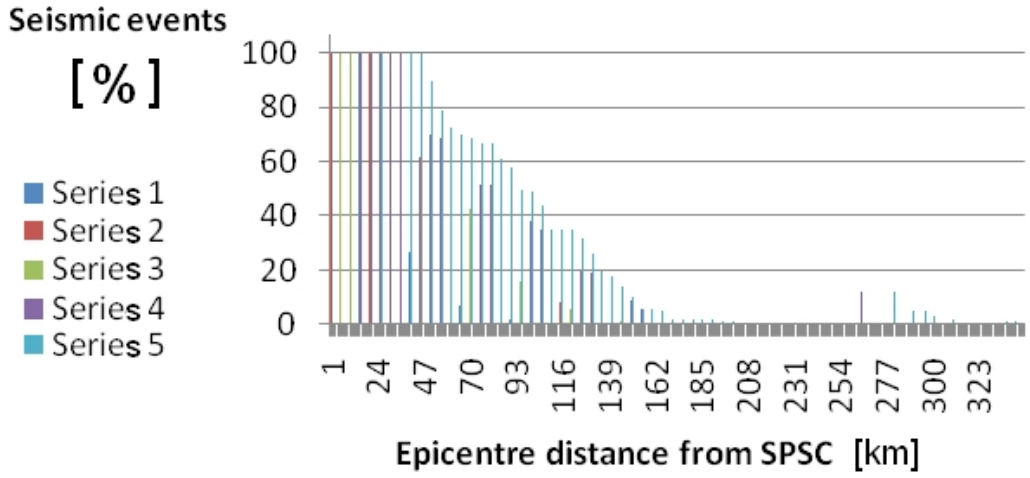


Fig. 5. Percentage of unusual animal behaviour which respond to seismic activity around SPSC, where series 1: 0 < M ≤ 1; series 2: 1 < M ≤ 2; series 3: 2 < M ≤ 3; series 4: 3 < M ≤ 4; series 5: 4 < M ≤ 5

During *phase A*, dogs, cattle, sheep, equines, bats and birds cried all together simultaneously, for a long time and sometime up to half an hour, with agitation, emitting shrills, howls or high sounds. Then, they stopped their laments all together, with a stupefying synchrony [5,9]. This silence lasted 3-5 hours before the local first seismic shock and it was strange and worrisome, like the quiet that precedes the storm. Normally, territorial competitions, sexual calls, dangers by intruders were expressed by domestic animals and birds with vocalizations not occurring at the same time; these shrills were more various as succession of frequencies, with longer phrases between two pauses. Ache and loneliness (for dogs, cats, cattle, equines) gave long vocalizations on two or three descendent frequencies, repeated more and more with reducing intensity. These were the differences between anomalous animal sounds during pre-seismic phases and normal animal sounds.

It was interesting to observe that dogs living in farms, as opposed to dogs living in urban areas, at first ululated. These howls were similar to those they emit when they heard ambulances or church bells. Then, dog howls modulated in barking, at the same time, with short and repeated sounds. This barking was composed by two articulations with an ascendant order of frequencies for all dogs, but small sized dogs repeated the same

vocalization more frequently in a minute. The two articulations formed a dissonant interval. In case of ambulances or church bells only dogs cried, not other animals, and they stopped their cries when ambulances or bells stopped their sound: so dogs did not bark after (it was possible to know the journey of the ambulance by the howls of the different dogs along the way). In case of seismic precursors, the barks after the howls were very prolonged and contemporaneous. Cocks also shrilled, but with a vocalization composed by three sounds, on the same intonation, the last of them prolonged. This short scheme of three sounds was also repeated three times in sequences separated by short pauses, repeated many times with agitation. This agitation was similar to the same shown when there was a fox, a stone marten or a hawk. In these latter cases the tripartite phrase was interrupted by other phrases modulated differently with melodic variations on the last sound: in this case, cocks shrilled in different moments according to their proximity to the “danger” and not all together and at the same time, as in seismic precursors. Also magpies and crows chattered with agitation, but with cries similar to the bipartite sounds of dogs. This behaviour shown a tonal language for all these animals, it was important for us to distinguish the musical sequence. During *phase A*, little variations of the magnetic intensity and drastic reductions in variations of the magnetic angle declination were recorded. Magnetic anomalies started with great variations, a few days or some weeks before the earthquake, the sudden commencement did not coincide with the beginning of *phase A*.

After the simultaneous vocal stop, the worrisome silence followed, *phase B*. During the *phase B*, a stop of the magnetic and electric variations and a stop of radon emission were always noted.

A continuous monitoring of infra-sounds was operating in SPSC: the background noise was comprised in the values 0.1-3 Hz, with several factors having an influence on it, like the Biglione creek nearby, whose flow variations can increase it up to 7 Hz. During *phase A*, it was not possible to record in SPSC any difference in the background noise that can be related to a seismic event. Then, 30-40 seconds before the seismic shock (*phase C*) infra-sounds of 3.5-5 Hz were recorded, lasting a few seconds, with a particular progressive “crescendo” and then a progressive “decrescendo” of intensity.

3.2 Non-vocal Anomalous Behaviour Different from the Usual Pattern

The most evident non-vocal animal behaviour was the advanced awakening from hibernation, possibly due to an increase in temperature [4], to electric currents [11,25] or to emissions of dangerous gas [4,26].

Unusual flight behaviour was observed with the beginning of sudden variations in the magnetic declination. The sudden beginning can be followed for up to a few days by a variation of the absolute value of magnetic declination δ and by a variation of the intensity of the geomagnetic field. In these occasions, the needles of the SPSC compasses had a dampened oscillating motion around a new local North-South axis. At the beginning of the δ oscillation preceding seismic activity, unusual flight behaviour was often noted. During this first moment it was noted that domestic animals were nervous and insects and arachnids more aggressive, until magnetic variations were great. A few days before Ferrara’s area earthquake on May 20th and 29th 2012, M = 6.0 and 5.8 respectively [27], and the L'Aquila earthquake on April 6th 2009, M = 6.3 [28], it was observed, in some areas of Piedmont, unusual flight behaviours in female blackbirds, male tits and bats. In the morning of May 18th 2012, 8:30 LT, instruments recorded in SPSC a declination variation δ of 7° towards East. In the following moments a female blackbirds listed and banged against a wall of SPSC. A high

magnetic declination variation of 15° East two days before the L'Aquila earthquake was also observed. The geomagnetic situation the week before these earthquakes was quiet.

In *phase C* farm animals sought safety from cow-houses, barns, pens or from other buildings. Animal shrills and their agitation alarmed people, so this animal behaviour has often saved people. For example, before the earthquake of April 2nd 1808, at 17:43 LT, with magnitude M = 5.7 [8] and with epicentre in Luserna San Giovanni, a woman of San Germano and her sons were saved due to the cows cries, so other people inside houses saved themselves, thanks to the agitation of their cows a few seconds before the seismic shock [1]. Also during *phase A* anomalous animal behaviours consisted in to have sought safety. A local earthquake in Val Pellice, occurred on May 28th 2008, during a severe rainstorm, caused at the same time four landslides: two on Vandalino Mountain, one at Rorà and one at Villar Pellice, killing four people. Half an hour before the seismic event and landslides a male goat saved all his female goats, guiding them away from their pen, which was subsequently destroyed. He returned with his herd the following day.

3.3 Radioactivity and Temperature Measurements

High values of β and γ particles, up to 56.0 μS/h, were recorded two days before the two earthquakes of M = 4.6, 19:14 LT, and M = 4.8, 19:15 LT, both occurred the August 21st 2000, in the provinces of Asti and Alessandria. The radon meter measured more than 1,517 Bq/m^3 in air (α particles) at the same time. The same day a viper and an unknown snake climbed at the first floor, by run-ladder. Three days after high radioactive emission, many insects and arachnids were founded dead in SPSC basement, cellar and garden. In Fig. 6a are reported continuous α particles (Radon) values in SPSC for the April-June 2012 time span. Coloured lines report dead snails in SPSC garden and snakes entering in SPSC before the earthquakes. The same behaviour was observed during the next months, July-September 2012, when radioactivity showed a strong variation (see Figs. 6b and 6c). Statistical analysis of Radon measurements produced a mean value m = 3.37 pCi/l in SPSC with standard deviation 1.71 pCi/l. The distribution was well fitted by a Log-normal distribution, confirming past results [29]. The distribution of the logarithms of Radon values is a normal distribution [30] for which the cumulative distribution function is

$$F = 1/2+1/2\ \mathrm{Erf}\{(\mathrm{Ln}\,[x] - \mu)/(\sigma\sqrt{2})\} \quad (1)$$

with

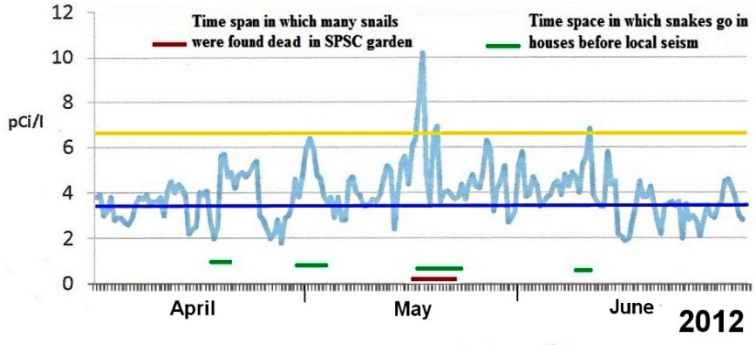
$$\mu = \mathrm{Ln}\,[m^2/(v+m^2)^{1/2}] \quad (2)$$

and

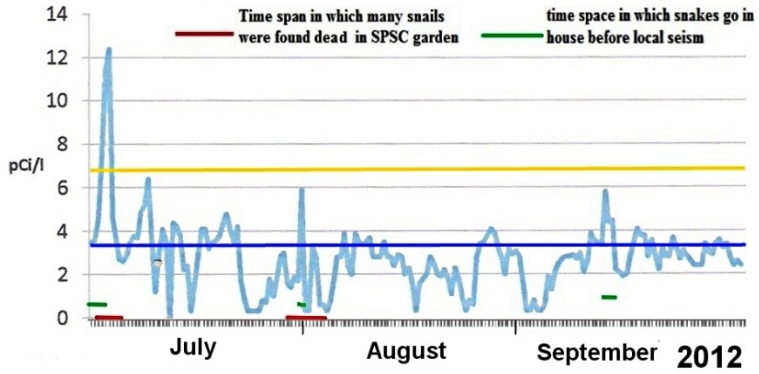
$$\sigma = (\mathrm{Ln}\,[1+v/m^2])^{1/2}, \quad (3)$$

where v is the variance. By choosing 1 - F = *P* = .05, the Log-normal distribution limit value to obtain the same *P* value was calculated to be x = 6.61 pCi/l. Average and limit values for *P* = .05 were indicated respectively by blue and yellow lines in Fig. 6. Anomalous behaviour from snakes was observed during or just before the sudden emission of Radon, with values of more than 6 pCi/l. Instead, anomalous reactions from snails were noticed to occur some time after, when Radon values decreased. It can be added that observations regarding snakes and snails occurred only between spring and fall.

(a)



(b)



(c)

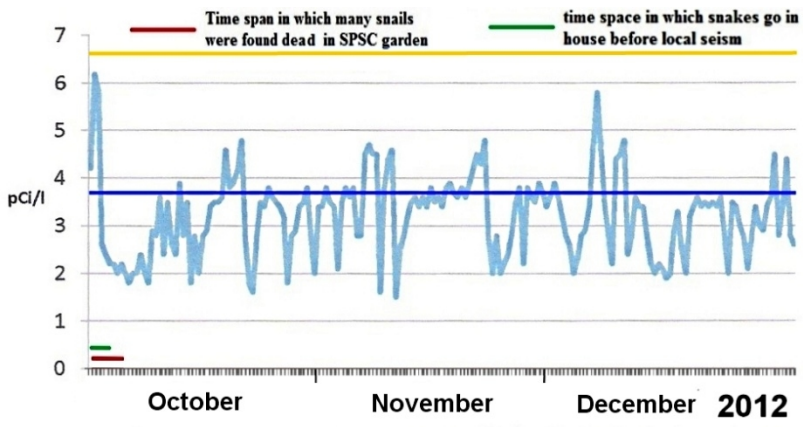


Fig. 6. Continuous Radon measurements in SPSC during three periods: (a) April-June; (b) July-September and (c) October-December 2012; Red and green lines indicated respectively snail and snake behaviours; blue and yellow lines indicated respectively average and limit value to have *P* = .05

During winter, a rise in temperature of about 5-6 °C above the mean seasonal values at SPSC was recorded before moderate earthquakes. This can explain the premature awakening of animals in hibernation (bats, insects, amphibious and reptiles) and premature

larvae development. This unusual animal behaviour appeared as a short term precursor, usually 12-15 hours before. An increase in the water temperature of rivers and lakes and/or to the emission of warm and dangerous gas (radon, sulphurous gasses, hydrocyanic anhydrite, ozone, CO_2…) can causes the death of fish. Three days before the two earthquakes of M = 4.6, 19:14 LT, and M = 4.8, 19:15 LT, both occurred the August 21st 2000, it was reported in Torre Pellice the death of all fishes of a little artificial lake fed by the Biglione creek, whose temperature increase was of 6 °C, temperature recorded in the night. Also some frogs and fresh water shrimps died near Biglione.

4. CONCLUSION

Scientific knowledge of pre-seismic phenomena is still in its infancy. Certainly, unusual animal behaviours can give a significant contribution to strengthen the awareness to environmental changes. Even if the Valle Pellice is a moderate seismic area, it was possible to observe several phenomena concerning unusual animal behaviour. A moderate seismic activity could also generate unusual animal behaviours if the area magnifies magnetic, electric and radioactive variations, due to interesting geological structures, like an intrusive volcano with geothermal activity. The multi-parameter monitoring created with the SPSC located in Torre Pellice, western Piedmont, started a systematic comparison between animal behaviours, physical and chemical measurements during moderate seismic activity.

When the increase in temperature, in radon concentration, or in magnetic declination are great, anomalous animal behaviours can be observed, which can be interpreted as reactions to save themselves or to reduce the damage to the health. The comparison "a posteriori" with local seismic activity can be resumed in the following points:

(a) a particular tripartite sequence of animal vocal language was noted: *phase A*, lasting up to 2 hours, 0.5-10 hours before moderate and near seismic activity, *phase B* characterized by the absence of alarm calls and finally *phase C* immediately before (20-40 seconds) the seismic shock characterized by alarm signals;
(b) Increased emission of Radon^{222} in the air above average values (α particles) many hours (sometimes days) before the seismic shock with its sudden decreasing a few hours before, and an increase of β and γ emission before the seismic shocks;
(c) Variation in the pH values of water, on meadows and in rivers;
(d) Variations in the magnetic declination and magnetic intensity;
(e) Increase of the temperature in the subsoil contemporaneously to increased radon emission.

The birth of a multi parameter observatory in this region is necessary in order to verify systematically such observations in relation with seismic activity. If significant physical phenomena and animal behaviours are recorded thanks to the SPSC instruments, it will be possible to study the causal links connecting them and direct or indirect links with the preparation of impending earthquakes. To exclude the cause of the observed animal behaviours be any bacteria or viruses, periodic analysis should be included in SPSC monitoring.

The *phase C* is corroborated by the observations of other researchers in case of other earthquakes [4,9,26]. It was supposed that this behaviour could possibly be due to ultrasounds emitted by rocks [11], and the emission of ultrasounds before rock fractures was demonstrated with the experimental work on local characteristic “Luserna stone” [31,32].

Being so, the multi-parametric monitoring requires ultrasound sensors to verify such supposition.

ETHICAL APPROVAL

All authors hereby declare that all experiments consisted in observation of animal behaviour in the home and in their natural environment, no constraints were imposed on them.

ACKNOWLEDGMENTS

Tanks to Angelo Agostino, Alberto Carpinteri, Giulio Fanti, Giampaolo Giuliani, Francesco Lattarulo, Giovanni Martinelli, Lisa Pierotti, Riccardo Sandrone, Alessandro Vaio and Paolo Volpe.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Garola L. Description of the earthquake in the valleys of Lusern, St. Martin and district of Pinerolo, there occurred April 2, 1808 with its baneful effects of it. Bulletin of the Historical Society Pinerolo. Series III, Year XXIX, Pinerolo. 2012;178-189.
2. Reycend JJ. Letter from a former military a lady of Turin. In Corrispondence Vaud. Turin. 1808;13-14.
3. Taramelli T, Mercalli G. The Ligurian earthquake of February 1887. In Annals of the Central Office for Meteorology and Geodynamics. Typography Metastasio, Rome, Italy. 1888;8.
4. Tributsch H. When the snakes awake: Animals and earthquake prediction. MIT Press, Cambridge, MA, USA; 1982.
5. De Liso G. Characterization of the territory in the identification of local seismic precursors in the western Piedmont. In Proceedings of the 29th National Conference GNGTS. October 26 to 28, Meadow. 2010;208-211.
6. De Liso G, Fidani C, Viotto A. Multiple parameter monitoring and seismic precursory phenomenology in unusual animal behaviour in Western Piedmont. In Acts 2 of the 32nd National Conference GNGTS, November 19 to 21, Trieste. 2013;60-66.
7. Compagnoni R, Sandrone R. Geo-petrographic features of the Hautes Alpes Italian between the Val di Susa and Val Po Piemontese Federation of Mineralogy and Paleontology, Turin; 1981.
8. Boschi E, Ferrari G, Gasperini P, Guidoboni E, Valensise G. Catalog of Strong Earthquakes in Italy from 461 BC to 1980. ING-SGA, Bologna; 1995.
9. Fidani C. Biological anomalies before the 2009 L'Aquila earthquake. Animals. 2013;3(3):693-721.
10. Rikitake T. Prediction and Precursors of Major Earthquakes. Terra Scientific Publishing Company, Tokyo, Japan; 2003.
11. Ikeya M. Earthquakes and Animals: From Folk Legends to Science. World Scientific, London; 2004.

12. Perrone G, Morelli M, Piana F, Fioraso G, Nicolò G, Mallen L, Cadoppi P, Balestro G, Tallone S. Current tectonic activity and differential uplift along the Cottian Alps/Po Plain boundary (NW Italy) as derived by PS-InSAR data. Journal of Geodynamics. 2013;66:65-78.
13. Schmid SM, Kissling E. The arc of the western Alps in the light of geophysical data on deep crustal structure. Tectonics. 2000;19(1):62-85.
14. Duchene S, Blichert-Toft J, Luais B, T´elouk P, Lardeaux JM Albar´ede F. The Lu–Hf dating of garnets and the ages of the Alpine high-pressure metamorphism. Nature. 1997;387:586-589.
15. Butler RWH, Matthews SJ, Parish M. The NW external Alpine thrust belt and its implication for the geometry of the western Alpine orogen. In Alpine Tectonics, Geological Society of London Special Publication 45, eds Coward M, Dietrich D & Park RG. The Geological Society, London. 1986:245–260.
16. Delacou B, Sue C, Champagnac JD, Burkhard M. Present-day geodynamics in the bend of the western and central alps as constrained by earthquake analysis. Geophysical Journal International. 2004;158:753–774.
17. Pavoni N. Regularities in the pattern of major fault zones of the earth and the origin of arcs. In Origin of Arcs, ed. Wezel FC. Elsevier, Amsterdam; 1986.
18. Devoti R, Esposito A, Pietrantonio G, Pisani AR, Riguzzi F. Evidence of large scale deformation patterns from GPS data in the Italian subduction boundary. Earth and Planetary Science Letters. 2011;311:230-241.
19. Rikitake T. Earthquake prediction. Earth Science Review. 1968;4:245-282.
20. De Liso G, Lattarulo F, Viotto A. Piezonuclearità, piezoelectricity and piezomagnetismo of the rocks of gneiss and territorial characterization of seismic phenomena in the western Piedmont, new perspectives of study. In Proceedings of the 30th National Conference GNGTS, November 14 to 17, Trieste. 2011;603-604.
21. Fidani C, Albarello D, Arcaleni M, Martinelli G, Siciliani PM, Tardioli S, Vannucchi A. Emilia earthquake: VLF transmitters and ELF signal from the Central Italy Electromagnetic Network (CIEN). In Proceedings of the 31 GNGTS, November 20-22, Power. 2012;415-420.
22. Fidani C. The Central Italy Electromagnetic Network and the 2009 L'Aquila earthquake: Observed electric activity. Geosciences. 2011;1:3-25.
23. Viotto A. Realization of a ground electrical current monitoring in Piedmont in 2010, following the circuital scheme proposed by the geologist Dr. Kurt Dietric, at http://www.vlf.it/kurt/elf.html.
24. Viotto A. Realised the mechanical variations on vertical axis which are recorded in μV by an iron-core inductor, only seismic tremors are recorded on vertical axis; 2010.
25. Serpieri A. New observations on the earthquake in Italy March 12, 1873 and reflections on the presentiment of animals for earthquakes. Proceedings of the Royal Institute of Lombardy. 1873;6:25-33.
26. Rikitake T. Earthquake prediction work in Sichuan Province, China, with special reference to the Songpan-Pingwu earthquakes. Chinese Geophysics, American Geophysical Union. 1982;2:139-156.
27. Lavecchia G, De Nardis R, Cirillo D, Brozzetti F, Boncio P. The May-June 2012 Ferrara arc earthquake (northern Italy): Structural control of the spatial evolution of the seismic sequence and of the surface pattern of coseismic fractures. Annales Geophysics. 2012;55(4):533-540.
28. Bindi D, Pacor F, Luzi L, Massa M, Ameri G. The Mw = 6.3, 2009 L'Aquila earthquake: Source, path and site effects from spectral analysis of strong motion data. Geophysical Journal International. 2009;179:1573-1579.

29. Zhua HC, Charlet JM, Poffijn A. Radon risk mapping in southern Belgium: An application of geostatistical and GIS techniques. The Science of the Total Environment. 2001;272:203-210.
30. Johnson NL, Kotz S, Balakrishnan N. Continuous univariate distributions. Wiley series in probability and mathematical statistics: Applied Probability and Statistics (2nd ed.), New York. 1994;1.
31. Lacidonia G, Manuello A, Carpinteri A, Niccolini G, Agosto A, Durin G. Acoustic and electromagnetic emissions in rocks under compression. Proocendings of SEM Annual Conference, June 7-10, Indianapolis, USA. 2010;57-64.
32. Carpinteri A, Lacidogna G, Manuello A, Borla O. Piezonuclear Transmutations in Brittle Rocks under Mechanical Loading: Microchemical Analysis and Geological Confirmations. In Symposium on Recent Advances in Mechanics, Academy of Athens, Athens, Greece, 17-19 September, book part III: 361-382, Editors Anthony N. Kounadis, Emmanuel E. Gdoutos, Editors Affiliations: Academy of Athens, Dept. of Civil Engineering, Democritus University of Thrace; 2009.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=490&id=31&aid=4277