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ECOLOGICAL INTEREST OF DRAINING GALLERIES

Raoul MANENTI¹

RÉSUMÉ. — *Intérêt écologique des galeries de drainage.* — Les environnements souterrains artificiels peuvent être très intéressants d'un point de vue écologique. Les galeries drainantes sont des sources artificielles avec un développement hypogé constitué par une galerie presque horizontale qui s'étend à l'intérieur d'un relief. Il s'agit d'une technique de captage très ancienne qui a créé des habitats souterrains non ou peu étudiés et qui sont potentiellement très intéressants d'un point de vue écologique. Nous avons étudié 18 galeries drainantes dans le nord-ouest de l'Italie. Nous présentons des données écologiques spécifiques qui peuvent aider à formuler des conclusions générales sur les caractéristiques écologiques de ces habitats hypogés. Les galeries drainantes, qui dans la région d'étude atteignent 120 m de longueur, offrent la présence de biotopes humides permanents et ont des caractéristiques climatiques semblables à celles des grottes. Elles constituent des refuges et des sites de reproduction tant à des organismes typiques de la faune cavernicole qu'à beaucoup de taxons provenant de l'extérieur. Nous n'avons pas observé d'influence statistiquement significative de l'accessibilité des sites sur leur niveau de biodiversité. Du point de vue de la conservation les galeries de drainage présentent une valeur écologique certaine, surtout dans les zones dépourvues d'environnements souterrains naturels.

SUMMARY. — Artificial subterranean habitats can be of important ecological interest. Draining galleries are a typology of artificial springs with underground development characterized by an almost horizontal tunnel that penetrates the side of a slope, to catch the subterranean water and bring it outward. They are a very ancient spring catching technique and provide interesting unstudied subterranean habitats. In this study we surveyed 18 draining galleries in NW Italy. We provide specific environmental data that can help to support broad conclusions on the ecological features and value of these habitats. We found that they house permanent waterbodies, have lengths up to 120 m, are characterized by climatic conditions similar to those of natural caves. We collected several taxa of organisms, adapted to subterranean life as well as coming from outside environment, which find inside draining galleries shelter, roosting and breeding sites. We tested the role of accessibility in determining galleries biodiversity and we found that the latter is scarcely affected. From a conservationist point of view draining galleries can have important ecological value, particularly in areas devoid of natural subterranean habitats.

The study of underground environment can be of considerable scientific interest because subterranean habitats have peculiar features and can provide useful insights from an ecological and evolutionary point of view (Tercafs, 1988). Also, artificial subterranean habitats can be of important ecological and conservation value (Isaia *et al.*, 2010; Manenti *et al.*, 2009). In several situations, artificial subterranean networks, such as mines, ancient underground tunnels or other underground artificial buildings, can show environmental features resembling those of caves. Moreover in territories with no natural human accessible underground habitats they can provide interesting study opportunities of the underground systems (Isaia *et al.*, 2010).

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Some artificial springs often have well developed underground catchment buildings (Manenti, 2008). One of the more diffused typology is the draining galleries. They are characterized by an almost horizontal tunnel that penetrates the side of a slope, to catch the subterranean water and bring it outward. They catch the water directly in the ground water table affecting, in the time, its level. Draining galleries are a catchment technique based on gravity and associated to traditional agriculture; they are found in Europe, Asia and Northern Africa (Balland, 1992). Morphological characteristics of the tunnels, length and water depth vary according to the regions and to the ways of digging.

Draining galleries are an argument difficult to be catalogued: deeply connected to the agricultural customs, to the traditions and to the religious beliefs, they reflect the structure and the values of the society that build them. Furthermore they often show several aspects that escape the interest of specific discipline (Balland, 1992).

This particular technique could be born around the 2nd millennium BC in the Iranian plateau where it permitted the growth of the Protoiranians' agriculture (Gravier, 2008; Larcena, 2009). The technique was developed generation by generation and exported elsewhere under the Persian empire. From the II to the III AC century the technique knew a great development in the region with the "Qanat", as are called the Iranian draining galleries, developing into webs of more than 60 km with depth reaching 300 m (Larcena, 2009). In 1973 in Iran were numbered 20.800 Qanats (Balland, 1992).

According to the hypothesis proposed by Larcena (2009) the technique propagated from the Iranian centre by successive waves. Westwards it reached Europe thanks to Greek civilization first and Etruscans and Romans after, while in the east Turks diffused it in the Balkans and in central Europe. Eastwards the draining galleries can be found up to China and Turkestan (Sala & Deom, 2008). It is also not excluded that this technique could have originated independently in different countries. Even if they are less well known than other spring typologies, draining galleries are widespread in Italy. Some of them are very ancient, such as the Etruscan spring flow tunnels (Caponetti, 2005) or the galleries in the towns of Matera and Siena (Kucher, 2005).

From an ecological point of view draining galleries are unstudied except for very local surveys published in the grey literature or for studies often limited to some particular biological taxa (Manenti & Bianchi, 2010; Manenti & Ficetola, 2011; Manenti *et al.*, 2011; Pezzoli, 1996, 2010). They offer an underground habitat accessible to humans in areas where subterranean spaces are often missing; a challenge aspect to investigate is to understand if and in which measure they can host cave dwellers organisms.

We recently performed an ecological study on prealpine artificial underground springs (Manenti & Bianchi, 2010) considering different typologies of subterranean springs. With this study we want to focus on draining galleries in order to describe the main ecological features of these artificial underground habitats, evaluate the biodiversity that they can host and understand the factors affecting it.

MATERIALS AND METHODS

We surveyed the draining galleries in Lombardy (Northern Italy) between the districts of Lecco, Como, Milan and Bergamo (Fig. 1). The study area is comprised in the catchment basins of the Lambro, Adda and Seveso rivers. It is characterized by hilly and mountainous reliefs with a good cover of broadleaved woodlands. In order to identify and reach the springs, we used information available in local studies on troglophilous molluscs and amphibians (Manenti & Bianchi, 2010; Manenti *et al.*, 2009; Pezzoli, 1996) we collected information from local people and local environmental organization, and we directly explored the countryside. In most cases, they are hidden and difficult to reach (Manenti, 2008).

From November 2010 till January 2012, we surveyed each springs 3-10 (median: 3) times. Five galleries were surveyed 10 times. One time every winter month from November till February of 2010 and 2011-2012 were recorded physical data such as temperature at gallery end (measured at the middle of air column), water temperature, difference with inside and outside temperature, and difference between end gallery temperature at the middle of air column and at the roof of the gallery. We recorded four environmental variables to describe these subterranean habitats: (a) ease of access, measured using a rank scale (1 = completely closed by doors or other obstacles; 2 = difficult access because of obstacles; 3 = open and accessible), (b) ease of access of water basins using a rank scale (1 = completely closed by

doors or other obstacles and apparently inaccessible; 2 = difficult access because of doors or other obstacles; 3 = open and accessible), (c) seasonality of the water basins (during the period of study and comparing the data already found in the local literature), (d) biotic features (numbering and identifying the faunistic taxa found). Using the total number of taxa collected we calculated the percentage of them found in the three different categories of accessibility in which we divided the galleries. We performed ANOVA in R environment to test the accessibility role in affecting galleries biodiversity. When possible we measured maximum and minimum illumination at the entrance and at the end of the gallery (i.e., light intensity, measured in lux) with an ARW DT-1300 Lux meter.

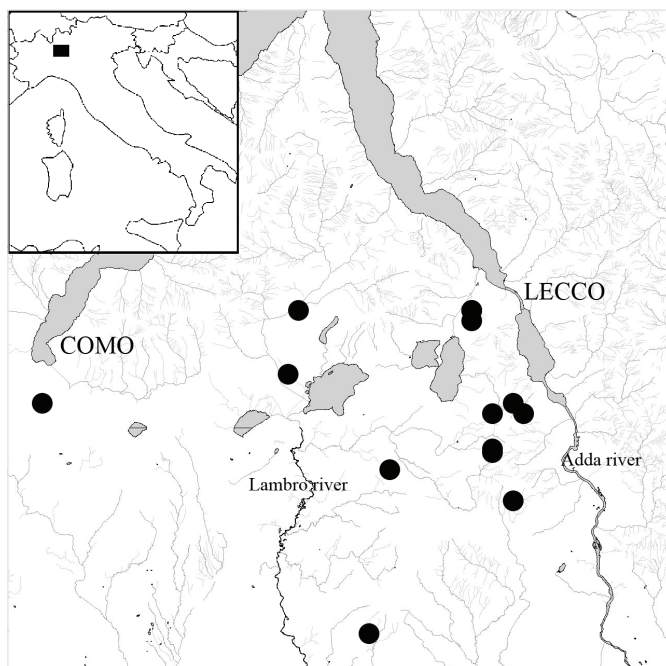


Figure1. — Study area and draining galleries location (black circles). Because of geographic proximity some circles are superimposed.

RESULTS

GENERAL FEATURES

We surveyed 18 draining galleries. Most of the sites were already known from our previous study on prealpine artificial hypogeous springs, while 5 were discovered during this research. In the study area, draining galleries have a limited width (max 2 m); and a length varying from 3.5 up of 120 meters (Tab. I).

In tables I, II and III we provide specific environmental data (temperature, humidity, water depth, light levels, etc.) that can help to support broad conclusions on the ecological features and value of these habitats. As shown in Tab. II, all the draining galleries provide permanent water collections. The brooks and the pools within galleries usually have various depths (average 20 cm, maximum 72 cm). Their structure varies a lot from gallery to gallery. 70 % of the sites have one or more pools built in order to collect water and let sediment fall on the bottom. Generally the sediment varies from fine to extremely fine.

Most galleries (55.5 %) have significant calcareous concretions caused by the high calcium carbonate rate dissolved in the spring water. In dry and wet seasons we observed changes in water collection by the galleries but they were not dramatic and didn't remarkably affect the level of water collections.

TABLE I
Draining galleries surveyed

ID	Commune	Locality	Coordinates UTM datum Rome 1940	Lu tot (m)	Altitudine (m s.l.m.)
g1	Castello di Brianza	Ceppo superiore	1527615 E 5066703 N	11.40	410
g2	Galbiate	Sorgente 13 PMB	1529124 E 5075616 N	6.97	660
g3	Galbiate	Sorgente 14 PMB	1528997 E 5075611 N	3.80	620
g4	Inverigo	Molinello 4	1578695 E 5065604 N	5.30	275
g5	Briosco	Cascina Madonnina	1518942 E 5060846 N	4.10	270
g6	Bulciago	Sotto ai "Morti dell'Avello"	1523414 E 5066617 N	3.74	310
g7	Castello di Brianza	Val Sorda verso Cologna	1527306 E 5067367 N	3.95	370
g8	Castello di Brianza	Val Sorda	1527445 E 5067466 N	8.70	420
g9	Albese con Cassano	Posca	1513226 E 5072095 N	120.00	490
g10	Valgreghentino	Taiello	1532422 E 5067526 N	12.70	330
g11	Airuno	Alta Val Tolsera	1531582 E 5067059 N	6.60	610
g12	Como	Prestino	1505034 E 5072142 N	18.00	415
g13	Galbiate	Eremo	1528887 E 5075371 N	79.50	740
g14	Albavilla	Buselacc	1513960 E 5072519 N	23.60	565
g15	Albavilla	Buselacc	1513941 E 5072517 N	19.40	565
g16	Albese con Cassano	Cava	1513268 E 5071751 N	6.90	458
g17	Castello di Brianza	Roncaccio	1527535 E 5067087 N	7.20	503
g18	Canzo	Second'alpe	1523924 E 5078176 N	8.10	800

TABLE II
General features of the draining galleries

ID	water collection	spring	Gallery accessibility	Water accessibility	Landscape	Wd (cm)	Light max 4 m (lux)	Light max end (lux)
g1	permanent	permanent	3	3	wood	14	0.4	0
g2	permanent	permanent	2	2	wood	55	0.8	0.02
g3	permanent	permanent	2	1	wood	50	10.2	0.03
g4	permanent	permanent	3	3	wood	60	0.03	0.03
g5	permanent	permanent	3	2	field	85	1.05	1.05
g6	permanent	permanent	3	3	wood	63	80	80
g7	permanent	permanent	1	2	wood	18	2.1	0.01
g8	permanent	permanent	3	3	wood	6	3.8	1.7
g9	permanent	permanent	2	3	wood	72	2.8	0
g10	permanent	permanent	1	2	wood	55	14.8	0.02
g11	permanent	permanent	2	1	wood	7	35	0
g12	permanent	permanent	3	3	wood	10	20.6	0
g13	permanent	permanent	3	3	wood/urban	40	8.9	0
g14	permanent	permanent	1	3	wood	12	6.7	0
g15	permanent	permanent	1	2	wood	10	3.5	0
g16	permanent	permanent	3	2	wood	11	12	0
g17	permanent	permanent	2	1	wood	67	18	0.01
g18	permanent	permanent	3	3	wood	24	0.96	0.03

PHYSICAL CONDITIONS

During winter months we regularly recorded temperature in five galleries (Tab. III). As shown, from November to February draining galleries have an air temperature higher on average of 1.7 to more than 2 C°. In winter draining galleries show also an interesting stratification with a temperature at the roof level which is in average 4.5 degrees higher than that in the middle of the tunnel.

TABLE III
Temperature winter features recorded in 5 draining galleries

Gallery	T Air inside (middle)	T Water	Winter	
			ΔT middle/roof	ΔT outside/inside
G1 Ceppo	9.25	11.8	4.525	2.21
G2 Val del Faè	8.065	9.55	2.325	1.85
G10 Eremo	9.07	10.98	3.12	1.78
G19 Orrido 4	8.90	11.3	2.9	2.06
G8 sopra acuedotto	9.01	10.77	3.4	1.92

The intensity of light and the extension of tunnels reached by light vary during the seasons. Generally in winter the sites show a higher degree of illumination because the lack of leaves on trees lets light penetrate more. Considering all the data recorded during the gallery surveys, the maximum illumination observed has been of 78 lux. All the draining galleries with the major lengths have a more or less extended aphotic area. It varies from 20.5 to 89.4 % of the gallery length.

BIOTIC FEATURES

Table IV provides the inventory of species or genus found for each of the documented galleries.

TABLE IV
Organisms found during galleries surveys

Taxon			Spring	Habitat
Mollusca Gastropoda	<i>Physa fontinalis</i>	g6		A
	<i>Helix pomatia</i>	g1, g4, g10		T
	<i>Cepaea nemoralis</i>	g1, g6		T
	<i>Oxychilus draparnaudi</i>	g1, g6, g10, g13, g14		T
	<i>Pomatias elegans</i>	g9, g10		T
	<i>Arion rufus</i>	g1, g4, g6		T
	<i>Limax maximus</i>	g9, g12		T
Mollusca Bivalvia	<i>Pisidium</i> sp.	g1		A
Chilopoda	<i>Scutigera coleoptrata</i>	g1, g10		T
Diplopoda	<i>Cilindrojulus</i> sp.	g1, g6, g9, g13		
Crustacea	<i>Niphargus</i> sp.	g1, g6, g9, g13		A
Amphipoda	<i>Gammarus pulex</i>	g1, g8, g9, g12,		A
Crustacea Isopoda	<i>Oniscus asellus</i>	g1, g3, g4, g9, g11, g12, g13		T
	<i>Armadillidium vulgare</i>	g1		T

	Taxon	Spring	Habitat
Chelicerata Arachnida	<i>Meta menardi</i>	g1, g2, g3, g5, g6, g8, g9, g11, g12, g13, g14, g16, g18	T
	<i>Metellina merianae</i>	g1, g3, g6, g7, g8, g12, g13, g14, g16, g18	
	<i>Tegenaria paretina</i>	g8, g13	T
	<i>Tegenaria</i> sp.	g1, g10, g12, g15, g18	
	<i>Phalangium</i> sp.	g3, g12	T
	<i>Leptoneta</i> sp.	g1, g9, g13	
	<i>Nesticus</i> sp.	g15	
Hexapoda	Chironomidae	g1, g6	A
	Tipulidae	g10, g13	A
	Limnephilidae	g4, g6, g8, g9	A
	Culicidae	g1, g8, g10, g13	T
	<i>Limonia nubeculosa</i>	g1, g2, g3, g6, g8, g10, g11, g13	T
	<i>Triphosa sabaudiata</i>	g9, g13	T
	Japygida	g1, g4, g9	T
Amphibians Caudata	<i>Salamandra salamandra</i>	g1, g2, g5, g6, g8, g9, g10, g12, g13, g14, g18	T/A
Amphibians Anura	<i>Rana temporaria</i>	g1, g9	T
	<i>Rana latastei</i>	g1, g8, g14,	T

A = aquatic. T = terrestrial.

On the whole we recorded 31 different taxa. In most cases they are organisms coming from the outside environment that found shelter in the galleries. Although in the draining galleries it is possible to find regularly taxa typical of the groundwater habitats such as the crustaceans of the genus *Niphargus*, these environments are also commonly used by interesting troglophilous species such as the arachnids *Meta menardi* and *Metellina merianae*. During our surveys we usually observed both adult specimens and egg cocoons, showing that these subterranean habitats host stable populations of these species. *M. menardi* was recorded in 61 % of the sites and *M. merianae* in 55 % of them; the two species coexist in 38 % of the galleries. The spider *Meta menardi* is considered as a well adapted species of the twilight zone community in European subterranean systems (Smithers, 2005).

Very abundant, especially during summer, is also the dipteran *Limonia nubeculosa* that likely provides an important food resource for Arachnids and other predators in the tunnels.

The most accessible galleries host the greatest percentage of the total number of the taxa that is possible to find inside galleries (Fig. 2). At the same time the association between human action to prevent galleries ease of access and the diversity of taxa is scarcely significant (Fig. 3 – $P > 0.054$).

Especially arachnids were often found in galleries with completely closed entrances.

DISCUSSION

Housing permanent water basins can be very important especially in some of hilly areas, as for example the Regional Park of Monte Barro, where stable and superficial water collections are lacking (Nardo & Guglielmin, 1996). Collecting water directly from the water table, draining galleries provide stable subterranean damp habitats. As for water collections in natural caves they have quite constant temperatures, but seem not to be exposed to dramatic changes in water levels as it can happens in several caves. The length of the galleries varies a lot from one to another; also the degree of illumination is very variable depending on entrance exposition and on the season. All the galleries show a more or less extended totally dark area. Microclimatic conditions are very similar to those of natural caves; it is interesting to point out the winter stratification of temperature in the air column that can affect the spatial distribution of the organisms overwintering inside.

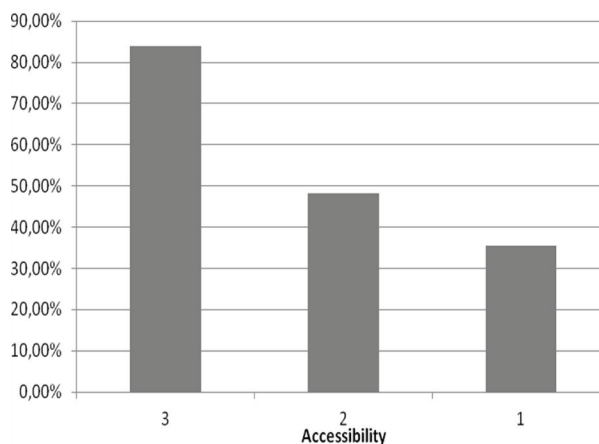


Figure 2. — Percentage of the total number of taxa found in the three categories of accessibility employed (3 = highly accessible, 2 = difficult, 1 = entrance totally closed).

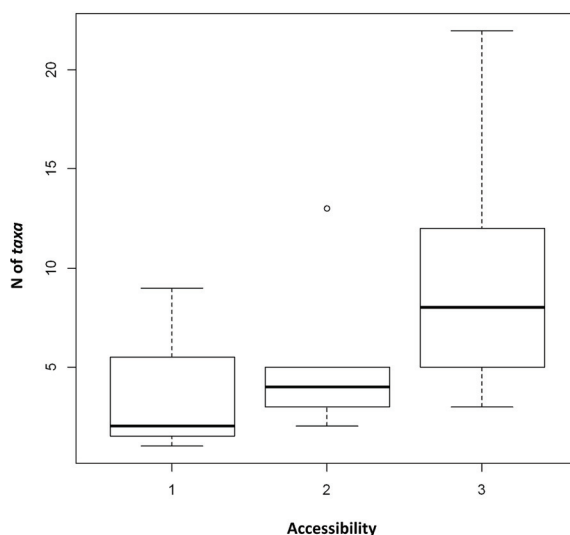


Figure 3. — Boxplot of the number of taxa found in every gallery vs the accessibility level of the sites (3 = highly accessible, 2 = difficult, 1 = entrance totally closed).

Draining galleries can host a wide variety of organisms; of particular interest can be the aquatic fauna where it is possible to find typical elements such as the crustaceans of the genus *Niphargus*. Specific investigations not performed in this study have shown that the water collections of the galleries can be very suitable to detect the occurrence also of stygobious molluscs (Pezzoli, 1996, 2010).

Thus in draining galleries we observed an interesting occurrence of troglophilous and soil organisms; these habitats can also be very useful as shelters and breeding sites for species that usually are not considered as cave dwellers such as some amphibians. For them is important

the role played by accessibility that is a direct consequence of the use of the galleries. The reproduction of the fire salamander is well known in underground habitats (Manenti *et al.*, 2011) and accessibility plays a major role in affecting it (Manenti *et al.*, 2009; Manenti & Ficetola, 2011). However the general biodiversity of draining galleries is scarcely affected likely because of the high exploitation ability of these habitats by endogenous and small troglophilous invertebrates.

Our results show that draining galleries are artificial subterranean habitats with interesting abiotic and biotic features. Even if they are less well known than other spring typologies, draining galleries are widespread in Italy. Some of them are very ancient, such as the Etruscan spring flow tunnels (Caponetti, 2005) or the galleries in the towns of Matera and Siena (Kucher, 2005). They house small brooks and/or water reservoirs. Draining galleries are frequently obsolete and unused. In most cases, they are hidden and difficult to reach (Manenti, 2008).

From a conservationist point of view draining galleries are biotopes with important naturalistic value that need to be considered in the conservation managing plan of the territory. In a perspective of maintaining and requalification of these environments it is necessary to preserve the accessibility to the structures by the epigeal and troglophilous fauna.

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