ALPINE MARMOT (Marmota marmota, L.)

Mann C. S.*, Macchi E.**, Janeau G.*
*I.R.G.M. - Faune Sauvage, I.N.R.A. - BP 27, 31326 Castanet-Tolosan Cedex (France)
**Dipartimento di Produzioni Animali, Facoltà di Medicina Veterinaria, Via Nizza 52, 10126 Torino (Italy)

IBEX J.M.E. 1:17-30

1 Systematic Status

Class:	Mammals	Sub-family:	Sciurinae
Order:	Rodents	Genus:	*Marmota*
Family:	Sciuridae	Species:	*marmota*

French: Marmotte; German: Murmeltier (n); Italian: Marmotta; Spanish: Marmota.

Species belonging to the genus *Marmota* (according to Nowak & Paradiso, 1983: 11 species):

M. monax, M. flaviventris, M. caligata:	North-América
M. olympus, M. vancouverensis*, M. broweri*:*	North-América
(* Species belonging to the "caligata group" in Ellerman 1940, *M. broweri* as *M. caligata broweri*)	
M. caudata, M. menzbieri:	Asia
M. camtschatica:	Asia
(belonging to the "*caligata* group" in Ellerman, 1940);	
M. bobak:	Europe + Asia
M. marmota:	Europe

2. Origins and distribution

2.1 Origins:

The first rodents - During the Paleocene (some 60 million years ago), in Asia, a group of mammals appeared with a novel masticatory apparatus that enabled them to gnaw (with strong incisors) and chew (with cheek teeth), gnaw and chew... in quick succession. From this fossil group of mammals known as the mixodonts (*Mixodentia* = *Anagalida*) and to which for instance the chinese *Heomys orientalis* belonged, two "sibling orders" (Hartenberger, 1977) branched out: the rodents and the lagomorphs.

According to current knowledge, rodents first appeared in China during the Paleocene, some 56 million years ago (see fig.1) (Li Chuan Kuei, 1977; Mein, 1992). They radiated outwards extremely fast since true rodents already exis-ted at the start of the Lower Eocene (-55 M Y) not only in Asia (*Cocomys*) but also in America and Europe (migration Asia → America → Europe) all of which communicated quite freely in that period (Russell, 1968).

The first American and European rodents belonged to the family *Paramyidae* (Wood, 1962): *Paramys atavus* appeared in North American forests in the late Paleocene/early Eocene (Chaline & Mein, 1979; Vianey-Liaud, 1985) and *Paramys* sp. in Europe as early as the Lower Eocene (Hartenberger, 1989). They both deserve special mention here as the present dental pattern of *Marmota* is exactly the same as that of these very ancient rodents! (Hartenberger, 1992 *pers. comm.*)

At the beginning of the Lower Eocene, Europe and North America were finally completely separated by the Atlantic. The land-area of Europe was at that time an island separated from Asia by a shallow sea and for 15 million years original fauna developed there. However, events were to change drastically.

The T.E.E. and the "Grande Coupure" - The end of the Eocene, about 35 million years ago (recent datings give 34 MYA), was marked by worldwide climatic changes (the Terminal Eocene Event) and deep tectonic movements which led to the disappearance of the sea in Eastern Europe. The combination of these climatic and tectonic events in Europe led to what palaeontologists call the "Grande Coupure", *i.e.* a tremendous modification of the fauna in the early Oligocene. Broadly, climatic changes caused most species of that period to die out* (Hartenberger, 1983), including rodents**, and the end of Europe's isolation meant that external species (mostly from Asia) were free to occupy the newly abandoned ecological niches (*ibid.*).

This was a major step in the history of rodents as almost all of the old European Eocene branches disappeared and the first members of the modern families, especially the Sciuridae, took over from them.

Appearance and development of the Sciuridae... - They appeared as early as the Lower Oligocene both in North America (*Protosciurus*) and in Europe (*Palaeosciurus*, Vianey-Liaud, *op. cit.*) and have evolved considerably since (flying, arboreal and terrestrial forms), especially as regards the American ground squirrels (Mein, *op. cit.*).

...up to the marmots - North America is probably the birthplace of the Marmotini which date back to the lower Miocene with *Miospermophilus* (Black, 1963; Mein, *op. cit.*) and subsequently radiated both in America and in Eurasia (Chaline & Mein, *op. cit.*).

The genus *Marmota* also appeared in America, during the Pliocene (Black, *op. cit.*), and then migrated along with the horse across the frozen Bering Straits to Eurasia at the end of the Tertiary/beginning of the Quaternary (Mein, *op. cit.*).

Marmots reached Europe around 250,000 years ago, before or during the Riss *** glaciation.

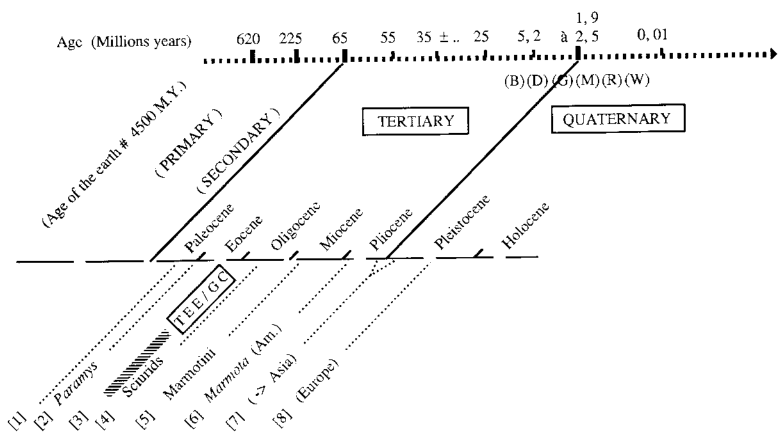
During the Würm period (a series of successive glacial phases interrupted by warmer episodes) marmots in Europe lived in the lowlands during the colder phases and sought refuge in the mountains during the warmer ones. The split between *Marmota bobak* and *Marmota marmota* started at that time by an alternation of contact (in the lowlands during the glacial phases) and isolation (in the mountains during the interglacials) of populations (Chaline, 1972). The split became final after the ultimate retreat of the Pleistocene ice about 10,000 years ago when *Marmota marmota* sought permanent refuge in the mountains.

* even complete groups were wiped out, such as the European primates (Mein *op cit.*).

** except for the *Gliridae* (Hartenberger pers. comm. 1992)

*** fossils of *Marmota* from the Riss period in Europe (Chaline, 1972; Mein, *op cit.*)

Fig. 1 - Major steps during the Tertiary and the Quaternary in the evolution leading to *Marmota marmota*



2.2 Distribution - *Marmota marmota* was widespread after the Würm period: from Central Europe (Carpathians) to the Pyrenees, including the Apennines and the Dinar Alps in the south. But its distribution then considerably receded during the Quaternary under the pressure of climate and other events.

At the present time, marmots are found (Fig. 2) in the Carpathians, Tatras mountains included (Huber, 1978), in the Pyrenees, in the Alps, in part of the Apennines and in some other locations (see below).

In many of these areas however, the species was (re)introduced both to establish new nuclei or for restocking already existing populations.

Such operations have been carried out: in the Pyrenees since 1948 both on the French and Spanish sides (Couturier, 1964; Herrero, 1978; Nebel, 1992), in the French Alps, Jura, Vosges and Massif Central (*e.g.* Magnani, 1992; Ramousse, 1992), in the Swiss Jura (Neet, 1992), in the Tosco-Emiliano Appennines and Italian Alps (Ferri *et al.*, 1988; Chiesura Corona, 1992; Panseri, 1992) and here and there in Europe (*e.g.* Roumania, Ramousse, *op. cit.*).

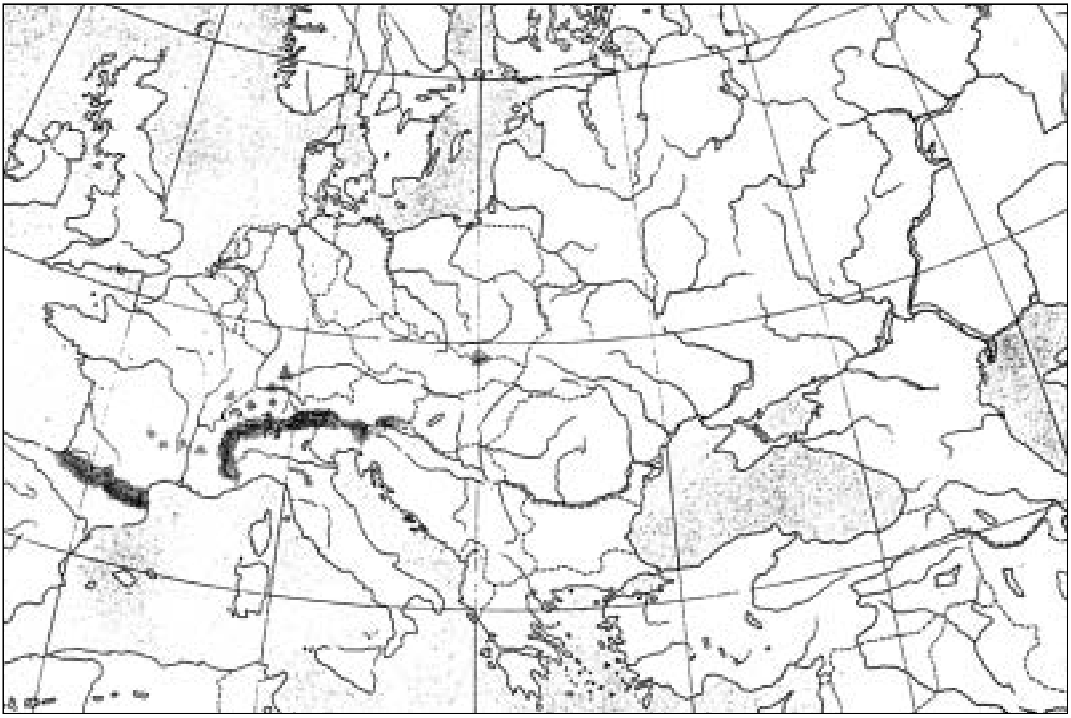


Fig. 2 - Distribution of *Marmota marmota*

3. Tracks

The presence of marmots is best recognised by their call: alarm call upon the approach of a walker, repeated calls at dawn or towards the end of the day. Burrows are more easily spotted by the debris in front of them than by the openings themselves: this debris is conspicuous from a great distance as it remains bare and is only colonised by vegetation if the hole is seldom or never used. In the summer, these two clues (call and debris) give a reliable indication of the presence of marmots from a distance, and with a little patience will help in spotting the animals themselves.

The latrines (a shallow hole in the ground, often beneath a block) can be found if you have a good sense of smell or after careful exploration and it is then possible to tell whether the faeces are recent.

From July to early August paths such as those that run from burrow to burrow are quite conspicuous and show up the routes most com-

monly taken by the animals.
When the winter turns into spring (end of April to May) and if the snow cover is even and deep enough the often dirt-stained burrow openings are visible from quite a distance. Footprints can also be found in the snow but are quickly spoilt by the repeated passages of the animals and even more by the sun.

4. Physical Features

Size, weight and gait - The marmot is a stubby animal with short ears, a stout body and hardly any neck, a morphology adapted to the life of a burrower. An adult (head + body) measures roughly 50-60 cm in length, and its tail is roughly 15 cm long. Body weight varies tremendously with the season because of hibernation (see § 7). As a rough guide, the weight of an average adult is around 5 kg (or more) in September and drops to 2.5 kg (or less) in April just after hibernation.
Its walking gait is slightly rolling and its run has been well described by Hainard (1988): "like the shaking of a mat" and Huber, (1978): "gives the impression that the marmot is crawling hurriedly"...

Pelt - The thick pelt is shed once a year between June and August. Its colour varies quite a lot and is a mixture of various shades of brown, beige, fawn, and dark grey (snout) in proportions that vary from one individual to another. Cases of yellow colouring, dark colouring and weak albinism occur occasionally (Couturier, 1964). True albinism, although very rare (only one case known to Couturier, 1964), can be perennial as in two family groups in Aosta Valley where such individuals have been regularly observed since 1950-1955 (Vevey *et al.*, 1992).

Sexual discrimination - No morphological criteria can be used to discriminate between the sexes from afar. However, on close inspection the distance between the anus and the urethral orifice can be used to identify the sex of an animal (Couturier, 1964; Zelenka, 1965).

Miscellaneous - The dental formula is typical of that of rodents (No canines, full set of premolars etc.):

$$\frac{1 \quad 0 \quad 2 \quad 3}{1 \quad 0 \quad 1 \quad 3}$$

- The forelegs have 4 digits and the hind legs 5. All digits have strong nails.
- The retina is totally devoid of rods and therefore unsuitable for night vision. It is also devoid of a fovea, giving the animal a visual acuity "certainly better than that of other rodents, whilst not as good as that of humans" (Rochon-Duvigneaud, 1955). The field of vision is very wide both sideways and upwards, because of the location of the eyes mainly.

5. Ecology and Ethology

5.1 Preferred habitat - The marmot is rare in the mountain belt and in the forested subalpine belt, it is mainly an inhabitant of the subalpine and alpine meadows. The highest local densities are found in scree with large to medium sized blocks long since stabilized and totally or partially overgrown with vegetation. The most populated parts of the grassland are those where blocks are present both on the surface and underground. The marmot also lives by the edge of the forest but is not a true forest dweller.

5.2 Burrows - Although the marmot can be observed for long stretches during the daytime outside its burrow, it actually spends most of its time within it: over 6 months during the winter, and night-time as well as a good deal of the daytime (see Sala, 1992) during the rest of the year. However, we still know very little about this habitat.
The openings are the most conspicuous part. The internal architecture of the tunnels and widenings or "chambers" is not as readily observable. Finally, we know next to nothing about the activity of the animals within except that they hibernate there.
Marmots dig three kinds of holes (Bopp, 1956; Pigozzi, 1983) as well as the ones they start to dig here and there and then abandon. These are: (i) true exits (main and auxiliary), (ii) "escape holes", (iii) latrines (see § 3). There is no well defined relationship between the number of holes and the number of animals that live in a specific area.
In most cases studied, the exits face south or south-east, probably for thermal reasons. Other orientations can be observed, depending on the local situation.
Superficially, "escape holes" look like auxiliary exits but they are actually short excavations (50 cm to 3-4 m) leading to a dead end and are not linked to the underground network of tunnels. They are considered to play an important part in the marmot's anti-predation strategy, which relies on the early detection of intruders

followed by immediate sheltering. In woodlands, the large number of holes, both "true" and "false", is related to the marmot's poor visibility under such conditions (Macchi *et al.*, 1992).
Numerical data dealing with the tunnel network are scarce in literature. Huber (1978) mentions networks reaching a total length of 40 m, Bopp (1956) gives a map of holes and their connecting paths above ground on an area over 25 m x 50 m and for the Asiatic species, *Marmota camtschatica*, Zimina & Gerasimov (1973), according to Kapitonov (1960), refer to tunnel lengths of up to 113 m. Usually, however, lower values are reported (3 to 10 m) mainly in reviews (*e.g.* fauna, popularization) on *Marmota marmota*.
The observation of tagged individuals yielded the following results in some areas: (a) animals can emerge from a hole shortly after (2-5 minutes) having entered another hole over 100 m away, (b) many holes that seemed more seldom used than the main openings are in fact interconnected. This evidence suggests that complex and extensive underground networks exist under certain conditions at least: long established colonies, scree with medium to large blocks, high local population "density" of marmots*.
Finally, the organization, number of chambers and utilization of the burrow are all still a matter of seemingly contradictory opinions.
According to recent work (Durio *et al.*, 1987), the hibernation chamber is very often located beneath a large block which provides it with thermal protection and which keeps it dry.
But is the hibernation burrow seperate from the summer burrow, or is it part of it? Observations and opinions diverge (Zelenka, 1960, Huber, 1978, Durio *et al.*, 1987, etc.), probably because the facts themselves are heterogeneous.
The literature occasionally mentions estivation burrows. These burrows are more specific than their name implies as they are involved in full-scale summer migrations across several hundred metres with a return to the point of departure**. This phenomenon is currently believed to be quite rare (as already presumed in Couturier, 1964) and limited to a few particular sites where it occurs year after year. It probably takes place under special as yet unidentified conditions relating to the vegetation, ground, social structure and so on. It could also be linked to the complex [post-]juvenile dispersal (see 5-4).
In summary, the size and complexity of burrows are extremely variable. Couturier (1964) acknowledged this by distinguishing between "simple burrow" and "labyrinthine den" and so did Bibikov (1968) who indicates that they "... vary tremendously, both between and within species [of marmots] ...".
These variations in size, depth and complexity are most certainly due to differences in the type of ground, age of the settlement and number of individuals. It is likely that in the sort of environment they live in, marmots exploit natural fractures and voids between rocky elements (Huber, 1978) and improve difficult passages by digging. It is reasonable to assume, as Naef-Danzer (1983) does, that "large burrows with many openings are the work of several generations of marmots".

* Under such circumstances, the existence of underground connections linking the family groups cannot be discarded, neither can the possibility of social exchanges, even if they are only structural.

** A similar observation was reported by Barash (1974) in a colony of the American marmot *Marmota caligata*.

5.3 Diet and foraging behaviour - The marmot is primarily a herbivore that consumes a wide diversity of plants (aerial parts but also bulbs and roots). It forages selectively (inflorescence, leaves, stalks, seeds) and wastes little. Its diet, which varies throughout the feeding season, also includes an ill-defined amount of small animals *e. g.* insects and worms.
From late April to early May, alpine grasslands offer little in terms of plant variety or quantity. Crocuses and bulbs, etc. are available between snow patches which show large fluctuations from one year to another. Furthermore a marmot awakening from hibernation must face two contradictory constraints: (1) after a long period of fasting, feeding must resume very progressively for physiological reasons and (2) its body reserves are seriously depleted or exhausted when requirements return to those of a normal active animal.
However, we have observed that some individuals hardly ever approach the vegetation patches during the first 2-3 weeks after they emerge. Do they feed underground (on roots, small animals etc.)?
Foraging time then increases and is estimated at 40% of the time spent above ground during the summer (for example Barash, 1976; Naef-Danzer, 1983).

5.4 Social structure and territorial behaviour

It is currently agreed that the basic social entity is the family group. This group is usually composed of one reproductive female, one reproductive male, a variable number of offspring of different age classes: young less than one year old, immature individuals and even occasional adults that theoretically do not reproduce. A family group can thus include over 10 individuals.

A family group sometimes lives slightly apart from its nearest neighbours ("isolated family group", Mann & Janeau, 1988) in which case its home range is completely separate. However, family groups often come together in "colonies" with a slight overlap of their home ranges (Zelenka, 1965, Mann & Janeau, *op. cit.*)*.

Does territoriality occur? If so,
in which part of the home range, and when?
Does agonistic behaviour occur?
Which individuals are involved and when?

Answers to such questions in the literature tend to be heterogeneous. Territorial behaviour varies from pronounced (Naef-Danzer, 1983, 1985; Arnold, 1986) to discreet or even almost absent (Müller-Using, 1956; Barash, 1976) and the frequency of agonistic behaviour ranges from high to minimal (Müller-Using, 1956; Naef-Danzer, 1983) via variations according to the time of year (Couturier, 1964; Zelenka, 1965).

The following statements can be made:

- Each family group has its own home range.
- Scent markings, especially cheek rubbing, mark the home range**.
- During the mating period, a relatively agonistic phase occurs and is sometimes associated with territorial intolerance. These kinds of behaviour are generally conducted by reproductive males against other males, both mature and immature.
- Outside this period, the home range is maintained by "peaceful" means and each group respects the neighbouring home ranges whether they overlap or not. This is certainly partly done by using avoidance tactics, and also, in our opinion, recognition-tolerance tactics the details of which remain obscure.
- Agonistic behaviour (fighting, chasing) very seldom occurs outside the mating period and is directed against individuals from outside areas (and hence from other groups).

The long-term persistence of groups (Naef-Danzer, 1985) and stability of the extent and outline of the home range (Mann & Janeau, *op. cit.*) are remarkable, but what causes this constancy is not well understood. The following questions arise amongst others. At what age do the offspring leave the family group? Where do they go? What becomes of them? Post-juvenile dispersal is currently one of the main topics in marmot research. Only long-lasting individual tagging will yield reliable results, but this technique has not been satisfactorily mastered yet.

* In the asiatic species *M. camtschatica*, Jarov (1972) also observed an overlap of the home range accounting for about 20% of the total area.

** This scent marking is not necessarily territorial. According to Armitage (1976) in the American *M. flaviventris*, olfactive marking would be related to social functions (hierarchy).

6. Life History Traits (Reproduction and population dynamics)

Reproduction - Fertilization takes place between the second half of April and early May. In the wild, gestation lasts from 33 to 34 days (Psenner, 1957) and 2 to 4 young are usually born although litters of up to 7 young can occur (Naef-Danzer, 1985). A newborn pup weighs some 30-40 grammes (Couturier, 1964). The age at which it is reported to first emerge from the burrow varies from one author to another: between 2 and 3 weeks (Couturier, 1964), 5 weeks (Zelenka, 1965). The sex ratio seems balanced both at birth (Couturier, 1964) and in adults (Zelenka, 1965).

It has been estimated that most females reach sexual maturity in their 3rd year but values for males are not as reliable. The periodicity of reproduction in adult females is also quite difficult to assess precisely: the value 0.5, which indicates that a female reproduces every other year, is sometimes given but this figure is only an average taken over all females. Among the factors which make this sort of assessment difficult is the fact that in the wild, animals do not necessarily exhibit reproductive activities as soon as they have reached puberty, nor every year thereafter for that matter. It is currently admitted that the reproduction ability depends on a complex set of ecological, physiological and ethological factors: build-up of reserves before hibernation (which is more difficult for females that have littered and suckled their young around June), physiological state at the end of hibernation, social structure of the groups (status of the individuals, possible dispersal) etc.

Lifespan - Potential longevity has been estimated at 15-20 years by several authors, but actual longevity in the wild remains unknown for lack of tagging and sufficiently long-term surveys.

Death causes - The main causes of death in marmots are:
- Failure to withstand the winter in animals that had not accumulated enough body reserves (fat) or consumed them too quickly. This kind of mortality mainly affects small animals, *i.e.* the young (see § 7).
- Predation, especially among the young, by stray dogs, foxes, birds of prey and occasionnally man (see § 9 and 10).

It is likely that pathological conditions have relatively little effect (see § 8). They can, however, act as weakening factors and hence enhance the above causes.

Numbers - Considering the kinds of environment marmots live in and their colonization pattern, whether a particular valley, slope, or other area is populated or not (with an estimate of the number of animals if feasible) is more relevant to the distribution of the species than density.

Density is only of interest for comparisons at the group level. It acts as an index of both the quality of the environment and of the social structure, the relative importance of each of which is hard to determine.

7. Hibernation

The strategy the Alpine marmot uses to face the winter has developed into storing energy reserves as body fats and reducing its expenditure by entering a lethargy which lasts over 6 months. The broad lines of the yearly cycle are typical of those for a hibernator (Morrison & Galster, 1975): a homeothermal period (active) and a heterothermal period (hibernation).
- The homeothermal period is divided into 4 phases: (i) reproduction, (ii) recuperation and growth, (iii) maintenance, (iiii) preparation for hibernation.
- The heterothermal period is divided into 3 phases: (i) onset of hibernation, (ii) deep hibernation, (iii) waking up. Each of these phases is characterised by a succession of periods of slumber and wakefullness (*i.e.* heterothermy and homeothermy) of unequal length.

This sequence is controlled in all hibernators by a complex combination of endogenous and exogenous factors ("seasonal endocrine cycle", "endocrine syndrome ... essential for hibernation ... not sufficient on its own", Kayser, 1975).

We shall not delve into the details of this control, which has already been described and discussed in the specialised literature. Let us simply state that most endocrine glands, including the pituitary and adrenal glands, undergo considerable modification throughout the cycle. The most important exogenous factors for entering hibernation are probably:
- the decrease in the number of daylight hours during the summer, which facilitates or enables the endocrine modifications required for hibernation;
- the decrease in temperature and available food resources in the autumn, which to a variable extent depending on the species, are required to trigger the lethargy.

Hibernation in *Marmota marmota* - After a period of intense summer feeding during which the reserves that will be needed are gradually accumulated as body fats, the animal starts to fast as soon as food resources begin to dwindle. It then enters its burrow around late September or early October and plugs up a few sections of variable length (1 to 3 sections, 60cm to 8m long, Couturier, 1964) of the access tunnel to the chamber where it will spend the winter with the other members of its group. It then becomes less active and falls into ever longer and ever deeper phases of lethargy.

In midwinter and if thermal conditions are appropriate (ambient temperature around 4°C) the animal will be in deep lethargy most of the time except for a few short albeit regular periods when it is awake, occurring roughly every 20-25 days (Couturier, 1963, 1964; Malan, 1992).

In the spring, the animal will gradually become more active, and the phases of lethargy lighter and shorter (a reversal of what happens when it enters hibernation) until it finally fully awakes and emerges from its burrow.

Metabolism and body weight - Deep lethargy is characterised by a very low body temperature (in the marmot: rectal temperature 4.5 to 6°C, for an ambient temperature of 3 to 6°C, Couturier, 1963, 1964) and a tremendous slowing down of all metabolic functions. The heart rhythm of marmots for instance can drop to 2 or 1 beat per minute (Couturier, *ibid*) or even less (Castellano *et al.*, 1993).

This reduction in metabolism saves a tremendous amount of energy. The expenditure of an hibernator during the phases of deepest lethargy can be as low as 1/30 to 1/50 of what it is in the summer, or 1/100 of what it would be if the animal had "elected" to remain homeothermic during the cold season. This drop in energy expenditure is the keystone to the animal's ability to survive for 6 months solely on its body reserves without any food intake.

As an indication of the loss of body weight*, a young animal that weighs 1 to 2 kg when entering hibernation will weigh only 0.6 to 1 kg in the spring, whilst a 2-3 kg yearling will emerge at 1-2 kg and a 5 (± 2) kg adult will weigh only 2.5 (± 0.5) kg. This holds of course for the animals that survive the winter.

* When considering a large enough group of animals, whether young, yearlings or adults, it is always possible to find values ranging from 1 to 2 for the weight at the onset of hibernation, weight at the outcome of hibernation or the weight loss.

Favourable and unfavourable factors - Unfavourable factors for a hibernator are all those that somehow or other, by means of accident or under more "normal" circumstances, lead to a premature exhaustion of the animal's body reserves and hence to its death. Two main classes of factors can be distinguished: (i) those that cause insufficient reserves to be accumulated such as littering in females, slow growth and fattening in some young and (ii) those that cause an early exhaustion of reserves by an excessive consumption *i.e.* those that reduce the length and depth of lethargy. In the marmot for instance, poor plugging of the burrow will result in the circulation of cold air increasing heat loss from the animals which in turn obliges them to increase their metabolism raising their energy consumption. To make matters worse, the lower temperatures cause the animal to wake up more often.

Favourable factors are on the whole the opposite of the ones just described. Arnold (1985, 1990) observed that in *Marmota marmota* the greater the number (and size) of hibernating animals, the greater the winter survival rate especially among young of less than one year. For each individual, surfaces in contact with its congeners lose less heat than those in contact with the surrounding air. And considering that the heat loss from lethargic animals is minimal, the presence of a larger number of individuals together could mean that a more "favourable" temperature is maintained by sheer bulk effect.

More questions... - Among the many questions relative to hibernation in marmots, some can be answered readily but others remain unsolved.

- How can Asiatic marmots that hibernate in the permafrost cope with very low temperatures? The burrow temperature can reach -14 to -17°C whereas it has often been written that *Marmota marmota* wakes up if the ambient temperature drops to 0°C. There is no major contradiction here. If an animal is well insulated from cold surfaces with litter etc. and if its burrow is properly plugged (no air circulation to increase heat loss)*, then it will expend slightly more energy to keep its temperature above 0°C but lethargy will on the whole be playable.
- Why does a hibernating animal wake up at regular intervals, on average every 3 weeks in the marmot and every week in the hedgehog? It was believed that this is necessary in order to get rid of toxic metabolic end products such as urea, but experiments have led to the rejection of this hypothesis (Malan, 1992) and the question remains.
- What causes marmots to awake in the spring at a relatively constant date for each location? Exhaustion of reserves and hormonal modifications (endogenous factors) play, as it is known, an essential part. But other exogenous (*e.g.* thermal modifications) and endogenous factors must also contribute.

* However this is not the case in respiratory chambers used to study the mechanisms of hibernation: the animal generally has no litter and a continuous air flow is required for the measurement of respiratory exchanges (Malan *pers. comm.*).

8. Pathology

Studying the pathology of a species means taking into account for each disease (i) the effective contamination of the species (frequency and extent of the infection of individuals, effects on their physical state), (ii) potential sensitivity (when effective contamination has not been demonstrated) and (iii) relationship to other species susceptible to contamination.

Our knowledge of the alpine marmot's pathology is still rather scanty, especially where bacterial and viral diseases are concerned.

What we do know, however, enables us to claim that on the whole *Marmota marmota* is in pretty good health. Whereas the marmot does get contaminated by ruminants on the alpine grassland and especially by sheep (see further on under Helminths), the opposite does not hold. Marmots therefore can hardly be a risk for ruminants.

8.1 Infectious diseases (bacterial and viral) - By compiling the work of several authors (Zabolotny, 1915; Bibikov, 1968 & 1992; Summers *et al.*, 1978; Popper *et al.*, 1981; Tyler *et al.*, 1981; Roth *et al.*, 1982; Derrel & Olfert, 1986; Louzis & Mollaret, 1987; Bassano *et al.*, 1989 & 1992, Formozov, *et al.* 1991), a survey of the bacterial and viral infectious diseases that can affect rodents in general, the genus *Marmota* and *Marmota marmota* in particular, yields the following results:

- Tularaemia (a bacterial zoonosis caused by *Pasteurella* (*Francisella*) *tularensis*), which is quite widespread among European wild rodents and Listeriosis (a bacterial disease that occurs in man and animals and is caused by *Listeria* sp., including *L. monocytogenes*) have never been observed in the alpine marmot. However, both diseases have been found in Asia in *Marmota bobak*.
- Leptospirosis (a bacterial zoonosis caused by *Leptospira* sp.) does affect *Marmota monax*, but this infection has no fixed symptoms and does not lead to death.
- Salmonellosis from *Streptococcus enteritidis* (human and animal bacterial disease with a risk of intoxication/infection in man after eating infected animals) and Pasteurellosis: the exact species of *Marmota* and the place of occurence were not indicated.
- Rickettsia (bacteria close to viruses) causing exanthematic Thyphus have been found in *Marmota flaviventris* (USA) and *Marmota bobak* (Kazakhstan).
- Rabies (a viral zoonosis caused by *Lyssavirus* sp.): though the genus *Marmota* is susceptible to rabies*, rodents do not seem to play any part in the transmission of the disease.
- Forms of viral hepatitis serologically related to human hepatitis B can afflict *Marmota monax*.
- The Plague (a viral disease of man and animals caused by *Yersinia pestis* and transmitted by fleas) has been absent from Europe since the 19th century but species of the genus *Marmota* (especially *Marmota bobak sibirica*) are, in Asia, currently reservoirs of the virus and thus of infection. The 1915 epidemic in Manchuria which killed 40,000 people could have been due to marmots. The virus has also been isolated from Marmota *flaviventris* in the U.S.A. and in Canada (in Bibikov, 1992).

* According to Fischbein *et al.*, 1986, 64% of the 104 registered cases of rabies in rodents in the U.S.A. between 1971 and 1984 (1980-1984 essentially) concerned *Marmota monax*. And most of these were related to rabies in the racoon.

8.2 Diseases caused by endoparasites - The following facts relating to endoparasites in the marmot have mostly been drawn from Sabatier (1989). These are mainly gastro-intestinal parasites. (Parasites infesting other organs: Protozoa *Sarcocystis* sp. and *Toxoplasma*, see Table 1, as well as the cestode *Taenia crassisseps* in larval cestodiasis of the cysticercosis type, see Table 2).

Protozoa (see Table 1) - Coccidia from the genus *Eimeria* are the main protozoan parasites of marmots (see Table 1). In coccidial infections involving *Eimeria*, an equilibrium is usually reached between the infection and the partial immunity of the host. As a result, no disease breaks out in marmot species under such circumstances, except for the odd case and probably in young individuals that are repeatedly infected before they have acquired the corresponding immunity. In *Marmota marmota* however, no mention of any disease caused by an *Eimeria* coccidiosis, whether fatal or not, appears in the literature. As for toxoplasmosis, the infection is not generally accompanied by any precise symptoms and is usually not deadly.

Helminths (see Table 2) - It has been suggested that *Marmota marmota* might act as a

Table I - Protozoa (Coccidia) detected in *Marmota marmota* (Sabatier, 1989).

- Single host cycle, parasites of the digestive tract:	*Eimeria arctomysi*:	rather frequent
	Eimeria marmotae:	rather frequent
	Eimeria monacis:	1 case
	Eimeria perforoides:	1 case
- Two-host cycle:	*Sarcocystis* sp.:	2 cases, muscle tissues (including heart)
	Toxoplasma gondii:	2 cases, various organs including CNS

NB: Bibikov (1968) reported also *Eimeria* os and E. *menzbieri* in genus *Marmota*.

reservoir for the small fluke (Trematode) *Dicrocoelium lanceolatum* from which ruminants such as sheep could be infected. As a matter of fact, because this parasite shows such a marked “preference” when it infects its host, it is highly unlikely that the contamination of ruminants by *Marmota marmota* is any more than incidental. On the other hand, ruminants are probalby the main if not the only source of contamination for *Marmota marmota*.
The only frequent cestode among those in table 2 is *Ctenotaenia marmotae*, which is not usually very harmful.
Nematodes are quite common parasites among wild rodents. They sometimes cause very severe pathologies, but apparently this is not the case in *Marmota marmota*. Some are fundamentally not very pathogenic, such as the Oxyuridae *Citellina alpina* and *Oxyuris marmotae* or *Ascaris laevis*. Although the latter is very common in *Marmota marmota*, it does not reach levels that could cause serious disorders in the young. Other parasitic nematodes only infest *Marmota marmota* as an occasional or even rare host, such as the Strongyloidea *Ostertagia circumcincta* and *Ostertagia trifurcata* or *Trichuris* sp. The presence of Strongyloidea and *Capillaria hepatica* might be due to contamination by small domestic or occasionally wild ruminants on the alpine grassland.

8.3 Other diseases

- Ectoparasites mentioned by Sabatier (*op. cit.*) include:
• 2 mites: *Hirstionyssus blanchardi*, frequent, and *Laelaps agilis*, one single case;
• 2 insects: *Gyropus ovalis*, a biting louse, *Oestromyia* sp., a member of the Diptera and the agent of a cutaneous myiasis.

- The marmot can act as a vector of the soil keratinophilic fungi *Microsporum gypseum*, *Microsporum canis*, *Microsporum cookei*, *Trichophyton mentagrophytes* and *Trichophyton* sp. (Gallo *et al.*, 1992). These fungi can cause ringworm and present three main characteristics: i. They seem to infect only previously weakened animals; ii. Their spores are very resistant (*Microsporum canis:* 3 years); iii. Some

Table II - Helminths detected in *Marmota marmota* (Sabatier, 1989 essentially):

Trematodes (Tapeworms):	- *Dicrocoelium lanceolatum*	(“Small Fluke”)
	- *Dicrocoelium dendriticum*	(Bassano *et al.*, 1992)
Cestodes:		
- Infestation with adults:	*Ctenotaenia marmotae* (***)	(predominant in males)
	Paranoplocephala transversaria	(extremely seldom in Europe, mainly found in Asia)
- Infestation with larvae:	*Cysticercus longicaulis* (*Taenia crassiceps*):	4 cases + cyst in the armpit
	Tetrathiridium sp. (*Mesocestoides* sp.):	1 case (probably very rare)
Nematodes:		
- Oxyuridae:	*Citellina alpina* (**)	
	Oxyuris marmotae	(probably occasional)
- Ascaridae:	*Ascaris laevis* (*)	(self-elimination in September)
- Strongyloidea:	*Ostertagia* (*Teladorsagia*) *circumcincta*	
	Ostertagia (*Teladorsagia*) *trifurcata*	(*M. marmota* probably an incidental host)
	Nematodirus spathiger	(Bassano *et al.*, 1992)
- Trichocephaloidea:	*Trichuris* sp.	(rare and in small numbers)
	Capillaria hepatica	(probably occasional)
	Capillaria caundiflata	(Bassano *et al.*, 1992)
- Spiruridae:	Eggs: 2 references / Adults: other species of the genus *Marmota*	

(*) (**) (***) The most frequent and most numerous parasites; mean number of parasites per animal: (*) = 3 to (***) > 200

NB: Bibikov (1968) reported: - Cestodes: *Ctenotaenia reggiae* and *Paranoplocephala ryjikovi*; - Nematodes: *Citellina marmotae*, *C. triradiata* (Oxyuridae) and *Ascaris tarbagan* + *Dictyocaulus filaria* (pulmonary strongyloid) in *M. bobak centralis*; + *M. moniliformis* in *Marmota menzbieri*.

of them can lead a saprophytic life in the soil.
- *Marmota* is also affected by cardiovascular diseases and laboratories specialised in this field use it as an experimental animal.

Appendix

Results of the anatomo-pathological examination of a sample of 11 marmots from Aosta Valley (Bassano *et al.*, 1989).

Pathologies (Location):	
Pericarditis, Myocarditis (Heart):	1
Bronchopneumonia (Lung):	1
Haemorrhagic enterocolitis (Intestine):	1
Haemorrhagic gastritis (Stomach):	2
Cystircercosis due to C. *longicaulis* (muscle and hypoderm):	9

9. Interaction with other species

Feeding competition

When marmots live on the alpine grassland, domestic ungulates (sheep and cattle) can compete with them for food, but in more rugged terrain such as scree only wild ungulates can occasionally do so. Let us also mention, voles and Orthoptera during their pullulation phases.

Prey-predator interactions - Predation by foxes (*Vulpes vulpes*) is quite frequent but in many areas it is negligible when compared to predation by sheepdogs and stray dogs. The eagle (*Aquila chrysaetos*) is probably the marmot's main winged predator although the goshawk (*Accipiter gentilis*) does attack young marmots successfully around the tree line (Perrone *et al.*, 1992).

Other interactions - Trampling (domestic ungulates) certainly prevents marmots from settling in some parts of the grassland (herding areas, catching pens, salt-lick locations).
- Pathogenic organisms can be exchanged among the different hosts of the biotope, whether these are temporary (domestic ungulates) or permanent (marmots, voles, wild ungulates, predators) (see § 8, introduction).

10. Interactions with man

Beyond the indirect interactions in which dogs and domestic ungulates are involved (see § 9), various forms of direct interaction take place, the extent and impact of which vary a great deal.

10.1 Hunting - The marmot is classified as game in some countries (France, Switzerland, Austria). No reliable quantitative data are available regarding current marmot kills but this form of hunting is less and less practised and apparently only by a few enthusiasts. Although poaching with traps still occurs, in no way does it cause as much damage, either immediately or in the long term (burrow destruction), as drawing used to when it was widely practised in many areas.

10.2 Tourism - Studies on the interaction between marmots and mountain leisure (Neuhaus *et al.*, 1992) tend to confirm that the animals are fairly tolerant, except when dogs are present (even if kept on the leash).

10.3 Releases - Marmot resettlements have been performed in the past and still are for various reasons: entertainment, hunting and as a link in the food chain of predators.
Unfortunately, the releases are often carried out under sub-optimal conditions and losses are considerable both during and even more so after the transfer both on the original and on the release locations. No progress can be expected until some effective thinking has taken place and serious methodological studies carried out. The release site, the capture site and the category of animals to be transferred must all be selected with care to avoid destroying existing colonies for the sake of a hazardous resettlement.

Basic considerations:
Recognition of the family group as a fundamental structure and some basic knowledge regarding survival during hibernation (number of animals hibernating together etc., see § 7) imply that appropriate precautions should be taken.
Capturing is easier early in the season.
Transplanted animals must be given the oppor-

tunity to shelter adequately upon arrival. They will then have to dig and fit out suitable shelters while accumulating body reserves for the coming winter.
Females about to litter should never be captured and transplanted because of the stress involved. Capture of females that have just littered should also be avoided because the young which are still tied to the nest and could not be captured would then be sacrificed.

Suggestions:
Capture
- Trapping should occur towards the end of June. This is neither too early, so that the animals can recuperate from the previous winter's tiredness and so that some time has elapsed since the females littered, nor too late, so that the mammary glands of the suckling females are still visible and so that the transplanted animals have enough time to settle down and fatten before the wintertime.
- Only females that did not give birth (mammary gland inspection) should be kept *i.e.* adult females that did not reproduce during the current year (see § 6) or sub-mature females (which have wintered once or twice).

Sorting out the females is probably the trickiest part. The principles are simple enough, putting them into practice is not.
- The sex ratio should be around 1.
- The capturing here and there of only isolated animals that do not know each other should be avoided. Capturing large numbers from medium-sized groups should also be avoided as this puts the group in jeopardy.

Capturing a whole family group (without newborn) from within a large colony or capturing part of a 12-15 strong family group seems theoretically acceptable.

Release
- The animals should be released in scree areas where large blocks abound, or better yet where cliffs are present, as natural clefts provide the newcomers with both an immediately available shelter and, in the medium term, the prospect of riding out the coming winter in acceptable conditions.
- Animals captured together should be released together and no less than 6 to 8 animals should ever be released in any one location.

N.B. Observations from successful releases often coincide with regard to an odd and important fact: the animals are barely visible during the first 1-2 years after the operation and reappear later on.

Studies and research - The behaviour of American marmots has been extensively studied over the last twenty years, probably because the coexistence of several species with all their ecological and social differences enables interesting comparisons to be made.
In Europe, the marmot's physiology has aroused much interest because of hibernation. However, except for the independent work of research or wildlife management institutes and of isolated individuals working alone, nothing else has been initiated by the establishment.
Only recently has a trend towards more concrete, better structured and longer term programmes taken shape in several countries. The international symposium on the marmot which took place in Aosta Valley (First International Symposium on Alpine marmot and genus *Marmota*, St Vincent - 28-30/10/91) and which gathered over 250 participants stands as a testimony to this trend.

Acknowledgements: We thank M. Cuisin, J. Ducos de Lahitte, J. - M. Gourreau, J. - L. Hartenberger, G. Jolivet and A. Malan who were helpful in answering some technical questions or otherwise, "INRA Traduction" (Ph. Butler) for translation.

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