THE CHEMICAL ECOLOGY OF MUSTELIDS

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Summary

The Mustelidae or weasel family is the largest family in the order of mammals known as the Carnivora with sixty-seven highly specialized species having the ability to exploit a variety of contrasting environments. Mustelids lead complex social lives that require effective transfer of information in order to be maintained. One way of achieving this is through odor, via scent marking. There are a number of theories regarding the exact role played by scent marking behavior (e.g., territorial defense, resource marking, maintenance of social organization/dominance hierarchies, navigation/food location) and regarding types of information conveyed (e.g., reproductive condition, family/clan identity, individual identity). There are a variety of odor sources used by mustelids (e.g., urine/faeces, skin glands, scent producing organs). Therefore odor may be comprised of chemicals provided by undigested food material, chemicals synthesized by the animal or produced by bacteria (scent organs often provide a moist, warm, anaerobic environment favorable for bacterial development). Analytical work carried out investigating the chemical make-up of mustelid scent marks has revealed them to be a complex mix of compounds. Analysis of odor profiles (chemical extraction, separation, quantification and identification) needs to be integrated with behavioral studies in order to pinpoint the active components. Understanding scent marking would allow significant insight into mustelid social behavior and ecology. E.g., this could lead to solutions for both conservation management (many mustelids are threatened with extinction, e.g., the black-footed ferret, *Mustela nigripes*) and economic problems (e.g., the European badger – a host for bovine tuberculosis?).

1. Introduction: what are Mustelids?

The Mustelidae, or weasel family is the largest and most diverse of the 7 families in the order of mammals known as the Carnivora. There are sixty-seven species of Mustelidae (thirteen of which are found in Europe) and these are divided into 5 sub-families: the Mustelinae (stoats, weasels, martens, polecats, wolverines); the Melinae (true badgers); the Mellivorniae (honey badger or ratel); the Mephitinae (skunks); and the Lutrinae (otters). There has often been disagreement over these classifications, but although repeatedly questioned they remain the 'industry benchmark'.

Figure1. The weasel (juvenile), *Mustela nivalis*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

Figure2. The stoat, *Mustela erminea*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

The Mustelidae therefore contain some well-known species and the success of these species demonstrates the evolutionary principle of *adaptive radiation*. Early forms of mustelid lived in forests and were less specialized, but as they evolved they diversified into more highly specialized species with the ability to exploit a variety of contrasting environments.

Western European Mustelids are typically terrestrial, e.g., the weasel (*Mustela nivalis*), the stoat (*Mustela erminea*) and the polecat (*Mustela putorius*) [Figures 1, 2 & 3 respectively].

Figure3. The polecat, *Mustela putorius*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

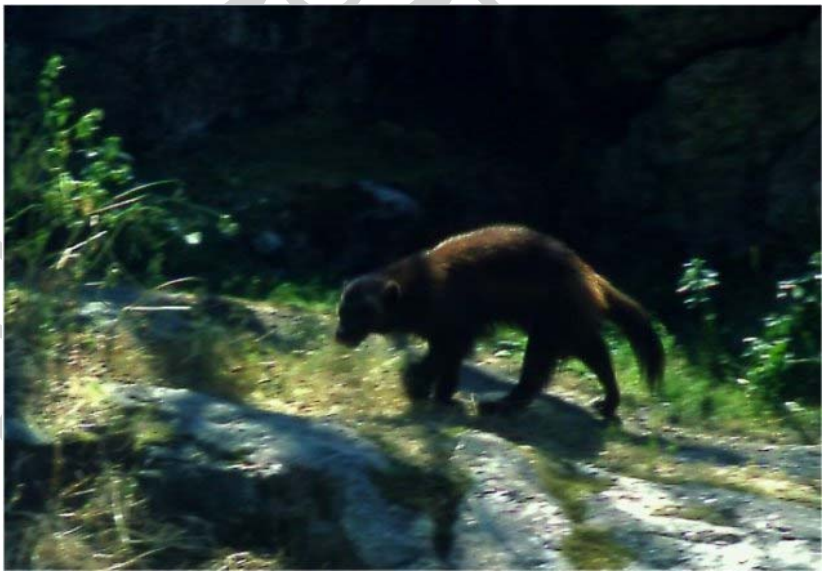

Figure4. The wolverine, *Gulo gulo*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

The larger and less familiar Wolverine, *Gulo gulo* (Figure 4) has adapted to the harsher conditions found in Northern Europe and America and has been observed to predate upon sheep during the summer months in Norwegian mountain ranges.

The Pine marten, *Martes martes* (Figure 5) is mainly arboreal and an adept climber, perfectly at home in the trees of more northern European forests, although in Britain it happily exists in rocky and more open environments. The Pine marten's closest European cousin is the Beech marten, *Martes foina*. It has similar adaptations and its range overlaps with that of its cousin, however it does not compete, as it prefers deciduous woodland and more cultivated areas. Additionally, it has a more southerly distribution.

Figure5. The pine marten, *Martes martes*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

Figure6. The sea otter, *Enhydra lutris*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

Other highly specialized Mustelid species include the otter, which is remarkably adapted to its semi aquatic existence. Examples include the European otter, *Lutra lutra* (see Section 3, Figure 9), quite at home on land, but only when observed in water do its adaptations to this quite different environment become apparent. In contrast the Sea

otter, *Enhydra lutris* (Figure 6) has adapted to an almost completely marine lifestyle, rarely coming ashore.

The badger, *Meles meles* (see Section 4, Figure 10), e.g., is far more omnivorous than other mustelid species, but feeds mostly on a diet of invertebrates. It leads a subterranean existence and can dig out extensive burrow systems allowing long periods to be spent underground.

Mustelids have a typically solitary nature (although there are exceptions, e.g., the Giant otter, *Pteronura brasiliensis* (Figure 7) and individuals are generally territorial.

Figure7. The giant otter, *Pteronura brasiliensis*
(Photograph, Dr. Pat Morris, Royal Holloway, University of London)

Occasionally, more than one species will occur in close proximity, and there is some evidence for interference. Generally, mustelids have social organization where females are resident in small ranges within the much wider territory of a male.

Sufficient food resources to rear offspring are the main concern for female mustelids when choosing a home range to occupy. Males will maximize their reproductive output when their territories encompass as many female ranges as possible. Therefore food resources also ultimately determine male ranges. This classical model of intra-sexual territoriality is typical of socio-biological organization in many other mammal families, e.g., Ursidae, Viverridae and Felidae.
There are exceptions however, with more *social* species bucking the trend, unusual not only in mustelids, but also in the Carnivores as a whole.

Another theory states that mating systems are not an evolved feature of each species, but appear as individual strategies. Mustelid social organization and behavior can be flexible showing variation even *within* populations. For instance, in Britain badgers typically form clans of up to 12 individuals, comprising both males and females. Elsewhere in their range individuals exhibit intra- and inter-sexual territoriality having either a solitary existence or living in pairs. Further complications arise from a study of male stoat movements that become noticeably altered during the mating season. This coincides with a change in resource priority from food to females.

So, how do mustelids maintain such diverse socio-biological systems, and what strategies are used in territorial defense?

It is well known that mammals use 'social odors' extensively to convey messages, both intra- and inter- specifically and the Mustelidae are no exception. Understanding mustelid scent marking is important, as it constitutes their primary form of communication.

2. Scent marking in mustelids.

Transmission of information between individuals is essential for the maintenance of the complex social lives of carnivores including that of the mustelid family. The means of transferring such information can differ, the main routes being sound (e.g., vocalization), vision (e.g., cues such as facial expression or body language), touch (e.g., more direct contact through fighting and grooming) and of course *odor*.

The use of odor signaling can be more useful than other methods especially under circumstances where visual and auditory signals are hard to detect, e.g., at night or underground. A record of an animal's spatial and temporal movements can be provided with the deposition of a scent mark, which is able to persist in the environment long after the signaling animal has moved on.

2.1 The Function of scent marking

But what is the precise function of scent marking? There are a number of hypotheses concerned with this question.

Some focus on its role in the maintenance and defense of territories. They put forward the idea that scent marks convey information about a territory resident. Territoriality in mammals often appears where resources are limited, and so in energetic terms, it is important for individuals to minimize the energy expended in defending it, whilst still maintaining an effective defense.

Defense of a territory using scent dramatically reduces the chances of direct contact/conflict between rivals. The potential risks involved in physical confrontation are great and so scent marking brings with it many advantages. Individual recognition through scent marks has been shown to exist in some species of carnivore and this could provide a mechanism for the avoidance strategy.

Scent marking is often observed at particular places inside mustelid territory, for instance on conspicuous objects, at the point where paths dissect a specific linear feature, or at the junctions of paths. The specific positioning of these hinterland scent marks implies that they could also function as *intra*-group communications. So, just as scent marking could prevent *inter*-group encounters between individuals, so too could it perform a similar role in the prevention of *intra*-group encounters.

It is possible then that scent marks are used to convey fairly complex information from one individual to another. To this end the odor of a mammalian scent mark is normally a complicated mixture of chemicals, and a blend of factors governs the response it will produce. These include the context of the scent mark and the previous experience and developmental status of the receiving animal.

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Biographical Sketch

M.J. Davies, originally from South Wales, discovered higher education rather later than expected, beginning a degree in Zoology at the University of Wales, Cardiff in his late twenties. During his time there he became involved in local conservation projects through the student conservation society. This, coupled with his interest in otters generated by his final year dissertation [involving the investigation of guard hair morphology in the European otter (*Lutra lutra*)] led him to his current position. He is now based at the University of Hull, East Yorkshire working on his PhD entitled: 'The chemical basis of odor recognition in the European otter (*Lutra lutra*)'. His project seeks to investigate the chemical nature of otter scent marks (spraints), and to identify the relevant odor chemicals within them through bioassay using both wild and captive animals. Although scent marks from the European otter are the main focus, other species are also being studied, from a range of different otter species (e.g., the Asian short-clawed otter, *Aonyx cinerea*) to other members of the mustelid family (e.g., the European badger, *Meles meles*) to relatively unrelated mammal carnivores (e.g, the Gray wolf, *Canis lupus*).