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Source: Folia Zoologica, 60(1) : 47-53

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/fozo.v60.i1.a8.2011

Folia Zool. – 60 (1): 47–53 (2011)

Winter activity patterns in an invading Mediterranean population of American mink (*Neovison vison*)

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Received 30 June 2010; Accepted 17 September 2010

Abstract. Patterns of daily activity and the factors affecting it were studied in an invading Mediterranean population of American mink, *Neovison vison*, radiotracked in the northeast of Spain during the post breeding season (winter – half year). We distinguished between local activity, defined as active behaviour without spatial displacement, locomotion activity as active locomotion behaviour while foraging or travelling, and inactivity. We studied the effect of sex, age, daylight (nocturnal or diurnal), month, river flow and average rainfall on the activity of eight males and three females. Male mink presented more locomotion activity than females and subadult mink had more locomotion activity than adult mink. Average rainfall per day had a negative effect on locomotion, while daylight had no effect on either total activity or locomotion activity. Studied mink spent most of their time inactive in-den. These results are accordance with the patterns of activity shown by other native and invasive populations.

Key words: locomotion, local activity, inactivity, Mustelidae, postbreeding season

Introduction

The circadian activity patterns of most mustelid species correlate with photoperiod length (Hainard 1961, Ewer 1968), which seems to be the factor that mostly influences small carnivores' activity pattern (Ashoff 1966, Saint-Girons 1966). Other extrinsic and intrinsic factors affecting this pattern are temperature (Ewer 1968, Richardson et al. 1987, Buskirk et al. 1988, Jedrzejewski et al. 2000, Zalewski 2000), predator activity (Powell 1973, Richardson et al. 1987), prey abundance and activity (Gerell 1969, Zielinski et al. 1983), and sex, age or body mass (Zalewski 2000). Small mustelids are nocturnal or crepuscular, whereas diurnal activity is much less common (Halle & Steseth 2000).

The American mink (*Neovison vison*) is a riparian mustelid that, far from expected, has shown a variety of activity behaviour throughout the different areas and studies: nocturnal (Gerell 1969, Birks & Linn 1982, Yamaguchi et al. 2003), diurnal (García et al. 2009), diurnal in females and nocturnal or arrhythmic in males (Zschille et al. 2010), or without any pattern (Niemimaa 1995, Zuberogoitia et al. 2006). Although there is not a clear circadian activity pattern, mink spend more time inactive than active per day (Dunstone & Birks 1983, Ireland 1990) being most of the time inside their dens (Dunstone & Birks 1983).

In this paper we describe the patterns of activity in an invasive mink population established in Catalonia (Northeast of the Iberian Peninsula), one of the few Mediterranean areas affected by its invasion. Mink behaviour can differ from other areas due to contrasting environmental conditions, such as Mediterraneity. Mediterranean environments present high variability

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in seasonal patterns with strong autumn rainfalls and subsequent floodings, and extremely dry and hot summers with temporal rivers (Di Castri & Mooney 1973). Our main aim was to describe the daily activity rhythm and to evaluate possible differences between total activity (both local movement and locomotion) versus inactivity, and locomotion activity versus local activity (local movement) and to analyse how sex, age, daylight, month, river flow and average rainfall affect them. Information on the patterns of activity in the areas affected by the invasion of the species will allow us to improve the efficiency of trapping efforts and to know which prey species can be most affected by mink predation or competition.

Study Area

The study was conducted in Bages region (1°53' N, 41°49' E) in the centre-eastern part of Catalonia (Spain). The area included 6 km of the River Llobregat, 5 km of its tributary Gavarresa, and their banks. The average annual rainfall was about 490 mm and the altitude ranges between 160 m and 350 m. The riparian vegetation is dominated by *Arundo donax*, *Typha latifolia*, *Phragmites sp*., *Juncus sp*., *Rubus ulmifolius*, *Populus alba* and *Salix spp*. This typical Mediterranean habitats are characterised by a strong summer drought and torrential autumn rainfalls whose subsequent floodings reduce vegetation cover each year.

Material and Methods

Mink trapping and radiotracking

One trapping session was conducted each year with a total of 588 trap-nights per each session in 2003 and 2004. The sessions were set each year between October and December in both rivers. Animals were live-trapped in single cage traps (15 x 15 x 60 cm) located on both river sides with a separation of 300–400m between them and checked daily. After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), manipulated animals were released in the capture area once fully recovered. Trapping was made during the post breeding season (September to February) when there are no juvenile mink (all animals older than 5 months). Animals were sexed and aged (subadults 5–8 months old; and adults > 8 months old) based on a combination of teeth condition and weight (Maran & Robinson 1996).

The captured animals were marked with a transponder (Trovan Ltd., Madrid, Spain) in order to distinguish between new captures and recaptures. Some of them were fitted with waterproof radiotransmitters collar necks (frequency 150 and 151 MHz, BioTrack, Ltd., Wareham, Dorset, UK and Tinyloc Ltd., Mataró, Spain). Radiocollars weighted approximately 15 g, < 3% of the lightest adult mink captured during the study (510 g). All procedures were approved by the Scientific Ethical Committee of the Department of Environment and Housing of the Catalonian Government (Spain).

A receiver TR4 (Telonics Ltd., Mesa, Arizona, USA) was used connected to a multidirectional or a bidirectional antenna. Radiolocations were recorded by homing to the animals (U.T.M. positions, using a Garmin GPS, Romsey, Hampshire, UK) without triangulation as mink movements follow the river course (Gerell 1970, Birks & Linn 1982, Ireland 1990, Bonesi 1996). For six-ten hours daily shifts animals were radiotracked every hour unless it took longer to find them. Radiotracking shifts changed every three-four days. Additionally, male 2, male 3, male 6 and female 4 were 24h period-radiotracked. Hour time was set as Universal Time Coordinates (UTC).

Transmitters used had a sensor of activity. This sensor allows detecting differences in signal pulse rate and differences in signal strength. Differences in pulse rate inform if animals have an active or an inactive behaviour. Active behaviour can imply spatial displacement (locomotion) or local movement without locomotion. Differences in signal strength detect active behaviour implying locomotion (Kenward 1987). Thus, animals were classified as either active or inactive depending on changes in the signal pulse rate. Simultaneously, active behaviour was set as local movement or locomotion. Overall, classification was as follows: local activity, locomotion activity and inactivity. A total of 903 radiolocations were gathered between October and February (Table 1).

Activity analysis

We distinguished between local activity, locomotion activity and inactivity. Local activity was defined as active behaviour without displacement, locomotion activity as active locomotion behaviour while foraging or travelling (active behaviour with displacement), and inactivity as the lack of active behaviour. Diurnal time was set between dawn and dusk for each day and nocturnal between dusk and dawn.

Activity versus inactivity behaviour

Total activity (all local and locomotion activity radiolocations pooled together, n = 376) *versus* inactivity (inactivity radiolocations, n = 527) was studied, analysing the influence of sex, age, daylight (diurnal and nocturnal), month, river flow and average rainfall per day using

Table 1. *Data of captured individuals during the trapping sessions 2003 and 2004. Age refers to subadult (SA) or adult (A).*

Individual	Age	Tracking period	*N° Radiolocations*
2003			
Male 2	A	24/9–4/12	200
Male 3	A	2/10–16/11	118
Male 4	A	13/11–29/12	34
Female 1	A	23/9–4/12	190
Female 2	SA	7/11–28/11	20
2004			
Male 5	A	19/10–2/11	28
Male 6	SA	2/12–15/2	99
Male 7	A	21/12–1/2	40
Male 8	SA	10/11–22/12	53
Male 9	A	10/11–3/12	38
Female 3	A	19/10–9/12	83

GLMM fitted to a binary distribution. Factors were set as fixed effects. Individual and river (Llobregat or Gavarresa) were set as random effects. By considering individual as random effect, the problem of different number of repeated measures per individual was avoided.

Locomotion activity versus local activity

Finally, we also studied locomotion activity (n = 187) *versus* local activity (n = 189). The influence on locomotion activity of sex, age, daylight, month, river flow and average rainfall was analysed using GLMM under the same conditions as before.

River flow (m^3/s) was measured as daily mean flow for both rivers Llobregat and Gavarresa in the study area. Rainfall (mm) was measured as daily mean rainfall in the study area.

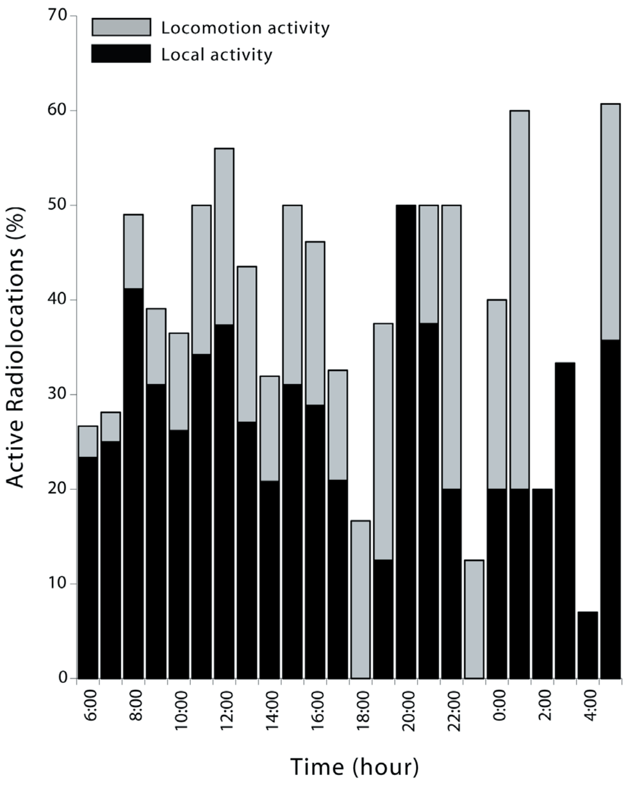

Fig. 1. *Daily local activity and daily locomotion activity of American mink. Values are given as percentage of activity locations per hour.*

Results

A total of 27 mink were trapped and 17 of them were fitted with radiocollars. Overall, we obtained data from 11 individuals. The rest of them dropped the collar, or were lost due to collar failure.

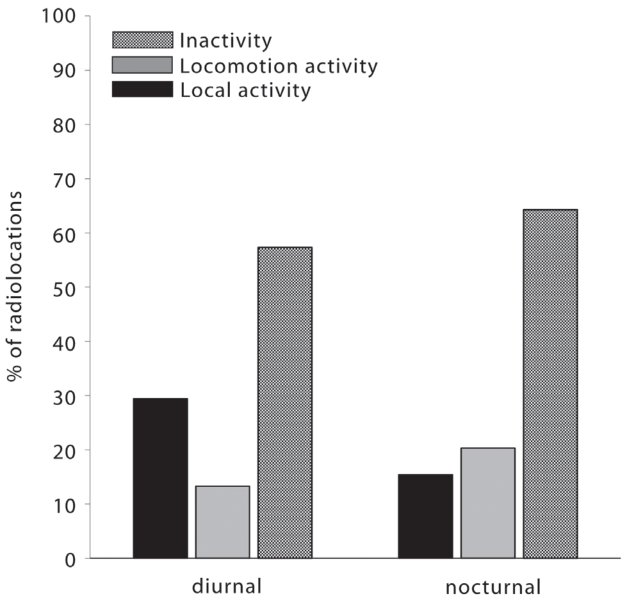

Fig. 2. *Diurnal and nocturnal inactivity, local activity and locomotion activity. Values are given as active and inactive percentage of radiolocations.*

Activity analysis
Individuals tracked spent almost half of their time active with a total of 27.6% of local activity and 13.9% of locomotion activity (Fig. 1). During the daylight period minks spent 29.4% of their time with local activity and 13.3% with locomotion activity while during the night they spent 15.4% with local activity and 20.3% with locomotion activity (Fig. 1 and 2).

Activity versus inactivity behaviour
There was no significant effect of any factor on total activity (Table 2 and Fig. 1).

Locomotion activity versus local activity
The GLMM for locomotion *versus* local activity enabled us to detect a positive effect of sex and age (Table 2 and Fig. 3a and 3b) and a negative effect of average rainfall (Table 2). Daylight was not a significant factor for locomotion activity, although mink presented slightly more locomotion activity during the night (Table 2 and Fig. 3c and 1).

Discussion

Activity
Based on the results, American mink in the study area, and during the study period (October–February), used little time in foraging and travelling, and spent most of the time inside or close to their dens active or inactive what is in concordance with Dunstone & Birks (1983) in the United Kingdom.

Table 2. *Results of the GLMM for total activity (active vs inactive) and locomotion activity (locomotion vs local activity). Individual and river were introduced as random effects in the models. d.f.: degrees of freedom. Significant factors are in cursive.*

Model-fixed effect	F	d.f.	*P*
Total activity			
Sex	2.85	1	0.14
Age	2.48	1	0.16
Daylight	4.36	1	0.07
Month	1.63	3	0.28
Flow	0.08	1	0.78
Rainfall	1.70	1	0.19
Locomotion activity			
Sex	9.37	1	0.022
Age	7.23	1	0.036
Daylight	4.75	1	0.08
Month	3.01	3	0.16
Flow	0.10	1	0.75
Rainfall	5.82	1	0.016

Daily rhythm did not show any general pattern as it has happened with other mink populations (Zuberogoitia et al. 2006, Zschille et al. 2010) in contrast with other studies that found an activity pattern (Harringtond

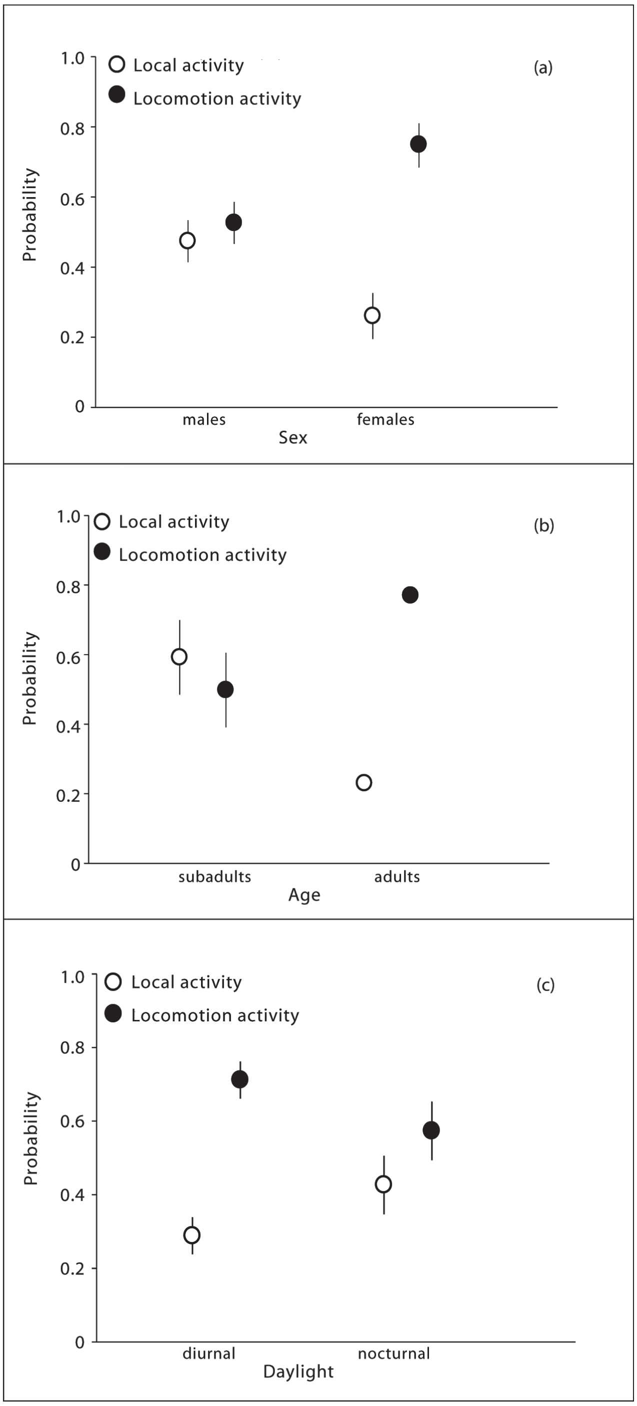

Fig. 3. *Probability of (a) Locomotion and local activity according to sex, (b) Locomotion and local activity according to age, and (c) Locomotion and local activity according to daylight. Values are given as mean and their standard error calculated from the GLMM all else being equal.*

& Macdonald 2008, García et al. 2009). Irregular patterns with a similar percentage of active nocturnal and diurnal radiolocations, as we found, have also been observed in other studies (Gerell 1969, Birks & Linn 1982, Niemimaa 1995, Marcelli et al. 2003).

Activity of carnivores is known to coincide with that of their most common prey (Laundré & Keller 1981, Zielinski et al. 1983, Ferguson et al. 1988) and the same pattern is typical for American mink (Gerell 1969, Bonesi et al. 2000). Scats collected in the study area during autumn and winter showed that crayfish, fish and small mammals are the main food sources for both sexes (Melero et al. 2008). Fish and crayfish can be hunted either in daylight or at night. Only small mammals are predominantly, although not exclusively, active at night or twilight (Halle & Stenseth 2000, Brown 2009). Thus, American mink in the studied area can hunt at both diurnal and nocturnal periods since it seems there was no constrain on prey availability at day or night. This can explain the low difference between diurnal and nocturnal activity found in our study.

Other possible causes for activity patters are the avoidance of intra-specific competition and potential predators (Gerell 1969, Lodé 1995, Lodé 1999, Zuberogoitia et al. 2006, García et al. 2009, Zschille et al. 2010), environmental factors, physiological constraints and energy requirements (Marcelli et al. 2003). However, none of the studied factors were significant for the total activity analysis.

Activity versus inactivity behaviour and locomotion activity versus local activity

The biological factors sex and age affected only the locomotion activity of the studied mink. Once again this correlates with most mustelids locomotion activity pattern as males tend to be more active than females and subadults use to be also more active than adults (Ireland 1990, Dunstone 1993, Palazón & Ruiz-Olmo 1997, Garin et al. 2002a, b, Revilla & Palomares 2002, Zschille et al. 2010). This result may imply that there is sexual segregation in feeding strategies between mink, since feeding segregation might involve differences in activity behaviour (Birks & Linn 1982, Dunstone & Birks 1983, Zschille et al. 2010).

River flow did not affect either total activity or locomotion activity, as it probably does not affect foraging or displacement. Mink are good swimmers and changes in flow are not big enough to imply a decrease in hunting efficiency. However, average rainfall per day affected locomotion activity. Although this factor was not important for other populations, the Mediterranean population was negatively affected by rain since Mediterranean areas have irregular rain patterns with infrequent but strong autumn storms that may disturb individual behaviour.

Zschille et al. (2008) and Fournier et al. (2001) did not recommend the use of radiocollars from the point of view of the animal welfare. Recapture minks presented a good physical condition but some of them presented neck injuries caused by collars. This is a common problem with radiotracking animals such as mink or polecat with radiocollars that can influence behaviour of the animals. Therefore, we want to express our support for the research on alternative methodologies.

Acknowledgements

The Universitat de Barcelona, the Generalitat de Catalunya and Life Project 02MNAT(E/864) funded this study. Y.M. was supported by a FPU Fellowship granted by the Spanish "Ministerio de Ciencia y Tecnología" (AP 2002-2653). ER was supported by a Ramón y Cajal contract (RyC2003). The Catalan "Stació Meteorològica de Catalunya" provided the official data of flow and rainfall. We are also grateful to Albert Roura, the staff of the "Centre de Recuperació d'Animals Torreferrusa" and of the "Servei de Protecció de Fauna". We thank the anonymous reviewers for their useful comments.

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