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ACTIVITY PATTERNS OF THE STONE MARTEN *MARTES FOINA* ERXLEBEN, 1777, IN RELATION TO SOME ENVIRONMENTAL FACTORS(†)

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ABSTRACT – Three stone martens (2 males, 1 female) *Martes foina* Erxleben, 1777, were radio-tracked for 4, 2.5 and 12 months respectively, in a rural hilly area in Siena County, Central Italy. Food habits were assessed by faecal analysis, as percentage of occurrence and estimated volume. Diel, nocturnal, diurnal and crepuscular activity were measured as the proportion of active fixes on a 48 hours/fortnight basis. Seasonal variation of all activities was assessed and correlated to mean T°C, daylength, food and trophic niche breadth. Daily time budgets were also measured and compared between months and seasons. Fruits were the staple food in summer/autumn, followed by vertebrates and invertebrates. Vertebrates and invertebrates were the main food source in winter and spring. No significant difference of activity could be found between the three animals. Diel activity reached its maximum in summer, and decreased significantly throughout the rest of the year. Diel activity did not differ significantly between subsequent seasons, whereas a statistically significant difference was found between every other season. Nocturnal activity peaked in winter and dropped in summer. It significantly differed between seasons but for spring vs. summer and autumn vs. winter. Diurnal activity differed significantly between seasons, but for spring vs. summer, when it reached its maximum, and for autumn vs. winter when it was at its minimum. Crepuscular activity remained constant throughout the year. The 24-hour distribution of active fixes showed a bimodal pattern in spring and summer, while in autumn and winter the activity pattern was unimodal, with a nocturnal peak. Time budget differed between seasons, but for autumn and winter vs. spring. Significant correlations between activities and abiotical variables (except rainfall) were direct, but for nocturnal activity. No significant correlation was found with precipitation. Activity was not significantly correlated to any food category, except reptiles, a spring and summer prey. Coleoptera and Orthoptera, the main invertebrate food, and fruits, correlated poorly to activity. Surprisingly, food does not seem to be the primary factor responsible for variation in activity patterns.

Key words: Stone marten, Activity patterns, Food habits, Abiotical variables.

RIASSUNTO – *Attività della fuina* Martes foina *Erxleben, 1777,* ***in*** *relazione a alcuni parametri ambientali* – Tre faine (2 maschi, 1 femmina) *Martes foina* Erxleben, 1777, sono state studiate con tecniche radiotelemetriche per 4, 2,5 e 12 mesi rispettivamente, in un area rurale della provincia di Siena. L'alimentazione è stata valutata tramite analisi fecali, come frequenza di comparsa e volume stimato. L'attività totale, notturna, diurna e crepuscolare sono state misurate come proporzione

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di rilevamenti attivi e elaborate quindicinalmente. La variazione stagionale dell'attività è stata correlata a T°C media, fotoperiodo, piovosità, alimentazione e ampiezza di nicchia trofica. L'attività totale è stata ripartita in fasce orarie e comparata tra le stagioni. La frutta costituisce la base dell'alimentazione, il suo uso è massimo in estate e autunno, seguito da vertebrati e invertebrati, che invece costituiscono la principale fonte di cibo in inverno e primavera. Non sono state riscontrate differenze significative tra i tre animali per quantità e ripartizione dell'attività in fasce orarie. L'attività totale è massima in estate e decresce significativamente nel resto dell'anno. L'attività notturna (massima in autunno e in inverno) differisce significativamente tra le stagioni, tranne che per l'estate rispetto alla primavera e per l'inverno rispetto all'autunno. Anche l'attività diurna differisce significativamente tra le stagioni, tranne che per la primavera rispetto all'estate (quando è massima) e per l'autunno rispetto all'inverno (quando raggiunge un minimo). L'attività crepuscolare resta costante per l'intero periodo di studio. La ripartizione in fasce orarie dell'attività mostra un andamento bimodale in primavera e estate, mentre è unimodale in autunno e inverno, con un picco notturno. La ripartizione in fasce orarie dell'attività differisce significativamente tra le stagioni, tranne che per l'inverno rispetto all'autunno e **alla** primavera. Le correlazioni tra le attività e le variabili abiotiche (eccettuata la piovosità) sono dirette, tranne che per l'attività notturna. Non è stata trovata nessuna correlazione significativa con la piovosità. L'attività è risultata significativamente e direttamente correlata soltanto con i rettili, tra tutti i componenti della dieta. Coleotteri e Ortotteri, il cibo principale tra gli invertebrati, e la frutta, risultano scarsamente correlati con l'attività, Sorprendentemente le risorse alimentari non sembrano essere il fattore maggiormente responsabile delle variazioni d'attività.

Parole chiave: Faina, Attività, Alimentazione, Variabili abiotiche

INTRODUCTION

Social organisation (e.g. Kruuk, 1989; Mills, 1989), feeding habits and mating system, (e.g. Mills, 1982), home range size (e.g. Harris, 1980; Macdonald, 1981; Lovari et al., 1991), activity pattern (e.g. Cavallini & Lovari, 1991; Zielinski et al., 1983) of Carnivores may vary in relation to seasonal and geographical environmental differences.

The stone marten *Martes foina* Erxleben, 1777, is widely distributed, from Spain to the Eastern Pacific coast (Anderson, 1970). Few data are available on the biology of this mustelid, particularly on the effects of ecological factors on its habits. In Italy, Genovesi (1993) made a substantial attempt to assess relationships between habitat changes, social organisation and ranging behaviour.

Because of their body shape, body size and thermal insulating adaptations, American martens *Martes americana* and weasels can be strongly influenced in energy balance by weather conditions (e.g. Scholander et al., 1950; Buskirk et al., 1988; Buskirk & Harlow, 1989; King, 1989). Modifications of physiological parameters, e.g. body temperature, have been shown to help the survival of these animals in cold weather (Buskirk et al., 1988). To compensate for energetical stress, behavioural changes can occur (Buskirk et al., 1988 and 1989; Weber, 1989a-b). Furthermore, seasonal environmental changes exert an indirect influence on the behaviour of Carnivores, through variations in their food supply (e.g. red fox: Zabel & Taggart, 1989; Cavallini & Lovari, 1991; black-backed jackal: Ferguson et al., 1988; American marten: Zielinski et al., 1983; for a review, Macdonald, 1983).

The aims of this paper were the following: i) to assess seasonal variation in activity patterns, ii) to investigate the relationships between activity patterns and temperature, photoperiod, precipitation, and food use.

STUDY AREA

The study was conducted in a rural hilly area of about 900 ha in Siena County, Central Italy (43°18' N, 11°05' E), at an altitude from 150 to 370 m a.s.l. Clay, sands and lacustrine conglomerates, dating to the Upper Miocene and to the Pliocene, characterize this area (Lazzarotto & Mazzanti, 1976). It was covered with mixed wood (*Quercus cerris, Q. pubescens, Q. ilex, Acer campestre, Fraxinus ornus, Carpinus betulus, Juniperus communis, J. oxycedrus, Spartium junceum, Cytisus scoparius*), interspersed with fallow and cereal fields. *Prunus spinosa, Pyrus pyraster, Malus sylvestris, Cornus mas, C. sanguinea, Rosa canina, Rosa* sp., *Rubus* sp. and *Crataegus* sp. were common in wood margins, in hedgerows of abandoned fields and cultivations, and in abandoned farms. *Prunus domestica, P. avium, P. armeniaca, Pyrus communis, Malus domestica, Ficus carica* and *Sorbus domestica* occurred in the neighbourhoods of 4 inhabited and 14 abandoned farms in the study area. *Salix* sp., *Alnus* sp., *Scirpa* sp., *Typha* sp. and *Phuagmites* sp. were common along ponds and watercourse banks. Three vineyards and four olive groves (two of them were abandoned) were also present. Hunting (from September 15 till the end of December) was allowed over about 450 ha, mainly on pheasants, hares and wild boars. So called *"red fox control"* operations also occurred in winter and early spring, as well as some songbird poaching. About 100 sheep were grazing over an area of about 400 ha.

METHODS

The study was carried out from July 1990 to June 1991. An adult female (henceforward, F1, body weight = 1 kg) was radio-tracked for a full year (5802 locations, n=24 fortnights). A yearling male (M1, body weight = 0.8 kg) was followed till transmitter failure, from July to November 1990, (799 locations, n=8 fortnights). Male M2 (body weight = 0.9 kg), trapped when 4-5 months old, was radio-tracked from August to October 1990 (956 fixes, n=6 fortnights), till it lost his collar. Martens were trapped in 2-entrance metal box traps (35x35x80 cm), checked every morning. They were aged by tooth wear (Larson & Taber, 1971; Van Bree et al., 1974), anaesthetized with chetamine chloridrate (Ketalar, $\bar{x}$ = 0.94 ml/kg), and their gular patches were photographed for identification (Waechter, 1975; Broekhuizen, 1983; Müskens, 1984). Martens were then equipped with 150-151 MHz radio-transmitters (SB2 model. loop antenna, AVM) and the signal was monitored with a 3-element directional Yagi aerial and a CE-12 Custom-Electronics receiver. Each radiocollar weighed 30 g.

Autocorrelation of fixes (Swihart & Slade, 1985a-b) does not necessarily influence movement and range estimates (Andersen & Rongstadt, 1989; Reynolds & Laundré, 1990), whereas relevant biological data may be missed when locating an animal at time intervals long enough to ensure statistical independence between fixes (Gese et al., 1990). We radio-tracked our animals continuously (1890 animal-hours; focal animal sampling, Altmann, 1974), with an estimated time interval between locations long enough for a marten to entirely cross its home range (see Lair, 1987). A 15' time interval between locations was chosen, as martens could travel at speeds of 0.9-1.5 Km/15' (Posillico, 1993: 35). Martens were radio-tracked for six hours/telemetry session/week, i.e. 48 hours/fortnight/animal. Radio-tracking data were elaborated on a fortnight and seasonal basis (summer: July-September; autumn: October-December; winter: January-March; spring: April-June). Temperature data were taken once a day, using a sun shielded min/max thermometer placed in the study area. Rainfall data (in mm and number of rainy days) were provided by Istituto Idrografico dei Genio Civile, Pisa (Fig. 1).

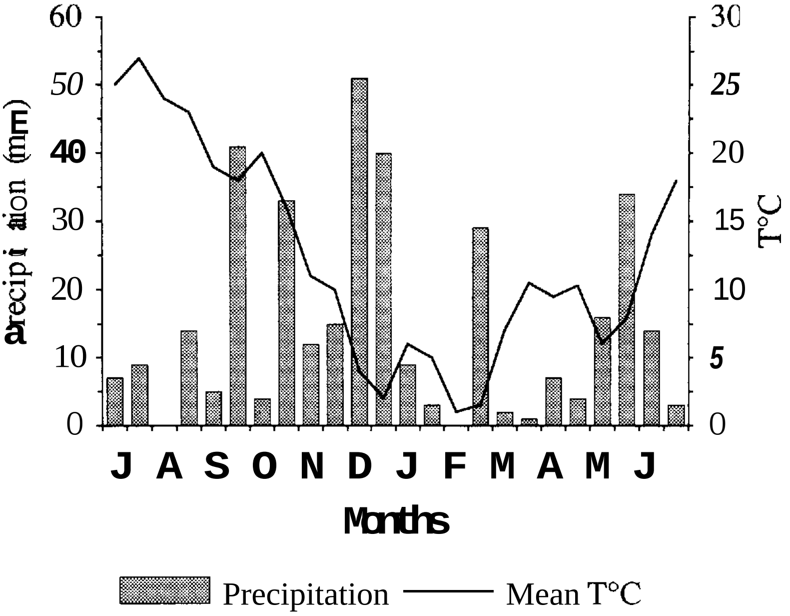


Fig. 1 – Precipitation (mm) and mean temperature (°C) in the study area (July 1990 - June 1991).

Activity

Activity was monitored at each fix, following Garshelis & Pelton (1980) and Eguchi & Nakazono (1980). Diel activity (assessed as the proportion of active fixes over total fixes in 24 hours, and as the number of activity hours in 24 hours), was divided in nocturnal, diurnal and crepuscular (i.e. 1h before and after sunset, and 1h before and after sunrise) activity.

Food habits

Scats were collected weekly during the study period: 263 in the home range of M2 and F1 (which shared the same area), and 115 in the home range of M1. At the end of each week, fresh scats were collected in the squares (62.5x62.5 m) frequented by each marten in that week, to maximise the probability of collecting faeces from our study animals.

Excrements were stored in polythene bags and deep-frozen, to be thawed later on and analysed as described by Kruuk & Parish (1981) and Kruuk (1989). Each sample was washed in a tea sieve (1.3 mm mesh), and the sediment was examined under a binocular microscope to detect the presence of earthworm chaetae. Food remains were recognized by comparison with reference material. Feathers were identified after Day (1966). The identification of small mammals was made by both teeth (Toschi 1965) and hair characteristics (Faliu et al., 1980; Debrot et al., 1982).

For each kind of food, the percentage of occurrence and the estimated volume were calculated according to Kruuk & Parish (1981) and Kruuk (1989).

We used the standardized Levins index, B_{sta} (Colwell & Futuyma, 1971), applied to the percentage of occurrence and estimated volume of food categories, to evaluate the trophic niche breadth.

Statistics

The Spearman rank correlation coefficient (r_S) and the simple linear regression were computed to evaluate associations between activity and environmental factors. Inter - individual and intra - individual, i.e. between seasons, differences in activity patterns and food habits were respectively assessed through the Mann-Whitney U-test and the Wilcoxon matched pairs test (Siegel, 1956). **A** x^2 goodness of fit was used to test normality of time budgets and all variables considered. One-way analysis of variance was performed to detect differences between the time budgets of **all** animals.

Tab. 1 – Mean values of total and seasonal diel, diurnal, crepuscular and nocturnal activity of F1, M1 and M2.

		DIEL %	DIURNAL %	CREPUSCULAR %	NOCTURNAL %
F1	Summer	53.5	20.3	7.7	59.8
	Autumn	44.7	1.0	3.5	88.2
	Winter	34.8	5.7	6.1	95.5
	Spring	28.2	32.3	5.8	74.0
	Total	40.3	14.9	5.8	79.4
M1	Summer	47.6	17.9	11.3	70.8
	October	52.1	13.0	6.0	81.0
	Total	48.7	16.7	10.0	73.3
M2	Summer	57.3	30.2	10.7	59.1
	October	52.i	5.9	11.8	82.2
	Total	55.4	21.4	11.1	67.5

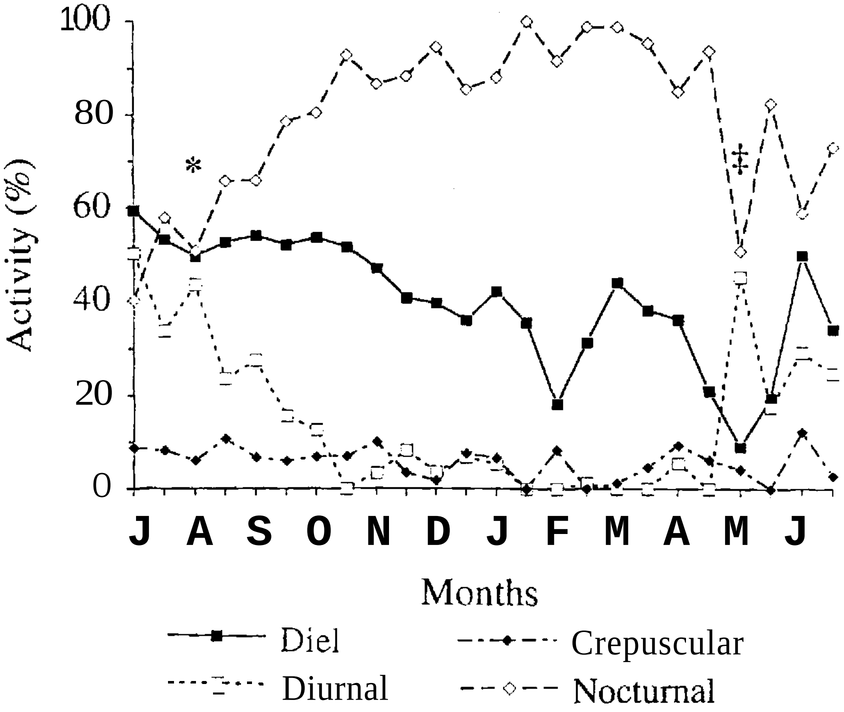


Fig. 2 – Diel, diurnal, crepuscular and nocturnal activity of F1 on a fortnight basis (n=24). *: mating season; ‡: parturition.

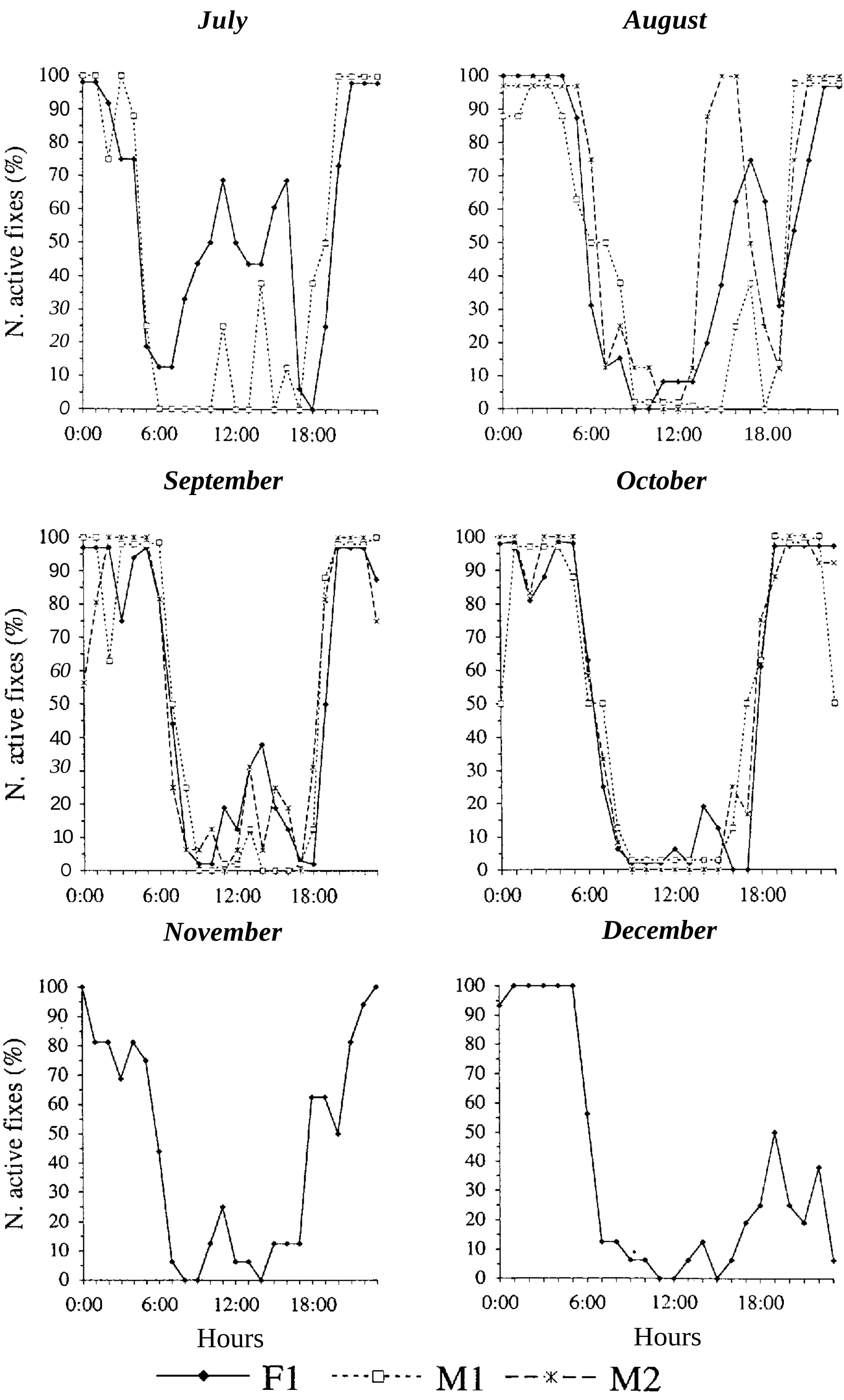


Fig. 3 – Monthly variation of time budgets (July - December 1990)

RESULTS

Activity

No pattern of activity was significantly correlated between the three animals, but no significant difference was found when comparing quantitatively each type of activity (diel, diurnal, crepuscular, nocturnal) between different individuals.

Diel, diurnal and nocturnal activities showed quantitative changes throughout the study period (Tab. 1). In July diel activity was maximum, and martens were consistently active in daylight hours (Fig. 2). Later on, diurnal activity decreased, while nocturnal activity was resumed again by early autumn. This pattern lasted till November for the males, and till the time of parturition for the female (Fig. 2). Until this moment, her activity continued to be strictly nocturnal, but after giving birth F1's activity pattern changed suddenly. Diel activity raised again till the levels of the past July, and was divided almost equally between day and night. Several significant seasonal differences in diel, nocturnal and diurnal activity were found for Fl (the only animal tracked long enough to make this comparison possible), while no difference could be detected for her crepuscular activity (Fig. 2). A positive correlation was found between diel activity, as percentage of active fixes, and diel activity, as hours of activity each day ($r_s = 0.96, p<0.001$). Two major drops of diel activity were noted, in connection to severe meteorological conditions (a snowfall followed by a decrease in temperature, -12°C, in January-February) and to the last phases of pregnancy and parturition (April) (Fig. 2). Diel activity in summer differed from those in autumn, winter and spring. (T=3-3.5, $p<0.01$). Autumn activity differed from that in spring (T=3, $p<0.01$) but not from the winter one. No significant difference could be found between spring and winter diel activity. Nocturnal activity peaked in autumn/winter and dropped in summer (Fig. 2). It differed between seasons (T=3.3-3.7, $p<0.01$), but for summer vs. spring and autumn vs. winter. Diurnal activity differed between seasons (T=3.3-3.7, $p<0.01$), but for spring vs. summer (when it was at its maximum), and for autumn vs. winter, when it reached its minimum (Fig. 2).

Monthly (n=12, F1; n=4, M1; n=2.5, M2) and seasonal time budgets proved significantly and directly correlated between all martens ($r_s = 0.59\text{-}0.88, p<0.001$). The time budget of all animals were normally distributed ($x^2 = 0.29$, 7 d.f., p=1.0). No significant difference of activity was found, in the 24-hour cycle, between all animals (but for time budget of M1 *vs*. M2, in August) (one way ANOVA $F_{2\text{-}69} = 0.397$, $p>1.0$).

The time budget of F1 showed a nocturnal peak, followed by a smaller peak in the central part of the day, in spring and summer (Fig. 3; Fig. **4)**. Only data from July to October were available for MI, and from August to October for M2, but they were correlated with those of F1. However, M1 showed a notably smaller peak of diurnal activity than F1, in July (Fig. 3). Activity peaked at night, particularly from 21:00h to 03:00h. The secondary peak occurred in the central part of the daylight hours (Fig. 3; Fig. 4). In autumn and winter the activity pattern was unimodal, with almost no diurnal activity (Fig. 3 and Fig. 4). No significant difference was detected in the time budget of each stone marten between consecutive months, but (in the case of F1) for December/January vs. February/March, and for April/May vs. May/June (T=2.07-3.5, $p<0.05$). On the other hand, F1 time budget differed when compared between seasons (T=2.47-3, $p<0.05$), but for winter and autumn vs. spring.

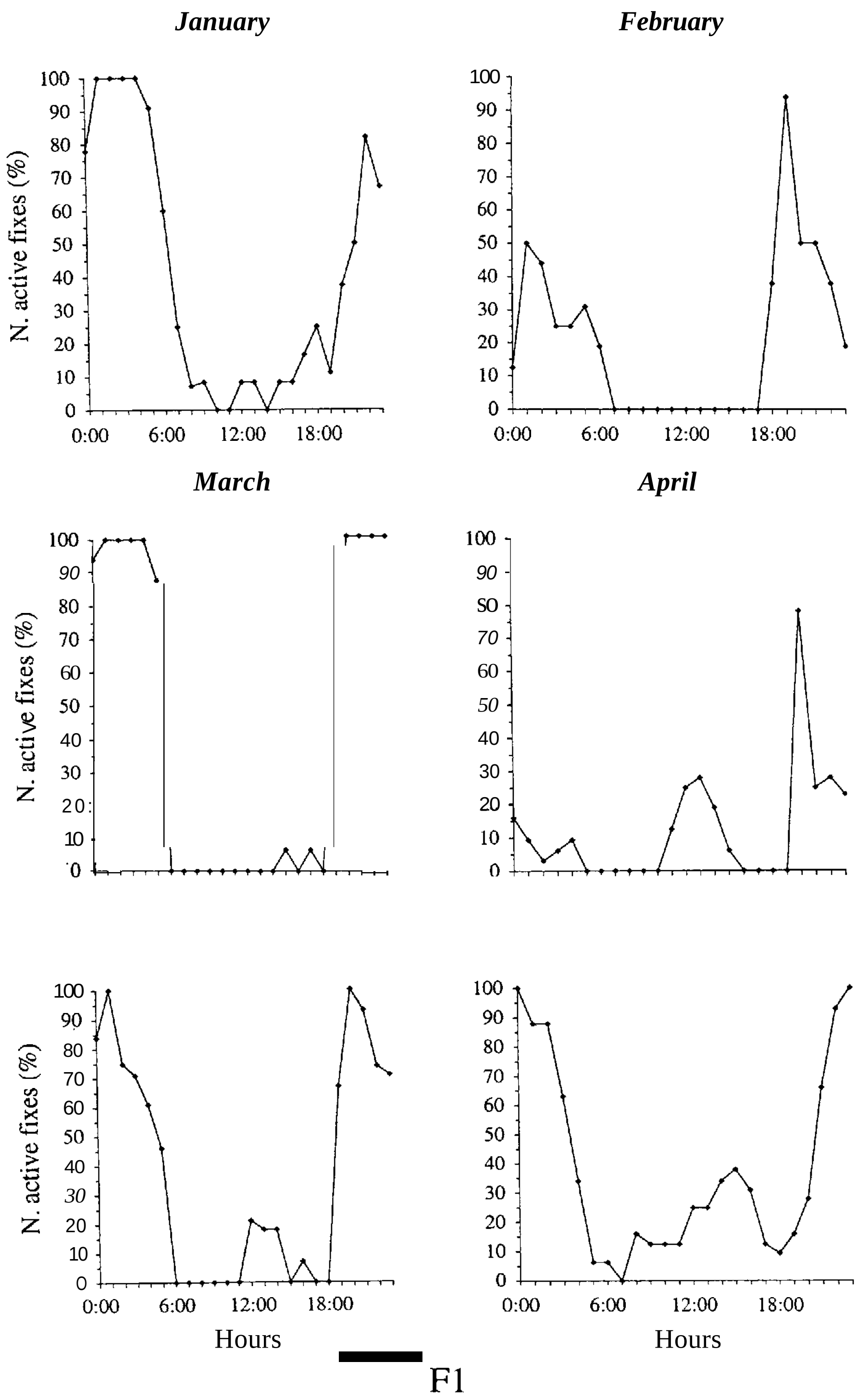


Fig. 4 – Monthly variation of time budgets (January - June 1991).

Food habits

No significant difference could be found in the use of fruits, invertebrates and vertebrates, as estimated volume and frequency of occurrence, between M2/F1 and M1.

Serafini & Lovari (1993) reported that fruits were the staple of the diet during most of the year, in our study area: vol. = 51.5%, occ. = 77%. Two periods may be detected in the diet of F1, a "fruit-dominated period", i.e. summer/autumn, and an "animal protein dominated period", i.e. winter/spring (Fig. 5). Fruits were the most important item in the diet from summer to mid-winter (Fig. 5). Sorb apples, blackthorn fruits and figs were the most important fruit categories in diet. Fig

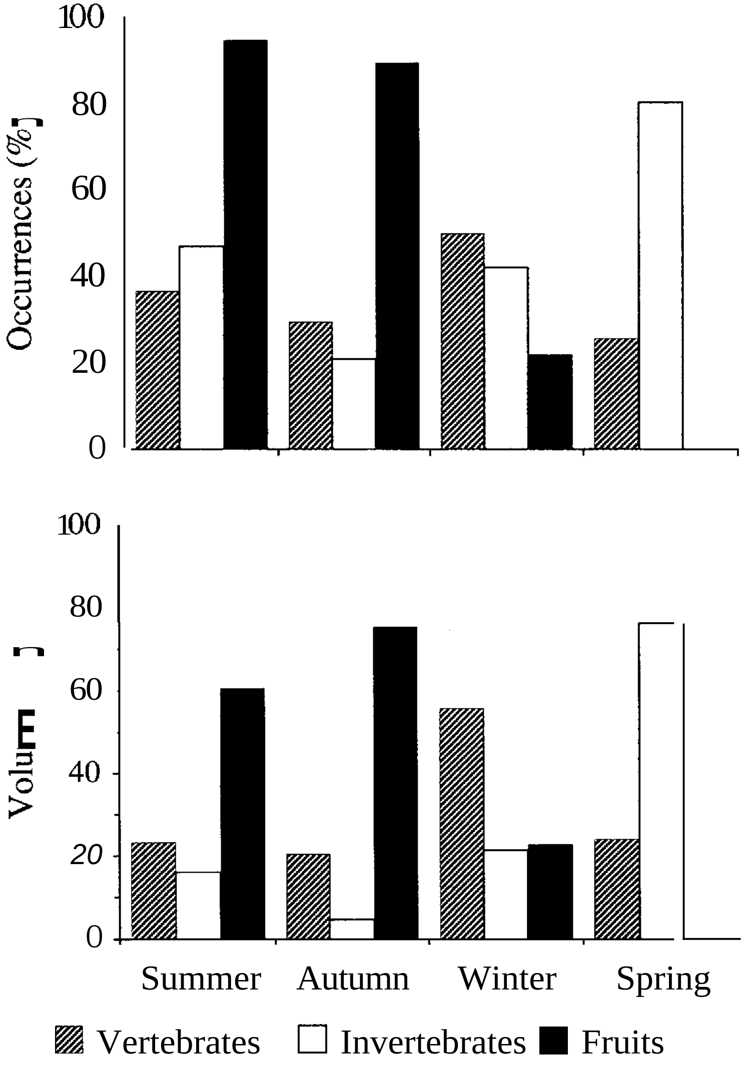


Fig. 5 – Seasonal percentages of occurrence and estimated volume of fruits, vertebrates and invertebrates in the diet (n = 378, pooled data for all individuals).

consumption (vol. = 11.796, occ.= 23.3%) peaked in summer, whereas sorb apples (vol. = 16.2%, occ.= 21.8%) and blackthorn fruits (vol. = 11.796, occ. = **19.9%)** were eaten in the colder season (Fig. 6). **A** significant difference between fruits and vertebrates, as well as between fruits and invertebrates, was found in the diet of all martens (T=2.07, $p<0.05$ and T=3.6, $p<0.001$, respectively). For **F1,** fruits were inversely correlated to vertebrates and invertebrates (Tab. 2). During the fruit-dominated period, vertebrates followed fruits in order of importance, being used more than invertebrates (Fig. 5), both in volume and in percentage of occurrence (T=2.58, $p<0.01$). Fruits in diet dropped to zero throughout winter, while vertebrates gained importance and their consumption peaked in mid-winter (Fig. 5). Rodents were the most important vertebrate in diet (vol. = 12.3%, occ. = 19.6%). Their consumption remained constant throughout the study period, while predation on birds (vol. = **8.4%**, occ. = **14.7%)** peaked during winter **(Fig.**6). In this season, invertebrate volume was similar to fruit volume (Fig. 5). The difference between invertebrate and vertebrate use in winter was significant (T vol. = 3.6, $p<0.01$, T occ. = 3.9, $p<0.01$). Later, vertebrate importance declined, while a rapid growth in invertebrate use took place, peaking between winter and spring. Since then, invertebrates remained the staple till late spring (Fig. 5). Coleoptera (vol. = 7.2%, occ. = 25.2%) and Dermaptera (vol. = 5.9%, occ. = **15.4%)** were the most important invertebrates preyed upon (Fig. 6).

A strongly significant and inverse correlation was found between vertebrates and invertebrates from late winter through spring (i.e. when fruits are not eaten at all) (Tab. 2). On the contrary, the correlation between vertebrate and invertebrate volumes and occurrences in diet, from summer to mid-winter, was not significant.

Tab. 2 – Correlations between the percentages of occurrence and estimated volume of fruits, vertebrates and invertebrates. Both r_s (Spearinan rank correlation coefficient) and the probability level are reported (*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$; n.s.: not significant); n = 15 for all correlations, except for ‡: n=10.

		Vertebrates	Invertebrates
Occurrence	Fruits	- 0.7**	- 0.55*
	Vertebrates		- 0.9** ‡
	Invertebrates	0.2 n.s.	
Volume	Fruits	- 0.83***	- 0.73***
	Vertebrates		- 0.9** ‡
	Invertebrates	- 0.1 n.s.	

Tab. 3 – Seasonal trophic niche breadth values (B_{sta}) (n = 378, pooled data for all individuals).

	Occurrence	Volume	N. of scats
Summer	0.49	0.41	180
Autumn	0.48	0.36	117
Winter	0.64	0.64	36
Spring	0.81	0.68	45

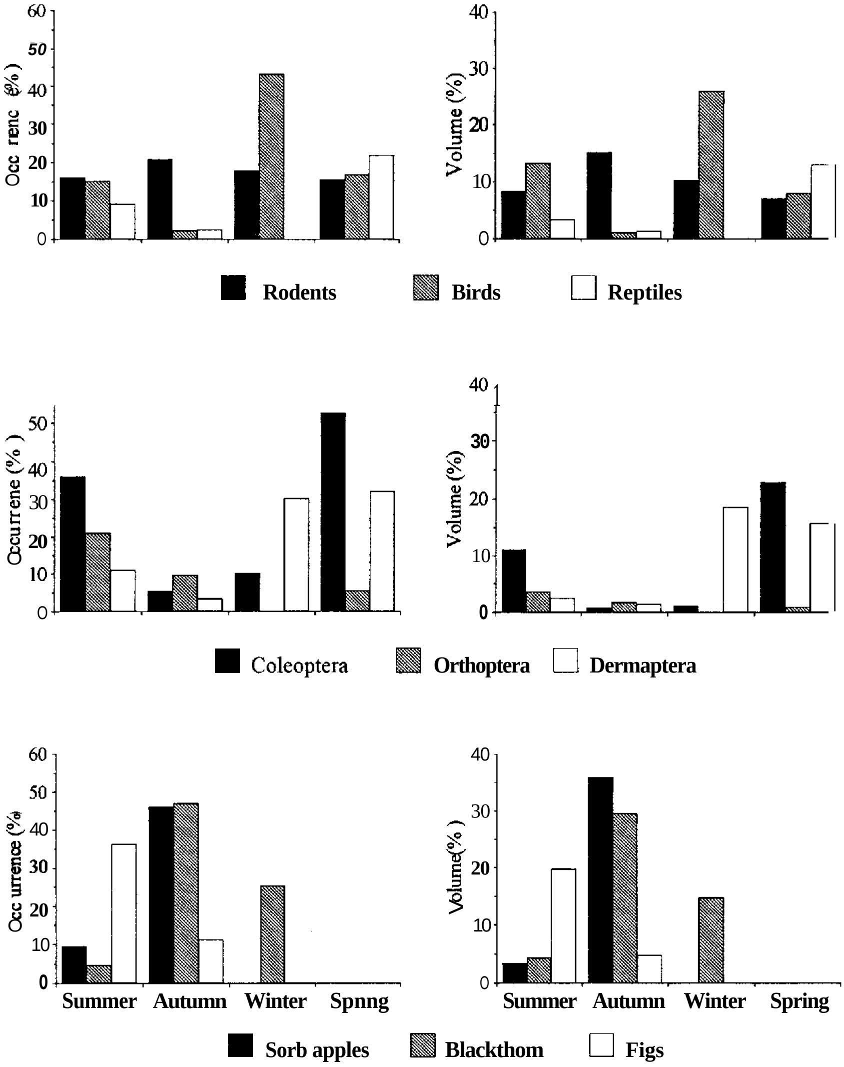
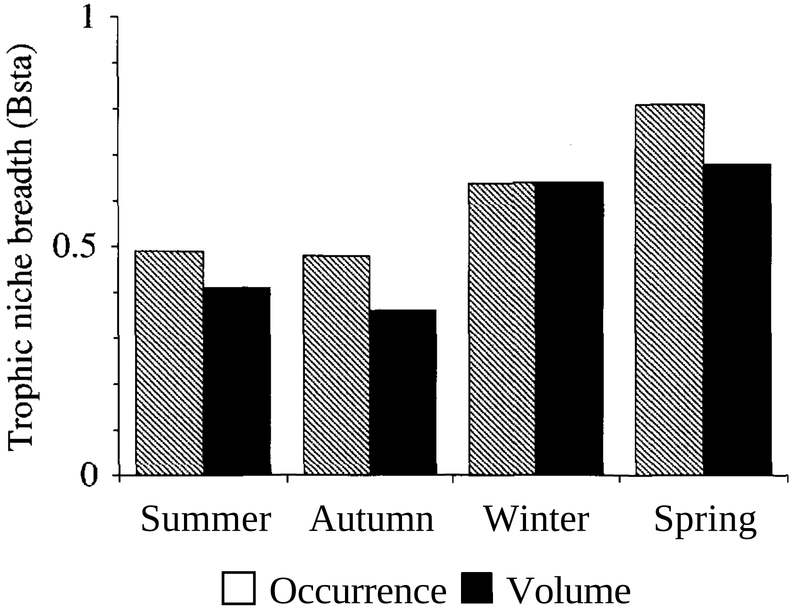


Fig. 6 – Seasonal percentages of occurrence and estimated volume of the main food categories in diet (n=378, pooled data for all individuals).

The trophic niche breadth (B_{sta}) peaked during winter and especially spring, while a minimum was reached in autumn and, to a lesser extent, summer (cf. Serafini & Lovari, 1993) (Fig. 7; Tab. 3). No significant difference was found between winter and the other seasons, while spring B_{sta} (vol.-occ.) differed from those of summer and autumn (T=2.04, $p<0.05$). No significant difference could be detected between the trophic niches of summer and autumn.

Trophic niche breadth variation was significantly associated to fruit intake (r, vol. =-0.70, $p<0.01$, (r, occ. =-0.58, $p<0.05$), vertebrate volume (r, = 0.53, $p<0.01$), and invertebrate frequency of occurrence (r, = 0.49, $p<0.05$). The comparisons with all other food categories (cf. Serafini & Lovari, 1993) were not significant.



Fig, 7 – Seasonal variation of trophic niche breadth (Bsta) (n = 378, pooled data for all individuals).

Other ecological relationships

The diel activity of F1 and M2 correlated significantly and directly to mean temperature and photoperiod (Tab. 4). Such a relationship has not been found for M1. For all martens nocturnal and diurnal activity were, inversely and directly associated to mean T°C and daylength respectively, but only for F1 and M2 significantly (Tab. 4). Linear regression analysis showed that daylight variation explained a substantial part of diurnal/nocturnal activity variation (r^2=70%). For all martens, a direct significant relationship could be found between crepuscular activity and mean T°C (Tab. 4).

No significant correlation was found between activity and precipitation, measured as both mm of rainfall and number of rainy days.

No activity of M1 correlated significantly to vertebrates in diet, but for reptiles (Tab. 5), whereas M2's activity was stronger influenced by vertebrate food than that of M1. M2's diel, diurnal and nocturnal activities were significantly associated to reptile consumption, inversely for the nocturnal and directly for the other two activities (Tab. 5). Diurnal and diel activities of M2 were directly correlated to birds in diet (r_s vol. = 0.68, $p<0.05$, r_s vol. = 0.72, r_s occ. = 0.62, $p<0.05$ respectively), but his diel activity and birds occurrence (%) were correlated only almost significantly. Diel and diurnal activity of M2 also correlated inversely to ungulate carrions (r, = -0.64, $p<0.05$; r_s = -0.68 $p<0.05$ respectively). No significant correlation could be found with his crepuscular activity, but for Coleoptera and Orthoptera, while nocturnal activity was correlated significantly to birds (r, = -0.65, $p<0.05$, % occurrence only almost significant).

Tab. 4 – Correlations between abiotical variables and diel, diurnal, crepuscular and nocturnal activity in stone martens. Both r_s (Spearman rank correlation coefficient) and the probability level are reported (*: $p< 0.05$; **: $p<0.01$; ***: $p<0.001$; without asterisks: not significant); n = 24 for F1; n = 8 for M1; n = 10 for M2.

		DIEL	DIURNAL	CREPUSCULAR	NOCTURNAL
F1	Mean T °C	0.76***	0.59**	0.42*	- 0.68***
	Photoperiod	0.5*	0.79***	0.3	- 0.84***
	Rainfall (mm)	- 0.04	0.04.	- 0.05	0.04
	Rainly days	- 0.1	0.1	- 0.03	0.02
M1	Mean T °C	0.5	0.4	0.88*	- 0.64
	Photoperiod	0.4	0.5	0.9*	-0.66
	Rainfall (mm)	- 0.1	- 0.6	- 0.3	0.66
	Rainly days	- 0.1	- *0.5*	- 0.2	0.4
M2	Mean T °C	0.8***	0.73***	0.68**	- 0.7"'''
	Photoperiod	0.7*	0.9**	- 0.2	- 0.86***
	Rainfall (mm)	- 0.5	- *0.5*	*0.3*	0.4
	Rainly days	- 0.4	- *0.5*	- 0.4	0.3

Tab. 5 – Correlations between the main food categories in diet and diel, diurnal, crepuscular and nocturnal activity in stone martens. RV: reptiles (volume); RO: reptiles (occurrence); CV: Coleoptera (volume); CO: Coleoptera (occurrence); OV: Orthoptera (volume); **OO:** Orthoptera (occurrence). Both r_s (Spearman rank correlation coefficient) and the probability level are reported (*: p< 0.05; **: p<0.01; ***: p<0.001; without asterisks: not significant); n = 24 for F1; n = 8 for M1; n = 10 for M2.

		RO	RV	CO	CV	OO	OV
F1	Diel	0.5*	*0.5"*	-0.0	0.1	0.6***	0.6**
	Diurnal	0.5*	*0.5"*	0.4*	0.5*	0.3	0.2
	Crepuscular	0.4*	0.5"	-0.0	0.1	0.3	0.3
	Nocturnal	-0.6**	*-0.5'"'*	-0.5*	-0.5"	-0.1	-0.3
M1	Diel	0.9"	0.8*	-0.3	0.0	0.3	0.7*
	Diurnal	0.7*	0.7*	0.2	-0.2	0.3	0.0
	Crepuscular	0.5	0.5	0.4	-0.1	-0.4	-0.1
	Nocturnal	-0.9	-0.9*	0.1	0.1	0.1	0.1
M2	Diel	0.7"	0.8**	0.1	0.1	-0.2	0.1
	Diurnal	0.7'"'	0.8**	*0.04*	0.0	0.3	0.2
	Crepuscular	-0.2	-0.5	0.8"	0.7*	0.8*	0.7"
	Nocturnal	-0.7"	-0.7"	-0.1	-0.1	-0.3	-0.4

No significant correlation was found between vertebrate presence in F1's diet, except reptiles, and variation of her activity patterns (Tab. 5). Reptile consumption, in percentages of estimated volume and occurrence, was correlated significantly and directly with mean temperature and daylength ($r_s = 0.59$, $p<0.05$, and $r_s = 0.52$, $p<0.05$). Reptiles are a marginal food over the year, building up just 2.2% in volume, and 5.6% in occurrence. Only in spring and summer, the importance of reptiles in the diet grows up: vol. = 11.1%, occ. = 20% in spring, and vol. = 3.5%, occ. = 9.2% in summer. If we correlate activity patterns and reptile consumption only for these periods, all but the correlation with crepuscular activity become not statistically significant (r, vol. = 0.55, $p<0.05$, and r_s occ. = 0.63, $p<0.05$), indicating that predation on reptiles was possibly concentrated at dusk and/or at dawn.

M1's activity did not correlate significantly to invertebrates in the diet. M2's diel, nocturnal and diurnal activities did not correlate significantly to any invertebrate category, but crepuscular activity was significantly associated to total invertebrate, total insect, Coleoptera and Orthoptera consumption (almost significantly, as to total insect estimated volume). Coleoptera were correlated to diurnal, and nocturnal activity of F1 (Tab. 5). Coleoptera were a seasonal food of F1, as the direct correlation with mean T°C and photoperiod suggest (r_s vol. = 0.54, $p<0.01$, r_s vol. = 0.7, $p<0.001$, and r_s occ. = 0.54, $p<0.01$, r_s occ. = 0.7, $p<0.001$), with two peaks in their use during spring and summer (vol. = 20.4% and occ. = 53.3% in spring; vol. = 8.5%, occ.=36.1% in summer). Linear regression analysis showed that beetles explained only a small part of diurnal and nocturnal activity variation (r^2 = 14.4%; r^2 = 12.8%).

Percentage of estimated volume and occurrence of Orthoptera were significantly correlated only to diel activity of F1 (Tab. 5). There was a significant direct correlation of Orthoptera with both mean T°C and daylength (r, vol. = 0.65, r_s occ. = 0.7, $p<0.001$, and r_s vol. = 0.47, r, occ. = 0.5, $p<0.05$, respectively).

M1's diel activity correlated significantly to apples in diet (r_s vol. = 0.79, r_s occ. = 0.76, $p<0.05$), while M2's diel activity was correlated to pears (r, vol. = 0.67, r_s occ. = 0.63, $p<0.05$). No significant relationship could be assessed between activity and any kind of fruit in the diet of F1.

Diel activity and trophic niche breadth of F1 were significantly correlated (r, vol. = -0.52, r_s occ. = -0.54, $p<0.01$).

DISCUSSION

The stone marten has been reported as mainly nocturnal (Broekhuizen, 1983; Herrmann, 1989; Genovesi, 1993), but in our study the daylight activity of F1 equalled her nocturnal activity at parturition time, in spring, and in early summer, i.e. during mating and cub rearing. This is consistent with the activity distribution in the 24 hours cycle, showing a continuous nocturnal unimodal peak **all** year round, with a strong decrease in spring and summer. This pattern has also been observed in closely related mustelids as the Eurasian marten *Martes martes* (Marchesi, 1989), American marten (Zielinski et ai., 1983) and fisher *Martes pennanti* (Leonard, 1980; Arthur & Krohn, 1991). Diel activity increase in denning females has also been noted for the fisher (Leonard, 1980; Arthur & Krohn, 1991). When comparing activity patterns of denning females vs. non-denning females or males, these authors found **a** significant greater amount of diel activity for denning females. We cannot compare the post-partum activity of F1 to the activity levels of male martens in the same period, and strong individual variation may occur even between individuals of the same sex, belonging to the same population (e.g. red fox: Cavallini & Lovari, in press). However, the sharp variation of F1's activity pattern from pre- to post-partum periods could be explained by two major constraints. First, F1 must have faced an increased energy demand to meet, through lactation, the nutritional requirements of her offspring (cf. East & Lockie, 1964; Farrel & Wood, 1968; Leonard, 1980; Powell & Leonard, 1983; Cheeseman et al., 1987; Cresswell & Harris, 1988; Arthur & Krohn, 1991). Second, the scarce thermoregulatory efficiency of young cubs (Eisenberg, 1981; King, 1989) should make a female change her circadian activity rhythm to visit her litter often. Also, the activity pattern of all martens, especially F1, shows that diurnal activity was greater when nights were shorter. The linear regression analysis indicates that photoperiod variation explains up to 70% of diurnal/nocturnal activity variation (cf. Genovesi. 1993).

Human activities can influence the circadian activity of carnivores (dog: Fox et al., 1975; red fox: Eguchi & Nakazono, 1980; cougar: Van Dyke, 1986; feral cat: Haspel & Calhoon, 1993; stone marten: Herrmann, 1989). Herrmann (1989) noted a certain synchronism between the end of human activity in German towns and the onset of martens' activity. In our study area, martens could avoid human disturbance (hunt and agriculture) not only by modification of their activity pattern, but also by moving from one area to another where human pressure was less heavy, within the home range. In fact, dense and extended hedgerows made activity possible in daylight, even in the immediate surroundings of inhabited farms. **All** our martens had a part of their home range in hunting areas. Their reaction to hunting was individually variable. M1 and another adult male (not considered in the present study) experienced a shift in their home ranges and activity centres in coincidence with the start of the hunting season (Posillico, 1993). Conversely, F1 and M2 continued to occupy the same portion of their home range.

The survival of overwintering *Martes* and *Mustela* can be severely affected by cold weather, because of their elongated body shape, small body size (King, 1989), scarce insulating properties of their fur (Scholander et al., 1950) and poor underskin fat deposits (Buskirk & Harlow, 1989). Buskirk et al. (1988) reported that exceptionally cold weather (or a combination of strong wind and low temperatures) significantly influenced the length of resting periods of *Martes americana:* in such. hard climatic conditions, inactive bouts may last up to 55 hours, and diel activity may drop to zero. In our case, the gradient between body and ambient temperatures was not of the same magnitude of that reported by Buskirk et al. (1988) (40°C vs. almost 70°C), but F1's diel activity sharply dropped during the coldest period of the year (following a snowfall) in synchrony with a sudden lowering of temperature, to rise again together with it. (Fig 1; Fig. 2).

Food habits, as well as distribution, abundance and detectability of food resources, are known to influence activity rhythms. The activity of a predator may be synchronized with and adapted to the activity rhythms of its main prey, as these can be detected more easily when active (Laundré & Keller, 1981; Zielinski et al., 1983; Ferguson et al., 1988). In our study, only reptile consumption, among vertebrates, correlated significantly and inversely to nocturnal activity and directly to diel, diurnal and crepuscular activity. The significant correlation between crepuscular activity and reptiles in diet suggests that predation on them might be concentrated at dusk and/or at dawn. At dusk, lizards bask in the sun (Avery, 1978, 1993), thus becoming particularly exposed to predation. Overall, reptiles are a marginal food for martens (Bertolino & Dore, 1991; Genovesi, 1993; Lucherini & Crema, 1993; Serafini & Lovari, 1993), eaten only in summer and spring, when these ectothermic vertebrates are active.

Coleoptera and Orthoptera correlated significantly and directly, both in volume and occurrence, only to Fl's activity. Their presence in her diet was much more conspicuous than reptiles. Orthoptera and Coleoptera are a dispersed food (Cavallini & Lovari, 1991), thus requiring a prolonged activity to feed on them (cf. Lucherini et al., 1988). The linear regression analysis suggests that variation of beetles and grasshoppers in diet explains poorly diurnal and nocturnal (for Coleoptera) and diel (for Orthoptera) activity variation: 14.4%, 12.8%, 13.4% respectively. This cautions on considering Orthoptera and Coleoptera as important factors influencing the martens' activity patterns.

Fruit presence in Fl's diet was inversely correlated to trophic niche breadth, suggesting that the strongly "fruit dominated" summer-autumn diet, in spite of the great number of food items eaten other than fruits, exerted a depressing effect on the trophic niche. Fruits, the most represented item in diet for all our martens, correlated poorly to activity variation. If abundant, this concentrated food resource, available throughout the whole daily cycle, predictable in time and space, is unlikely to generate an activity increase. A decrease of activity (from reduced search time) may be expected because of its easy availability (red fox: Cavallini & Lovari, 1991). This does not seem to have occurred in our study. Other factors, relevant to e.g. territorial behaviour (see also Genovesi, 1993) and energetical expenditure (Weber, 1989a), were likely involved.

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REFERENCES

ALTMANN, J. 1974. Observational study of behaviour: sampling methods. Behav., 49: 227-267.

ANDERSEN, D.M. & O.J. RONGSTADT. 1989. Home range estimates of red-tailed hawks based on random and systematic relocations. J. Wildl. Manage., 53: 802-807.

ANDERSON, E. 1970. Quaternary evolution of the Genus *Martes*. Acta Zool. Fenn., 130: 1-132.

ARTHUR, S.M. & W.B. KROHN. 1991. Activity patterns, movements, and reproductive ecology of Fishers in Southcentral Maine. J. Mamm., 72: 379-385.

AVERY, R.A. 1978. Activity patterns, therinoregulation and food consumption in two sympatric lizard species (*Podarcis muralis* and *P. sicula*) from central Italy. J. Anim. Ecol., 47: 143-158.

AVERY, R.A. 1993. Diel variation in area of movement of the lizard *Podarcis sicula*. Ethol. Ecol. Evol., 5: 511-518.

BERTOLINO, S. & B. DORE. 1991. Dati preliminari sulla dieta della faina nel Parco Regionale "La Mandria" (Torino). Atti 2" Conv. Naz. Biol. della Selvaggina, Bologna. Ricerche Biologia della Selvaggina (supplemento), vol. i9: 643-646.

BROEKHUIZEN, S. 1983. Habitat use of beech marten in relation to landscape elements in a Dutch agricultural area Proc. 16th Int. Congr. Game Biologists, Strebske Pleso (Czechoslovakia), pp: 614-624.

BUSKIRK, S.W. & H.J. HARLOW. 1989. Body-fat dynamics of the American marten in wintcr. J. Mamm., 70: 191-193

BUSKIRK, S.W., FORREST, S.C., RAPHAEL, M.G. & H.J. HARLOW. 1989. Winter resting site ecology of marten in Central Rocky Mountains. J. Wildl. Manage., 53: 191-196.

BUSKIRK, S.W., HARLOW, H.J. & S.C. FORREST. 1988. Temperature regulation in American marten in wintcr. Nat. Geogr. Res., 4: 208-218.

CAVALLINI, P. & LOVARI S. 1991. Environmental factors influencing the use of habitat in the red fox *Vulpes vulpes*. J. Zool., Lond., 223: 323-339.

CAVALLINI, P. & LOVARI S. Home range, habitat selection and activity of red foxes in a Mediterranean coastal ccotone. Acta theriol. (in press).

CHEESEMAN, C.L., WILESMITH, J.W., RYAN, J. & P.J. MALLINSON. 1987. Badger population dynamics in a high density area. Symp. Zool. Soc., Lond., n° 49: 301-323.

COLWELL, R.R. & D.J. FUTUYMA. 1971. On the measurement of niche breadth and overlap. Ecology, 52: 567-572.

CRESSWELL, W.J. & S. HARRIS. 1988. The effects of weather conditions on the movements and activity of badgers *(Meles meles)* in suburban environment. J. Zool., Lond., 216: 187-194.

DAY, M.G. 1966. Identification of hair and feather remains in the gut and faeces of stoats and weasels. J. Zool., Lond., 148: 201-217.

DEBROT, S. FIVAZ, **G.,** MERMOD, C. & J.M. WEBER. 1982. Atlas dcs poils des mammiferes d'Europe. Neuchâtel, Institut de Zoologie, pp. 208.

EAST, **K.** & J.D. LOCKIE. 1964. Observations on a family of weasels (*Mustela nivalis*) bred in captivity. Proc. Zool. Soc., Lond., 143: 359-363.

EGUCHI, K., & T. NAKAZONO. 1980. Activity studies of Japanese red foxes *(Vulpes vulpes* japonica Gray). Jap. J. Ecol., 30: 9-17.

EISENBERG, J.F. 1981. The mammalian radiations. An analysis of trends in evolution, adaptation, and behavior. The University of Chicago Press, Chicago.

FALIU, L., LIGNEREUX, Y. & J. BARRAT. 1980. Identification des poils des mammiferes pyreneens. Doñana Acta Vertebrata, 1: 125-212.

FARREL, D.J. & A.J. WOOD. 1968. The nutrition of the female mink **(*Mustela* *vison*)**. I. The metabolic rate of mink. Canadian J. Zool., 46: 41-45.

FERGUSON, J.W.H., GALPIN, J.S. & M.J. DE WET. 1988. Factors affecting the activity patterns of black-backed jackals. J. Zool., Lond., 214: 55-69.

FOX, M.W., BECK, A.M. & E. BLACKMAN. 1975. Behavior and ecology of a small group of urban dogs. Appl. An. Ethol., 1: 119-137.

GARSHELIS, D.L. & M.R. PELTON. 1980. Activity of black bears in the Great Smoky Mountains National Park. J. Mamm., 61: 8-19.

GENOVESI, P. 1993. Strategia di sfruttamento delle risorse e struttura sociale della faina (*Martes foina* Erxleben, 1777). Tesi di Dottorato di Ricerca, Dipartimento di Biologia Animale e dell'Uomo, Università di Roma, pp. 93.

GESE, E.M., ANDERSEN, D.E. & O.J. RONGSTADT. 1990. Determining home range size of resident coyotes from point and sequential locations. J. Wildl. Manage., 54: 501-506.

HASPEL, C. & R.E. CALHOON. 1993. Activity patterns of free ranging cats in Brooklyn, New York. J. Mamm., 74: 1-8.

HARRIS, S. 1980. Home ranges and patterns of distribution of foxes in an urban area as revealed by radio tracking. In Amlaner C.J. & D.W. Macdonald (eds.), **A** handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, pp. 685-690.

HERRMANN, M. 1989. Intra population variability in the spatial and temporal organization of stone martens. Rome, 5th I.T.C., Abstracts 2nd Vol, pp. 602-603.

KING, C.M. 1989. The advantages and disadvantages of small size to weasels, *Mustelu* species. In Gittleman, J.L. (ed.), Carnivore behavior, ecology and evolution. Chapman & Hall, London, pp. 302-334.

KRUUK, H. 1989. The social badger. Oxford University Press, Oxford.

KRUUK, H., & T. PARISH. 1981. Feeding specialization of the european badger (*Meles meles*) in Scotland. J. Anim. Ecol., 50: 773-788.

Lair, H. 1987. Estimating the location of the focal center in red squirrel home ranges. Ecology, 68: 1092-1101.

Larson, J.S. & R.D. Taber. 1971. Criteria of sex and age. In Giles, R.H. (ed.) Wildlife management techniques. The Wildlife Society, Washington, pp. 144-202.

Laundré, J.W. & B.L. Keller. 1981. Home range use by coyotes in Idhao. Anim. Behav., 29: 449-461.

Lazzarotto, A. & R. Mazzanti. 1976. Geologia dell'Alta Val di Cecina. Boll. Soc. Geol. 6: 1365-1487.

Leonard, R.D. 1980. The winter activity and movements, winter diet, and breeding biology of the fisher *(Martes pennanti)* in Southeastern Manitoba. M.S. thesis, University of Manitoba, Winnipeg, 181 pp.

Lovari, S., Cavallini, P., Crema, G., Lazzeretti, L., Lucherini, M., Ricci Lucchi, M., & P. Valier. 1991. Parametri ambientali e uso dell'habitat della volpe (*Vulpes vulpes* L., 1758) in alcune aree del Parco Naturale della Maremma (Gr). In Prigioni C. (ed.): Atti 1° Simp. Ital. Carnivori, Hystrix, (n.s.) 3: 21-29.

Lovari, S., Valier, P. & M. Ricci Lucchi. 1994. Ranging behaviour and activity of red foxes in relation to environmental variables, in a Mediterranean mixed pinewood. J. Zool., Lond., 232: 323-339.

Lucherini, M. & G. Crema. 1993. Diet of urban stone martens in Italy. Mammalia, 57: 274-277.

Lucherini, M., Lovari, S., Crema, G. & P. Cavallini. 1988. Attività di maschi di volpe *Vulpes vulpes* (L.) in relazione alle risorse alimentari in un'area costiera mediterranea. Atti 1° Conv. Naz. Biol. della Selvaggina, Bologna. Ricerche Biologia della Selvaggina (supplemento), vol. 14: 419-424.

Macdonald, D.W. 1981. Resource dispersion and the social organization of the red fox (*Vulpes vulpes*). In Chapman, J. & D.E. Pursley (eds.) Proc. Worldwide Furbearer Conf., vol. 2: 918-949. University of Maryland Press.

Macdonald, D.W. 1983. The ecology of carnivore social behaviour. Nature, 301: 379-384.

Marchesi, P. 1989. Ecologie et comportement de la martre (*Martes martes*, L.) dans le Jura Suisse. Doctoral thesis, Université de Neuchâtel, Faculté des Sciences, Neuchâtel, Suisse.

Mills, M.G.L. 1982. The mating system of the brown hyena in the Southern Kalahari. Behav. Ecol. Sociobiol., 10: 131-136.

Mills, M.G.L. 1989. The comparative behavioral ecology of hyenas: the importance of diet and food dispersion. In Gittleman, J.L. (ed.) Carnivore behavior, ecology and evolution. Chapman & Hall, London.

Müskens, G.J.D.M. 1984. Uiterlijke ken merken van boommarter en steenmarter. Lutra, 27: 274-286.

Posillico, M. 1993. Attività, spostamenti e home range della faina (*Martes foina* Erxleben, 1777) in relazione a parametri ambientali abiotici. Tesi di laurea, Dipartimento di Zoologia, Università di Napoli, pp. 92.

Posillico, M., Valier, P., & S. Lovari. 1992. Activity and ranging behaviour of a female stone marten: relationships with temperature and photoperiod. Atti 54° Congr. Uni. Zool. Ital.. Perugia, 377-378.

Powell, R. A. & R.D. Leonard. 1983. Sexual dimorphism and energy requirements for reproduction of female fisher (*Martes pennanti*). Oikos, 166-174.

Reynolds, T. & J.W. Laundré. 1990. Time intervals for estimating pronghorn (*Antilocapra americana*) and coyote (*Canis latrans*) home ranges and daily movements. J. Wildl. Manage., 54: 316-322.

Scholander, P.F., Walters, V., Hock, R. & L. Irving. 1950. Body insulation of some arctic and tropical mammals and birds. Biol. Bull., 99: 225-236.

Serafini, P. & S. Lovari. 1993. Food habits and trophic niche overlap of the red fox and the stone marten in a Mediterranean rural area. Acta theriol., 38: 233-244.

Siegel, S. 1956. Nonparametric statistics for behavioral sciences. McGraw-Hill, New York, pp. 312.

Swihart, R.K. & N.A. Slade. 1985a. Testing for independence of observation in animal movements. Ecology, 66: 1176-1184.

Swihart, R.K. & N.A. Slade. 1985b. Influence of sampling interval on estimates of home range size. J. Wildl. Manage., 49: 1019-1025.

Toschi, A. 1965. Fauna d'Italia Vol. 7° Mammalia: Lagomorpha, Rodentia, Carnivora, Ungulata, Cetacea. Calderini, Bologna.

Van Dyke, E. 1986. Reactions of mountain lions to logging and other human activity. J. Wildl. Manage., 50: 95-102.

Van Bree, P.J.H., Van Soest, R.W.M. & L. Stroman. 1974. Tooth wear as an indication of age in badgers and red foxes. Zeit. Säug., 39: 243-248.

Waechter, A. 1975. Ecologie de la fouine en Alsace. Terre vie, 29: 399-457.

Weber, D. 1989a. Beobachtungen zu Aktivität und Raumnutzung beim Iltis (*Mustela putorius* L.). Revue suisse Zool., 96: 841-862.

Weber, D. 1989b. The ecological significance of resting sites and the seasonal habitat change in polecats (*Mustela putorius*). J. Zool., Lond., 217: 629-638.

Zabel & Taggart. 1989. Shift in red fox, *Vulpes vulpes*, mating system associated with El Niño in the Bering Sea. Anim. Behav., 38: 830-838.

Zielinski, W.J., Spencer, W.D. & R.H. Barrett. 1983. Relationship between food habits and activity patterns of pine martens (*Martes americana*). J. Mamm., 64: 387-396.