

## SETTLEMENT DYNAMICS OF AN INTRODUCED ROE DEER POPULATION ON A MEDITERRANEAN PENINSULA

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### INTRODUCTION

The European roe (*Capreolus capreolus*) is present in most of the wooded landscapes of temperate Europe, but almost absent from Mediterranean biotopes (Maublanc *et al.*, 1991). We monitored an introduction of roe, native to an Atlantic deciduous forest, to a Mediterranean peninsula (Bideau *et al.*, 1992 ; Guilhem *et al.*, 1995). The introduction site mainly supported typically Mediterranean vegetation but also included a narrow area that was wet and whose vegetation was more characteristic of temperate deciduous forests. Two alternative results might be expected. Based on the current range of the species, we might expect the area of « temperate » vegetation to be particularly attractive to the released animals. On the other hand, roe of both sexes are known to be very faithful to their home ranges, and adult males exhibit « territorial » behaviour in spring and summer (Bramley, 1970 ; Strandgaard, 1972 ; Sempéré, 1980 ; Bideau *et al.*, 1983). On the basis of these two behavioural characteristics, we might expect the resulting spatial organisation of the population to be mainly dependent on the area first experienced by each individual and on the tendency, for the males, to have exclusive ranges.

### MATERIAL AND METHODS

#### STUDY AREA

The study was performed on the « Island » of Sainte Lucie, a 266-hectare peninsula located on the Languedoc coastline (43° 03' N, 3° 04' E), in Southern France, and managed by the « Conservatoire du Littoral et des Rivages Lacustres du Languedoc-Roussillon » (Regional Agency for the Conservation of Shores). Inserted between lagoons, this flat peninsula (max. elevation : 39 m) is connected

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to the mainland by a narrow strip of land to the North and by a commercial salt marsh to the South. The vegetation is typically Mediterranean over its largest part (Guilhem *et al.*, 1995) : pine (*Pinus halepensis*) and evergreen-oak (*Quercus ilex*) woods take up one third of the peninsula, while two types of evergreen dry scrub, one mainly composed of *Quercus coccifera*, *Pistachia lentiscus*, *Phyllirea* sp., *Rosmarinus officinalis* (« kermes-oak scrub » below), the other of *Cistus albidus* and *Bupleurum fruticosum* (« cistus scrub » below), take up another third. The last third of the study area is more heterogeneous and composed of ancient fields, grasslands and saltwort (*Salicornia* sp.) marshes. The North-East wet boundary (about 13 % of the whole peninsula) particularly consists of fresh or brackish marshes with reeds (*Phragmites communis*) and rushes (*Juncus* sp.), and a vegetation more characteristic of temperate deciduous forests, with species such as elm (*Ulmus campestris*), ash (*Fraxinus excelsior*), aspen (*Populus tremula*), elder (*Sambucus nigra*), ivy (*Hedera helix*) and blackberry (*Rubus* sp.). The peninsula was free of any wild ungulates before the roe deer introduction.

#### NATIVE AREA AND MONITORING OF THE INTRODUCED ANIMALS

The roe were brought in from Chizé forest, a 2,614-hectare enclosure located in Western France (46° 10' N, 0° 27' W) and managed by the « Office National de la Chasse » (National Game Agency). This is an oak (*Quercus pedunculata*, *Q. pubescens*), beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) deciduous forest, including species cited above for Sainte Lucie's wet habitat, such as elm, ivy and blackberry (the leaves of the last two species are known to constitute an important part of the diet of Chizé forest roe deer : Maizeret *et al.*, 1989).

The animals were captured in large nets during drives, and their age was estimated by dentition examination (Van Laere *et al.*, 1989). Five roe fitted with coloured collars and 8 roe fitted with radio-collars (AVM SB2 radio-transmitters) were introduced on Sainte Lucie peninsula in mid-December 1987 and late March 1988, respectively (Tab. I). However, 2 young males released in poor physical condition, one wearing a coloured collar and the other a radio-collar, died a very short time after introduction onto the peninsula.

The animals equipped with radio-transmitters were located with a single Yagi antenna and a Yeasu FT-290R receiver from a vehicle. Each individual was located 4 times per 24 hours (6.00, 11.00, 16.00 and 22.00 hours), over at least 7 days per fortnight (that is a min. of 28 and an average of 45 locations per fortnight), from late March to late October 1988. During each location, owing to the dense path network, the receiver was rarely at > 400 m from the radio-tracked animal, and the records of the two bearings to locate it were never separated in time by > 10 minutes. Each radio-location was assigned to a specific 100 m × 100 m square of a map grid. Visual observations were made by day or by night from the radio-tracking vehicle, also equipped with a spot-light, to locate the animals fitted with coloured collars and the fawns subsequently born on the peninsula.

#### DATA ANALYSIS

A minimum-convex-polygon was drawn for every successive fortnight for each of the radio-tracked roe. Because of the shape of the peninsula, the polygon

TABLE I

*Main characteristics of the roe introduced onto Sainte Lucie peninsula.*

	Individual	Sex	Age (years) in spring 1988	Body weight (kg) when released	Other characteristics
Animals introduced in mid-December 1987 and wearing coloured collars	Fb	female	12**	26	pregnant
	Mj	male	3	18	1 tine / antler
	Fo	female	4	22	pregnant
	Mr †	male	1	10	1 tine / antler
	Fv	female	6	22	pregnant ?
Animals introduced in late March 1988 and wearing radio- collars	F1	female	6	25	pregnant
	M2 †	male	1	19	1 tine / antler
	M3	male	1	18	1 tine / antler
	F4	female	12**	25	pregnant
	M5	male	4	23	3 tines / antler
	F6	female	1	17	not pregnant
	F7	female	2	21	not pregnant
	F8	female	12*	19	pregnant

Note : Body weight varies little between early winter and early spring in European roe deer : Hewison *et al.*, 1996. † : animal dead a very short time after its release. \* and \*\* : animals already captured and tagged in the native area in 1977 and 1978, respectively.

sometimes overlapped the water of the lagoons. The parts of the polygon which corresponded to the lagoons were then withdrawn. The home range of an individual for a given period (month, rutting period, time since introduction) was subsequently defined as the union, in the mathematical sense, of the polygons of the fortnights composing the considered period.

In order to know if the wet habitat was preferred by the radio-tracked animals, the proportions of this habitat were calculated for each roe both in its home range and on the whole peninsula excluding its home range. These two proportions were then compared for the whole animal set using Wilcoxon's signed-ranks T test. Furthermore, for each roe, the observed frequencies of location in the different vegetation types were compared to the proportions of these vegetation types on the home range using  $\chi^2$  goodness of fit tests.

The other tests used for statistical inferences (Mann-Whitney U test and Fisher's exact test) were non-parametric. In case of multiple binary comparisons (pairwise comparisons of the mean home range sizes of the radio-tracked roe ; comparisons of the relative location frequency in the different habitats to the proportions of these habitats within the range of a given individual), the threshold of the binary tests was lowered to  $0.05/c$  (where  $c$  is the number of binary tests), so that the probability of a type I error did not exceed 0.05 (Scherrer, 1984).

## RESULTS

### SPATIAL STABILIZATION OF THE ANIMALS

Two cases of emigration out of the peninsula were noted. Both occurred within the first 6 months after introduction and both involved females > 9 years old

(despite the small sample size, the proportion of roe which emigrated was statistically greater beyond than below 9 years of age : Fisher's exact test,  $P = 0.05$ ). Female F4 left in mid-April 1988 ; she stopped large scale movements in mid-May, shortly before giving birth on a farm 14 km North of Sainte Lucie. Female F8 moved away with her fawn, born on the peninsula, in September 1988. Before she left, she showed unstable spatial behaviour. She exhibited, in particular, great mobility and concurrently a large home range (the largest recorded for a fortnight : 112 ha) in mid-May, probably just before giving birth (Fig. 1).

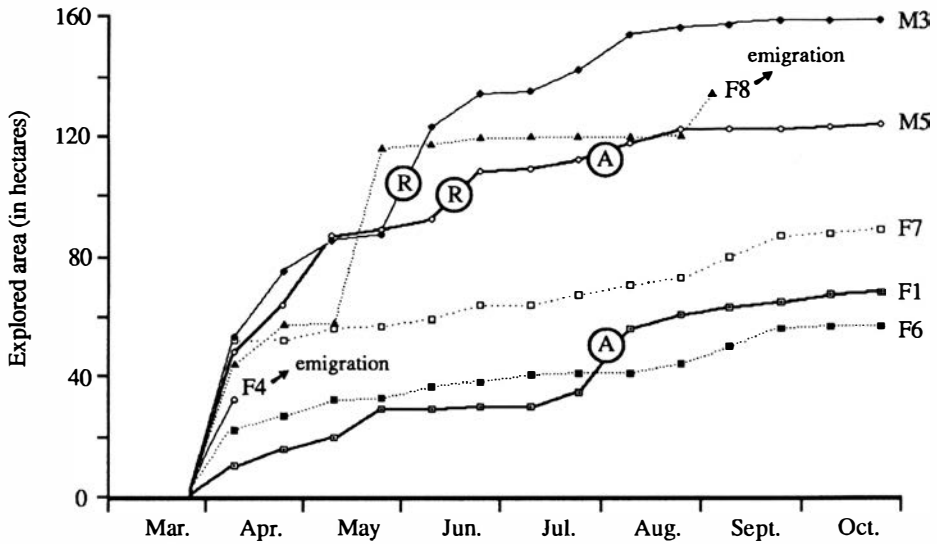


Figure 1. — Areas explored since introduction by the radio-tracked roe during the settlement phase (R : inter-repulsion of males M3 and M5 ; A : inter-attraction of female F1 and male M5).

In contrast to F8, the radio-tracked females which remained on the peninsula, F1, F6 and F7, tended to settle very quickly : the area they had experienced since introduction reached a threshold at the beginning or at the end of May, i.e. 3 or 4 fortnights after their introduction (Fig. 1). The later increase of the utilised area shown by female F1 in early August, i.e. during the rutting period, was due to her interaction with male M5. This male, following female F7, extended his home range slightly southwards (Fig. 1) and so encountered female F1 (for the first time since introduction to our knowledge). Immediately after this event, M5 and F1 were located together on M5's usual home range but outside that occupied by F1 until that time. Then female F1 and male M5 continued to use the novel areas they had experienced during the following months.

Though they exhibited rather large fortnightly home ranges (Tab. II), the radio-tracked males, M3 and M5, began to show spatial behaviour similar to that of females F1, F6 and F7, in that neither seemed to use new areas during May (Fig. 1). However, they had widely overlapping home ranges at that time. Subsequently, their interactions (and perhaps also those of M3 with male Mj,

TABLE II

Mean area  $\pm$  SE (in ha) occupied per fortnight by each of the radio-tracked roe between late March and late August 1988 ( $n = 10$  for each individual).

F1	F6	F7	F8	M3	M5
19 $\pm$ 4 (F6, F7, F8)	23 $\pm$ 2 (F1, F7, F8)	29 $\pm$ 4 (F1, F6, F8, M3)	33 $\pm$ 11 (F1, F6, F7, M3, M5)	47 $\pm$ 4 (F7, F8, M5)	55 $\pm$ 6 (F8, M3)

In brackets : roe whose mean fortnightly home range size is statistically indistinguishable from that of the considered individual (results of Mann-Whitney U tests made with a threshold of  $0.05/15 \approx 0.0033$ ).

observed together in « display » behaviour in early June), led them to have approximately exclusive ranges from mid-July. This entailed a slight increase of the area explored by M5 (Figs 1 and 2), a complete change of home range for M3 (Figs 1 and 2), and finally a slight retreat of M5 from the centre of M3's new range (Fig. 2).

#### OUTCOMING SPATIAL DISPLAY OF THE HOME RANGES

As previously noted, the radio-tracked males M3 and M5 had quite exclusive home ranges at the end of the settlement phase (Figs 2 and 3). However this did not seem to be the case for males Mj and M5 (Fig. 3). Females often had overlapping home ranges (Fig. 3), and some of them, especially the early introduced Fb and Fo (which were also frequently seen together), even showed a

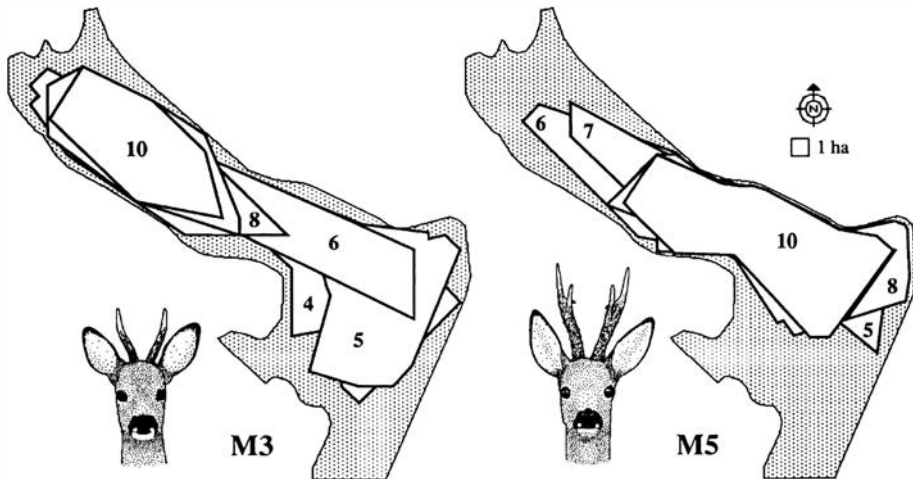


Figure 2. — Successive monthly home ranges of the two radio-tracked males, between late March and late October 1988 (the numbers indicated are those of the months).

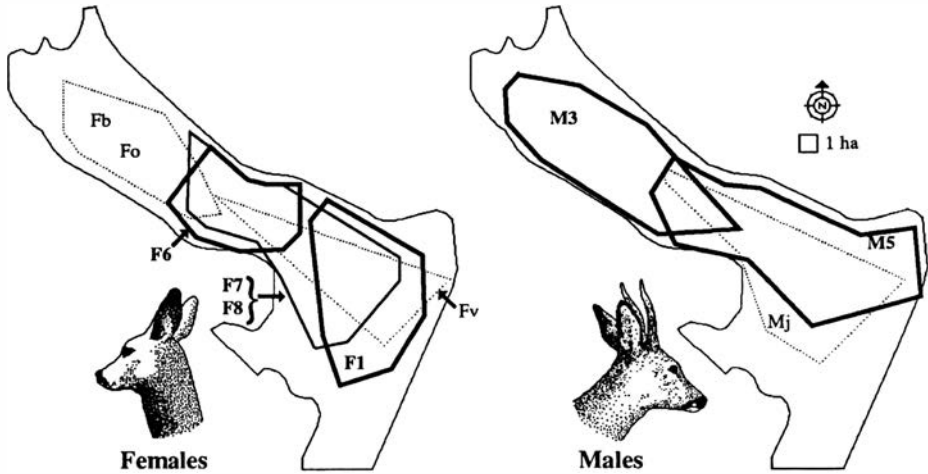


Figure 3. — Continuous lines : home ranges of the radio-tracked roe between July 11th and August 25th 1988, i.e. during the rutting period. Dotted lines : polygons of the visual observations of the roe wearing coloured collars, recorded between late March 1988 and late September 1989. For sake of clarity of the drawing, the highly overlapping home ranges of females F7 and F8, as well as the observation polygons of females Fb and Fo, have not been distinguished.

particularly strong spatial association. Finally, male M3's range overlapped with those of females Fb and Fo, while M5 and Mj's ranges overlapped with those of the other females.

#### HABITAT USE IN SUMMER

Table III describes the habitat use of the radio-tracked roe during the rutting period, i.e. at the end of the settlement phase (except for female F8) and during the driest period of the year when the wet habitat should be the most attractive.

The wet habitat did not seem to be particularly selected. Its proportion was similar if not slightly lower within the radio-tracked roe's summer ranges than outside them (11.3 % vs 14.5 % ; Wilcoxon test ;  $T = 3$ ,  $n = 6$ ,  $P = 0.22$ ). Among the deer which remained on the peninsula, male M5 and female F6 frequented the wet habitat more often than expected according to its proportion within their respective ranges (Tab. III). However, according to the same criterion, male M3 and female F7 seemed rather indifferent to the wet habitat while female F1 even seemed to avoid it. Female F8 which eventually emigrated exhibited the greatest tendency to use this vegetation type. Interestingly, female F4 showed a similar tendency before her departure in mid-April since 29 % of her locations ( $n = 38$ ) were in the wet habitat.

Concerning the other vegetation types, few general tendencies appeared. The pine and evergreen-oak woods often took up a large part of the summer ranges though, generally speaking, the radio-tracked roe did not use them more than expected according to the proportion of pine and evergreen-oak wood within their

TABLE III

Relative location frequencies in the different vegetation types (F, in %) and proportions of the same vegetation types within the home range (P, in %), for each of the radio-tracked roe, for the period July 11th — August 25th 1988.

	Pine/evergr. oak wood		Kermes- oak scrub		Cistus scrub		Grasslands & former fields		Wet habitat		Saltwort marsh	
	F	P	F	P	F	P	F	P	F	P	F	P
F1 (n = 140)	50	57	37*	15	6	10	5	5	2*	13	0	0
M3 (n = 146)	43	38	16	14	36	33	1	4	1	4	3	7
M5 (n = 134)	48	52	7	9	12	12	1	4	31*	18	1	5
F6 (n = 139)	29*	42	7	6	16	24	21*	9	25*	13	2	6
F7 (n = 146)	64*	46	11	18	5	9	12	8	8	12	0*	7
F8 (n = 130)	44	45	3*	22	17	12	0*	6	36*	8	0*	7
Average	46	47	13	14	15	17	7	6	17	11	2	5
Peninsula composition	31		19		16		7		14		13	

n : location number. \* : location frequency significantly different from that expected according to the proportion of the vegetation type within the home range of the considered animal (results of  $\chi^2$  goodness of fit tests, d.f. = 1, made with a threshold of  $0.05/6 \approx 0.0083$ ). The peninsula composition is given excluding the commercial salt marsh of the South since no home range overlapped with that habitat.

respective home ranges (Tab. III). By contrast, the saltwort marshes were rarely visited while the commercial salt marsh of the South was avoided.

## DISCUSSION

Given the small number of deer monitored, the analysis conducted could only be expected to reveal strong habitat preference or avoidance. With this restriction in mind, we can only say that the wet habitat does not seem to have been particularly attractive to the roe. The attraction was not in any case sufficient to keep the males from their tendency to have exclusive ranges or to restrict the ranges of the females.

In contrast, attachment to an area already experienced seems to have been of great importance, since most of the radio-tracked roe which remained on Sainte Lucie mainly established their home range in the area they first used. Moreover, as also reported for other roe deer introductions (Sempéré *et al.*, 1986 ; Dubray *et al.*, 1990), settlement in an unfamiliar area seems difficult for old animals. A high level of attachment to a previously experienced area might explain this fact (Wecker, 1963 ; Heuts & Boer, 1971 ; Wickler, 1976) and, in the present case, the emigration of the very old females F4 and F8. The animals whose relation with their environment has been shaped over several years in a particular area seem to experience, when translocated, a strong perturbation which is accompanied by an increase in locomotor activity. It is noteworthy that the females who emigrated

were among the roe which showed the strongest affinity for the wet habitat, i.e. the habitat supporting the vegetation most similar to that of their native area.

An important role was played by the interactions between individuals in the settlement dynamics of the roe, i.e. repulsion between males (at least between M3 and M5), attraction between females and males (well exemplified by F1 and M5), and perhaps also attraction between females (as suggested by the high degree of overlap of some females' ranges). So, despite a radical change of environment, the spatial organisation of the population after settlement was roughly similar to that usually described for the European roe deer in temperate forests (Kurt, 1968 ; Prior, 1968 ; Bideau *et al.*, 1983 ; Vincent *et al.*, 1983 ; Maublanc *et al.*, 1991).

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## SUMMARY

Roe deer (*Capreolus capreolus*) native to a deciduous forest of Western France were equipped with coloured or radio-transmitter collars, then released on a 266-hectare Mediterranean peninsula, on the edge of the current range of the species. Most of the roe settled on the area they first experienced on the peninsula. This fast spatial attachment and the interactions between animals led to a spatial organisation of the population roughly similar to that usually described for European roe deer in deciduous forest. Despite the presence of a strip of Atlantic type vegetation on the peninsula boundary, the animals mainly established their home ranges in Mediterranean habitats.

Key words : habitat selection, spatial attachment, territorial behaviour, spatial organisation, deer, introduction, Mediterranean habitat.

## RÉSUMÉ

Des chevreuils (*Capreolus capreolus*), originaires d'une forêt de l'Ouest de la France, ont été marqués puis relâchés sur une presqu'île méditerranéenne de 266 hectares, en bordure de l'aire de répartition actuelle de l'espèce. Les animaux se sont pour la plupart établis sur l'espace qu'ils ont fréquenté lors de leurs



premiers déplacements sur la presqu'île. Ce rapide attachement à l'espace et les interactions entre individus ont conduit à une organisation spatiale de la population, voisine de celle ordinairement décrite pour le Chevreuil d'Europe en forêt décidue. Malgré la présence d'une végétation plus atlantique sur les marges de la presqu'île, les animaux ont principalement établi leurs domaines dans des milieux méditerranéens.

Mots-clés : cervidé, organisation spatiale, sélection de l'habitat, attachement à l'espace, comportement territorial, introduction, milieu méditerranéen.

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