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Bonn. zool. Beitr.	Bd. 39	H. 2/3	S. 163—170	Bonn, August 1988

Reproductive cycle and population structure of *Sorex coronatus* Millet, 1828 (Insectivora, Soricidae) in the northern Iberian Peninsula

María José López-Fuster, Enrique Castién & Joaquín Gosàlbez

Abstract. In this paper the reproductive cycle and the population structure of *Sorex coronatus* is presented, based on 245 specimens (139 ♂, 106 ♀) captured in Quinto Real (Navarra) from September 1984 to August 1986. In the prospected territory the breeding season lasts from the end of February to the beginning of November, with a period of maximum activity in March-July. The ♂ generally reach sexual activity the same year they are born. In the case of the ♀, activity is mostly attained in the second calendar year. Nevertheless, those ♀ born in the first litters of the breeding season can reproduce before their first winter. The average number of embryos per litter is 3.692± 1.109 (n=13, 2—6). During her life, one ♀ can theoretically produce 3—4 litters. The characteristics of the reproductive cycle are reflected in the annual population structure of the species. In function of the appearance and disappearance of the specimens from the population, it is possible to assume that *S. coronatus* has a life span of 14—21 months.

Key words. Mammalia, Soricidae, *Sorex coronatus*, reproduction, population structure, northern Spain.

Introduction

The existence of chromosomic type A (*Sorex coronatus*) as a sibling species of *Sorex araneus* was first reported by Meylan in 1964. Since then, several types of studies have been carried out in order to determine the taxonomic-systematic status of the species and its phylogenetic relationships. The results obtained to date have enabled Hausser et al. (1985) to draw up a model of the process of speciation within the *araneus*-group (sensu Hausser 1976).

In spite of the amount of research already undertaken, the reproductive characteristics and population dynamics of the species are practically unknown. Bibliographical data dealing with these aspects are limited to works by Godfrey (1979) and López-Fuster (i. p.). However, those by Delost & Delost (1960) and Vericad (1970) may also be quoted although they refer to *S. araneus*, while their reports actually correspond to *S. coronatus*.

The greatest amount of information on the reproduction and populational structure of the European *Sorex* species come from northern and central Europe. One of the motives of the present study, however, has been to furnish data on the above aspects of a southern *Sorex* population.

The present paper analyses the reproductive cycle of *S. coronatus* in the northern Iberian Peninsula and comments on the population structure of the species throughout the annual cycle.

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Material and Methods

The material analysed was made up of 245 specimens (139 ♂, 106 ♀) caught in Quinto Real (Navarra) from September 1984 to August 1986. The monthly distribution of these specimens was as follows: January: 17 ♂, 8 ♀; February: 15 ♂, 8 ♀; March: 18 ♂, 11 ♀; April: 15 ♂, 19♀; May: 9 ♂, 8 ♀; June: 12 ♂, 8 ♀; July: 13 ♂, 11 ♀; August: 15 ♂, 4 ♀; September: 6 ♂, 8 ♀; October: 5 ♂, 13 ♀; November: 5 ♂, 4 ♀; December: 9 ♂, 4 ♀.

The specific determination of the specimens has been carried out according to colouring and by means of the application of the discriminant function proposed by Hausser & Jammot (1974). In the studied area, *S. coronatus* is the only species representing the "*araneus*" group.

The specimens were caught at altitudes ranging between 700 and 1200 m, at the margins of a beech wood (*Fagus sylvatica*), preferably next to blackberry (*Rubus* sp.) bushes and heather (*Erica cinerea*, *E. vagans*, *Calluna vulgaris* and *Vaccinum myrtillus*).

The relative age of the specimens was calculated according to the relative wearing down of their teeth and the month of capture. Two age categories were established: 1K: individuals in their first calendar year, inmature or not, caught in the year they were born; 2K: individuals in their second calendar year, caught in the year following their year of birth.

The sexual activity of the specimens was evaluated according to the following characters: in the ♂, maximum testicular length and citological analysis of the testicular contents, by the Diff-Quick method (Gosàlbez, López-Fuster & Durfort 1979); in the ♀, state of the uteri and ovaries, the presence of embryos and *maculae cianosae* and the degree of mammary gland development.

The males with a high proportion of spermatozoids in their testicular contens are considered sexually active ♂, and the females with irrigated and dilated uteri, or which are pregnant or nursing, are sexually active ♀.

Results and Discussion

Table 1 shows the degree of sexual activity of *S. coronatus* according to sex, relative age and month of capture. The individual and the group variation in testicular length throughout the annual cycle is given in figure 1 and table 2, respectively.

Table 1: Degree of sexual activity of *Sorex coronatus* in the northern Iberian Peninsula, according to sex, relative age (1K:+, 2K:*) and month of capture. In.: inactive; Ev.: evidence of sexual activity (♂ with few spermatozoids in the testicular contents; ♀ with slightly developed uteri but neither pregnant nor nursing); Ac.: active; Pr.: pregnant; N.: nursing.

	♂			♀			
	In.	Ev.	Ac.	In.	Ev.	Pr.	N.
January	1*	—	15*	7*	1*	—	—
February	—	1*	14*	2*	5*	1*	—
March	—	—	18*	1*	5*	1*	1
April	3+	—	12*	6+	1*	5*	7*
May	4+	—	5*	1+	—	3*	4*
June	10+	—	2*	5+	—	1*	2*
July	10+	—	3*	6+	—	1*	4*
August	11+	1+	3*	2+	1+,1*	—	—
September	4+	1+	1*	4+,1*	—	1*	2*
October	3+	—	2*	10+,1*	1*	—	1+
November	1+	1+	2+,1*	3+	—	—	1*
December	1+	—	7+,1*	4+	—	—	—
Total	47+, 1*	3+, 1*	9+, 77*	41+, 12*	1+, 14*	13*	1+, 21*

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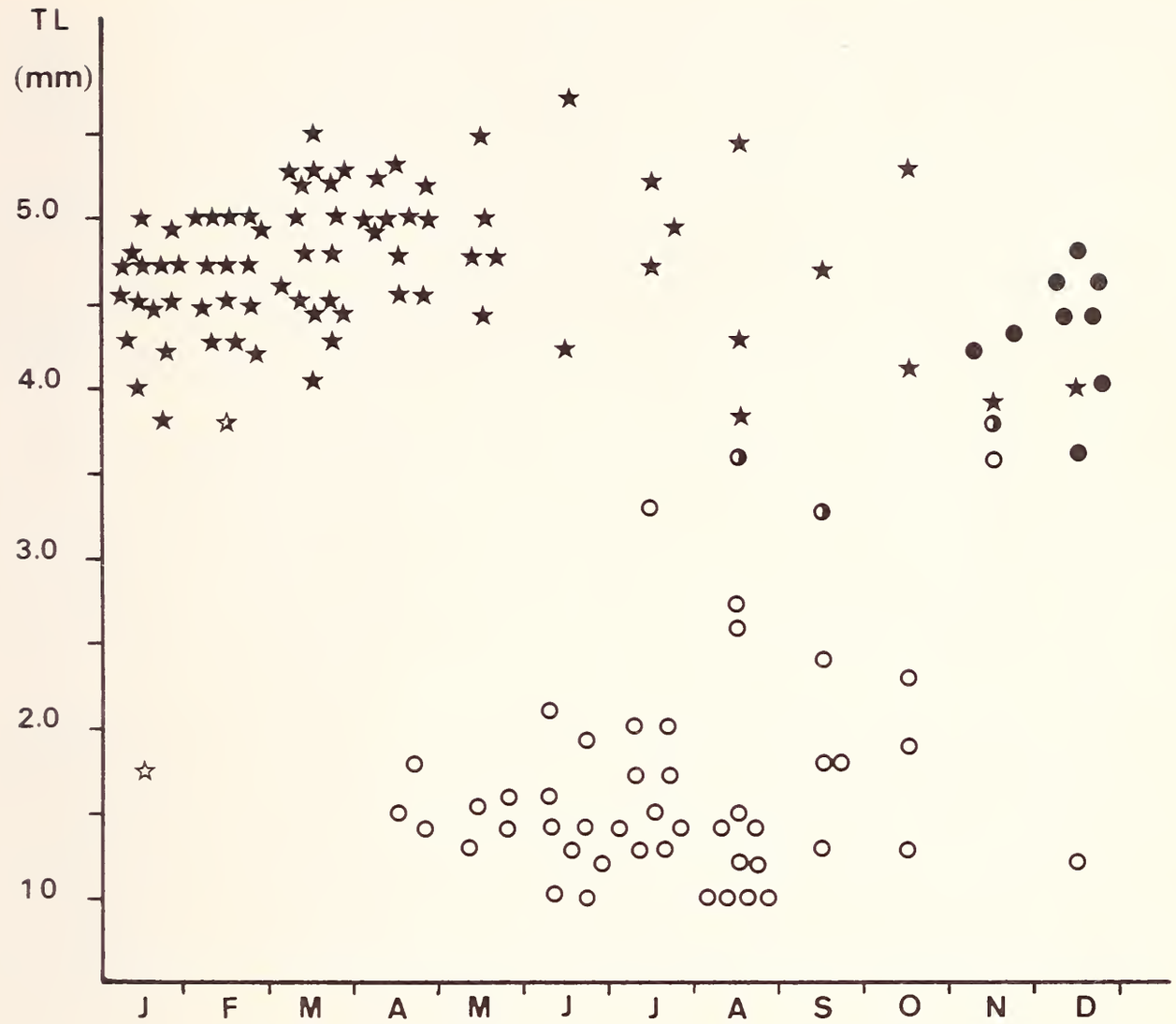

Figure 1. Variation of testicular length (TL) of *S. coronatus* in the northern Iberian Peninsula throughout the year. Inactive (○), semi-active (◑) and active (●) first-year-specimens. Inactive (☆), semi-active (⯪) and active (★) second-year specimens (Semi-active = with reduced spermatogenic activity).

The results obtained indicate that the ♂ from 1K, or at least those born in the first litters of the breeding cycle, reach sexual maturity in their birth year. From the moment they appear in the population context (April) to October, the majority of these specimens (95.7 %, n = 45) are inactive, with testicular length ranging between 1.0 and 3.3 mm, and with no spermatozoids (Figure 1). However, from August onwards, certain spermatogenic activity is detected, growing more intense as autumn progresses, especially from November. In December, the majority of ♂ from 1K are sexually active (87.5 %, n = 7), with abundant spermatozoids; Table 1). Only the individuals born in the last litters of the reproductive cycle (October) do not reach sexual activity until mid-winter (January—February), in their second calendar year. As the first litters in the annual cycle are produced in March and the first young specimens with signs of spermatogenesis are caugth in August, it is possible to estimate that the ♂ reach sexual activity from 6 months onwards.

The specimens from 2K show sexual activity all through the year (Table 1, Figure 1). Testicular length ranges between 3.6 and 5.7 mm, with maximum average values

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between March and July. From July, the average testicular length drops slightly, but in no case is testicular reduction seen to occur.

Generally speaking, these results are similar to those obtained by Delost & Delost (1960) in France and López-Fuster (i.p.) in the Iberian north-east. However, it must be pointed out that Delost & Delost (1960) when referring to ♂ in *S. araneus* (to be taken as *S. coronatus*) report the existence of a period of sexual inactivity in November—December, although they do not rule out the possibility of spermatogenesis being permanent throughout the year. Vericad (1970) indicates the capture of only two inactive ♂, of unspecified age, in October and November respectively.

In the case of the ♀, the period of sexual activity lasts from the end of January to start of November, reaching maximum intensity in March—July (Table 1). In the population context, pregnant females are found from February (25. II.) to September (14. IX.), and nursing ones from March (17. III.) to November (6. XI.). The nursing ♀, caught in November, showed recent *maculae cianosae* (n = 3) which indicates that, on a population level, the gestation period can last, at least, until the end of October.

The results shown in Table 1 indicate that the ♀ in their second calendar year are responsable for reproduction (breeding), whereas the majority of ♀ from 1K remain inactive. Nevertheless, a small fraction of young ♀ (4.65 %, n = 2) reach sexual maturity in their year of birth. The capture of a nursing female from 1K, in October, indicates that maturity does, in some cases, become functional. It may be assumed that these ♀ belong to the group of those born in the first litters of the annual cycle (March) and therefore, at the point of reaching sexual maturity, their age is around 6—7 months. The ♀ born in following litters do not reach sexual activity until their second calendar year when their age is over 9—10 months.

Once the cycle of sexual activity is over, the mature ♀ gradually move into a state of sexual inactivity lasting from mid-November to the end of January. No case of winter reproduction has been found, which differs from the observations made by

Table 2: Statistical values of testicular length in *S. coronatus* in the northern Iberian Peninsula, according to relative age (1K, 2K) and month of capture.

	1K				2K			
	n	$\bar{x}$	s	range	n	$\bar{x}$	s	range
January					16	4.356	0.782	1.7—5.0
February					15	4.606	0.357	3.8—5.0
March					17	4.829	0.429	4.1—5.5
April	3	1.566	0.208	1.4—1.8	11	4.963	0.220	4.6—5.3
May	4	1.462	0.137	1.3—1.6	5	4.900	0.400	4.4—5.5
June	9	1.444	0.364	1.0—2.1	2	4.950	1.060	4.2—5.7
July	10	1.760	0.600	1.3—3.3	3	4.933	0.251	4.7—5.2
August	12	1.633	0.855	1.0—3.6	3	4.500	0.818	3.8—5.4
September	4	2.300	0.734	1.3—3.3	1	4.700	—	—
October	3	1.833	0.503	1.9—2.3	2	4.700	0.848	4.1—5.3
November	4	3.975	0.330	3.6—4.3	1	3.900	—	—
December	8	3.950	1.174	1.2—4.8	1	4.000	—	—

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López-Fuster (i. p.) in the northeastern Iberian Peninsula. In France, Delost & Delost (1960) point out that the female anoestrous cycle lasts from the end of October to February, with complete involution of the genital tract.

No bibliographical references to litter in *S. coronatus* are known. In the sample analysed, the average number of embryos per litter ist 3.692 ± 1.109 (n = 13, 2—6), a much lower value than that observed for *S. araneus* in the northeastern Peninsula ($\bar{x}$ = 6.33, n = 3; Sans-Coma 1979). It must be pointed out that that litter size is exceptional in the Soricinae. For example, in *S. araneus*, *S. minutus* and *Neomys fodiens* average values of 6.0 embryos per litter have been reported (see e.g.: Vogel 1972; Röben 1969; Grainger & Fairley 1978; Brambell & Hall 1937; Michalak 1983).

According to the data obtained in the present study, it is not possible to establish exactly the number of pregnancies that a ♀ may undergo throughout her reproductive cycle. However, an estimate of the frequency of pregnancy, proposed by Emlen & Davis (1948), based on the formula F = (T/V) · %, may be made. In this expression, T is the reproductive period, considered in days; V is the number of days in which pregnancy is visible and % is the percentage of visible pregnant females in relation to the total of adult females during the period T. In the present case, T has been considered the period between 25th February (first pregnancy detected), and 14th September (last pregnancy confirmed), that is, 202 days. According to Godfrey (1979) pregnancy in *S. coronatus* last around 24—25 days. In order to calculate V, the days when pregnancy is not visible must be substracted from the above value (24—25). Given the lack of definite data on the species under study, the results obtained by Brambell (1935) on *S. araneus* have been taken into account. These indicate that 2/11 of the pregnancy period are not visible, as the fertilized ovules have still not been implanted in the uteri. Thus, in the case of *S. coronatus*, the term V could approximately equal 20 days (24.5—2/11 24.5).

The ratio of pregnant females according to the total number of adult females is 0.309 (13/42). By applying the values obtained to the formula by Emlen & Davis (1948), a pregnancy frequency of 3.12 (F = 202/20 · 0.309) may be obtained. Since the average number of embryos per litter is 3.692, the potential average of individuals that a ♀ may conceive during the period considered by Wijngaarden's method (1954) is 11.519 (F · $\bar{x}$ embryos/litter). According to the values calculated a ♀ may be assumed to produce 3 litters in her lifetime, or even 4 in those cases where sexual maturity is achieved in the year of birth.

The data furnished by Sans-Coma (1979) and López-Fuster (i. p.) on *S. araneus* in the Iberian north-east, enable a pregnancy frequency oscillating between 2.69 and 3.45 to be calculated, according to the proven nursing period and the probable one, respectively. According to these values, a ♀ could conceive an average of 19 individuals in an annual cycle. This value is higher than that obtained in *S. coronatus*, although it must be remembered that, according to Churchfield (1980), only 50 % of *S. araneus* in England survive the first two months of life. The importance of juvenile mortality in *S. coronatus* is still unknown.

The characteristics of the reproductive cycle are reflected in the population structure shown by the species throughout the annual cycle (Table 3). The beginning of the gestation period (February) leads to the first individuals of the year appearing in the population context, in mid-April, once they have left the nest. Their stay in

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the nest lasts approximately 20—25 days. As a result of the successive litters that are born during the breeding season, the proportion of young individuals (1K) increase considerably from June onwards. From this moment, the first year specimens make up the majority of the population (Table 3). This relative increase is favoured by the slow disappearance of adult individuals (2K). This phenomenon is clearly detected from June, reaching maximum intensity in December. However, it must be taken into account that species behaviour during the breeding period (birth, nursing and care of the newborn individuals) means an increase in the possibility of catching young specimens during this period.

By the start of winter, an almost complete renewal of the population structure has taken place. Thus, at the beginning of the second year, the population is exclusively made up of adult specimens (2K), born the previous year, which form the reproductive potential of the species.

The data obtained in the present paper reveals the existence of important differences between *S. coronatus* and *S. araneus*, previously reported by López-Fuster (i. p.). In the Iberian Peninsula, *S. araneus* does not reach sexual maturity until the year after birth. The reproductive period of the species stretches from April to October, with a proven nursing period from June to August. In *S. coronatus*, the ♂ show sexual activity in the year of birth itself, and some ♀ may reproduce before the first winter is over. In the populational context, the reproductive cycle lasts from the end of February to the beginning of November, reaching peak activity between March and July. The implications derived from the differences between both species are discussed by López-Fuster (i. p..).

No three-year specimen was caught, in the sample analysed. According to the moment of appearance and disappearance of individuals in the population context, the average life span of *S. coronatus* in the study area ranges between 14 and 21 months.

Table 3: Population structure of *S. coronatus* in the northern Iberian Peninsula throughout the year. 1K: first-calendar-year specimens; 2K: second-calendar-year specimens.

	1K		2K		
	n	%	n	%	N
January	—	—	25	100.00	25
February	—	—	23	100.00	23
March	—	—	29	100.00	29
April	9	26.47	25	73.53	34
May	5	29.41	12	70.50	17
June	15	75.00	5	25.00	20
July	16	66.67	8	33.33	24
August	15	78.95	4	21.05	19
September	9	64.29	5	35.71	14
October	14	77.78	4	22.22	18
November	7	77.78	2	22.22	9
December	12	92.31	1	7.69	13
Total	102	41.63	143	56.37	245

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Acknowledgement

The authors wish to thank Prof. Dr. Valentín Sans-Coma (Málaga) for reading the manuscript and for his helpful suggestions.

Zusammenfassung

Es werden Angaben gemacht sowohl über den Fortpflanzungszyklus als auch über die Populationsstruktur von *Sorex coronatus* aufgrund der Bewertung von 245 Exemplaren (139 ♂, 106 ♀). Die Spitzmäuse wurden in Quinto Real (Navarra) von September 1984 bis August 1986 gesammelt. In diesem Gebiet dauert die Vermehrungsperiode der Art von Ende Februar bis Anfang November, jedoch prägt sich die Fortpflanzungsintensität in den Monaten März—Juli am stärksten aus. Des öfteren erreichen die ♂ Geschlechtsreife schon im 1. Kalenderjahr (1K), die ♀ dagegen im 2K. Nur die ♀ der ersten Jahreswürfe können sich vor dem 1. Winter fortpflanzen. Der Gesamtmittelwert der Embryonen je Wurf beträgt 3.692± 1.109 (n = 13, 2—6). Im Laufe des Lebens kann ein ♀ durchschnittlich 3 bis 4 Würfe gebären. Die Dynamik der Populationsstruktur läßt sich aufgrund der Merkmale des Fortpflanzungszyklus gut deuten. Die Lebensdauer von *S. coronatus* wird auf 14 bis 21 Monaten geschätzt.

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Dra. María José López-Fuster, Departamento de Biología Animal (Vertebrados), Facultad de Biologia, Universidad de Barcelona, Avda. Diagonal 645, 08028-Barcelona, Spain.
Lic. Enrique Castién, Sociedad de Ciencias Aranzadi, Sección Vertebrados, Plaza Ignacio Zuloaga, s/n, San Sebastián, Spain.
Prof. Dr. Joaquín Gosàlbez, Departamento de Biología Animal, Cátedra de Vertebrados, Facultad de Biología, Universidad Complutense, Ciudad Universitaria, 28040-Madrid, Spain.

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Zeitschrift/Journal: Bonn zoological Bulletin - früher Bonner Zoologische Beiträge.

Jahr/Year: 1988

Band/Volume: 39

Autor(en)/Author(s): López-Fuster María José, Castién Enrique, Gosalbez [Gosálbez Gosalbez-Noguera] Joaquim [Joaquím]

Artikel/Article: Reproductive cycle and population structure of Sorex coronatus Millet, 1828 (Insectivora, Soricidae) in the northern Iberian Peninsula 163-170