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BIOLOGY OF THE YELLOW-NECKED FIELD MOUSE, *APODEMUS FLAVICOLLIS* (MELCHIOR, 1834) IN NORTH-EASTERN ITALY, UNDER FIELD AND LABORATORY CONDITIONS*

BIOLOGIA DEL TOPO SELVATICO DAL COLLO GIALLO, APODEMUS FLAVICOLLIS *(MELCHIOR, 1834) NELL'ITALIA NORD-ORIENTALE, IN CONDIZIONI NATURALI E IN LABORATORIO*

Abstract – Biology of *A. flavicollis* in North-eastern Italy seems to be different from other European populations. Skull measurements are intermediate between those observed in South Italian and European yellow-necked mice. Space, temperature and photoperiod effects on reproduction are investigated, the latter do not seem to be affected by these factors. Notices about population dynamics and life history traits are reported.
Key words: Reproduction, Biometry, Ectoparasites, *Apodemus flavicollis*.

Riassunto breve – *Gli* A. flavicollis *dell'Italia nord-orientale presentano caratteristiche diverse da quanto osservato in varie popolazioni europee. Per le misure del cranio essi sono intermedi tra le popolazioni centromeridionali italiane e le popolazioni del centro Europa. Sono stati investigati gli effetti di spazio, temperatura e fotoperiodo sulla riproduzione: nessuno di questi fattori sembra essere determinante. Si riportano notizie sulla dinamica di popolazione e sul ciclo biologico.*
Parole chiave: *Riproduzione, Biometria, Ectoparassiti,* Apodemus flavicollis.

Introduction

The biology of *Apodemus flavicollis* (MELCHIOR, 1834) is well-known in Europe generally, but there are but scanty data about the Italian populations. Also rare are works on the biology of yellow-necked field mouse under laboratory conditions.

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Most recent investigations on Italian *Apodemus* spp. concern the distinction between the sibling species *A. sylvaticus* and *A. flavicollis* or their distribution in Italy.

The distribution of *A. flavicollis* is limited by forestation. Movements of individuals seem to be constrained by roads and open areas (MADER, 1984; PELIKAN, 1986). Hence although yellow-necked mouse is not a rare species, it becomes an important factor in monitoring environmental quality.

Study area

Investigations were carried out in the regions of Veneto and Friuli, North-eastern Italy. Five capture sites were established in central Veneto, between Bassano and Asolo. This area is characterized by a patchwork landscape; cultivated fields, wineyards and small villages alternating with woodland areas.

Three capture sites are chestnut and black locust woods with dense underbush of hazel, common elder, blackberry, butcher's broom, clematis and garlic; oaks are occasionally present. One site is in a very small wood among roads, houses and cultivated fields, one site is the borderline between a houseyard and a small wood; composition is similar to previous woods. All sites are 200-250 metres a.s.l..

A. agrarius (PALLAS), *A. sylvaticus* (LINNAEUS), *Muscardinus avellanarius* (LINNAEUS) and *Sorex araneus* (LINNAEUS) were occasionally captured.

Four additional capture sites were established in Friuli in Tarvisio Forest, near Austrian and Yugoslavian borders; all these sites are mixed forest habitats with spruce, beech, alder and willow. Mice were mostly captured near rivers.

Methods

Mice were collected monthly using 40-60 snap traps and 30 live traps placed near burrow holes. The distances between trapping points were less than five metres. Traps worked for 2-4 nights depending on weather conditions. No more than two sites were visited every month.

After capture 136 dead mice were frozen at −20°C until dissection for biometric purposes and investigation on reproductive biology.

Sexual activity was estimated on external and inner morphology of genitalia; the major section area of testes, length x width x $\pi/4$ was used as an indicator of male activity. Area >45 mm^2 is typical of mature males (ADAMCZEWSKA, 1961).

Females were regarded as adult when weighting more than 20 g (ADAMCZEWSKA, 1961). Number of embryos and maculae uterinae were estimated by inspection of uterus.

Reproductive rate was calculated on the formula SxT/Td (EMLEM & DAVIS, 1948; INNES & MILLAR, 1987), where S is the ratio of pregnants out of the total of mature females, T is the length of breeding season in days and Td is the length of the time span (in days) during which embryos are detectable. Age was estimated on teeth consumption according to ADAMCZEWSKA (1967).

Before dissection mice were washed with 70% ethanol to remove ectoparasites. Mites were studied by Prof. F. Pegazzano and Dr. M. L. Liguori of Istituto Sperimentale per la Zoologia Agraria of Florence, ticks and insects were studied by Dr. G. Manilla and Dr. M. Bologna of L'Aquila University.

Skulls were handly cleaned after 10 minutes treatment with 5% calcium bicarbonate, then dried for 48 hours at 60°C after oxydation with 40% hydrogen peroxyde. 4 body measurements were taken with the help of a caliper to 0.1 mm accuracy, 11 skull measurements with caliper 0.05 and 5 measurements with stereomicroscope to 0.01 accuracy.

14 *A. flavicollis* belonging to the collection of Istituto di Entomologia Agraria, Padua University, were also used for biometrical investigation. 10 parameters of seventy specimens of Veneto and sixteen specimens of Friuli populations were used for discriminant function analysis.

Photoperiod: Natural	Photoperiod: Controlled	Temperature
MAY85-DEC88		Nat
JUL86-DEC88		Nat
MAY85-DEC88		Nat
JUL87-DEC88		Nat
JUL84-JUL85	JAN85-MAY85	Cont
NOV84-JAN85	JAN85-JUL87	Cont
	JAN85-MAY87	Cont
	JUL86-JUL87	Cont

Tab. I - Scheme of experiments on laboratory reproduction. Length of rearing periods are indicate (Normal cages, Cages with ground).
- *Schema degli esperimenti sulla riproduzione in cattività. È indicata la durata dei periodi di allevamento (Gabbie normali, Terrari).*

45 live mice were used to estimate temperature, photoperiod and space influence on sexual activity.

Breeding pairs or single mice were reared in 32x22x18 cm cages: wood shavings were provided for litter, small wood boxes and straw for nesting, food were standard laboratory rats pellets, sometimes natural food was provided, food and water was available ad libitum.

Three additional cages (60x40x50 cm) with 20 cm of ground in their bottom were used to estimate the importance of vertical and orizontal space (ISING & NIETHAMMER, 1979). Natural and controlled conditions of photoperiod and temperature were tested. In this latter case temperature was 20-23°C, UR 30-60% and time of lighting was 15 hours long (tab. I).

Laboratory born mice were weighted 2-3 times a week during the first month of life; three brood components were marked with toe-clipping 3 days after birth; their development was observed.

A sample of captured mice were classified by starch gel electrophoresis by Dr. M.G. Filippucci of Rome University. Electrophoresis results confirmed classification based on external morphology.

Result and discussion

Laboratory studies

17 broods from ten females were obtained. One female bore six times: twice it was under natural photoperiod and controlled temperature, four times under controlled photoperiod and temperature. One female bore once under controlled conditions. Under natural photoperiod and temperature one female bore three times, one two times and five females once. All births but one occurred in normal cages.

Were a total of 56 mice born during this investigation, the average number of sons for brood was 3.6 (Variance=2.24) with a maximum of six. Two times only a mouse was born: it was probably the survivor of a larger brood.

All births took place after a minimum of seven months of adaptation to captivity conditions. Males were not separated from their females in 15 of 17 pregnancies but no post-partum coupling was observed. Consequently the average interval between two births of the same female was 56.6 days.

In agreement with literature reports (BAUMLER, 1981; JENSEN, 1978, 1982) a small percentage of males (5-10%) remained active during the winter under natural light

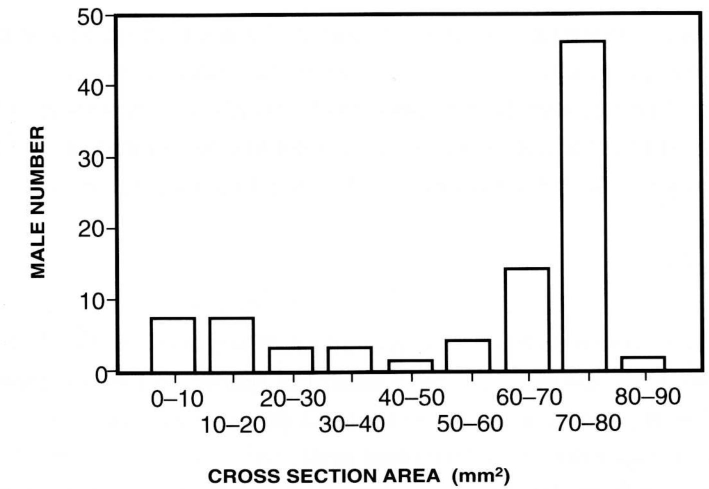

Fig. 1 - Cross section area of testes.
- *Andamento dell'area trasversa del testicolo.*

and temperature conditions. Changing from non-activity to activity needs only few days (HUMINSKI, 1969). As a consequence bimodal distribution of testes section area was observed in natural populations (fig. 1). Under controlled photoperiod and temperature males remained in continuous activity.

Reproduction of yellow-necked field mouse under laboratory conditions is very difficult to obtain. JEWELL & FULLAGAR (1965) obtained reproduction in captivity, they used standard cages with running wheels under controlled conditions, but they didn't report any other notice about results.

ISING & NIETHAMMER (1979) report about fecundity and reproductive rate. They reared mice in big cages with ground bottom under natural light and controlled temperature. Reproduction was uninterrupted during the whole year and there were always post-partum coupling. Number of mice per brood was 4 during summer and 3.8 during winter. They exclude the possibility of reproduction in normal mice cages.

A. flavicollis reproduction is possible under natural and controlled conditions; photoperiod, temperature, cage dimensions and ground presence do not seem to be key factors in sustaining sexual activity.

Five out of 17 broods of this investigation were not reared and small mice died 2-5 days after birth; sometimes they were eaten by the female. After a brood failure females stopped reproduction and never resumed it again. The female which bore six times lived two years after her last pregnancy without reproducing again.

Disturbance caused by laboratory controls is the main cause of reproductive failures (EISENBERG, 1981), females are able to reproduce only when disturbance is kept at a minimum. Running wheels or the possibility to escavate burrows allow to reduce the stress caused by disturbance in captivity conditions. The stress is probably the reason of lack of post-partum oestrus observed during this investigation.

Mice development

Small mice were born blind and without fur. When mice are 3 days old they are able to move quickly and their ears are opened. Fur appears and sex distinction is possible at the 7th day of life, weaning begins at 12 days and eyes open at 13. Lactation stops at 18 days and mice are independent at 21.

Weight growth of one brood is plotted in fig. 2. It is very similar to some

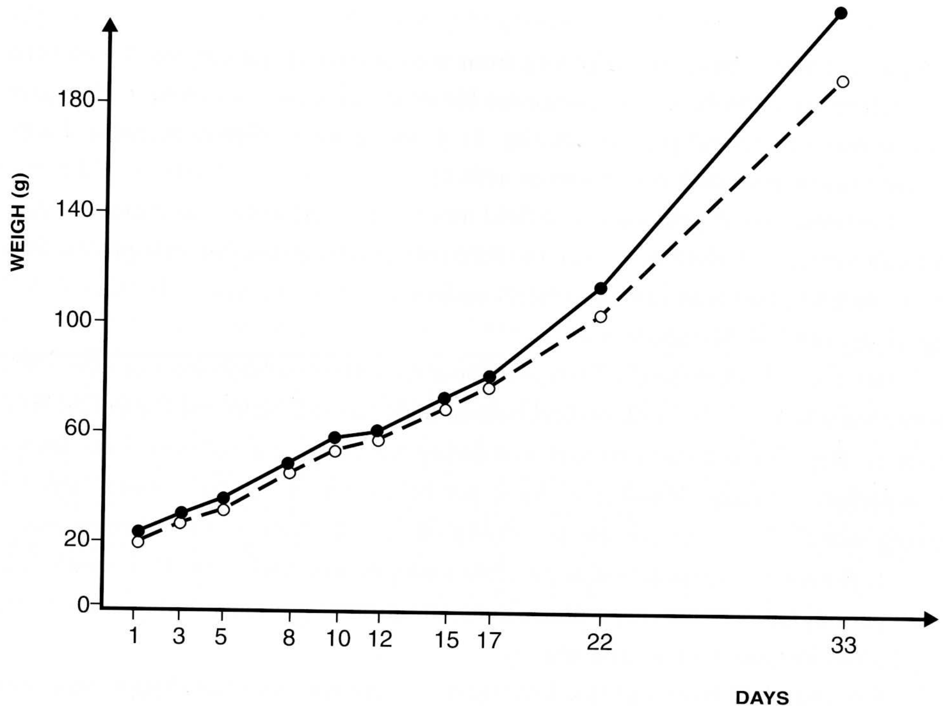

Fig. 2 - Growth curve of *A. flavicollis*. Dashed line: females; continuos line: males.
- *Crescita di* Apodemus flavicollis. *Linea tratteggiata: femmine; linea continua: maschi.*

description in *Crocidura hirta* (PETERS, 1852), *Suncus murinus* (LINNAEUS) (cit. by DENALY, 1974) and *A. sylvaticus* (GURNELL & RENNOLLS, 1983). The curve presents a stop in the growing trend. This point corresponds to the beginning of weaning. So weaning start and reduction of lactation cause a crisis time in the growth of small mice; their weight increment becomes 0 or negative during the first 2 days of beginning of weaning period.

Reproduction in natural populations

The breeding period begins in January, when almost 80% of male are active. Pregnant females appear in February. The last birth took place during the first ten days of November, when no active males were captured, but maculae uterinae were detectable till December. One active male was caught in the same month.

The breeding period is estimated as almost 290 days long, from the last ten days of January to the first week of November. Similar length was reported in Moravia (PELIKAN, 1966a) but the breeding period of *A. flavicollis* seems to be shorter in other regions of Europe (STEINER, 1966; JUDES, 1979a, 1979b; DOHLE & STUBBE, 1981).

8 females had embryos in uterus, 16 had maculae uterine and 5 both. The average number of embryos is 4.61 (Var.=0.36), the average number of maculae is 4.85 (Var.=1.9). These values are smaller than those reported for non Italian populations, almost 5-6 sons for brood are described (PELIKAN, 1966b; STEINER, 1966; ZEJDA, 1976; PELIKAN, 1986). The Veneto populations of *A. agrarius* has also smaller broods than those of non Italian populations (ZULIAN, 1985).

It is possible to see embryos in uterus during the last 18 days of pregnancy (STERBA, 1977). Percentage of pregnant females on total active females is 13/39=33%. Using EMLEN & DAVIS (1948) formula every female is estimated to produce 25 sons in 5.4 births every year.

This is a higher value as compared to literature reports: almost 21 sons and 3-4 births for year (PELIKAN, 1966; NIETHAMMER & KRAPP, 1978; JUDES, 1979a).

Difference among Italian and European populations may be due to difference in environmental conditions, mainly in food supply.

Population dynamics

Population dynamics studies of small mammals require regular grid of trapping (PELIKAN, 1971), but it is possible to estimate the population trend during the year by

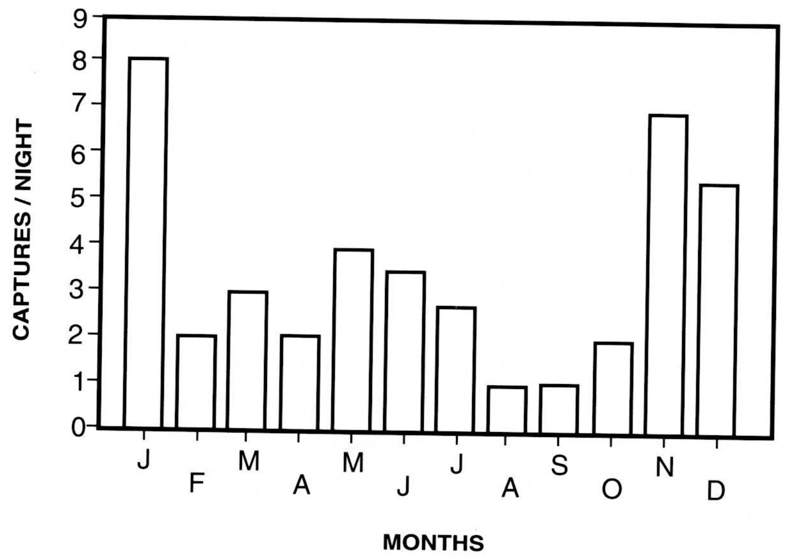

Fig. 3 - Population dynamic.
- *Dinamica di popolazione.*

plotting captures/night versus months. Fig. 3 shows a clear bimodal trend of captures, the two peaks corresponding to high reproduction activity in the population. Autumnal population growth is the most important during the year, corresponding to maximum food availability and is responsible for population increase. In chestnut woods the food was abundant till April, whereas summer corresponds to a minimum of population size because of the lack of suitable food, because yellow-necked mouse is a seed eater and does not like grasses (HOFFMEYER, 1976).

A similar trend was reported by ADAMCZEWSKA (1961) in Poland. This is probably typical of yellow-necked mouse and has adaptative importance in relation to food supply. Food availability seems to be very important in regulating length and intensity of the breeding period (WATTS, 1970). Because of bimodal trend of population it is possible to affirm that the breeding period comprises two separate phases. Only a small percentage of mice born in autumn survive at summer deprivation and only a small percentage of spring mice can overwinter. So two generations are partially overlapping during the year.

It is important to notice that *A. agrarius* in Veneto study area presents a shorter and no bimodal breeding period (ZULIAN, 1985), so the population dynamics of the two sympatric mice species seem to reduce interspecific competition.

	Veneto		Friuli	
Measured with caliper 0.1				
TC body-tail length	87.56	(14.17)	95.99	(21.66)
O ear length	16.09	(1.53)	17.02	(0.89)
C tail length	85.91	(12.64)	108.04	(8.39)
PP hind foot length	22.39	(1.44)	22.79	(0.81)
Measured with caliper 0.05				
CB condylobasal	23.78	(2.85)	25.38	(0.94)
LuCr length of skull	26.37	(1.88)	27.19	(0.76)
LuNa length of nasals	9.61	(1.12)	9.69	(0.64)
Lupa length of palatal bridge	11.32	(0.91)	12.07	(0.17)
IM3 distance incisor M3	12.67	(0.98)	13.40	(0.36)
Dia length of diastema	6.97	(0.89)	7.66	(0.29)
IO interorbital width	4.15	(0.15)	4.27	(0.13)
LaZ zygomatic arc width	13.46	(0.83)	13.70	(0.45)
LaCr skull width	11.82	(0.42)	11.99	(0.23)
HaCr skull heigth	8.44	(0.63)	8.63	(0.32)
Man mandible length	13.40	(0.96)	14.02	(0.50)
Measured with stereomicroscope				
FI length of foramina incisiva	5.18	(0.62)	5.55	(0.18)
LuPP length of palate	4.78	(0.58)	4.99	(0.34)
LuAS length of upper molar row at alveoli	4.29	(0.44)	4.57	(0.25)
LuAI length of lower molar row at alveoli	4.15	(0.24)	4.24	(0.17)
I septional dept of incisor	1.48	(0.17)	1.55	(0.12)

Tab. II - Biometrical measurements; average and standard deviation (SD) are reported.
- *Schema delle misure eseguite; sono riportati il valore medio e la deviazione standard (DS).*

Centroid of Friuli group	= 20.07		Distance of Mahalanobis		= 4.138
Centroid of Veneto group	= 15.93		F = 4.81	10 and 75 DF	$p = 1^{-4}$
Centroid of centroids	= 17.00				
Variable	Costant	%	Variable	Costant	%
FI	–2.87	–20.87	IO	6.92	20.48
LuPP	8.26	–25.58	LaCr	–1.82	– 6.93
LuAS	7.27	43.71	LuPa	3.41	59.86
LuAI	–1.13	– 2.54	LaZ	–0.39	– 4.64
Man	–1.93	–25.68	Dia	4.23	62.18

Tab. III - Discriminant function analysis.
- *Analisi discriminante.*

Biometry

Description, average values and standard deviation for biometrical measurement are in tab. II.

Discriminant function analysis (tab. III) was high significant ($F=4.81$ $p=1^{-4}$ $df=75$), overlapping is 17.44% so Veneto and Friuli populations are well distinct. Dia, LuPa and LuAS are, in that order the most important variables.

Veneto population has smaller dimensions and higher SD than Friuli population. Friuli samples were captured only during the summer; for this reason frequency of young animals is very low because of population dynamics; so lack of young animals causes the minor SD in Friuli population.

The North-eastern Italian populations are comparable with other European and Italian populations (FELTEN, 1952; ADAMCZEWSKA, 1959; HAMAR et al., 1966; STEINER, 1966; HAITLINGER & RUPRECHT, 1967; NIETHAMMER, 1969; VAN DER STRAETEN et al., 1977; DOLAN & YATES, 1981; CRESTI et al., 1984; DEMETER & LAZAR, 1984; FILIPPUCCI et al., 1984; AMORI & CONTOLI, 1986) but Friuli mice are larger and more similar to Middle Europe *A. flavicollis*. The Veneto population are more similar to Central Italy mice.

Moult

Moult doesn't seem to follow a seasonal trend. The post-juvenile moulting pattern is easily distinguible from the adult moult because of its symmetry, as happens in *A. sylvaticus* (FULLAGAR, 1967; ROBEN, 1969).

Ectoparasites

The following list is arranged according to KRANTZ (1978) and HOPKINS & ROTHSCHILD (1966).

Acarina Gamasida
Laelapidae
- Laelapinae: gen. *Laelaps* (KOCH), *Hyperlaelaps*, *Hypoaspis* (CANESTRINI)
- Haemogamasinae: gen. *Eulaelaps* (BERLESE), *Haemogamasus* (BERLESE)
- Hestionyssinae: gen. *Hirstionyssus* (FONSECA)

Rhodacaridae: gen. *Euryparasitus* (OUDEMANS)

Acarina Actinedida
Trombiculidae: gen. sp.
Pygmephoridae: gen. sp.
Acarina Acaridida
Lystophoridae: gen. sp.

Acarina Ixodida
Ixodidae: *Ixodes ricinus* (LINNAEUS)

Insecta Anoplura
Haematopinidae: *Polyplax serrata* (BURMEISTER)

Insecta Siphonaptera
Hystrichopsyllidae
- Ctenophthalminae: *Ctenophthalmus agyrtes impavidus* (JORDAN)
- Hystrichopsyllinae: *Hystrichopsylla talpae transalpinae*

Insecta Coleoptera
Leptinidae: *Leptinus testaceus* (MÜLLER)

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