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REPRODUCTION AND DENSITY-DEPENDENT REGULATION IN POPULATION OF MANDARIN VOLE (*MICROTUS MANDARINUS*)

TAI Fadao ZHAO Yajun* WANG Tingzheng
(*College of Life Sciences, Shaanxi Normal University, Xi'an*, 710062)

Abstract

Based upon the investigation of population ecology of mandarin vole during 1992～1994 in suburban area of Lingbao city, Henan province, we obtained the following results. The total sex ratio (female/male) was 1.207 3 (females 961, males 796). The mandarin vole reproduces in each month. The pregnancy rate, the litter size, the sex ratio, the reproduction index and the descended testis rate showed obvious yearly and seasonal differences, and were different in different age groups. The studies also revealed that reproduction characteristics were regulated obviously by population density. Under the years when the population density was increased, we observed that the sex ratio, pregnancy rate and reproduction index were lower. In the grids of high-density population, the reproductive intensity was suppressed too. Percentage of pregnant females, descendant testis rate were lower than those in the grids of low density population.

Key words Mandarin vole (*Microtus mandarinus*); Reproduction traits; Density-dependent regulation

Investigations of population reproduction play a important role in studying the regular patterns of population dynamics and forecast of population density (Lu et al., 1996), so the reproductions of many species of pest rodents such as *Mus musculus* (Hong et al., 1992), *Apodemus agrarbbius* (Zhang et al., 1989), *Microtus brandti* (Zhang et al., 1979; Liu et al., 1993; Zhou et al., 1992), and *Microtus pennsyluanicus* (Boosnrta et al., 1983) had been extensively studied. But reproductive ecology of mandarin vole (*M. mandarinus*) had been little studied because of many difficulties of obtaining specimens although this rodent had been harming crop very seriously in many areas (Zhang et al., 1983). Furthermore, there is increasing evidence that population density regulate population dynamics. This characteristic had already been found in several species of rodents (*Cricetulus barabensis, Mus musculus, M. brandti*) (Lu et al., 1996; Zhou et al., 1992). In order to forecast the trends of populations dynamics precisely and find ecological strategies to control mandarin vole, the authors investigated the sex ratios, pregnant rates, reproductive index and litter sizes during 1992～1994 and

* Present address: Northwest Plateau Institute of Biology, the Chinese Academy of Science, Xining, 810001
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discussed the population regulation by density.

MATERIALS AND METHODS

The study was carried out on a farmland in suburban of Lingbao city, Henan province, month by month during spring, summer, autumn of 1992～1994 (specimens were hard to obtain in winter because surface of soil was frozen). Grids with different densities were set up, which were separated originally by road, banks or ridges of the fields. The area of each grids was nearly a quarter of a hectare. We captured out all of mandarin voles in each grid using iron traps set in its burrows within five days as possible as we could. All specimens were weighed, measured and dissected as soon as we found voles being captured. Individual age of voles was determined with the body weight as an indicator (Tai et al., 1997). Numbers of litters, corpus luteums on ovary of females and numbers of males with descendant testes were counted. We calculated the percentage of pregnant females in 1992 and 1993, only conceiving females could be regard to be pregnant. Reproductive index = Mean litter size × Pregnancy rate. Absolute densities of different grids were calculated by area and rodent numbers. All data was analyzed with the soft package SPSS\PC+. At last we compared and analyzed the reproductive intensities and densities of different grids and different years to assess whether there was density feedback regulation of population.

RESULTS

1. Reproduction in different age groups

1 757 specimens had been collected and dissected from 1992 to 1994. The number of females was 961, of males, 796. The total sex ratio (females/males) was 1.36. There was significant difference between the two sexes ($X^2 = 15.5$, $df = 1$, $P = 0.005$). This showed that the number of females was more than that of males significantly (Table 1).

There is the same regular pattern in two years. In juvenile group, females were more than males. In sub-adult group, males exceed females slightly. Females were more a little in adult I group, higher significantly in adult Ⅱ one, and several times as much as males. Pregnancy rates and reproductive indexes were different among different age groups too. There were no pregnant females in juvenile group, a small number of sub-adult females was pregnant. Adults were main force of breeding. Pregnancy rate in adult Ⅱ group was maximum, dropped to 28.57% in adult Ⅲ group. Reproductive index in different age groups changed as well as stated above.

2. Reproduction in different seasons

Sex ratios, pregnancy rates, litter sizes, reproduction index in different seasons were calculated and arranged in Table 2 with densities.

It was found that there were no obvious differences between sex ratios of two same months in 1992 to 1993 (Wilcoxon Test, 2-Tailed Test, $P = 0.867$). The sex ratios of two years were 1.173 6 and 1.377, respectively. The sex ratios of each month were different although there were no obvious variation. Sex ratio is maximum in August of 1992 and July of 1993 and is minimum in April of 1993, and May of 1992.

Table 1 Traits of population reproduction in different age groups of mandarin voles

Age group	1992				1993			
	Sex ratio	Pre. rate	Litter size	Rep. index	Sex ratio	Pre. rate	Litter size	Rep. index
Juvenile	1.68	0.00	0.00	0.00	1.69	0.00	0.00	0.00
Sub-adult	0.96	2.11	3.75	0.11	0.95	7.60	3.20	0.24
Adult Ⅰ	0.88	23.60	3.21	0.76	1.50	30.90	3.21	1.00
Adult Ⅱ	2.30	54.28	3.30	2.01	2.31	51.92	3.03	1.58
Adult Ⅲ	3.00	28.57	3.10	0.90	11.00	50.00	3.70	1.85

Note: Pre. rate—Pregnancy rate (%); Rep. Index—Reproduction index

Table 2 The season changes of reproduction and densities in mandarin voles

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Mean
1992									
Sex ratio	1.13	1.03	1.16	1.06	1.60	1.13	1.17	1.37	1.17
Litter size	4.90	3.42	3.70	3.57	4.60	3.96	3.88	3.50	3.94
Pre. rate (%)	25.25	22.90	26.53	37.00	22.22	20.93	9.70	10.20	21.84
Rep. index	1.24	0.78	0.98	1.32	1.00	0.84	0.38	0.36	0.86
Den. (ind./hm^2)	540	347	158	122	153	231	357	269	261
1993									
Sex ratio	0.77	1.70	1.04	1.64	1.49	1.50	1.54	1.38	1.38
Litter size	5.67	4.44	3.29	2.88	3.15	3.20	3.27	4.00	3.80
Pre. rate (%)	33.33	31.30	26.15	25.00	28.87	22.10	14.15	5.00	23.40
Rep. index	1.90	1.39	0.87	0.72	0.90	0.70	0.46	0.20	0.91
Den. (ind./hm^2)	211	150	146	135	131	146	161	74	141

Note: Pre. rate—Pregnancy rate; Rep. Index—Reproduction index; Den. —Density

The results showed that the first reproductive peak appeared in March or April of 1992 to 1993. The pregnancy rates of first peak in 1992 was 25.5% and that of 1993 was 33.33%. The second breeding peaks were in July of 1992 and in August of 1993. The pregnancy rates of second peaks in 1992 and 1993 were 37% and 29%. This indicated that pregnancy rates in different seasons were obviously different. It is very obvious that in months while density was higher, the pregnancy rate was lower in 1992 (Figure 1).

The maximum litter size was 10, the minimum was 1. Most of litter sizes ranged from 1 to 8, but the most general litter sizes ranged from 2 to 5. Mean litter sizes of two years were 3.9 and 3.8, respectively. It displayed a trend in our data that the litter size decreased while litters developed and matured gradually. However, the mandarin voles always had only one to four pups surviving.

The mean litter sizes were different in different seasons too, but the difference was not obvious ($X^2 = 6.586$, $df = 7$, $P = 0.671$). Through calculating the data obtained above, the reproductive index of the two years could be arranged in table 1.

Percentage of males with descendant testes and pregnancy rate in every month had critical fluctuation. Percentages of males with descendant testes of different age groups were different, from sub-adult to adult Ⅲ group were 63.3%, 94%, 97.5%, 100%, respectively. This showed that almost all the males could join reproductive groups except the juvenile and some sub-adults.

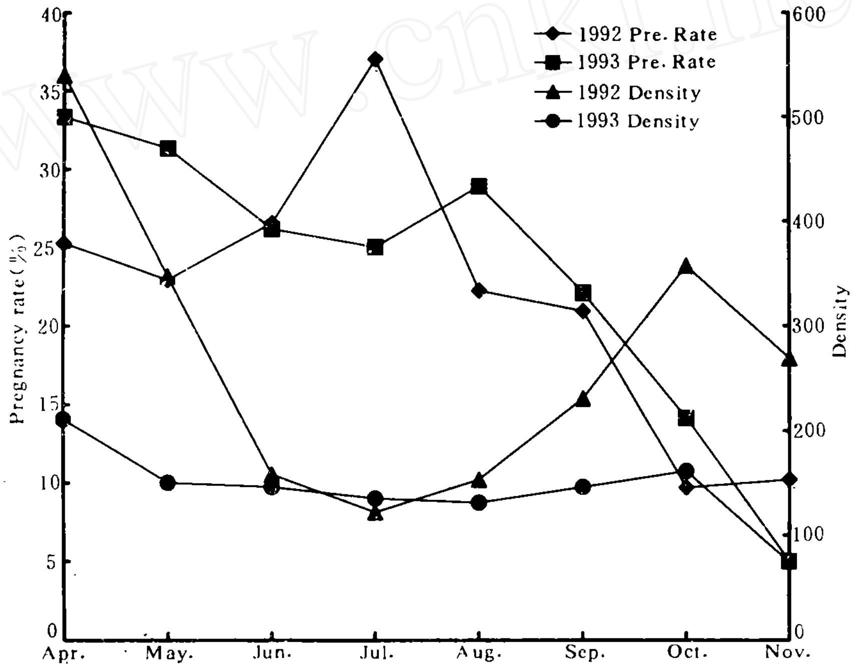

Fig. 1 Seasonal fluctuation of pregnancy rate and density in mandarin voles

3. **Reproduction in grids with different densities**

Population densities, pregnancy rates and percentages of males with descendant testes in different grids and different months were calculated and arranged in Table 3. Through correlatively analyzed, it was found that pregnancy rates and percentages of males with descendant testes were negative correlate with densities in every month. Further more, there were very significant negative correlation in May, June, September and October. Correlation coefficients were −0.94, 0.89, −0.90 and −0.99, respectively. For example, in September density in one grid was 225 ind./hm^2, pregnancy rate was 53.8%, but in another grid density was 300 ind./hm^2, the pregnancy rate was only 30.0%. These suggest that population density is a factor affecting the reprodution characteristics and regulating the population dynamics in mandarin voles.

DISCUSSION

1. **Traits of reproduction**

Sex ratio is an important parameter of population which affects pregnancy rate, thereby it affects the numbers in newborn rodents directly (Lu et al., 1996; Zhang et al., 1979). Our data of mandarin voles was highly consistent with investigation of those in Taigu county in Shanxi province (Zhang et al., 1984). The number of females mandarin voles exceeded males in every months except in April of 1993 (Table 2), which is the same as that of *M. pennsylvanicus* (Boonstra et al., 1983).

Table 3 Pregnancy rates and percentages of male with descendant testes in mandarin voles with respect to different grids and different seasons in 1992

	Den.	P.R.	r^1	D.R.	r^2		Den.	P.R.	r^1	D.R.	r^2
Apr.	705	36.70	0.642	33.30	0.290	Jul.	165	62.50	0.560		
	465	60.00		85.70			65	70.00			
	630	27.00		52.90			255	54.00			
	540	31.00		54.50		Aug.	135			50.00	0.803
May	150	36.00	0.210	62.50	0.947		180			50.00	
	540	35.00		38.23 *			210			36.00	
	450	38.00		36.36		Sep.	258	45.50	0.986	54.50	0.994
	300	40.00		47.36			300	30.00 **		27.00**	
Jun.	130	55.00	0.520	71.00	0.891		225	53.80		70.00	
	144	40.00		50.00*			240	47.00		60.00	
	105	60.00		55.00		Oct.	900	20.40	0.999	45.50	0.980
	285	23.00		21.40			225	53.30**		66.00*	
							630	34.40		50.00	

Note: Den. —density (ind./hm^2); P.R. —Pregnancy rate (%); D.R. —Descendant rate (%);
r^1-Correlation coefficient between densities and pregnancy rates; r^2-Correlation coefficient between densities and descendant rates;
* $0.01<P<0.05$; ** $0.001<P<0.01$

Reprodution traits of rodents were not only affected by environmental factors such as food, temperature, rainfall and agriculture activities, etc., but also regulated by inner factors such as age structure and population densities and so on (Lu et al., 1996; Zhang et al., 1979). Based on the statistic data obtained from 1992 and 1993, we found that mandarin voles could breed every month from April to November and the numbers of breeding vole were different in different seasons. Mandarin vole feed on fresh and tender part of plant such as wheat seedling or grass. In March or April, wheat growing in large area provided ample food for this rodent, and the climate was temperate. Perhaps these result in the first breeding peak. In July and August the lowest density and luxuriant grass may be the reasons which bring about the second peak. So there were two breeding peaks in a year. The first appeared in March or April, the second in July or August. The maximum month mean litter sizes of two years were 4.90 and 5.66 respectively, and always appeared in April, The resembles the conclusion drawn from reproduction studies of *M. brandti* (Zhang et al., 1979).

Variations of sex ratios in different age groups of mandarin vole and that of *M. brandti* were alike in many ways, but sex ratio of *C. barabensis* decreased gradually as age increased (Lu et al., 1996). These may be the result of different survival rates of different sexes in different species (Lu et al. , 1996). Another reason may be that the opposite sex in different age-groups had different social behaviors which resulted in different capture rates in different seasons (Lu et al. , 1996; Boonstra et al. , 1983).

Sex maturation was decided by the speed of development. Numbers of breeding female mandorin voles were different in different age groups (Table 2). A small number of the sud-adults and almost all adults could breed. Juveniles born in first reproduction peak (in March or April) could join the reproductive groups in June or July. The juveniles born in May could breed in September. Furthermore, according to the study of the replacement of age group (Tai et al. , 1997), We observed that the development of the rodent from juvenile to adult I lasted 3 months.

2. Regulation by density

Although there is increasing evidence that seasonal population fluctuation of mandarin vole not only is the reflection of age structure and reproduction capability, but also is restricted by climate factor. We found that population density in different seasons and years play an important role in regulating itself. Population was regulated by density in different seasons and years. Statistical data indicated that although sex ratios of juvenile groups and sub-adult groups in 1992 were almost the same as those in 1993, sex ratios of adult groups and total sex ratio were obviously higher than those in 1992. Mean density in 1992 was obviously higher than 1993. We infer that it may be caused by high-density which resulted in low reproductive intensity.

Although total pregnancy rate in 1992 was close to that in 1993, pregnancy rates in every month in 1992 were lower significantly than those in 1993, except in July ($t = -3.37$, $df = 4$, $P = 0.028$) (see Fig. 1). Moreover, the densities in these months were obviously higher than those in 1993. These studies revealed that in the high density population, the reproductive intensity was suppressed.

Mean reproductive index in 1993(0. 91)exceeded that in 1992(0. 86), and reproductive indexes in April, May and October of 1993 were significantly higher than those in 1992. This was probably caused by that total density in 1993 exceed that in 1992 and densities in April, May, October of 1992 were obviously higher than those in 1993 also. This supported the hypothesis in other respect that population was regulated by density.

The populations of mandarin voles were obviously regulated by densities in different season and year, in different grids. Pregnancy rate and percentage of males with descendant testes in high density population were lower than those in low density population. This result showed that in the high density population, the reproductive intensity was suppressed, which was similar to that of *M. brandti* (Zhou et al. , 1996; Christian, 1971).

Moreover, regulation of population densities of mandarin voles were more obvious than that of in other rodent such as *M. brandti*, *A. agrarius*, *mus musculus* and so on. Because of their living under ground more strictly, mandarin voles migrated in limited speed and scope of activities. Thus it is possible that the increase in population density of mandarin voles will strengthen the population pressure more obviously.

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中 文 摘 要

棕色田鼠种群繁殖特征及密度制约调节*

邰发道　赵亚军[1]　王廷正

(陕西师范大学生命科学学院，西安，710062)

1992年～1994 年在河南灵宝市郊黄土高塬农作区春夏秋逐月捕获并解剖棕色田鼠1 757只（雌性961只，雄性796只），总性比为1. 207 3。全年都有繁殖鼠出现，但怀孕率、胎仔数、性比、繁殖指数有明显的季节变化，年间也有一定的差异。不同年龄组的性比、怀孕率、胎仔数、繁殖指数、睾丸下降率不同。种群密度对繁殖特征有明显的调节作用。高密度年份的棕色田鼠的性比、怀孕率和繁殖指数低于低密度年份。高密度区种群的繁殖强度受到抑制，雌鼠怀孕率、睾丸下降率低于低密度种群。

关键词　棕色田鼠；繁殖特征；密度制约调节

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[1]中国科学院西北高原生物研究所，西宁，810001