兽类学报1997, 17 (3): 189～196
Acta Theriologica Sinica

EXPERIMENTAL MANIPULATIONS OF A CROPLAND RODENT COMMUNITY IN THE WESTERN SICHUAN PLAIN: DOMINANT SPECIES REMOVAL ①

ZENG Zongyong LUO Mingshu YANG Yuemin LIANG Junshu
XIE Rongkai DENG Xiaozhong DING Weijun SONG Zhiming
(*Department of Biology, Sichuan Union University, Chengdu*, 610064)

Abstract

During 1993～1995 we conducted an experiment in which we removed the dominant species of rodent, *Rattus nitidus*, from a 2 hm^2 plot in the Western Sichuan Plain and set a 1.5 hm^2 control plot in the same habitat. The experiment evaluates the extent to which the dominant species influences other rodent populations. Monitoring with live traps and statistical analyzing with paired t-testing of difference between the experimental and control plots revealed that: the removal of *R. nitidus* (1) resulted in increases of population density (*R. nevigicus* and *R. flevipectus*) and biomass (*R. confucians*) during a certain year or overall study period; (2) induced significant increases in the number of species and Shannon indexes of species diversity during 1995 and overall study period; (3) resulted in no significant changes in joint population density, biomass, evenness of species. These results indicate that occurrence of the dominant species plays a major role in regulating the number of species and determining the organization of cropland rodent communities. Competition between the dominant species and other rodent populations for resources was limiting the number of species in the community. But we have not identified which components in resources were working in limiting the species number and species diversity by our relative simple experimental manipulations.

Key Words Community; Cropland; Experiment; Population; *Rattus nitidus*; Rodent

1959 Hutchinson published his Homage to Santa Rosalia, or why are there so many kinds of animals? As first guess, Hutchinson outlined some important processes that generate and limit animal diversity. He had set much of the agenda for the next decades of community ecology. Species diversity in a community has become a major topic in ecology studies ever since (Brown, 1994).

Observational, comparative and experimental methods are three kinds of ones to detect the patterns of species diversity and the ecological processes generating the patterns. Recently attempts to elucidate the factors controlling species diversity of a community have relied increasingly on field experiments. This is an approach for testing theoretical predictions that offers important advantages over observational and comparative

① The National Natural Science Foundation has supported the project with grants 3880589 and 39270121
Received 26 November 1996, Accepted 22 April 1997

studies (Gurevitch et al., 1994). Despite the recent emphasis on experimental approaches to ecology, there have been few long-term, intensive experimental studies of cropland rodent communities. Such investigations can provide rigorous independent evidences of species diversity patterns and ecological processes producing the patterns. In addition, experimental manipulations offered us a perspective on what are the results of pest rodent control.

An example of the typical experimental-community-ecology studies abroad is Brown's experimental manipulation of seed-granivore community in a desert ecosystem. Brown and his colleagues (1985) added food in different-sized particles and in different temporal patterns, and exclused some or all rodent species and some or all ant species. Their results suggest that seed-eating rodents, ants and birds competed for limited food supply. At home Liu Jike et al. (1994) conducted field experimental studies on the multifactorial hypothesis of population system regulation for small rodents. Their experimental manipulations include addition of high-quality food and exclusion of rodent predators. The results show that food availability and predation have independent and additive effects on the vole population.

The cropland rodent community at our study sites was composed of 8 spceies, 4 genera (*Rattus*, *Apodemus*, *Micromys*, *Mus*), 1 family (Muridae). They are *R. nitidus*, *R. conficians*, *R. norvegicus*, *R. flavipectus*, *R. edwardsi*, *A. agarius*, *Micromys minutus* and *Mus musculus*, among which *R. nitidus* is the dominant species in the cropland rodent community. The purpose of the present paper is to detect the effects of removing the dominant species population of the community on dynamics of other populations and organization of the community in the Western Sichuan Plain.

METHOD

1. Study site

The study site is located on the west edge of the Western Sichuan Plain, Qionglai County, Sichuan Province, 103°24′E and 30°12′N, at an elevation of about 600 m. The terrain is relatively flat except where small hills stand. The typical subtropical agricultural plants here include rice-wheat, rice-rape seeds of rotation in the paddy field, maize, potato, sweet potato and carrot in nonirrigated land, and vegetables, tangerine and peach trees around villagers' houses. Both a 1.5 hm^2 control plot and a 2 hm^2 experimental plot are near by a reservoir and enclosed by small hills of 50~100 m high. The distance between the two plots is over 1 000 m.

On the top of hills woods make our experimental and control plots discrete and similar cropland habitat patches, between which frequent dispersal of some species occurred. When the dominant species was being removed, better food or den sites maybe became available. Individuals of the rodents might disperse into the experimental plot from the other patches nearby, which made it possible for us to monitor what were the changes of the community composition after removing the dominant species and to assess to what extent the dominant species was responsible for the species diversity of the cropland rodent community in the Western Sichuan Plain.

2 Experimental manipulations

Mark-recapture study of the rodent community on the control plot was conducted from January 1989 through December 1995. The experimental plot was set up for studying the changes of structure and dynamics of the cropland rodent community after removing *Rattus nitidus* in 1993.

On the control plot rodents were trapped for five nights per month (from January 1989 through December 1991) or per two months (From January 1992 through December 1995). Baited with corn, potato or sweet potato, 150 live traps (12×12×24 cm) were set at permanent grid stakes spaced at 10 m intervals per night. Each individual of rodents was marked by toe-clipping when first captured. At each capture, identification number, body mass, hind-foot length and tail length were recorded. We also collected standardized data on reproduction for each individual. For more details of the mark-recapture study, see Zeng et al. (1996a, b).

On the experimental plot 400 live traps at permanent grid stakes spaced at 5 m intervals were baited for fifteen successive nights and every individual of *R. nitidus* trapped was dissected after measuring body mass, hind-foot length and tail length in March of both 1993 and 1994. During the other trapping period, we used a monthly (1993～1994) or bimonthly (1995) regime to assess changes in the densities and biomass of other species of rodents in response to our experimental manipulations. At permanent grid stakes 200 live traps spaced at 10 m intervals were baited.

3 Statistical analyses

(1) Comparison of densities and biomass of populations between the experimental and control plot. The number of individuals and body mass of each species and the plot area was used to calculate the population density and biomass time series. For preventing the affects of other factors on population densities we selected only the trapping periods during which mark-recapture was conducted simultaneously on both kinds of plots from 1993 through 1995. For each kind of plot we have attained an overall time series and three month-to-month time series. We tested the difference of population densities and biomass between the experimental and control plot by paired t-testing for detecting the changes of population densities and biomass of other species after removing *R. nitidus*.

(2) Comparison of community variables between the experimental and control plot. Five community variables were estimated for the rodent community during each trapping period, including number of species, joint population density, Shannon index of species diversity, evenness of species. Joint population density is the sum of population densities of all species. Biomass was assessed by summing up body mass of all individuals for all species. The formula for calculating Shannon index of species diversity is $H_i = \sum -p_{ij} \ln p_{ij}$. Here, H_i is species diversity index during the ith trapping period and p_{ij} the pro-

portion of individuals of the j species to the total number of individuals of all species during the ith trapping period. Evenness of species is $E_i = H_i / H_{max}$ (Pielou, 1985). Then we attain three month-to-month time series and an overall time series of five community variables for both the experimental and control plot. We also used only data of the trapping periods during which mark-recapture was conducted simultaneously on both kinds of plots from 1993 through 1995.

RESULTS

1. Data set

On the experimental plot we recorded 332 captures, 292 individuals of 8 species in a total 32 000 trap-nights, over 25 trapping periods, March 1993 to December 1995. Totally 131 individuals of *R. nitidus* were removed and dissected. The maximum number of species, 8, was in March 1994 and the minimum, 2, in May and June 1993, April and May 1994.

On the control plot we recorded 275 captures, 178 individuals of 8 species (as the same species as on the experimental plot) in a total 15 000 trap-nights, over 20 trapping periods, February 1993 to December 1995. The number of species, peaked in August 1994 and was only 5, and the minimum was only 1 in July 1993 and March 1994. The low frequency of captures insured that sufficient empty traps were always available so that trap competition should not have influenced the results.

2. Effects of removing *Rattus nitidus* on other species

On the experimental plot, the population density of *R. nitidus* was less 1.88 individuals/hm^2 than that on the control plot (see Fig. 1). The population densities of the 6 species, except *Mus musculus*, increased more or less. Population density of *Rattus norvegicus* attained most. Biomass of *R. nitidus* on the experimental plot was less 253 g/hm^2, about 52.5%, than that on the control plot. *Rattus edwardsi* got more increase.

Other rodents, except *R. nitidus*, attained population density and biomass increase. For distinguishing the statistically significant results from random fluctuations of population densities and biomass, we conducted paired t-testing of difference of population densities and biomass between the experimental and control plot for 4 species of *Rattus* (Table 1).

The manipulations in the first year resulted in that population density and biomass of *R. nitidus* on the experimental plot was less than that on the control plot. But the decrease of population density and biomass in the second and third year was not significant. Both overall population density and biomass of *R. nitidus* decreased conspicuously. We find increases of population density of *R. flavipectus* in the first year, *R. norvegicus* in the second year and *R. confucianus* in the third year. But only overall population density of *R. flavipectus* significantly. On the other hand, only biomass of *R. confucianus* increased significantly in the second year.

3. Effects of removing *R. nitidus* on variables of the rodent community

Table 1 Paired t-testing results of difference of population densities and biomass between the experimental and control plot for 4 species of Rattus

	Species	1993	1994	1995	Overall
Population density	*R. nitidus*	$t=2.579$ $P<0.05^{**}$	$t=1.235$ $P<0.40$	$t=1.476$ $P<0.20$	$t=3.188$ $P<0.01^{***}$
	R. confucianus	$t=0.411$ $P<0.70$	$t=0.680$ $P<0.60$	$t=2.026$ $P<0.10^{*}$	$t=0.954$ $P<0.40$
	R. norvegicus	$t=0.391$ $P<0.80$	$t=2.987$ $P<0.05^{**}$	$t=0.383$ $P<0.80$	$t=0.861$ $P<0.50$
	R. flavipectus	$t=2.648$ $P<0.05^{**}$	$t=1.303$ $P<0.30$	$t=0.312$ $P<0.80$	$t=2.358$ $P<0.05^{**}$
Biomass	*R. nitidus*	$t=6.090$ $P<0.001^{***}$	$t=1.159$ $P<0.40$	$t=1.702$ $P<0.20$	$t=3.552$ $P<0.01^{***}$
	R. confucianus	$t=0.768$ $P<0.50$	$t=2.752$ $P<0.05^{**}$	$t=1.723$ $P<0.20$	$t=0.985$ $P<0.40$
	R. norvegicus	$t=0.485$ $P<0.70$	$t=1.229$ $P<0.30$	$t=0.362$ $P<0.80$	$t=0.219$ $P<0.90$
	R. flaviPectus	$t=0.958$ $P<0.40$	$t=0.314$ $P<0.80$	$t=0.499$ $P<0.70$	$t=0.698$ $P<0.50$
Sample size	-	7	6	6	19

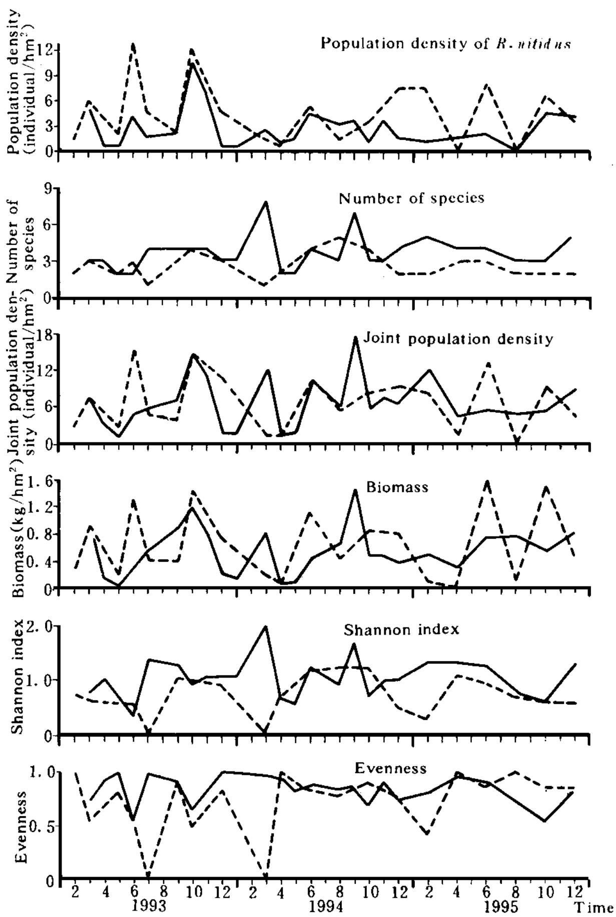

Fig. 1 Population densities of *R. nitidus* and fluctuations of five community variables on both the experimental (—) and control plot (---) from 1993 to 1995

We analyze five variables of the cropland rodent community: number of species, joint population density, biomass, Shannon index of species diversity, evenness of species. Figure 1 illustrates fluctuations of these variables on the experimental and control plot. We conducted paired t-testing of difference of these variables between the experimental and control plot for the rodent community. The paired t-testing results are showed in Table 2.

Table 2 Paired t-testing results of difference of five variables between the experimental and control plot

Community variable	1993	1994	1995	Overall
Mean number of species	$t = 0.892$ $P < 0.50$	$t = 0.760$ $P < 0.50$	$t = 3.953$ $P < 0.02^{**}$	$t = 2.179$ $P < 0.05^{**}$
Joint population density	$t = 1.321$ $P < 0.30$	$t = 0.410$ $P < 0.70$	$t = 0.253$ $P < 0.90$	$t = 0.458$ $P < 0.70$
Biomass	$t = 1.252$ $P < 0.30$	$t = 0.529$ $P < 0.70$	$t = 0.044$ $P < 0.90$	$t = 0.980$ $P < 0.40$
Shannon index of species diversity	$t = 1.538$ $P < 0.20$	$t = 0.866$ $P < 0.50$	$t = 2.717$ $P < 0.05^{**}$	$t = 2.373$ $P < 0.05^{**}$
Evenness of species	$t = 2.092$ $P < 0.10^{*}$	$t = 0.650$ $P < 0.60$	$t = 0.658$ $P < 0.60$	$t = 1.156$ $P < 0.30$
Sample size	7	6	6	19

The mean number of species on the experimental plot in the third year increased significantly, which resulted in the increase of number of species during the overall study period (1993~1995). We see a same pattern in Shannon index of species diversity. The other variables, except evenness of species in the first year, no any significant changes occurred.

DISCUSSION

At the expense of removing dominant species *R. nitidus*, the number of species in this cropland rodent community increased. We see an interesting phenomenon that the number of species during the third year after initiating the experimental manipulations increased significantly but not during the first or the second year. There was a two-year time lag between the removal of *R. nitidus* and the increase of number of species. We also observed time lags of one year to three years before we found any noticeable changes in the other rodent populations. The removal of *R. nitidus* should have made available more resources for exploitation by other rodents. The individuals of these species moved into the empty habitat patch.

Just like Brown's (1985) and Liu's (1994) experimental studies, our analysis provides us a strong evidence for a significant competitive interaction between *R. nitidus* and other species of cropland rodents. *R. nitidus* is one of the larger species of the rodent community. Our results support the suggestion that large species utilize a disproportionately large share of the resources within local ecosystem and large individuals within species monopolize resources, and that resulting selection pressure are responsible for the evolutionary trend towards increasing body size seen in many phyletic lineages (Brown et al., 1986). In other words, occurrence of the dominant species *R. nitidus* in this community limited the number of species. Once *R. nitidus* is removed, lessened competitive interaction makes more resources available and more rodents appear. From this we see some possible clues of patterns and processes of limiting community species diversity.

Although our study provides an good example of the valuable insights into species diversity of the cropland rodent community, it is far from an accurate representation of the patterns and processes that occur in unmanipulated communities. The limitations of our study include at least: (1) The spatial and temporal scale of our manipulations were arbitrarily limited. The experimental plot is just a tiny habitat patch in a vast sea of unmanipulated cropland. If we had been able to treat much larger areas, we are not sure that we will be able to obtain the same results. (2) Although the two plots are closed by hills and water, we cannot exclude completely effects of dispersal of *R. nitidus* from other habitat patches on population density in the experimental plot, because dispersal is one of the major traits of small mammals (Zeng et al., 1987; 1996b). (3) We could not identify what the components of resources were working to limit the patterns and processes of community species diversity by such relatively simple experimental manipulation in our study.

REFERENCE

Brown J H. 1994. The ecology of coexistence. *Science*, 263: 995~996.

Brown J H, Maurer B A. 1986. Body size, ecological dominance and Cope's rule. *Nature*, 324: 248~250.

Brown J H, Munger J C. 1985. Experimental manipulation of a desert community: food addition and species removal. *Ecology*, 66: 1545~1563.

Gurevitch J, Collins S L. 1994. Experimental manipulation of natural plant communities. *Tree*, 9: 94~98.

Hutchinson G E. 1959. Homage to Santa Rosalia, or why are there so many kinds of animals? *The American Naturalist*, 93: 145~159.

Liu J, Su J, Liu W. Wang X, Nie H, Li Y. 1994. Field experimental studies on the multifactorial hypothesis of population system reguiation for small rodents: an analysis of effects of food availability and predation on population dynamics of root vole. *Acta Theriologica Sinica*, **14** (2): 117~129.

Pielou E C. 1985. Mathematical ecology. Wiley-Interscience, New York.

Zeng Z, Brown J H. 1987. Population ecology of a desert rodent: *Dipodomys merriami* in the Chihuahuan Desert. *Ecology*, 68: 1328~1340.

Zeng Z, Ding W, Yang Y, Luo M, Liang J, Xie R, Dai Y, Song Z. 1996a. Population ecology of *Rattus nitidus* in the Western Sichuan Plain I. Population dynamics and body size. *Acta Theriologica Sinica*, 16: 202~210.

Zeng Z, Ding W, Luo M, Yang Y, Song Z, Liang J, Xie R. 1996b. Population ecology of *Rattus nitidus* in the Western Sichuan Plain II. Survival and movement. *Acta Theriologica Sinica*, 16: 278~284.

中 文 摘 要

川西平原农田啮齿动物群落的试验操作：去除优势种

曾宗永　罗明澍　杨跃敏　梁俊书
邓小忠　谢荣凯　丁维俊　宋志明
(四川大学生物系，成都，610064)

1993～1995年我们在川西平原面积为2 hm^2的试验样地进行了试验，内容是去除啮齿动物优势种大足鼠（*Rattus nitidus*），同时在相同生境中设置了1.5 hm^2的对照样地。试验估计了优势物种在多大程度上影响其他啮齿动物种群。用捕鼠笼活捕进行监测后试验样地和对照样地间差异的成对数据 t 检验显示，移除大足鼠后：（1）褐家鼠和黄胸鼠的种群密度、社鼠的生物量在某一年或整个研究期增加；（2）1995年及整个研究期的物种数和物种多样性 Shannon 指数显著增加；（3）结合密度、生物量和物种均匀性无明显改变。这些结果说明，优势种的存在对农田啮齿群落物种数和组织有重要作用，它与其它种群围绕资源的竞争限制了群落的物种数。但本研究相对简单的试验操作尚无法识别资源的什么成分在限制群落的物种数和物种多样性。

关键词　大足鼠；农田；种群；试验；啮齿动物；群落
