

Impacts of the Three Gorges Project and Converting Farmland into Lake on the *Microtus fortis* Population in Dongting Lake Region

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Abstract The outbreak of Yantze vole (*Microtus fortis*) population in Dongting Lake region is closely related to the evolvement of lake beaches , because the deposition of lake sediments results in the expansion of lake beaches , which provides the possibility of the increase of the vole's population. Reclaiming farmland from lake via building cofferdams , eliminating snails by building cofferdams for eradicating schistosomiasis , and over - hunting predators in the region cause the voles becoming a pest after the 1970s. In recent years , the Three Gorges Project and the conversion from farmland into lake have had deep impacts on the environment in the lake region. The dispatching of the down flow rate by the project has induced the expansion of the low and medium level beaches in the lake region , while converting farmland into lake directly has induced the expansion of the lake beaches , both of which have expanded the potential habitats of the vole's population. Therefore , more attention should be paid to the quantitative variation trend of the vole's population in the future.

Key words *Microtus fortis* , Population , The Three Gorges Project , Converting farmland into lake , Dongting Lake region

Yantze vole (*Microtus fortis*) , belonging to Cricetidae , can be found in 17 provinces of Northwest China , Northeast China and South China , as well as Russia's Siberia , Mongolia and Korea^[1-2]. In Dongting Lake region in the Yangtze River basin , the vole's population is often perched on lake beaches in the dry season from October to next April , and *Carex* spp. marsh and *Phragmites* spp. + *Triarrhena* spp. marsh are the optimal habitat; in the flood season , they have to move to farmland and downland to harm crops , and they have become an agriculture pest in the region^[2-3]. The outbreak of the vole's population in 2007 has captured global attention^[4]. Besides harming local agriculture , forestry and animal husbandry , the vole is the natural host of epidemic hemorrhagic fever , leptospira , Japanese encephalitis and tularaemia , and it is one of major infectors of leptospirosis and epidemic hemorrhagic fever^[1, 2]. The outbreak of the vole population in Dongting Lake region is closely related to human activities^[2-3]. Lake beaches and river beaches in the region are the optimal habitats of the vole population , as well as their breeding base in the dry season , so the expansion of beaches in the region inevitably leads to the increase of the vole's population in quantity^[2-3]. In recent years , the Three Gorges Project and the conversion from farmland into lake greatly affecting the local eco-environment have had impacts on the area and emergence time of the lake beaches , thereby influencing the vole's population , so we have made some surveys and studied on the impacts , and the comprehensive analysis of the results will be carried out next.

1 Historical reasons for the outbreak of the vole's population in Dongting Lake region

The harm of the vole's population in Dongting Lake region to crops in surrounding farmland in the flood season has been documented early^[5] , but its quantity was still small in the 1950s and 1960s , so the harm had not been paid more attention to. Since the 1970s the harm has become increasingly serious , and the outbreak of the vole's population often occurred since 1978 , so that farmers had no harvest sometimes , and it has become one of new agricultural pests in China^[2-3]. According to previous studies^[2-3] , the shrink of the lake and expansion of beaches are the root causes of the outbreak of the vole's population in Dongting Lake region. In 1825 , Dongting Lake covered 6 300 km² , and Jinjiang River burst its bank in 1852 and 1870 to form two estuaries Ouchi and Songzi , so there were four estuaries together with previous two estuaries Taiping and Diaoxian. 45% of silt from Jinjiang River was discharged into Dongting Lake through the four estuaries , so that the lake area reduced due to filling up with silt. In 1949 , it decreased to 4 350 km² because of the embankment around 1886. Since 1949 , " reclaiming farmland from lake via building cofferdams" and " eliminating snails by building cofferdams" reached three times of climax in the middle 1950s , the early 1960s and from the late 1960s to the early 1970s. Moreover , excessive deforestation in the upper reaches of the Yangtze River and " four rivers (Xiangjiang , Zichang , Yuanjiang and Lishui) " had made soil erosion more serious , so that one billion m³ of silt had deposited in the lake every year , and the lake beaches increased by 40 km² in area every year. Therefore , After West Dongting Lake had disappeared almost , South Dongting Lake had been also fragmented^[6-7] , and the lake area reduced to 2 691 km² in 1983^[8]. Now the lake beaches mainly distribute in Yueyang , Xiangyin , Yuanjiang and Hanshou counties as well as the lake districts of several state farms

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along the west bank of East Dongting Lake ,and their area is 1 282 km² ,accounting for 81.3% of total area of all lake beaches^[9] . In these regions ,the vole's population had the largest quantity. Jinpen and Beizhouzi farms along the west bank of East Dongting Lake are close to Luhu Lake with a large area of marsh ,so the vole's population had the largest quantity ,and 51.5 tons of the voles were found in Jinpen farm during the flood season in the 1980s^[2] . Nidation ,ingesting food ,activity and multiplication of the voles adapt to the vegetation in the marsh of lake beaches ,and the expansion of lake beaches is the increase of the voles' optimal habitat in area ,which provides basic conditions for the population growth^[2-3] .

In addition , " reclaiming farmland from lakes via building cofferdams" and "eliminating snails by building cofferdams" from the 1960s to the 1970s changed the eco-environment of Dongting Lake region , which led to the outbreak of the voles after the 1970s. First ,reclaiming farmland from lakes via building cofferdams sped up the deposition of lake sediments and expansion of swamp vegetation ,so the vole's population could breed in more places. Second ,the voles perching distant lake beaches would be drowned by floods before ,but the amount of floods flowing in the lake beaches decreased greatly after reclaiming farmland from lake via building cofferdams ,so the lake beaches became a voles' paradise ,and their number increased year by year. Third ,the voles hid under dams in the lake region during the flood season. Thus ,the survival and development conditions of the voles were improved through the expansion of their habitats and improvement of their security. From the late 1970s to the 1980s ,large amounts of people poured into the lake region to catch snakes. During 1976 - 1981 ,12 650 kg of snakes were purchased by Jinpen store ,and 7 250 kg of snakes were sold to a purchasing station of Yuanjiang County. That is ,about 20 tons of snake were sold to the stores in total ,so that snakes and stoats in the lake beaches almost disappeared in several years ,which results in the rapid rise of the vole's population in quantity^[2-3] . Besides ,the Three Gorges Project have had impacts on the emergence time of the lake beaches ,while converting farmland into lake directly has induced the expansion of the lake beaches ,both of which expand the potential habitats of the vole's population ,so more attention should be paid to the quantitative variation trend of the vole's population in the future.

2 Dynamic changes of the vole's population in Dongting Lake region in recent years

The quantity of the voles in farmland of Chunfeng site during flood season since the 20th century can reflect the dynamic variation of the voles in recent 20 years (Fig. 1) . As shown in Fig. 1 ,the peaks of the vole's population quantity appeared about ten years apart ,and the peaks and troughs lasted for around five years. The quantity of the vole's population was low from 2002 to 2004 ,and then it began to increase sharply in 2005. As the gradual appearance of the impacts of the Three Gorges Project and the conversion

from farmland into lake on the vole's population ,we judged that a new peak of the vole's population might appear ,so the first forecast of the breakout of the voles was issued on the website of Chinese Academy of Science^[10] . During the flood season in 2005 ,the outbreak of the vole's population occurred in some areas of Dongting Lake region as expected. From May to September in 2005 ,the trap success of the voles in farmland Chunfeng site reached 8.5% . In 2005 ,the region of Yiyang with the voles had an area of 90 000 hm² ,and it brought damage to 4 540 hm² of region ,while the direct loss reached 20 million yuan. The number of the vole's population in the lake beaches was also high in 2006 ,but the voles did not move to the farmland ,because the lake beaches were not submerged completely. The outbreak of the voles occurred and brough serious damage in 2007^[4] ,and the population quantity started to decrease in 2009.

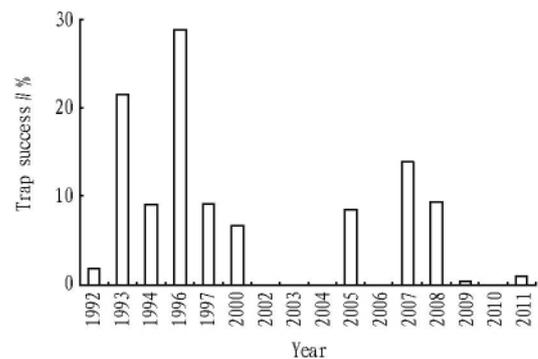


Fig. 1 Trap success of *Microtus fortis* in farmland in Chunfeng site during flood season from May to September

3 Impacts of the Three Gorges Project on the vole's population in Dongting Lake region

In previous studies^[11-13] ,the impacts of the Three Gorges Project on the vole's population have been analyzed and predicted. The results show that the dispatching of the down flow rate by the project has induced the expansion of the low and medium level beaches in the lake region ,which has expanded the optimal habitats of the vole's population. Moreover ,they were exposed for a longer time in winter and spring ,which has lengthened the breeding peak of the voles and might lead to the expansion of the vole's population. Due to the reduction of high level beaches and high water level in flood season ,large numbers of the voles migrated to farmland. According to the changing trend of the beaches in emergence days and area ,it is judged that the breeding period of the voles would be increased by 15 - 35 d ,and the quantity of the voles migrating to farmland in flood season might rise greatly according to the prediction formula of the vole's population^[14] . Hence ,some prevention and control measures need to be adopted before the outbreak of the voles.

In fact ,a new round of outbreak of the voles happened in 2005. We released an early warning about the outbreak of the voles in May ,2006 according to the quantity of the voles in beaches in early spring^[15] . But Chongqing and Sichuan in the upper

beaches of the Yangtze River suffered rare drought in 2006, and little water flowed into the upper beaches of the Yangtze River after the Three Gorges Project began to store water, while there was little rainfall in the lake region. Therefore, the lake beaches were not submerged completely in flood season as before, and the vole's population was stranded outside the levee, and returned to the beaches after floods subsided, thereby increasing the initial quantity of the voles in the lake beaches in 2007. Actually, the quantity of the voles in the lake beaches in January (winter) was the highest in 2007; there were 250 and 560 holes per hectare in the lake beach outside Chunfeng and Beizhouzi respectively, and the trap successes reached 11.3% and 17.8% respectively. Normally, the density of the vole's population was lower in winter. For instance, the trap success of the voles in the lake beaches in Chunfeng site was only 0.3% in December, 2005. After March or April, the quantity of the voles began to increase rapidly. If the water level of Dongting Lake rose normally, the outbreak of the voles would happen in 2007^[16]. In early May, the outbreak of the voles happened, and the trap successes of the voles in the lake beach in Chunfeng and Beizhouzi site were 52.1% and 63.9% respectively, reaching the maximum values in the history. Therefore, a report about the outbreak of the voles was submitted to Hunan Provincial Government and the State Council.

In 2008, drought appeared in a large area in the middle and lower reaches of the Yangtze River, so more water was discharged from the Three Gorges Reservoir in late October to alleviate the drought. Subsequently rainfall happened in Dongting Lake region, so that the lake suffered a rare autumn flood in early November. According to Table 1, after the outbreak of the vole's population occurred in 2007, the population quantity was still kept at a high level in 2008, and the trap successes of the voles in Chunfeng and Beizhouzi site were 31.6% and 16.6% respectively in April. In summer, the trap success of the voles in Chunfeng site was 9.5%. After floods subsided, the trap successes of the voles in the sites were 2.9% and 1.9% respectively in October, showing that some voles migrated back to the lake beaches, and total pregnant rate reached 50.0%. However, there was no vole in Chunfeng site in January 2009, and the trap success of the voles in Beizhouzi site was also very low, only 0.7%, lower than the density of the voles when they just moved to the lake beaches last year, showing that the vole's population just moving to the lake beaches suffered a crushing blow. Under normal circumstances, the voles migrating to the lake beaches in autumn began to breed^[17-18], so the population quantity in January was larger than that of last October^[2-3]. Due to the autumn flood in 2008, the population quantity of the voles in Chunfeng site was still lower in subsequent years. The autumn flood in 2008 had small impacts on the population quantity of the voles in Beizhouzi site, because the site has a higher elevation than Chunfeng site. In 2009 and 2010, the population quantity was large in spring and summer, and then it went down in 2011. In a word, the dynamic variation of the vole's population in quantity during 2005-2008 could reflect the impacts of the Three Gor-

ges Project on the vole's population in Dongting Lake region.

Table 1 Trap successes of *Microtus fortis* in census sites of Dongting Lake beaches during 2008-2011

Year	Month	Chunfeng		Beizhouzi	
		Number of snaptraps//d	Trap success//%	Number of snaptraps//d	Trap success//%
2008	1	295	1.4	308	0.7
	4	291	31.6	284	16.6
	7	316	9.5 (Farmland)*	231	39.4 (June)
	10	308	2.9	315	1.9
2009	1	285	0	294	0.7
	4	226	0.9	224	21.9
	7	278	0 (Farmland)	294	5.8 (June)
2010	10	320	0	310	2.6
	1	250	0	238	5.5
	4	236	0	159	36.5
	7	217	0 (Farmland)	202	2.5
2011	10	277	0	266	0
	1	277	0	233	0.4
	4	281	0	279	1.5
	6	264	0.8 (Farmland)	233	0.4

Note: * means that the data were from farmland instead of the lake beaches because the lake beaches were flooded.

4 Potential impacts of the conversion from farmland into lake on the vole's population in Dongting Lake region

According to the plan, the conversion from farmland into lake in Dongting Lake region can be divided into two types, that is, one means that all human production and life activities are stopped and original dams have been eradicated, while the other means that people do not live in the beaches, but engage in agricultural production activities. Among them, only the first type can affect the expansion of lake beaches, and the beaches reconverted from farmland will undoubtedly become the potential habitats of the voles; now 206 km² of farmland has been converted into lake^[19]. In the 1990s, lake beaches had an area of 1 600-2 200 km² when the water level of Dongting Lake was low, and the area was increased by about 10% because of the conversion from farmland into lake. From 1978 to 1995, due to the deposition of lake sediments in Dongting Lake, the area of lake beaches was increased by 13.53 km² every year, so the area of beaches reconverted from farmland is almost equal to the area of lake beaches increased by the deposition of lake sediments in 15 years. Moreover, the beaches reconverted from farmland play the same role in become the habitats of the voles as the mature beaches formed by the deposition of 20% lake sediments, and the vegetation growing in the beaches increased determines whether they will become the habitats of the voles.

After the implementation of the conversion from farmland into lake, the number of herb species in the beaches reconverted from farmland converted into lake had a great change. Due to the interference of summer flood, the number of species, total frequency and coverage were the lowest in autumn, and the number of species was decreased, but coverage was increased. Owing to the

impacts of floods, there were few species in the mature lake beaches, but their number changed slightly among different seasons; the coverage in spring before flood coming was the highest^[20]. For example, the numbers of species in the beaches reconverted from farmland and meadow of lake beaches were similar in autumn of 2005, but the numbers of species in the beaches reconverted from farmland was increased obviously in the next spring, showing that the vegetation was still in the middle stage of the succession (Table 2). Besides, *Carex* spp. liked by the voles in the beaches reconverted from farmland had become the first dominant species, but its importance values were still lower than these of lake beaches, and the voles inhabited in some beaches reconverted from farmland^[20]. However, there was a big difference between the two kinds of beaches in the characteristics of the vole's population. As shown in Table 3, in the beaches reconverted from farmland, total trap successes of *M. fortis* during 2003–2011 was obviously lower than these of *Apodemus agrarius* ($\chi^2 = 1.744, P < 0.001$); in the mature lake beaches, *M. fortis* was the first dominant species, and total trap successes of *A. agrarius* was lower ($\chi^2 = 1.920, P < 0.001$).

Table 2 Characters of the plant communities in different habitats

Habitat	Season	Number of species		Importance value of <i>Carex</i> // %	
		2005	2009	2005	2009
Beaches reconverted from farmland	Spring	46	39	15.5	17.2
	Summer	33	26	14.4	26.5
	Autumn	16	25	28.6	31.2
Meadow of the lake beaches	Winter	26	27	30.0	31.7
	Spring	17	15	31.8	40.6
	Summer*	–	–	–	–
	Autumn	13	8	39.7	48.2
	Winter	13	9	44.9	50.6

Note: The beaches were flooded by water in summer.

Table 3 Total trap success of *Apodemus agrarius* and *Microtus fortis* in different habitats during 2003–2011

Species	Beaches reconverted from farmland		Meadow of the lake beaches	
	Number of animals	Total trap success // %	Number of animals	Total trap success // %
<i>Apodemus agrarius</i>	313	3.59	5	0.05
<i>Microtus fortis</i>	99	1.14	523	5.45

Correlation analysis shows that the proportion and dominance of *M. fortis* in the population had high correlation with each indicator of *C. spp.* community^[20]. The dominance of *M. fortis* was significantly correlated with the importance of *C. spp.* ($r = 0.770, P < 0.001, n = 16$) and highly significantly correlated with the appearance frequency, relative frequency, coverage and relative coverage of *C. spp.* ($r = 0.787, P < 0.001, n = 16$; $r = 0.882, P < 0.001, n = 16$; $r = 0.935, P < 0.001, n = 16$; $r = 0.916, P < 0.001, n = 16$). In addition, the dominance of *M.*

fortis in the beaches reconverted from farmland was only 0.2319, obviously lower than that of *A. agrarius* (0.7330). If the beaches reconverted from farmland become mature, they may be more suitable for *M. fortis* inhabiting, which will be a major hidden danger to local agricultural production. Additionally, other advantages of the beaches reconverted from farmland are favorable for the vole's population. First, due to previous levees, the beaches reconverted from farmland were submerged by floods more slowly than previous beaches, and the voles moved to some tables and previous levees during flood season, so the voles in the beaches reconverted from farmland were affected slightly by floods. It's worth noting that the voles left in the beaches reconverted from farmland in flood season did not move far, so they bred rapidly in summer (the voles moved far in flood season normally, and the breeding of the vole's population had a trough in summer^[18]), which would result in the increase of the vole's population in autumn and winter^[21]. If the inner conditions for the outbreak of the vole's population are mature, another outbreak of the vole's population may occur in some beaches reconverted from farmland. On the whole, the conversion from farmland into lake provides potential habitats for the voles, while the succession of vegetation in the beaches reconverted from farmland creates conditions for the voles inhabiting here, thereby inducing the outbreak of the vole's population.

5 Conclusions

In Dongting Lake region, the quantity of the vole's population varied greatly in various years, and the outbreak of the vole's population occurred in the 1970s, 1980s and middle 1990s. Moreover, it occurred every ten years and lasted for around five years. The outbreak of the vole's population in 2007 was the inevitable result of annual variation of the population, but the Three Gorges Project and the conversion from farmland into lake have promoted the outbreak. On the whole, the two projects are beneficial to national economic construction and eco-environment of local wetlands, but they have also promoted the outbreak of the vole's population, to which more attention should be paid. On the other hand, the autumn flood of 2008 decreased the quantity of the vole's population in the lake beaches in winter, and thereby reduced the number of the voles moving to farmland during the flood season in the next year. The outbreak of the vole's population in Dongting Lake region in 2007 set the world on fire, so that people were fearful that the spring drought in 2011 would result in the outbreak of the vole's population. However, the quantity of the vole's population in the lake region had decreased, so we inferred that the outbreak of the vole's population would not occur in 2011. In fact, the quantity of the vole's population was always low from the winter of 2010 to the spring of 2011. In Chunfeng site, there were no voles captured from the meadow of lake beaches from January to May in 2011; in Beizhouzi site, the trap successes of the voles from January to June in 2011 were 0.43%, 0, 0, 1.45%, 1.57% and 0.43% respectively. As the beaches reconverted from farmland changed into mature lake beaches and the Three Gorges Project in-

creased the emergence time and area of lake beaches ,total quantity of the voles in the lake beaches will reach a new peak , so the prevention and control of the voles should be paid more attention to. The voles inhabiting in the lake beaches can maintain material and energy flows of the ecosystem ,but they will damage crops after moving to farmland in flood season. The most effective prevention and control measure is to break their migration channels ,that is ,we can build a wall or set barriers and burry cylinders to prevent the voles from moving to farmland^[2-3]. Moreover ,the economic and ecological benefit of using physical means to control the voles migrating are much better than these of chemical ways^[4 22].

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occupation of farmland ,and damage of environment. Therefore , in the process of highway and urban construction , it is required to strengthen planning and guidance , integrate urban and rural development , and build ecological and garden city.

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