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Summer Breeding of *Microtus fortis* in the Dongting Lake Area

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Key words
Dongting Lake flood season, *Microtus fortis*, Migration, Reproduction, Temperature and Light Conditions, Wildlife

ABSTRACT

The Yangtze vole (*Microtus fortis calamorum* Thomas 1902) is the dominant rodent species in the beach habitat of Dongting lake, primarily inhabiting the beach during the drought season and being compelled to migrate to the farmland and hillocks during the flood season. The hydrological dynamics of Dongting Lake are divided into flood and drought seasons each year, with the flood season typically overlapping with the summer months from June to September. Previous studies indicated that *M. fortis* in Dongting Lake can reproduce throughout the year; however, its reproductive capacity is lower in summer, primarily influenced by high temperatures and light cycles. However, our latest study revealed that even when *M. fortis* has not experienced long-distance forced migration caused by impending floods, its reproductive capacity does not exhibit a significant decline. In some cases, it may even increase instead of decrease, despite entering new agricultural habitats and being influenced by summer temperature and light conditions. Observations of the reproductive behavior of *M. fortis* living under natural indoor temperature and light conditions also demonstrates that the reproductive patterns in summer do not show any inhibitory effects compared to the other three seasons. Therefore, we concluded that *M. fortis* in the Dongting Lake region is capable of year-round reproductive activity. The primary constraint on summer breeding is, in all probability, the requirement for long-distance forced migrations, rather than any inadequacy in adapting to novel habitats or unfavorable summer temperature and light regimes.

INTRODUCTION

The Yangtze vole (*Microtus fortis*) is the dominant rodent species inhabiting beaches around Dongting Lake, which is the most suitable habitat for this species. The hydrological dynamics of Dongting Lake are typically divided into drought and flood seasons. During the drought season, when lake beaches were exposed, *M. fortis* mostly resided on them. However, during the flood season (generally from June to September), rising water forces *M. fortis* to migrate passively to the farmland within the hillocks until the flood recedes, and they can actively return to the lake beaches.

In a study on the reproductive characteristics of *M. fortis* in the Dongting Lake area, Wu *et al.* (1996) suggested that this species can reproduce throughout the year, with the main breeding season occurring from early autumn to late spring of the following year, whereas the reproductive rate is extremely low in the summer. The observed decline in *M. fortis* reproductive rate during the Dongting Lake summer season warrants investigation, as various potential contributing factors exist. These include unfavorable temperature and light conditions, excessive energy consumption during passive migration, reduced reproductive capacity due to adaptation difficulties in farmland habitats, and environmental pressures, such as the dual-season rice cultivation system in the region, which limits the settlement and reproduction time of *M. fortis* and induces inter-species competition. Guo *et al.* (1999) suggested that high temperatures and light cycles in summer are the primary factors influencing the reproductive capacity of *M. fortis*, and the physical

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exhaustion caused by their passive migration to farmlands intensifies the impact.

Recently, the hydrological dynamics of Dongting Lake have undergone significant changes owing to extreme climatic conditions. The flood season will not occur until 2023, providing excellent natural conditions for studying the factors affecting *M. fortis* reproduction in the Dongting Lake area, as they no longer undergo forced migration. Based on survey data of *M. fortis* on lake beaches during the summer of 2023 and previous years, as well as observations from indoor breeding experiments, this study explored the reproductive issues of *M. fortis* in the Dongting Lake area.

MATERIALS AND METHODS

Overview of the study area

Dongting Lake (27°39′~29°51′ N, 111°19′~113°34′ E, Lake average elevation 33.5m) is located in the northern part of Hunan Province, on the southern bank of the Yangtze River's middle reaches, spanning counties and cities such as Yueyang, Miluo, Xiangyin, Wangcheng, Yiyang, Yuanjiang, Hanshou, Changde, Jinshi, Anxiang, and Nanxian. Dongting Lake belongs to the transitional zone from the subtropical region to the north subtropical region, characterized by distinct seasons, with an average annual temperature of 16–17 °C and an average annual rainfall of 1200–1550 mm. The lake area topography comprises lakes, rivers, impacted plains, surrounding hillocks, and low hills. The region receives abundant rainfall, but it is unevenly distributed throughout the seasons, with a long flood season (from June to September) and significant fluctuations in water levels throughout the year (Xie *et al*., 2014). We conducted a 20-year investigation of rodent reproductive conditions starting in 2003, covering the entire Dongting Lake area, with survey points distributed across the eastern, western, and southern parts of the lake.

Field survey methods

The investigation was conducted using the line transect method in the Dongting Lake area from 1992 to 1994 and 2003 to 2023. Typically, the investigations were conducted in January (winter), April (spring), July (summer), and October (autumn). During the survey, sunflower seeds were used as bait, and large iron traps were used for rodent capture. On lake beaches, the traps were s*et al*ong straight lines, whereas in farmland areas, they were placed along field ridges. In both cases, attention was paid to the distance between the survey lines and the flood control embankments, with a minimum separation distance of 150 m between the lines. Approximately 80 traps were set per survey line, spaced five m apart, resulting in approximately 300 traps per survey point. The traps were set in the late afternoon (17:00–19:00) and retrieved the following morning. The captured *M. fortis* specimens were weighed, and their body and tail lengths were measured. Additionally, reproductive conditions were observed through anatomical examinations, including testicle position in male mice, pregnancy status, and litter size in females.

Experimental design in the laboratory

The animals used in this study were provided by the Institute of Subtropical Agriculture, Chinese Academy of Sciences, and comprised offsprings produced from live captured individuals in the Dongting Lake area. Healthy, unrelated pairs of males and females were selected for breeding. Each breeding pair was individually housed in plastic cages with dimensions of 37 × 27 × 17 cm (length × width × height). They were fed with experimental animal basic maintenance feed from the Lescon Company, Hunan Province. Sterilized wood shavings were used for bedding and replaced regularly. Food and water were freely accessible. Indoor housing conditions were not controlled, allowing for natural fluctuations in temperature and light conditions. Litter size was recorded after breeding.

Statistical analysis

Based on the factors that limit *M. fortis* reproduction, three were selected: (A) long-distance forced migration caused by flooding, (B) migration to farmland habitats after flooding, and (C) summer temperatures and light conditions. Based on the actual survey data, these three factors were combined into the following categories: (1) ABC, (2) AB, (3) AC, (4) BC, and (5) C. First, after flooding, *M. fortis* undergoes long-distance migration into farmland habitats and is influenced by summer temperature and light conditions. The second combination implies that after flooding, *M. fortis* migrates into farmlands without being affected by summer temperatures and light conditions. The third combination implies that after flooding, *M. fortis* undergoes long-distance migration but does not enter farmland habitats while being influenced by summer temperatures and light conditions. The fourth combination implies that after flooding, *M. fortis* enters farmland without undergoing long-distance migration and is influenced by summer temperature and light conditions. The fifth combination implies that *M. fortis* neither undergoes long-distance migration nor enters farmland habitats and is only affected by summer temperatures and light conditions. Among these five combinations, selected data from specific years were chosen for analysis. The selected *M. fortis* specimens were all sub-adult and above, with age classifications based on carcass weight (Wu *et* *al*., 1996).

In data analysis, the reproductive index (♀) was calculated as the number of offsprings divided by the total number of rodents (female mice). The data normality was assessed using the one-sample Kolmogorov-Smirnov test. If the data were normally distributed, a t-test was used to compare the means. If the data did not follow a normal distribution, a nonparametric Mann–Whitney U test was employed. The chi-square test (X^2) or Fisher's exact test was used to compare the rate of testes in the scrotum in male mice, the pregnancy rate in female mice, and the breeding rate across different years. The mean values were presented as mean ± standard deviation (Mean ± SD), and $P < 0.05$ was considered statistically significant, while $P < 0.01$ was considered highly significant. The aforementioned analyses were performed using IBM SPSS Statistics 26, and figures were generated using OriginPro 2021 and Adobe Illustrator 2021.

RESULTS

Reproductive status of Microtus fortis *in the wild*

When all three factors are present, that is, when *M. fortis* undergoes long-distance migration into farmland and is influenced by summer temperatures and light conditions, the years available for data analysis in this scenario are 2007, 2008, 2012, 2020, and 2021. Overall (Table IA), *M. fortis* demonstrated a significant decrease in four reproductive parameters (rate of testes in the scrotum, pregnancy rate, breeding rate, and mean litter size) before and after flooding. Both reproductive indices I and I♀ decline from 0.97 and 2.69 to 0, with all female mice ceasing reproduction after flooding. Looking at each year separately (Table IB), changes in the six reproductive parameters of *M. fortis* before and after flooding consistently decreased. Particularly, the number of testes in the scrotum exhibited highly significant differences before and after flooding in 2007 and 2008. The pregnancy rate demonstrated highly significant differences before and after flooding in 2007, 2008, and 2012 and significant differences in 2020. Except for 2021, the breeding rate demonstrated significant differences before and after flooding in all years, with 2008 showing significant differences. Mean litter size exhibited highly significant differences before and after flooding every year, leading to the direct reproduction cessation. The most significant changes in the two reproductive indices before and after flooding occurred in 2008, with I decrease from 1.94 to 0 and I♀ decreasing from 4.68 to 0.

When flooding occurred earlier, forcing *M. fortis* to undergo long-distance migration into the farmland before being influenced by summer temperatures and light conditions, the years available for data analysis were limited to 1993 and 1994. Overall (Table IIA), *M. fortis* shows a decrease in six reproductive parameters (rate of testes in the scrotum, pregnancy rate, breeding rate, mean litter size, reproductive index, and reproductive index (♀))

Table I. Total reproductive status of *M. fortis* that migrated long distances to farmland after the flood and were affected by (A) summer temperature and light; (B) independent of summer temperature and light; (C) affected by summer temperatures and light but have not entered farmland; (D) in a flood-free year (2023).

Periods	Habitats	N	Rate of testes in scrotum (%)	Rate of pregnancy (%)	Rate of breeding (%)	Mean litter size (Mean±SD)	I	I♀
(A) Summer temperature and light								
Pre-flood	Beach	687	61.05**	49.19**	62.50**	5.48±1.05(2-8)**	0.97	2.69
Post-flood	Farmland	173	15.19**	0.00**	30.85**	0**	0.00	0.00
(B) Independent of summer temperature and light								
Pre-flood	beach	97	69.35**	51.43**	77.14*	5.56±1.46(4-9)	1.03	2.86
Post-flood	farmland	136	17.14**	6.06**	51.52*	4.25±0.83(3-5)	0.13	0.26
(C) Affected by summer temperatures and light but have not entered farmland								
Pre-flood	beach	244	69.74**	79.35**	84.78**	5.75±1.45(2-11)*	1.72	4.57
Post-flood	beach	241	42.75**	13.64**	41.82**	4.73±1.03(3-6)*	0.23	0.50
(D) In a flood-free year (2023)								
Pre-flood	beach	166	53.33**	24.59	50.82	4.40±1.58(1-8)	0.40	1.08
Post-flood	beach	206	71.88**	37.18	46.15	4.28±1.05(2-7)	0.60	1.59

* indicates that there is a significant difference in this parameter before and after the flood ($P < 0.05$), and ** indicates that there is a. significant difference in this parameter before and after the flood ($P < 0.01$); The range of litter sizes in parentheses in the column of mean litter size.

Table II. Reproductive status of *M. fortis* that migrated long distances to farmland after the flood and were (A) affected by summer temperature and light; (B) independent of summer temperature and light; (C) affected by summer temperatures and light but have not entered farmland.

Year	Periods	Habitats	N	Rate of testes in scrotum (%)	Rate of pregnancy/%	Rate of breeding (%)	Mean litter size (Mean±SD)	I	I♀
(A) Affected by summer temperature and light									
2007	Pre-flood	Beach	115	44.59**	41.46**	68.29*	5.12±0.76(3-6)**	0.76	2.12
	Post-flood	Farmland	89	7.14**	0.00**	31.91*	0.00**	0.00	0.00
2008	Pre-flood	Beach	128	64.00**	81.13**	86.79**	5.77±0.80(4-8)**	1.94	4.68
	Post-flood	Farmland	28	26.67**	0.00**	46.15**	0.00**	0.00	0.00
2012	Pre-flood	Beach	176	86.61	63.27**	83.67*	5.13±0.98(3-8)**	0.90	3.24
	Post-flood	Farmland	14	66.67	0.00**	37.50*	0.00**	0.00	0.00
2020	Pre-flood	Beach	66	41.18	37.50*	43.75*	5.92±1.55(2-8)**	1.08	2.22
	Post-flood	Farmland	23	0.00	0.00*	6.67*	0.00**	0.00	0.00
2021	Pre-flood	Beach	203	48.06	25.68	35.14	5.42±1.18(3-7)**	0.51	1.39
	Post-flood	Farmland	19	12.50	0.00	36.36	0.00**	0.00	0.00
(B) Independent of summer temperature and light									
1993	Pre-flood	Beach	24	92.31**	100.00**	100.00**	6.09±1.56(4-9)**	2.79	6.09
	Post-flood	Farmland	71	10.34**	0.00**	35.71**	0.00**	0.00	0.00
1994	Pre-flood	Beach	73	63.27*	29.17	66.67	4.71±0.70(4-6)	0.45	1.38
	Post-flood	Farmland	68	41.46*	14.81	70.37	4.25±0.83(3-5)	0.25	0.63
(C) Affected by summer temperatures and light but have not entered farmland									
2006	Pre-flood	Beach	74	75.47**	90.48**	95.24**	5.37±1.90(3-9)**	1.38	4.86
	Post-flood	Beach	75	34.29**	0.00**	40.00**	0.00**	0.00	0.00
2008	Pre-flood	Beach	128	64.00*	81.13**	86.79**	5.77±0.80(4-8)**	1.94	4.68
	Post-flood	Beach	149	47.19*	25.00**	45.00**	4.73±1.00(3-6)**	0.48	1.18
2009	Pre-flood	Beach	45	75.00	52.38**	57.14	6.36±2.14(2-11)**	1.56	3.33
	Post-flood	Beach	17	28.57	0.00**	30.00	0.00**	0.00	0.00

* indicates that there is a significant difference in this parameter before and after the flood ($P < 0.05$), and ** indicates that there is a significant difference in this parameter before and after the flood ($P < 0.01$); The range of litter sizes in parentheses in the column of mean litter size.

before and after flooding. The rate of testes in the scrotum and the pregnancy rate exhibited highly significant differences ($p < 0.01$), whereas the breeding rate also showed significant differences ($p= 0.012 < 0.05$). Although there was no significant difference in the mean litter size before and after flooding ($p = 0.115$), noticeable changes were still observed, and the extremes of the litter size range also decreased. Both reproductive indices I and I♀ decrease from 1.03 and 2.86 to 0.13 and 0.26, respectively. Looking at each year separately (Table IIB), changes in reproductive conditions before and after flooding were more significant in 1993 than in 1994, with all reproductive parameters showing significant decreases. In 1994, the number of testes in the scrotum decreased significantly after flooding.

When flooding occurs, and *M. fortis* undergoes long-distance migration without entering farmland, while being influenced by summer temperature and light conditions, the available years for data analysis in this scenario are 2006, 2008, and 2009. Overall (Table IC), there is a significant decrease in all reproductive parameters of *M. fortis* after flooding. The rates of testes in the scrotum, pregnancy, and breeding demonstrated highly significant differences, whereas the mean litter size also showed a significant difference ($p= 0.012 < 0.05$). Both reproductive indices, I and I♀, decreased from 1.72 and 4.57 to 0.23 and 0.50, respectively. Looking at each year separately (Table IIC), except for 2008, when *M. fortis* did not cease reproduction after flooding, 2006 and 2009 demonstrated reproduction cessation. Besides the number of testes in the scrotum ($p= 0.067$) and the rate of breeding ($p= 0.252$) in 2009, which did not exhibit significant differences, other reproductive parameters demonstrated a significant decrease after flooding ($p < 0.05$), mostly at a highly significant level (p

< 0.01).

When *M. fortis* entered the farmland after flooding and went through the summer without being affected by flooding, the available years for data analysis were limited to August 1993 and 1994 (Fig. 1). It can be observed that after entering farmland, although influenced by summer temperature and light conditions, *M. fortis* is in a recovery phase for all reproductive parameters. In 1994, despite a decline in June and July during the reproductive recovery process, the parameters recovered during the typical summer temperatures and light conditions in July and August.

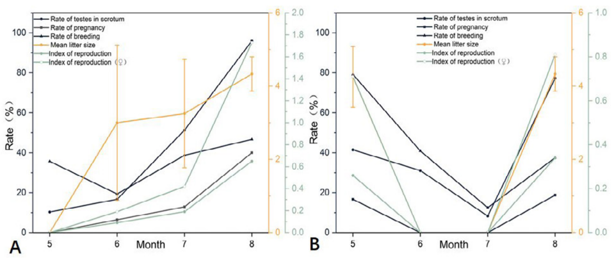

Fig. 1. *M. fortis* recovery process of reproduction in the summer after entering the farmland, the two charts are (A) in 1993 and (B) in 1994. The Y-axis of each line is the Y-axis of its color.

Given the extreme climatic conditions in 2023, the flood season did not occur in the Dongting Lake area. As a result, there was no large-scale migration of *M. fortis* into the farmland, and it was only influenced by summer temperature and light conditions. Looking at the reproductive status of *M. fortis* in this year (Table ID), there was a significant number of sub-adult *M. fortis* samples in both spring (166 individuals) and summer (206 individuals), with only the rate of testes in the scrotum showing a highly significant difference, which significantly increased from 53.33% to 71.88%. Although there were no significant differences in pregnancy rates or reproductive indices, they demonstrated an upward trend. The pregnancy rate increased from 24.59% to 37.18%, and both reproductive indices, I and I♀, increased from 0.40 and 1.08 to 0.60 and 1.59, respectively. The breeding rate and mean litter size remained stable.

Reproductive status of Microtus fortis *in the laboratory*

Table III presents the results of the indoor observations on the reproduction of *M. fortis*. Except for winter, *M. fortis* exhibited over 40 successful pregnancies during each of the other three seasons. The autumn season had the largest mean litter size, reaching 4.95±1.56 offsprings. Interestingly, there was one instance of an exceptionally large litter size in 11 offsprings. There were significant differences in the mean litter size between autumn and the other three seasons ($p_{\text{spring-autumn}} = 0.004 < 0.01$; $p_{\text{summer-autumn}} = 0.026 < 0.05$; $p_{\text{autumn-winter}} = 0.017 < 0.05$). While the mean litter size was the highest in summer at 4.09 ± 1.56 offsprings, exceeding those in spring and winter, the difference was not statistically significant.

Table III. Indoor reproduction of *M. fortis.*

Season	No.of pairs	No. of births	Mean litter size (Mean±SD)
Spring	15	46	3.76±1.74(1-8)[a]
Summer	15	46	4.09±1.56(1-9)[a]
Autumm	15	43	4.95±2.04(1-11)[b]
Winter	15	16	3.56±1.63(1-7)[a]

Letters in the mean litter size column indicate significant differences; the same means not significantly different from each other and different means significantly different from each other ($p < 0.05$); range of litter sizes in parentheses in the mean litter size column.

DISCUSSION

In this study, we established five scenarios based on the three factors that affect *M. fortis* reproduction in the Dongting Lake area. When *M. fortis* underwent long-distance forced migration, there was a significant decrease in the reproductive parameters before and after migration, as shown in scenarios (1), (2), and (3). Regardless of whether *M. fortis* enters farmland after migration, is influenced by the new agricultural environment, or is affected by summer temperatures and light conditions, its reproductive capacity is significantly limited after long-distance migration. However, when *M. fortis* did not undergo long-distance forced migration, as seen in scenarios (4) and (5), the reproductive capacity was not restricted. Based on our findings, long-distance forced migration may be the primary factor limiting the summer reproduction of *M. fortis* in the Dongting Lake area. This conclusion is supported over adaptation to the farmland environment or the effects of summer temperature and light conditions.

A previous study (Guo *et al.* 1999) suggested that summer temperature and light conditions were the main limiting factors for the reproduction of *M. fortis* in the Dongting Lake area. However, extreme climatic conditions observed in 2023 contradict this hypothesis. In the absence of the flood season, when *M. fortis* peacefully inhabits lake beaches without undergoing large-scale long-distance migration or entering a new agricultural environment, its reproductive capacity is not restricted. In fact, there was a significant increase in the rate of testes in the scrotum among males, as well as improvements in the pregnancy rate and reproductive indices. Even in the well-documented summers of 1993 and 1994, after migrating to farmland, *M. fortis* recovered its reproductive capacity despite rising temperatures. This recovery was especially evident in 1993, while the interruption in 1994 may be associated with frequent migration and re-migration of *M. fortis* due to significant fluctuations in flood conditions that year. Zhang *et al*. (2009) studied a small integrated *M. fortis* population in Huarong County, Hunan Province, and found that even after the reversion of farmland to lakes, the *M. fortis* population that remained in the dual-reverted embankments during summer maintained a high reproductive intensity compared to the lakeshore population in spring. This indicates that the *M. fortis* population that has not undergone long-distance migration still maintains a high reproductive intensity in the dual-reverted embankments during summer, in contrast to the sharp decline in reproductive capacity observed in the *M. fortis* population that is forced to migrate long distances into farmland during summer. This is similar to the findings of Sheng and Qian (1964) who investigated burrow communities in Guichi County, Anhui Province, China, in June 1960. They excavated 1258 burrow groups and obtained 1974 *M. fortis* samples. The total pregnancy rate of *M. fortis* weighing > 20 g was 33.0%, which was higher than the annual average for the Dongting Lake population (29.3%) and 12 times higher than the corresponding period. Their reproductive activity was also vigorous, indicating that, at least in early summer, as long as they do not undergo long-distance forced migration and have suitable habitats, *M. fortis* can still maintain a high reproductive capacity.

Under laboratory-controlled rearing conditions, *M. fortis* does not undergo long-distance forced migration caused by flooding or the influence of entering a new agricultural environment. Instead, it was only influenced by summer temperature and light conditions. In this scenario, summer reproduction is not restricted and may even be better than spring reproduction. This observation provides valuable insights even though we did not strictly record factors such as temperature and air humidity during the reproductive period.

Generally, heat stress (Hansen, 2009) has a significant impact on mammalian reproduction by affecting processes such as sperm production (Setchell, 1998; Hamilton *et al*., 2018; Capela *et al*., 2022), normal oocyte development (Zeron *et al*., 2001; Al-Katanani *et al*., 2002; De-Rensis *et al*., 2021), embryo development, placental growth, and lactation interruption (Wan *et al*., 2020; Iraqi *et al*., 2023). However, it appears that *M. fortis* is not affected by heat stress. This may be due to their burrow-dwelling lifestyle, spending extended periods underground during the day, and foraging at night. Consequently, the environmental temperature they experience does not reach the threshold required to cause heat stress. This particular factor was not considered in Guo *et al*. (1999). The utilization of exposed natural temperature and light conditions in their research may deviate from the actual circumstances. Additionally, although photoperiod can influence mammalian reproduction, small mammals in low-latitude regions are not sensitive to changes in photoperiod, as observed in *Peromyscus leucopus* populations in the southeastern United States (Lynch *et al*., 1981). These factors may partly explain why summer temperatures and light conditions are not the primary limiting factors for *M. fortis* in the Dongting Lake area.

Rodents of the *M.* genus prefer colder temperatures and are predominantly distributed north of latitude 35°. For example, *M.* species in North America are mainly distributed between 40° N and 70°N (Wolff, 1985), with very few species found south of latitude 30° (Rose and Birney, 1985). In high-latitude regions, where winters are cold, *M.* species primarily reproduce during summer and enter a reproductive quiescence period in winter (Keller, 1985). However, *M. fortis* in the Dongting Lake area exhibited distinct characteristics. It demonstrates year-round reproduction, and if not affected by flooding during summer, it can maintain a high reproductive capacity.

In the study of animal life histories, a fundamental axiom is the existence of trade-offs between different life history traits (Fisher, 1930). For instance, maximizing current reproductive output by increasing reproductive effort may occur at the expense of future survival or future reproductive output (Williams, 1966; Stearns, 1992; Charnov, 1993; Charlesworth, 1994). When *M. fortis* in the Dongting Lake area undergoes long-distance forced migration due to floodwater, it expends a considerable amount of energy. To ensure survival, it reduces the energy allocated to reproduction, resulting in a decrease in reproductive capacity. Additionally, upon migrating to a new environment, the challenges of finding food may increase, leading to delayed energy supplementation and the exacerbation of its impact.

Our study provides insights into the low summer reproductive capacity of *M. fortis* at Dongting Lake. By utilizing over 20 years of field survey data and data collected during the unique natural environment of 2023, we supplemented and corrected previous research findings. This study will help in preventing and controlling *M. fortis*, which is responsible for rodent outbreaks in the Dongting Lake area. This also holds significance for the study of reproduction in small mammals. However, this study did not investigate the specific mechanisms by which *M. fortis* is affected by flooding, nor did it consider the effects of population density constraints after migration. These aspects require further examination in future studies.

DECLARATIONS

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Ethical statement

All procedures in this study adhere to the guidelines for animal care and use specified by the Institute of Subtropical Agriculture, Chinese Academy of Sciences.

Generative AI or AI-assisted Technology Statement

The authors declare that no Genrative AI was used in the creation of this manuscript.

Statement of conflict of interest

There is no direct or indirect conflict of interest among the authors of this study. The organisms under study belong to the regional characteristic species, and the population data and reproduction data were obtained by the main author of this study during the field survey, and there is no conflict of interest with other organizations.

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