Zhang M and Xu Z, Archiv Zool Stud 2018, 1: 005
DOI: 10.24966/AZS-7779/100005

HSOA Archives of Zoological Studies

Review

The Effect of Three Gorge Project on the Small Mammals in Yangtze River of China

Meiwen Zhang[1]* and Zhenggang Xu[2]

[1]*Key Laboratory of Agro-ecological Processes in Subtropical Region/ Dongting Lake Station for Wetland Ecosystem Research, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha 410125, China*

[2]*Key Laboratory of Forestry Remote Sensing Based Big Data & Ecological Security for Hunan Province, Central South University of Forestry and Technology, Changsha 410004, China*

Abstract

Although most of the world's river systems are regulated by humans to some extent, information about the effects of river regulation on small mammals remains limited. This paper presents some studies of how the Three Gorge Project (TGP) affects small mammal community from published literature. The TGP represents one of the world's largest hydraulic projects. To control rodent-borne diseases during the large-scale hydraulic engineering construction, deratization in the area of Three Gorge Reservoir (TGR) had caused some changes in species compound of small mammal and the densities were keeping low. Studies from downstream of the dam (the Dongting Lake and Poyang Lake) showed that the hydrological and meteorological changes implemented through TGR operation might favor the small mammal community, resulting in higher species immigration to the beaches of lakes during the dry season. Those studies just presented some changes that have occurred in the small mammal community after the onset of TGR operation. It was not determined that the exact factors were had led to the observed changes in the small mammal community. Further research about succession mechanisms, and the factors that influence succession, is required through long-term surveys of the small mammal communities inhabiting the various habitats and its impact on public health.

Keywords: Beach; Dongting Lake; Poyang Lake; Rodentia; Small mammal; Three Gorge Reservoir

***Corresponding author:** Meiwen Zhang, Key Laboratory of Agro-ecological Processes in Subtropical Region/Dongting Lake Station for Wetland Ecosystem Research, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha 410125, China, Tel: + 86 13627485425; E-mail: zhangmw@isa.ac.cn

Citation: Zhang M, Xu Z (2018) The Effect of Three Gorge Project on the Small Mammals in Yangtze River of China. Archiv Zool Stud 1: 005.

Received: September 18, 2018; **Accepted:** November 06, 2018; **Published:** November 23, 2018

Introduction

China has the richest hydro resources on the planet; hence, the development of hydropower is of great importance to alleviate the energy crisis and environmental pollution resulting from this country's rapid economic growth during the 21st century [1,2]. The Three Gorge Project (TGP) represents one of the largest hydropower-complex and flood control projects in the world and has been ranked as the key project for the improvement and development of the Yangtze River. The project has economic and social benefits, such as preventing floods and associated disasters, adjusting water quantity, facilitating agricultural irrigation and generating energy. Although, the project has brought tremendous economic and social benefits also posed many adverse impacts on the eco-environment and society. Dams/ Reservoirs pose many environmental and ecological challenges and changing the temporal pattern of river discharge to downstream and ultimately the ocean [3].

Increasing numbers of scholars had assessed the effect of dam construction on river ecosystems, including water quality control, water and sediment regulation, biodiversity conservation in downstream areas and reservoirs [4-19]. In parallel, the impact of the TGP on the Yangtze River system had been the subject of much controversy since its launch [18,20]. Many studies had been conducted before and after the construction of the Three Gorges Reservoir (TGR) to determine its actual impact on the surrounding ecosystem [21-32].

There are some species of small mammals (mainly rodents) almost in all habitats. Small mammals, especially rodents, as the herbivores, and also the prey base for many predators, are an important link in food webs and energy flow in ecosystem. They play critical roles in ecosystem functioning, which constitute the primary link between primary producers and secondary consumers. Small mammals are also considered to be ecological indicators, because they are very sensitive to habitat changes. There have been some examples of ecological effects of river regulation on small mammals [33,34]. So the small mammal communities might be affected by the Three Gorge Dam (TGD) both in TGR area and downstream area of TGD along Yangtze River. Specially, small mammals were gotten the attention of the whole world for eruptive population of Yangtze vole (*Microtis fortis*) in Dongting Lake region in 2007 [35]. Although, there had been limited studies on the small mammal community, there were several study on the area of GTR, Dongting Lake and Poyang Lake area, which could reflect some general phenomena. Here, we conclude small mammal assemblage responses to changes induced by the hydroelectric dam in Yangtze River.

Small Mammals in the Area of Three Gorges Reservoir (TGRA)

Surveillance surveys in 19 townships of five points (Chongqing, Fengdu, Wanzhou, Fengjie and Yichang) in the TGRA near the Yangtze River from 1997 to 2012 showed that the dominant indoor species were *Rattus norvegicus*, *Mus musculus* and *Rattus tanezumi*, while Insectivora, *R. norvegicus* and *Apodemus agrarius* were the major species captured outdoors [36]. In order to prevent out breaks of rodent-borne diseases, sanitary clearance of the bottom of the reservoir and deratization were performed before every impoundment during the construction of the TGRA. Large-scale deratizations were carried out three times: in 2003 (when the Three Gorges reservoir first began storing water to 135m sea level), 2006 (storing water to 156m sea level) and 2008 (storing water to above 170m sea level). Surveillance data showed that a general decrease in both indoor and outdoor rodent densities [which was showed by relative population abundance, and was indicated by trap success, and calculated as the percentage of success in 100 traps: D = (100N/T) × 100%, where D is the relative population abundance, N is the number of animals caught by all traps and T is all traps collected] and sharp decreased after impoundment compared with before impoundment. After each deratization effort, the rodent density decreased sharply: 3.72% before 2003 to 0.15% in 2003; 1.98% before 2006 to 0.46% in 2006; and 3.41% before 2008 to 0.54% in 2008 [36].

Basing the surveys of Chang, et al. [36], the average indoor rodent density was 2.94%, with the highest and lowest recorded densities in 1997 (6.75%) and 2003 (1.37%), respectively; the average outdoor rodent density was 3.02%, highest in 1997 (7.19%) and lowest in 2006 (1.90%), which showed an overall decrease in the indoor and outdoor rodent density in the TGRA over time [36]. The deratization before impoundment had kept the low density in TGRA, which were reported also by other papers [37-42]. In total, the densities in TGRA did not increase following impoundment, although the small mammal population would migrate from inundated areas to regions of higher altitude due to riding water levels following impoundment.

On a larger scale, the compositions of the dominant species did not alter after impoundment, although the indoor and outdoor densities of different key rodent species changed differently over time [36]. Whereas, in some place of TGRA, such as Yichang, both the species and the predominant species of small mammal changed before and after impoundment [38,39]. As for the small mammal species composition, the indoor and outdoor dominant species before impoundment were *R. norvegicus* and those of the genus *Sorex*, accounting for 71.07% and 42.11%, respectively. The dominant species after impoundment, both indoor and outdoor, were *R. tanezumi*, accounting for 41.67% and 42.86%, respectively [39]. The result of the survey of rodent population by he in the upper of the dam also showed that the dominant species was *R. tanezumi* (28.24%) and the following were *A. agrarius* (26.47%), *M. musculus* (20.00%) and *Rattus losea*(14.71%) [43]. These observation might due to the tolerance of *R. tanezumi* and *A.agrarius* to drugs used for deratization and habitat change [44-45], for example the newly built houses for local immigration in the reservoir region after relocation, with harder floors are not suitable for ground-burrowing rodents such as *R. norvegicus*.

With full operation of hydroelectric facilities, as a result, some mountains had already become islands in the TGRA. A number of permanent and seasonal islands had been formed. After habitat insularization, the ecosystem functioning might be highly disrupted on small islands [46]. The investigation of the species composition and distribution of rodent populations at two geographic locations in the TGRA showed that the species richness of island and mainland rodent communities was not significantly different at either site, but the dominant species differed significantly between island and mainland habitats: the total rodent density on the islands was significantly higher than that of mainland areas [29]. Stable isotope analysis revealed that the dietary composition of rodents was more diverse on islands than at nearby mainland sites. Moreover, the island populations had greater overlap in food sources than did the mainland populations, suggesting more intense competition for food in the newly insularized habitats. Thus, habitat fragmentation due to the construction of the TGD might substantially increase intra- and inter specific competition among local rodent populations, leading to further changes in species composition and biodiversity [29].

Because *Anourosorex squamipes* utilized aquatic food sources, it had become the most abundant species on some island in TGRA. As water levels continued to rise and island area decreased, the population of *A. squamipes* might have an even greater advantage of food sources [29]. Some studies have already revealed that aquatic resources could serve as a complementary food source to fuel high reproduction among small mammal populations on islands [47].

In hydro-fluctuation belt of TGR, small mammals might move into the drawdown area of the reservoir [48]. The average capture rate was low and there was various species of rodent in hydro-fluctuation belt. The density and species composition of small mammals varied with different regions, altitude and monitoring time [42]. According surveillance by Liu, et al. [48] in June 2010, *A. agrarius* was the predominant species(80.65%), *R. tanezumi, A. squamipes* and *R. norvegicus* were also found; in September, *R. norvegicus* and *A. squamipes* were the predominant species. During 2010-2014, the captured small mammals were classified into six species: *A. agrarius, A. squamipes, R. norvegicus, R. tanezumi, M. musculus* and *R. edwardsi*. *A. agrarius* was the predominant species accounting for 46.55% and *A. squamipes* was next (25.86%) [42].

Small Mammals in the Downstream Area

Poyang Lake and Dongting Lake are the two largest freshwater lakes of the Yangtze River floodplain in China. Both lakes directly connect with the Yangtze River and represent the most frequently flooded areas in China. The region has asymmetrical annual precipitation, with 70~90% of total annual precipitation occurring during the rainy season, from May to October (with the greatest concentration of rain falling between May and July). For example, the annual water level of the Dongting Lake changes by as much as 15m, rising in summer and falling in winter. Both lakes extensively exchange water with the river, with the water level substantially elevating following the monsoon season, which is termed as a "winter-land, summer-water" ecohydrological condition that only favors a few rodents (such as *M. fortis* in Dongting Lake) that immigrate to the seasonal lake beaches.

Following the onset of TGR operation in 2003, the flow of the middle and lower reaches of the Yangtze River was altered, which in turn changed the exposure time (i.e., period not covered by water) of the beaches. During the water storage periods of the TGR, the water level of Dongting Lake decreased by 2.03m in 2006 and 2.11m in 2009 at the outlet of the lake, with extreme decreases of up to 3.30m and 3.02m, respectively [49]. Based on the regular pattern of beach emergence periods during the dry season, in parallel to simulated

water level data for the lake after TGD construction, Zou, et al., predicted that the period of low and medium level beach emergence in Dongting Lake would be significantly lengthened once the TGP was operational [50]. Furthermore, for the mid- and long-term periods (30 and 50 years) after the completion of the project, the emergence period of the entire beach is expected to gradually lengthen.

These changes in water level inevitably induced alterations to the inundation patterns of the wetlands of lakes, which, in turn, disturbed the ecological function of the lake wetlands as habitats for plant and animal communities. Therefore, the manipulation of flow regulation by the TGR might also influence the small mammal communities inhabiting the beaches of rivers and lakes in the middle reaches of the Yangtze River, downstream of the TGR. To date, a few small mammal studies have been conducted, with a focus on the small mammals inhabiting the beach areas in the Dongting Lake region and the Poyang Lake region [35, 51-55].

Small mammals in the beach of Dongting Lake area

Historical data for Dongting Lake showed that, before the TGP, extensive flooding in summer made the lake beaches unstable habitats for small mammal populations, other than *M. fortis* [54], with studies suggesting that the lake beach represented suitable living and breeding habitat for the vole living [56,57]. It was predicted that the regulation of water flow by the TGR might reduce water levels in fall and increase the amount of time that *M. fortis* had access to its preferred beach habitats, which would, consequently, result in larger vole populations and greater damage to surrounding crops [51,52]. The outbreak of the vole population in the Dongting Lake region during 2007 seemed to reasonably, support this forecast [35]. However, the percentage represented by the vole in species compositions has declined compared to that before dam operation, due to the immigration of other species, particularly the striped field mouse (*A. agrarius*) and the Norway rat (*R. norvegicus*), to beaches that were previously uninhabitable because of seasonally high water levels in the Dongting Lake region [54]. Out of the eight species captured on the beaches after the onset of TGR operation, only three (*M. fortis, R. norvegicus* and *M. minutus*) were recorded inhabiting the beaches during the 1990s (Table 1). Before the TGP, *M. fortis* was the only confirmed dominant species that inhabited the beaches of Dongting Lake. In comparison, once water was impounded by the TGR, *A. agrarius* and *R. norvegicus* became abundant (with marked population growth) [54]. In other words, the increase of *A. agrarius* and *R. norvegicus* in the species composition of beach habitats has caused the ratio of *M. fortis* to decline accordingly. Therefore, small mammals that are strongly affected by flooding would now benefit from the reduced extent and duration of water inundation because of water regulation management by TGR operations. The regulation of water discharged by the TGR had caused an increase in the species diversity (Diversity index included the dominant concentration, the Shannon-Weiner diversity index, the evenness index and so on) of the small mammal community on the beaches, which is becoming increasingly similar (Similarity coefficients included the Sorenon index and the Whittaker index) to that on farmlands adjacent to the lake [54].

Small mammals in the beach of Poyang Lake area

Although no studies of small mammal had not been published on the beaches surrounding Poyang Lake, based on the changes to the structure of the small mammal community described for Dongting Lake, Dai, et al., compared the communities of small mammal in beaches and farmland areas [55]. A similar situation has been documented around Poyang Lake following the TGP (Table 2). The numbers of small mammal species captured both on farmland and beaches was low (five species on farmland and four species on beaches). *A. agrarius* and *R. losea* were the dominant species on lakeside farmlands in the Poyang Lake region. Investigation of Poyang Lake showed that the species abundance and diversity indexes of the small mammal community on the beaches were similar to those on farm lands [55]. *A. agrarius, R. losea* and *R. norvegicus* were also found universally on the beach, suggesting that the farmland community has expanded to the beach habitat. Based on the similar structuring of the small mammal communities on the farmland and beach habitats of the Dongting Lake and Poyang Lake regions, the potential impact of the TGP on downstream lakes should be incorporated into future ecological impact assessments.

Conclusion of small mammals in beaches

Studies from the Dongting Lake and Poyang Lake showed more species of the small mammal immigrated to the beaches of lakes during the dry season. When flooding would normally occur, small mammals occupying beach habitats would be forced to aggregate on the dikes and migrate to farmland areas [58], with high population numbers potentially causing severe damage/losses to crops, as well as presenting a health hazard to humans. *A. agrarius* and *R. norvegicus* in Dongting Lake or *A. agrarius* and *R. losea* in Poyang Lake were found on all beaches after the onset of TGR water impoundment. Therefore, it is important to monitor fluctuations in the populations of small mammal to identify possible population outbreaks. In addition, shifts in the succession of the small mammal community structure on the beaches should be monitored, which may indicate potential trends leading to the outbreak of particular species.

Period	Species composition (%)*							
	Microtus fortis	*Apodemus agrarius*	*Rattus norvegicus*	*Micromys minutus*	*Niviventer fulvescens*	*Rattus nitidus*	*Suncus murinus*	*Erinaceus europaeus*
1990s	99.68 (622)	0.00	0.16 (1)	0.16 (1)	0.00	0.00	0.00	0.00
2003–2006	81.77 (314)	15.89 (61)	0.52 (2)	0.00	0.00	0.00	1.82 (7)	0.00
2007–2008	79.36 (919)	17.70 (205)	1.47 (17)	0.17 (2)	0.09 (1)	0.00	1.12 (13)	0.09 (1)
2009–2012	51.00 (559)	42.61 (467)	4.29 (47)	0.46 (5)	0.09 (1)	0.09 (1)	1.46 (16)	0.00
Total	74.00 (2414)	22.47 (733)	2.05 (67)	0.25 (8)	0.06 (2)	0.03 (1)	1.10 (36)	0.03 (1)

Table 1: Species composition of the small mammal community from 1992 to 2012 on the beaches of Dongting Lake (Zhang, et al., [54])#.

* The numbers in parenthesis are the animals of each species that were trapped.

Water storage (impoundment) was initiated at the TGR in a stepwise fashion from 135 m above sea level in late 2003, to 156m and 172m above sea level in late 2006 and late 2008, respectively (Fu, et al.,). From 2008 to 2012, experimental storage up to a final water level of 175m above sea level was conducted annually. Therefore, the evaluation of the small mammal communities was divided into four periods, based on the stage of water storage: (1) before construction in the 1990s, (2) the first partial filling period (2003-2006), (3) the second partial filling period (2007-2008), and (4) during experimental water storage to a final water level of 175m (2009-2012).

Period	Species composition (%)#					
	A. agrarius	*R. losea*	*R. norvegicus*	*M. musculus*	*M. minutus*	*S. murinus*
Beach	66.01 (101)	28.76 (44)	3.92 (6)	0.00	0.00	1.31 (2)
Paddy field	46.73 (157)	50.30 (169)	2.08 (7)	0.60 (2)	0.30 (1)	0.00
Dry field	80.65 (25)	19.35 (6)	0.00	0.00	0.00	0.00
Total farmland	49.59 (182)	47.68 (175)	1.91 (7)	0.54 (2)	0.27 (1)	0.00
Total	54.42 (283)	42.12 (219)	2.50 (13)	0.38 (2)	0.19 (1)	2 (0.38)

Table 2: Species composition of the small mammal community on lakeside farmland and beaches of the Poyang Lake region (Dai, et al., [55]).

The numbers in parenthesis are the animals of each species that were trapped.

Based on the index of diversity, the small mammal community on the beaches had already undergone major changes with a tendency toward diversification. TGD water regulation had created a transitional small mammal community, characterized by the encroachment of species from areas surrounding the lake into beach habitat. However, it remains unclear as to whether the observed changes will facilitate the control of rodent damage or whether the introduction of more species will generate greater damage to agricultural crops and human communities. Therefore, it is important to conduct studies on interspecies interactions.

Discussion

Although most of the world's river systems are regulated by humans to some extent, information about the effects of river regulation on small mammals remains limited. In fact, speculation about how river regulation affects mammal communities is more common than actual empirical data [33]. This paper presents some studies of how a dam, the TGP, affects a small mammal community. The TGP represents one of the world's largest hydraulic projects and, as such, has been the subject of much controversy. After decades of planning and 17 years of construction, the project has demonstrated comprehensive benefits with respect to various issues, including flood control, power generation and navigation. In parallel, various environmental and ecological issues have begun to emerge following the onset of TGR operation, particularly when operating at full capacity [10,20].

According to the results presented in reported study, in upstream area of the dam, impoundment had caused some changes in species compound of small mammal. The densities were keeping low as a whole duo to the deratization in the TGRA. Most investigation showed that measures that reduce rodent population densities could be effective in controlling rodent-borne diseases during the large-scale hydraulic engineering construction. Meanwhile, habitat fragmentation due to the construction of the TGD had led to further changes in species composition and biodiversity, nevertheless, the species richness of island and mainland rodent communities was not significantly different [29]. Along-term observations in Central Brazilian Amazonia showed small mammal assemblages further exhibited a nested structure in insular habitat, smaller and more isolated islands exhibited depauperate small mammal assemblages, in which some species were typically either missing or persisted at very low abundances [46]. So, it may need to have a long period of monitoring in TGRA.

Studies from the Dongting Lake and Poyang Lake showed that the hydrological and meteorological changes implemented through TGD operation might favor the small mammal community, resulting in higher species immigration to the beaches of lakes during the dry season. Water regulation might potentially affect small mammal communities by altering habitat, in addition to changing species movement and survival patterns [34, 59,60]. The possible underlying mechanism for such a shift in species distributions is the longer period of beach habitat exposure, which increases the opportunity for other species to establish home ranges and reproduce. It might be concluded that lake beach habitats have become suitable for harboring a broad variety of small mammal species, because of changes in habitat structure and composition (e.g., vegetation structure, habitat type, landscape composition, connectivity, substrate, moisture and size), in parallel to changes in flood regimes.

Those studies just presented some changes that have occurred in the small mammal community after the onset of TGR operation. It was not determined that the exact factors were had led to the observed changes in the small mammal community. Understanding how biodiversity is affected by hydropower projects is then of critical importance for management actions [46]. Therefore, future research should focus on determining to what extent and in what way the TGP has contributed toward changing the structure of the small mammal community inhabiting the up and downstream of TGD. Further research about succession mechanisms and the factors that influence succession, is required, through long-term surveys of the small mammal communities inhabiting the various habitats.

Meanwhile, it was said that leptospirosis and Hemorrhagic Fever with Renal Syndrome (HFRS) were endemic in Yangtze River. Rodents and Insectivora are the most important vectors of these diseases. Although effective deratization before impoundment during construction of the TGR likely helped to decrease the rodent density and prevent outbreaks of rodent-borne diseases, the development of some species of rodents and Insectivora in beaches of lakes downstream should be given more attention. They had immigrated to the beaches of lakes during the dry season, for example *A. agrarius, R. losea* and *R. norvegicus*. They are very important reservoir hosts of the causative pathogens of HFRS and leptospirosis. Specially, *A. agrarius*is the primary host of HFRS and leptospirosis, which also are remarkably resistant to many disease-causing pathogens, and have a strong potential to transmit diseases. Up to 17 diseases at least are known to be transmit by *A. agrarius*. Thus, long-term and effective surveillance of small mammal for monitoring future demographic changes as well as its impact on public health needs to be established.

Acknowledgment

The National Natural Science Foundation of China (30870402; 31170396), National Science and Technology Support Project of China (2012BAD19B02), National Key Technology Research and

Development Program of China (2014BAC09B03-02), Key Technology R&D Program of Hunan Province (2016TP1014), the Chinese Academy of Sciences (XXH13505-03-104) provided financial support for this study.

References

1. Huang H, Yan Z (2009) Present situation and future prospect of hydropower in China. Renewable and Sustainable Energy Reviews 13: 1652-1656.
2. Chang XL, Liu X, Zhou W (2010) Hydropower in China at present and its further development. Energy 35: 4400-4406.
3. Liu J, Zang C, Tian S, Liu J, Yang H, et al. (2013) Water conservancy projects in China: Achievements, challenges and way forward. Global Environmental Change 23: 633-643.
4. Rashad SM, Ismail MA (2000) Environmental-impact assessment of hydro-power in Egypt. Appl Energ 65: 285-302.
5. Brismar A (2004) Attention to impact pathways in EISs of large dam projects. Environ Impact Asses 24: 59-87.
6. Uowolo AL, Binkley D, Adair EC (2005) Plant diversity in riparian forests in northwest Colorado: Effects of time and river regulation. Forest Ecology and Management 218: 107-114.
7. McCartney M (2009) Living with dams: managing the environmental impacts. Water Policy 11: 121-139.
8. Tullos D (2009) Assessing the influence of environmental impact assessments on science and policy: An analysis of the Three Gorges Project. J Environ Manage 90: 208-223.
9. Berkun M (2010) Hydroelectric potential and environmental effects of multidam hydropower projects in Turkey. Energy Sustain Dev 14: 320-329.
10. Dai H, Zheng T, Liu D (2010) Effects of reservoir impounding on key ecological factors in the Three Gorges Region. Procedia Environ Sci 2: 15-24.
11. Zhai H, Cui B, Hu B, Zhang K (2010) Prediction of river ecological integrity after cascade hydropower dam construction on the mainstream of rivers in Longitudinal Range-Gorge Region (LRGR), China. Ecol Eng 36: 361-372.
12. Du L, Li Z, Liu B (2011) The pilot study on protection of the Three Gorge Reservoir wetland of Yangtze River. Procedia Environ Sci 10: 2484-2490.
13. Lin Q (2011) Influence of dams on river ecosystem and its countermeasures. Journal of Water Resource and Protection 3: 60-66.
14. Manzini F, Islas J, Macías P (2011) Model for evaluating the environmental sustainability of energy projects. Technol Forecast Soc 78: 931-944.
15. Nazareno AG, Lovejoy TE (2011) Energy production: Giant dam threatens Brazilian rainforest. Nature 478: 37.
16. Qiu J (2011) China admits problems with Three Gorges Dam. Nature.
17. Vaidyanathan G (2011) Dam controversy: Remaking the Mekong. Nature 478: 305-307.
18. Zhang QF, Lou ZP (2011) The environmental changes and mitigation actions in the Three Gorges Reservoir region, China. Environmental Science & Policy 14: 1132-1138.
19. Attwood SW (2012) Public health: Use snail ecology to assess dam impact. Nature 482: 162.
20. Fu BJ, Wu BF, Lü YH, Xu ZH, Cao JH, et al. (2010) Three Gorges Project: Efforts and challenges for the environment. Prog Phys Geog 34: 741-754.
21. Zheng J, Gu XG, Xu YL, Ge JH, Yang XX, et al. (2002) Relationship between the transmission of *Schistosomiasis japonica* and the construction of the Three Gorge Reservoir. Acta Trop 82: 147-156.
22. Jiao N, Zhang Y, Zeng Y, Gardner WD, Mishonov AV, et al. (2007) Ecological anomalies in the East China Sea: Impacts of the Three Gorges Dam? Water Res 41: 1287-1293.
23. Tian Z, Chen W, Zhao C, Chen Y, Zheng B (2007) Plant biodiversity and its conservation strategy in the in-undation and resettlement districts of the Yangtze Three Gorges, China. Acta Ecologica Sinica 27: 3110-3118.
24. Xie YH, Chen XS (2008) Effects of Three-Gorge Project on succession of wetland vegetation in Dongting Lake. Research of Agricultural Modernization 29: 684-687.
25. Yan Q, Yu Y, Feng W, Yu Z, Chen H (2008) Plankton community composition in the Three Gorges Reservoir Region revealed by PCR-DGGE and its relationships with environmental factors. J Environ Sci (China) 20: 732-738.
26. Liao J, Jiang M, Li L (2010) Effects of simulated submergence on survival and recovery growth of three species in water fluctuation zone of the Three Gorges Reservoir. Acta Ecologica Sinica 30: 216-220.
27. Yi Y, Wang Z, Yang Z (2010) Impact of the Gezhouba and Three Gorges Dams on habitat suitability of carps in the Yangtze River. Journal of Hydrology 387: 283-291.
28. Zhang JL, Zheng BH, Liu LS, Wang LP, Huang MS, et al. (2010) Seasonal variation of phytoplankton in the DaNing River and its relationships with environmental factors after impounding of the Three Gorges Reservoir: A four-year study. Procedia Environmental Sciences 2: 1479-1490.
29. Wang JZ, Huang JH, Wu JG, Han XG, Lin GH (2010) Ecological consequences of the Three Gorges Dam: insularization affects foraging behavior and dynamics of rodent populations. Frontiers in Ecology and the Environment 8: 13-19.
30. Wang L, Cai Q, Tan Lu, Kong L (2011) Phytoplankton development and ecological status during a cyanobacterial bloom in a tributary bay of the Three Gorges Reservoir, China. Sci Total Environ 409: 3820-3828.
31. Wang S, Dong RM, Dong CZ, Huang LQ, Jiang HC, et al. (2012) Diversity of microbial plankton across the Three Gorges Dam of the Yangtze River, China. Geoscience Frontiers 3: 335-349.
32. Zeng H, Yang X, Meng S, Wang H, Tang X, et al. (2011) Awareness and knowledge of schistosomiasis infection and prevention in the "Three Gorges Dam" reservoir area: A cross-sectional study on local residents and health personnel. Acta Trop 120: 238-244.
33. Nilsson C, Dynesius M (1994) Ecological effects of river regulation on mammals and birds: A review. Regulated Rivers: Research & Management 9: 45-53.
34. Falck MJ, Wilson KR, Andersen D (2003) Small mammals within riparian habitats of a regulated and unregulated aridland river. Western North American Naturalist 63: 35-42.
35. Zhang MW, Li B, Wang Y (2007) Analysis on causes of population outbreak of *Microtus fortis* in Dongting Lake region in 2007. Research of Agricultural Modernization 28: 601-605.
36. Chang ZR, Lu L, Mao DQ, Pan HM, Feng LG, et al. (2016) Dynamics of Rodent and Rodent-borne Disease during Construction of the Three Gorges Reservoir from 1997 to 2012. Biomed Environ Sci 29: 197-204.
37. Zhang LY, Yue MS, Dong DP (2005) Study on the Density of Rodents in Three Gorges Reservoir before and after the 2nd phase water storage. Chinese Journal of Vector Biology & Control1 6: 279-281.
38. Bing YX, Yong X, Xin Z, Yuan YH; Hao Z, et al. (2010) Analysis on changes of rodents density and species in Hubei-Yichang section of three gorges reservoir area before and after impoundment. Disease Surveillance 25: 813-815,819.
39. Bing YX, Yong X, Xin Z, Yuan YH, DeMing C, et al. (2010) Monitoring and trend analysis on disease vectors before and after impoundment of the Three Gorges Reservoir in Yichang, Hubei. Chinese Journal of Vector Biology & Control 21: 204-207.

40. Zhu BB, Li HF, Li ZJ, Xu Y, Dong M J, et al. (2010) Study on the trend of rodents in the Yichang section of the Three Gorges area from 1959 to 2009. Chinese Journal of Vector Biology & Control 21: 598-600.

41. Luo C (2013) Monitoring and analysis of rats and rodent-borne diseases in Three Gorges reservoir in Wanzhou from 1997 to 2009. Chinese Journal of Hygienic Insecticide & Equipments 19: 53-55.

42. Chang ZR, Lu L, Guo YH, Mao DQ, Zhao X, et al. (2016) The population dynamics of small mammals in Three Gorges Reservoirhydro‐fluctuation area, 2010-2014. Chinese Journal of Vector Biology & Control 27: 117-120.

43. He P (2008) Study of rodent's population and virus-taking status in Three Gorges Reservior Area during the third-phase sluice period. Master's thesis of Huazhong University of Science and Technology.

44. Zhang MW, Wang Y, Li B, Guo C, Chen AG (2003) Impact of anticoagulant rodenticide on rodent communities in agro-ecosystem in Yangtze Valley. Acta Ecologica Sinica 23: 320-329.

45. Zhang MW, Wang Y, Li B, Guo C, Chen AG (2004) The population recovery of rodent pests after application of anticoagulant in agro-ecosystem in the middle and lower reaches of Yangtze Valley. Acta Phytophylacica Sinica 31: 311-319.

46. Palmeirim AF, Benchimol M, Vieira MV, Peres CA (2018) Small mammal responses to Amazonian forest islands are modulated by their forest dependence. Oecologia 187: 191-204.

47. Stapp P, Polis GA (2003) Marine resources subsidize insular rodent populations in the Gulf of California, Mexico. Oecologia 134: 496-504.

48. Liu JL, Lu L, Guo YH, Wu HX, Wang J, et al. (2012) Surveillance of small mammals in drawdown area in the Three Gorge reservoir area，2010. Disease Surveillance 27: 456-458,484.

49. Sun Z, Huang Q, Opp C, Hennig T, Marold U (2012) Impacts and implications of major changes caused by the Three Gorges Dam in the Middle Reaches of the Yangtze River, China. Water Resource Management 26: 3367-3378.

50. Zou SL, Liu XQ, Liu XP, Guo C (2000) The impact of Three-Gorge Project on length of emergence period of Dongting lake beach. Resources and Environment in the Yangtze basin 9: 254-259.

51. Zou SL, Guo C, Liu XP (2000) The influence of lake beach's environmental evolution on the Yangtze vole disaster in Dongting Lake area. Journal of Natural Disasters 9: 118-122.

52. Zou SL, GuoC, Liu XP (2002) [Evaluation on the impacts of environmental changes and Three-Gorge Engineering on the population of Yangtze voles (*Microtus fortis*) in the Dongting Lake region]. Ying Yong Sheng Tai Xue Bao 13: 585-588.

53. Zhang MW, Wang Y, Li B, Huang GX, Guo C (2012) [Possible impacts of the Three Gorges Project and converting farmland into lake on the Microtus fortis population in Dongting Lake region]. Ying Yong Sheng Tai Xue Bao 23: 2100-2106.

54. Zhang MW, Wang Y, Li B, Guo C, Huang GX, et al. (2014) Small mammal community succession on the beach of Dongting Lake, China after the Three Gorges Project. Integr Zool 9: 294-308.

55. Dai NH, Lu P, Zhang MW, Zhang GH, Zhang C, et al. (2018) Small mammal communities on beaches and lakeside farmland in the Poyang Lake region after the Three-Gorges Project. Mannalia, 82: 438-448.

56. Wu ZJ, Chen AG, Li B, Guo C, Wang Y, et al. (1996) Studies on the breeding characteristics of Yangtze vole (*Microtus fortis*) in Dongting Lake area. Acta Theriologica Sinica 16: 142-150.

57. Xu ZG, Zhao YL, Li B, Zhang MW, Shen G, et al. (2015) Habitat evaluation for outbreak of Yangtze voles (*Microtus fortis*) and management implications. Integr Zool 10: 267-281.

58. Guo, C, Wang Y, Chen AG, Li B, Zhang MW, et al. (1997) Study on the migration of Microtusfortisin Dongting Lake area. Acta Theriologica Sinica17: 279-286.

59. Andersen DC (1994) Demographics of small mammals using anthropogenic desert riparian habitat in Arizona. J Wildlife Manage 58: 445-454.

60. Andersen DC, Wilson KR, Miller MS, Falck M (2000) Movement patterns of riparian small mammals during predictable floodplain inundation. J Mammal 81: 1087-1099.

Journal of Anesthesia & Clinical Care

Journal of Addiction & Addictive Disorders

Advances in Microbiology Research

Advances in Industrial Biotechnology

Journal of Agronomy & Agricultural Science

Journal of AIDS Clinical Research & STDs

Journal of Alcoholism, Drug Abuse & Substance Dependence

Journal of Allergy Disorders & Therapy

Journal of Alternative, Complementary & Integrative Medicine

Journal of Alzheimer's & Neurodegenerative Diseases

Journal of Angiology & Vascular Surgery

Journal of Animal Research & Veterinary Science

Archives of Zoological Studies

Archives of Urology

Journal of Atmospheric & Earth-Sciences

Journal of Aquaculture & Fisheries

Journal of Biotech Research & Biochemistry

Journal of Brain & Neuroscience Research

Journal of Cancer Biology & Treatment

Journal of Cardiology & Neurocardiovascular Diseases

Journal of Cell Biology & Cell Metabolism

Journal of Clinical Dermatology & Therapy

Journal of Clinical Immunology & Immunotherapy

Journal of Clinical Studies & Medical Case Reports

Journal of Community Medicine & Public Health Care

Current Trends: Medical & Biological Engineering

Journal of Cytology & Tissue Biology

Journal of Dentistry: Oral Health & Cosmesis

Journal of Diabetes & Metabolic Disorders

Journal of Dairy Research & Technology

Journal of Emergency Medicine Trauma & Surgical Care

Journal of Environmental Science: Current Research

Journal of Food Science & Nutrition

Journal of Forensic, Legal & Investigative Sciences

Journal of Gastroenterology & Hepatology Research

Journal of Gerontology & Geriatric Medicine

Journal of Genetics & Genomic Sciences

Journal of Hematology, Blood Transfusion & Disorders

Journal of Human Endocrinology

Journal of Hospice & Palliative Medical Care

Journal of Internal Medicine & Primary Healthcare

Journal of Infectious & Non Infectious Diseases

Journal of Light & Laser: Current Trends

Journal of Modern Chemical Sciences

Journal of Medicine: Study & Research

Journal of Nanotechnology: Nanomedicine & Nanobiotechnology

Journal of Neonatology & Clinical Pediatrics

Journal of Nephrology & Renal Therapy

Journal of Non Invasive Vascular Investigation

Journal of Nuclear Medicine, Radiology & Radiation Therapy

Journal of Obesity & Weight Loss

Journal of Orthopedic Research & Physiotherapy

Journal of Otolaryngology, Head & Neck Surgery

Journal of Protein Research & Bioinformatics

Journal of Pathology Clinical & Medical Research

Journal of Pharmacology, Pharmaceutics & Pharmacovigilance

Journal of Physical Medicine, Rehabilitation & Disabilities

Journal of Plant Science: Current Research

Journal of Psychiatry, Depression & Anxiety

Journal of Pulmonary Medicine & Respiratory Research

Journal of Practical & Professional Nursing

Journal of Reproductive Medicine, Gynaecology & Obstetrics

Journal of Stem Cells Research, Development & Therapy

Journal of Surgery: Current Trends & Innovations

Journal of Toxicology: Current Research

Journal of Translational Science and Research

Trends in Anatomy & Physiology

Journal of Vaccines Research & Vaccination

Journal of Virology & Antivirals

Submit Your Manuscript: http://www.heraldopenaccess.us/Online-Submission.php

Herald Scholarly Open Access, 2561 Cornelia Rd, #205, Herndon, VA 20171, USA.
Tel: +1-646-661-6626; E-mail: info@heraldsopenaccess.us
http://www.heraldopenaccess.us/