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A Study on the Response of Oncomelania Hupensis Diffusion to the Flow Regime of Dongting Lake

A Study on the Response of Oncomelania Hupensis Diffusion to the Flow Regime of Dongting Lake

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Abstract: The Dongting Lake is an area with most widely distributed *Oncomelania Hupensis* and most serious schistosomiasis epidemic region in China. In order to reveal the response of *Oncomelania Hupensis's* diffusion to the flow regime, this paper provides a set of flow condition parameters for correlating the diffusion and bred location of *Oncomelania Hupensis* with the flood level. Among eight parameters of flow condition, mean water level in flood season is the most one correlated with the change of flow condition in a flood year. It was illustrated that there was a quantitative relationship between the diffusion of *Oncomelania Hupensis* in Dongting Lake and the mean water level during flood season at Chenglingji Station. The result shows that there is a significant linear correlation between *Oncomelania Hupensis* area and mean water level during flood season in Dongting Lake. The research results not only are helpful for the forecast and prevention of schistosomiasis epidemic situation, but also technically support the spot check and killing of *Oncomelania Hupensis*.

Key words: *Oncomelania Hupensis*; Diffusion; Water flow parameters; Schistosomiasis; Dongting Lake

Introduction

Schistosomiasis is one kind of regional verminosis in human being and animals. Oncomelania Hupensis, the only in-between lodging host of schistosoma japonicum in China，lives in wet and shade environment where the inundated time ranges from 3 to 8 months each year. 94.4% of areas where Oncomelania Hupensis distributes are in Hunan, Hubei, Anhui, Jiangxi, Jiangsu provinces, and Hunan province takes 45.9%, which mainly locates in the Dongting Lake. The Dongting Lake is the area with most widely distributed *Oncomelania Hupensis* and most serious schistosomiasis epidemic situation in China.

The Dongting Lake made up of 6 water systems (Xiang, Zi, Yuan, Li, Miluojiang and Xinqiang river), 3 floodways (Songzi, Hudu and Ouchi), 3 lake basins (eastern, southern and northern lake), 228 protective embankments and an exit (Qilisan), linked with the Yangtze River by its floodways in Jingjiang River and the Qilisan exit, is a complicated and huge lake system with flow regime. In addition, the numerous protective embankments, complex canal systems as well as flat lakes lead to frequent floods during flood season followed by more serious flood disasters in Dongting district together with larger areas of *Oncomelania Hupensis*. It is obvious that the floods bring about *Oncomelania Hupensis* to diffuse and regenerate in bred location of Dongting Lake. This paper, by analyzing the diffusion trend of *Oncomelania Hupensis* and the flow regime process in Dongting Lake, is about to focus on the quantitative relationship between *Oncomelania Hupensis* diffusion and the flow regime, as to be not only contributed to the forecast and prevention of schistosomiasis epidemic situation, but also a technically support to the spot

checking and the perishing of *Oncomelania Hupensis*.

1 Floodwater influence on *Oncomelania Hupensis* diffusion in Dongting Lake

1.1 The change of Oncomelania Hupensis area in Dongting Lake

The areas of *Oncomelania Hupensis* are mainly centralized in the bottomlands out of dyke-enclosed places, and the diffusion of *Oncomelania Hupensis* in Dongting Lake is mostly influenced by the seasonal flood in the main stream of the Yangtze River and the flood in the Dongting Lake basin. The frequently seasonal floods in the Yangtze River and Dongting Lake valley cause *Oncomelania Hupensis* in the bottomland out of dyke-enclosed places to diffuse to inside, and then the areas of *Oncomelania Hupensis* in Dongting Lake (fig.1 [2]) are showing a trend of continuous growth from year to year. The areas of *Oncomelania Hupensis* increase 902hm^2, 4335hm^2, 2722hm^2, respectively, in comparison to the figures before in 1991, 1996, 1998, and there has been an appreciable increase in 1996 and 1998. The reason for the appreciable increase is that the floods destroyed many protective embankments and caused the serious diffusion of *Oncomelania Hupensis*. For example, there are 145 flood-destroyed protective embankments and 15.26×10^{4}hm^2 inundated area in 1996, while the flood in 1998 has destroyed 142 protective embankments and inundated 4.42×10^{4}hm^2[3,4]. So flood-destroyed protective embankments is the main factor that causes the serious diffusion of *Oncomelania Hupensis* in Donting Lake.

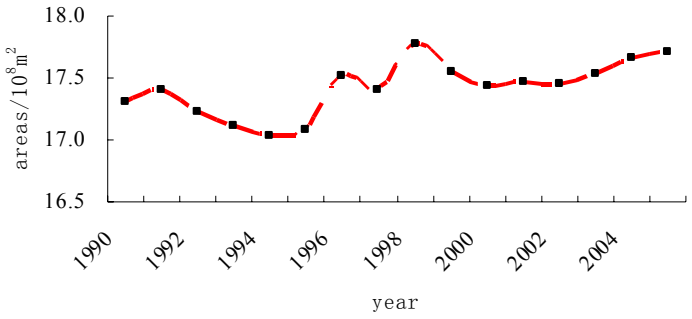

Fig.1 change of Oncomelania Hupensis area in Dongting Lake

1.2 Flood Influence on *Oncomelania Hupensis* diffusion in Dongting Lake

Oncomelania Hupensis, the only in-between lodging host of schistosoma japonicum, lives in weedy, shade environment with grass and involved the alternation of on land and in water. There is a vast expanse of wet and shade environment in Dongting Lake for *Oncomelania Hupensis* to breed, grow and diffuse. The headstreams of schistosomiasis commonly locate in the bottomlands out of dyke-enclosed places, which take up 96.2% of Oncomelania hupensis area of the whole Dongting Lake. Sediment accumulation and the high flood level weaken the overall capacity of protective embankments to withstand floods which cause waterlog and flood-destroyed embankments disaster. Flood caused *Oncomelania Hupensis* and epidemic water from outside of protective embankments to inside of ones, and then *Oncomelania Hupensis* will recur in the villages, land and shallow water area where *Oncomelania Hupensis* has been killed

ago. At the same time, a large number of trenches and brakes used for flood control and irrigation provide various routes of transmission for the diffusion of *Oncomelania Hupensis*. Therefore, there has been forming an out-in–out-in bad cycle with *Oncomelania Hupensis's* diffusion in Dongting Lake. At present，the flood is still the primary carrier of *Oncomelania Hupensis's* diffusion in Dongting Lake.

The flood impacts on *Oncomelania Hupensis's* diffusion can be summarized as following:

(1) Heavy floods result in a large-area diffusion of *Oncomelania Hupensis*. With more flood flow and higher flood level, there will be higher risk of dike bursting and larger areas *Oncomelania Hupensis* expands by floating in floodwater. In that case more *Oncomelania Hupensis* could be founded in bottomlands after a heavy flood and the areas where *Oncomelania Hupensis* distributes could be sequentially enlarged. In contrast, small flood discharge leads to low water level, and then the diffusion of *Oncomelania Hupensis* caused by flood will be lessened, which will not destroy the protective embankments and cause a large area of *Oncomelania hupensis* diffusion. So smaller flood will affect less on *Oncomelania Hupensis's* diffusion and its distribution in space.

(2) Heavy floods can reduce the density of living *Oncomelania Hupensis* in the survivable environment. Influenced by high flood level during flood season, floodwater not only inundates the spawning season of *Oncomelania Hupensis*, and reduces the density of living *Oncomelania Hupensis* and its breeding ability in bottomlands, but also prolongs the inundated time of bred location of *Oncomelania Hupensis*. Generally, the longer the duration of high flood level in bred location of *Oncomelania Hupensis* ,the more death in inundated bottomlands because *Oncomelania Hupensis* in water will die for a long time over 8 months, so the density of living Oncomelania hupensis in bottomlands will reduce. At the same time, when *Oncomelania Hupensis* floats to other place in floodwater, it will reduce the density of living *Oncomelania Hupensis* in the bred location.

(3) Heavy floods will increase the areas of *Oncomelania Hupensis*, but there is some lag effects compared with the flow regime which is more obvious in sister-flood years (floods happened in two continuous years) than in a single year, and the lag time may be 2~3 year or longer. The lag effect is not because of the increase of *Oncomelania Hupensis's* area lag flow regime of flood, but for the characteristic of *Oncomelania Hupensis's* diffusion and the limit of spot check of Oncomelania hupensis.

(4) The lag effect is more obvious in mainstream epidemic places than the epidemic places in lake districts.

2 Water flow parameters for *Oncomelania Hupensis's* diffusion in Dongting Lake

2.1 Characteristics of flow regime in Dongting Lake

Influenced by the water from Xiang, Zi ,Yuan, Li rivers and the change of the relation of the Yangtze River and the Dongting Lake, the flow regime in Dongting Lake shows some changeable characteristics as following: ①Influenced by the changes of water-sediment relation in Yangtze and Dongting Lake, flow discharge and sediment from three entrances of Jingjiang inflow to Dongting Lake have been reducing gradually, especially sediment discharge reduced greatly, so

the runoff, sand and sediment flowing into Dongting Lake have been on the decrease. ②Influenced by the integrated effect of heavy silting, enclosure and environmental system function transformation in Dongting Lake, the floodwater level of Dongting Lake is driven up during main flood season. ③The water-sediment relation in Yangtze and Dongting Lake has changed the back relation of outflow in Jingjiang River and Dongting Lake. As the relation between rivers and lakes changes further, backwater effect of outflow of Jingjiang River on Dongting Lake will enhance gradually, which would produce unfavorable effects on Qilishan outflow and sediment and water level during flood season in Dongting Lake. The new flow regime is the fundamental reason of frequent flood and waterlog disaster and Oncomelania hupensis diffusion in recent years. It not only brings the pressure of flood control and the risk of schistosomiasis epidemic infection, but also creates a bad epidemic situation control and *Oncomelania Hupensis's* diffusion.

2.2 Water flow parameters for *Oncomelania Hupensis* diffusion in Dongting Lake

Water flow parameters for Oncomelania hupensis diffusion are required to reflect the relationship between the flow regime and the district where *Oncomelania Hupensis* can be bred and distribute on one coin, and on the other coin the rule and characteristic of flow regime during flood season. The diffusion of *Oncomelania Hupensis* is mainly influenced by the hydrological factors such as flood level, flood discharge, high water level and its duration etc, while the bred location of *Oncomelania Hupensis* is mainly influenced by the factors of water condition such as change in scour and silting, change in water level, inundated height and inundated time in some height etc. Thus it can be seen that the influenced factors of the diffusion and bred location of Oncomelania hupensis are related to water level and flood discharge in flood season. Furthermore, water level, related to flood discharge nearly, can reflect the change of dry and wet in the bred location of *Oncomelania Hupensis*. Thus some characteristic water levels during flood season or other characteristic time are selected as the indicating parameters for *Oncomelania Hupensis's* diffusion to analyze the relationship between *Oncomelania Hupensis's* diffusion and the flow regime in Dongting Lake.

Indicating parameters for the change of water level during flood season mainly include the mean water level in flood season, the maximal water level and its appearance time, the duration of high water level which exceeds the maximal survival height of *Oncomelania Hupensis*. But considering the influence of flood on the diffusion and bred location of *Oncomelania Hupensis*, 8 indicating parameters are selected, which include the mean water level in flood season, the maximal water level and its appearance time, the duration of high water level ,days of inundated time less than one month, days of inundated time less than three months, days of inundated time between 5~6months, days of inundated time more than 8 months, water level scope of inundated time between 3~8months, water level scope of inundated time between 5~6months. Influence of indicating parameters on the diffusion and bred location of *Oncomelania Hupensis* is showed in tab.1.

Tab.1 water flow parameters for correlating the diffusion and bred location of *Oncomelania Hupensis*

Parameter style	parameters	characteristic
Integrated parameters	mean water level during flood season	Reflect the influence of flow regime on the diffusion and bred location of *Oncomelania Hupensis*
	maximal water level and its appearance time	It is most possible that *Oncomelania Hupensis* diffuses with flotage or floating in floodwater
	duration of high water level (maximal survival level of Oncomelania hupensis)	It is most possible that *Oncomelania Hupensis* diffuse to maximal Survival curve or down reaches and the duration which influences the diffusing scope of Oncomelania hupensis
Single parameters	days of inundated time less than one month	Diffusing time of Oncomelania hupensis by high flood level
	days of inundated time less than three months	Reflect the inundated time in no-*Oncomelania Hupensis* zone (higher than the maximal survival curve) and the fluctuant change of maximal survival curve. If it is more than 90, the maximal survival curve will move upward, otherwise, it will move downward
	days of inundated time between 5~6months	inundated time of optimum bred location of *Oncomelania Hupensis*
	days of inundated time more than 8 months	Reflect the inundated time in no-*Oncomelania Hupensis* zone (lower than minimal survival curve) and the fluctuant change of minimal survival curve. If it is more than 240, the minimal survival curve will move downward, otherwise, it will move upward
	water level scope of inundated time between 3~8 months	Reflect the fluctuating scope and its move direction of bred location zone response to flow regime
	water level scope of inundated time between 5~6 months	Reflect the fluctuating scope and its move direction of optimum bred location zone response to flow regime

3 A Study on the Response of *Oncomelania Hupensis* diffusion to the flow regime of Dongting Lake

3.1 Characteristic parameters' analysis of flow regime in Dongting Lake

The flow regime of Dongting Lake is influenced by the flood in the upper and middle reaches of the Yangtze River and that in Dongting drainage area, but the influence of flood from the Yangtze mainstream is especially remarkable, and the water level during flood season is also controlled by that of the Yangtze mainstream. It is well-known that the Yichang Station is the flood controlled station in the upper reaches of the Yangtze River while the Chenglingji Station is the flood controlled station in the upper and middle reaches of the Yangtze River and that in Dongting drainage area, so the Chenglingji Station is selected as the characteristic station to reflect the change of flow regime in Dongting Lake. With the statistic analysis of day-to-day water level at the Chenglingji Station from 1995 to 2006, the annual mean values of the characteristic

parameters are obtained respectively. For example, the mean value of water level during flood season is 29.10m, the mean water level which the inundated time equals to one month is 30.95m. All of the annual mean values of the characteristic parameters and the flow regime changes at the Chenglingji Station from 1995 to 2006 are showed in tab.2.

Tab.2 characteristic parameters' statistical analysis of the flow regime at Chenglingji Station from 1995 to 2006

parameter type	Parameters name	mean values (m)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Integrated parameters	mean water level during flood season(m)	29.10	29.02	29.35	27.51	31.42	30.34	28.20	27.61	30.05	29.00	28.53	29.01	26.13
	maximal water level(m)		33.65	35.27	32.56	35.92	35.67	31.84	29.86	34.88	33.6	32.05	31.6	29.68
	days of inundated time less than 1 month	30.95	37	51	16	88	67	20	0	47	22	10	21	0
	days of inundated time less than 3 months	28.49	91	82	43	109	103	108	59	119	84	78	109	20
	days of inundated time between 5~6months					36	30	17	53	38	23	20	34	27
Single parameters	days of inundated time more than 8 months	22.94				272	224	245	231	262	238	230	262	217
	water level scope of inundated time between 3~8months(m)	22.94 ～ 28.49				23.46 ～ 30.54	20.88 ～ 29.88	22.96 ～ 28.87	22.18 ～ 27.80	23.22 ～ 29.70	22.79 ～ 28.12	22.56 ～ 28.16	23.24 ～ 28.88	22.36 ～ 25.80
	water level scope of inundated time between 5~6months(m)	24.62 ～ 26.07				25.55 ～ 26.82	25.50 ～ 26.58	24.49 ～ 27.20	25.25 ～ 25.95	24.68 ～ 25.82	24.68 ～ 26.66	24.37 ～ 26.46	24.94 ～ 26.60	23.59 ～ 23.93

Analyzing the statistic results of these parameters, some characteristic changes of the flow regime in Dongting Lake are described as following:

(1) The maximal water level during flood season has a great and direct influence on the distance and scope of *Oncomelania Hupensis*'s diffusion. Generally speaking, the higher the flood level will be, the stronger ability *Oncomelania Hupensis* is taken with floodwater or some flotages in floodwater, the further distance *Oncomelania Hupensis* diffuses with flood. On the contrary, the smaller influence the diffusion of *Oncomelania Hupensis* is influenced by the flood. Whereas, the influence of the mean water level on the diffusion of *Oncomelania Hupensis* is similar to the former, but the latter could synthetically reflect the accumulative influence of the flow regime on the diffusion and bred location of *Oncomelania Hupensis* during the whole flood season. With the contrastive analytical results of the mean water level and the maximal water level in flood season (fig.2), there is a significant linear correlation between the mean water level and the maximal water level, and the relationship is showed in the formulation of $y=1.3467x - 5.8006$（$r=0.7865$，$p<0.05$）where y stands for the areas of Oncomelania hupensis with unit of hundred million m^2, x stands for the mean water level at Chenglingji Station during flood season with unit of m.

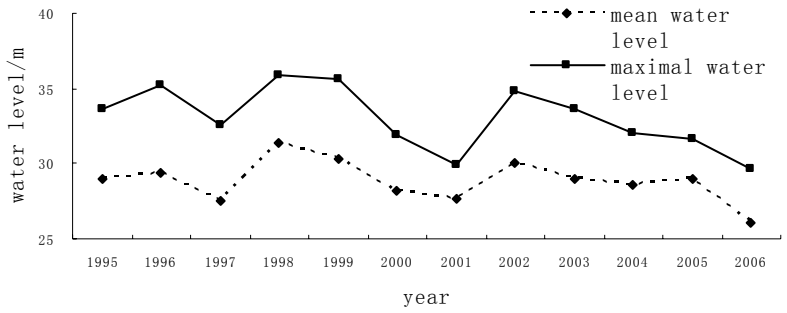

Fig. 2 change trends of the mean and highest water level in flood season in Dongting Lake

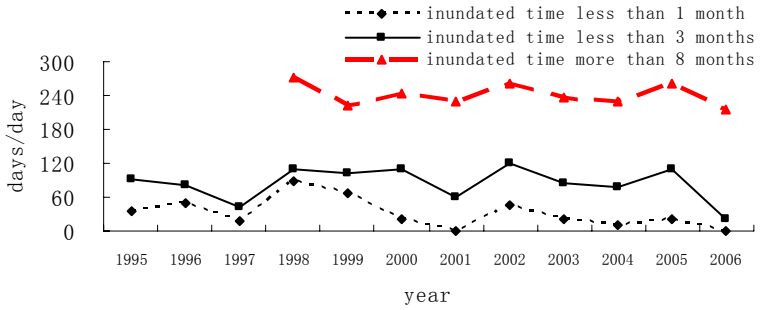

Fig.3 changes of water flow parameters in Dongting Lake

(2) With the contrastive analysis result of the changes of flow water parameters in recent 12 years (fig.3), there are the cohensive consistency in the different inundated times. In other words, there is a significant linear correlation between the mean water level and the days of inundated time less than one month or three months, and no-significant linear correlation between the mean water level and the days of inundated time more than 8 months. The relationship between the mean water level and the days of inundated time less than one month is showed in the formulation of $y=17.582x - 475.62$ ($r=0.8315$, $p<0.05$), and the relationship between the mean water level and the days of inundated time less than three months is showed in the formulation of $y=17.625x - 424.69$ ($r=0.6854$, $p<0.05$).Thus the mean water level during flood season can basically reflect the changes of inundated time under the different characteristic water levels.

(3) Oncomelania hupensis likes living in the zone where the days of inundated time are between 3~8months, and the zone inundated for 5~6months is most suitable for *Oncomelania Hupensis* to breed. Compared with the changeable intervals of bred location of *Oncomelania Hupensis* (fig.4) and the mean water level during flood season in Dongting Lake (fig.2), the suitable bred locations of *Oncomelania Hupensis* show some trends with the flow regime in Dongting Lake.

①In heavy flood years, such as in 1998, 1999 and 2002, there are the expanding trends of the scope suitable for *Oncomelania Hupensis* to breed compared with the common year. The lowest and highest survival curves of *Oncomelania Hupensis* both move upward, but the move of the highest survival curve is most striking, and the moving range is closely related to the flow regime in the heavy flood year.

②In low water year, such as in 2001, 2006, it shows the shrinking trends of the scope suitable for *Oncomelania Hupensis* to breed compared with the common year. Both of the lowest survival curves and the highest ones move downward, but the movement of the highest survival curve is most striking, and the scope of suitable bred location is the most relatively narrow.

③In common year, such as in 2000,2003 and 2004, the scopes of suitable bred location of

Oncomelania Hupensis are below the highest survival curve in heavy flood year and over the lowest survival curve in low water year, but the scope of optimum bred location of *Oncomelania Hupensis* is the largest.

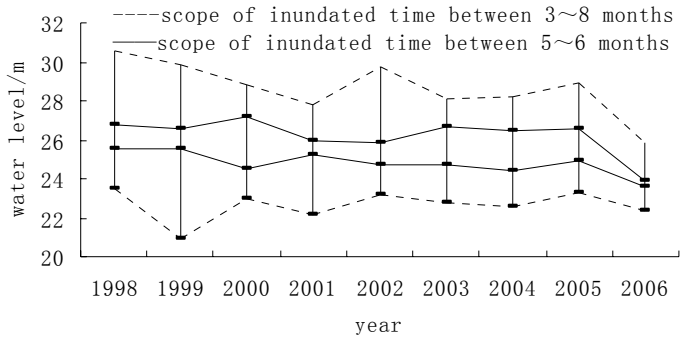

Fig.4 variational intervals of bred location of *Oncomelania Hupensis* in Dongting Lake

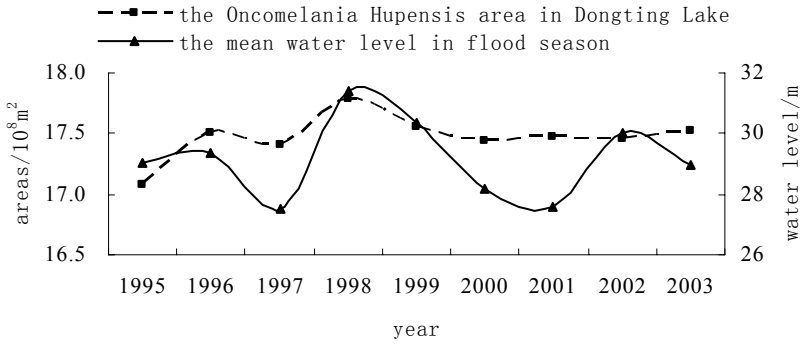

Fig.5 correlation between *Oncomelania Hupensis* area and mean water level in Dongting Lake

3.2 A Study on the Response of Oncomelania hupensis Diffusion to the flow Regime of Dongting Lake

The result of the water flow parameters changes in Dongting Lake indicates significant linear correlations between the average and highest water level during flood season and the amount of days in different inundated time. In addition, it generally reflects the scope and variable trend of the bred location of *Oncomelania Hupensis*. So the mean water level during flood season, the indicated parameter, can reflect the influence of the diffusion of *Oncomelania Hupensis* on the flow regime of Dongting Lake, and analyze the relationship between the diffusion of Oncomelania hupensis and the flow regime in Dongting Lake.

With the contrastive analysis result of the areas of *Oncomelania Hupensis* in Dongting Lake and the mean water levels at Chenglingji Station in recent years (fig.5), the areas of *Oncomelania Hupensis* have some changeable laws with the influence of water level during flood season at Chenglingji Station. Flood results in *Oncomelania Hupensis's* diffusion and expands distribution of *Oncomelania hupensis*. The bigger the flood, the larger the area of diffusion. If the water level in flood season is low, there has no significant change in the areas of *Oncomelania Hupensis* compared with the acute change of the flow regime in Dongting Lake. Whether there is a causal relationship between the flow regime and the areas of *Oncomelania Hupensis* in Dongting Lake, it can be judged by the correlation coefficient between the areas of *Oncomelania hupensis* in Dongting Lake and the mean water level during flood season at Chenglingji Station. Considering the fluctuation of flow regime, the continuity of *Oncomelania Hupensis* diffusion, the lag effect of

Oncomelania Hupensis areas to the flow regime and the influenced characteristic of flood to the diffusion of *Oncomelania Hupensis*, the smoothing technology in water level is introduced to reflect the influence of the acute flow regime to the diffusion of *Oncomelania Hupensis* in heavy flood and low water years or sister-flood years.

In order to reflect the influence of the flow regime to the diffusion of *Oncomelania Hupensis* and decrease the discord between the fluctuation of flow regime and the continuity of *Oncomelania Hupensis's* diffusion, the mean water levels in heavy flood and low water years or sister-flood years (such as in 1996/1997, 1998/1999/2000/2001 and 2002/2003) are processed with the smoothing technology based on the principle and calculation rule of smoothing treatment [2], and then the relativity was analyzed between the smoothed mean water level during flood season and the areas of *Oncomelania Hupensis* in Dongting Lake. By the result of linear correlation analysis (fig.6), there is a significant linear correlation between *Oncomelania Hupensis* area and mean water level during flood season in Dongting Lake, and the relationship is showed in the formulation of $y=0.1072x + 14.382$（$r=0.822$，$p<0.05$）.

The check table of correlation coefficient can be used for checking the correlation of the area of Oncomelania hupensis in Dongting Lake and the mean water level during flood season at Chenglingji station. If samples equal to 8 and the linear correlation coefficient $r_8>0.707$ with its 95% CI, there is a significant linear correlation between the area of *Oncomelania Hupensis* and the mean water level. In figure 6, the value of the correlation coefficient equals to 0.822(>0.707), so there is a significant linear correlation between the area of Oncomelania hupensis in Dongting Lake and the mean water level during flood season at Chenglingji station. The results can technically support the spot check and killing of Oncomelania hupensis.

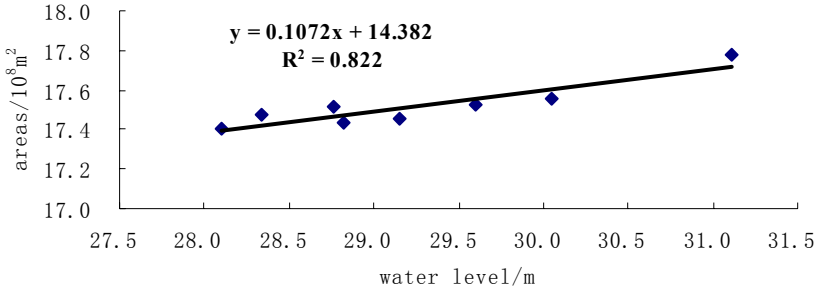

Fig.6 correlation between *Oncomelania hupensis* area and mean water level in Dongting Lake

4 Conclusion

It can be concluded in the following points:

(1) The Dongting Lake is an area with most widely distributed *Oncomelania Hupensis* and most serious schistosomiasis epidemic region in China. Influenced by frequent disasters of flood and waterlog and complex canal systems, the diffusion of Oncomelania hupensis in Dongting Lake cannot be controlled effectively and reoccur easily.

(2) Heavy floods increase the distribution of *Oncomelania Hupensis*, but there is some lag effect compared with the flood regime, and the lag effect is more obvious in sister-flood years than in a single year. The lag time may be 2~3 years or longer. The lag effect is more obvious in mainstream epidemic places than the epidemic places in lake districts.

(3) Eight water flow parameters, selected to correlate the diffusion and bred location of *Oncomelania Hupensis* and the flood level, mainly include the mean water level during flood

season, the maximal water level and its appearance time, the duration of high water level, days of inundated time less than one month, days of inundated time less than there months, days of inundated time between 5~6months, days of inundated time more than 8 months, water level scope of inundated time between 3~8months, and water level scope of inundated time between 5~6months. Among eight parameters of flow regime, mean water level in flood season is the most one correlated with the change of flow condition in a flood year.

(4) There is a significant linear correlation between *Oncomelania Hupensis* area and mean water level in flood season in Dongting Lake, and the relationship is showed in the formulation of $y=0.1072x + 14.382$（$r=0.822$，$p<0.05$）. The results are not only helpful for the forecast and prevention of schistosomiasis epidemic situation, but also technically support the spot check and killing of *Oncomelania Hupensis.*

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