Study on the Natural Water Resources and Its Variation Characteristics of Erhai (Plateau Lake) in Recent 67 Years

Li Hongyan

(Dali Branch of Yunnan Hydrology and Water Resources Bureau, Dali, Yunnan 671000)

Objectives： Erhai Lake, formed by Himalayan crustal movement, is the second largest plateau lake in Yunnan and revered as the "mother lake" of the Bai people in Dali. In 2017, Erhai Lake was incorporated into the "New Three Lakes" water pollution control system by the Ministry of Environmental Protection, thus becoming one of the "New Three Lakes". The favorable development environment of Erhai Lake serves as not only the cradle for Dali's politics, economy, and culture but also the cornerstone of its sustainable economic growth. Since the 21st century, there has been an intensified development and utilization of seawater resources in Erhai Lake, resulting in a rapid increase in the total amount of pollutants entering the lake. This has led to a continuous decline in water quality and damage to the water ecosystem of Erhai Lake. Especially in recent years, with the backdrop of global warming and rapid human development, there has been a noticeable decline in natural water resources within Erhai Lake. Water scarcity is a serious issue, resulting in prolonged hydraulic retention time and poor water circulation conditions. Additionally, nutrient concentrations exhibit significant spatial and temporal variation throughout the lake area while sediment properties have undergone changes. Therefore, through the study and analysis of Erhai Lake's natural water resources over the past 67 years and its changing patterns, we can gain insights into the varying impacts of meteorological and hydrological factors as well as human activities on the lake's aquatic resources. This will provide a scientific basis for decision-making and serve as a valuable data reference for safeguarding Erhai Lake, including measures such as regulating water resources, managing water usage, replenishing the lake, and transforming and developing its watershed.

Methods： Based on 67 years of monitoring hydrometeorological factors, including river flow, precipitation, evaporation, water level and outflow of Erhai Lake from 1956 to 2022, the natural water resources of Erhai Lake were calculated using hydrological analogy and water balance methods, the trend and periodicity of natural water resources in Erhai Lake have been investigated using the Manner-Kendall method and Morlet wavelet analysis method, and the factors that impact Erhai Lake's water resources, including precipitation, evaporation, and human activities.

Figure 1 Distribution of water system, division and stations in Erhai Lake Basin

Table1 Statistical table of natural water resources in Erhai Lake Basin

Partition			catchment area（km^2）	precipitation（mm）	Hydrological analogy method		water balance
					Adopting methods	water resources（100 million cubic meters）	water resources（100 million cubic meters）
Erhai Land Waters	north（A）	A1	1027	800-1400	Reduction of measured water volume at Liancheng Station	3.867	8.700
		A2	246.7		omparison of Reduction Water Volume and Area at Liancheng Station with Precipitation Correction	0.9428	
		subtotal	1274		——	4.8098	
	west（B）	B1	256.2	1000-2500	The flow measurement at Shanqingkou is conducted simultaneously with the flow at Liancheng and Diaocaogou stations, using the runoff correlation method	2.402	
		B2	175.3		Comparison of Water Volume and Area at Shanqingkou with Precipitation Correction	0.5241	
		subtotal	431.5		——	2.9261	
	Southeast（C）	C1	309.7	800-1400	Comparison of Water Volume and Area of Sanshao Reservoir with Precipitation Correction	0.5456	
		C2	30.0		Comparison of Water Volume and Area at Diaocaogou Station with Precipitation Correction	0.0671	
		subtotal	339.7		——	0.6127	
	eastern（D）	D	270.6	700-900	Comparison of Water Volume and Area of Sanshao Reservoir with Precipitation Correction	0.4324	
	amount to		2315	——	——	8.781	
Erhai Lake District	Lake District（E）	E	249.6	700-1000	The difference between precipitation and evaporation in the lake area	-0.9100	
Whole basin			2565	——	——	7.871	7.790

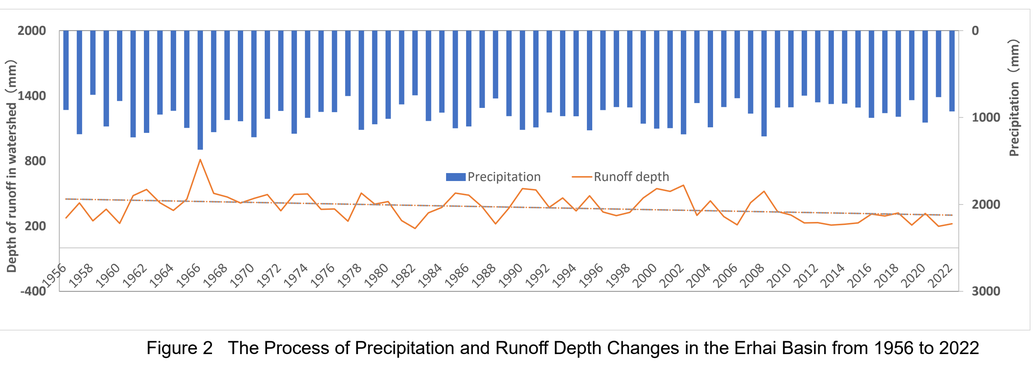


Figure 2 The Process of Precipitation and Runoff Depth Changes in the Erhai Basin from 1956 to 2022

Table2 Mann Kendall trend characteristics of natural water resources in Erhai Lake

Time	Year	Flood season	Dry season	Spring	Summer	Autumn	Winter
Statistic U	-2.66	-2.68	-1.77	2.73	-2.26	-3.15	-2.44
Trend	Decline	Decline	Decline	Rise	Decline	Decline	Decline
significance	Remarkable	Remarkable	Not significant	Remarkable	Remarkable	Remarkable	Remarkable

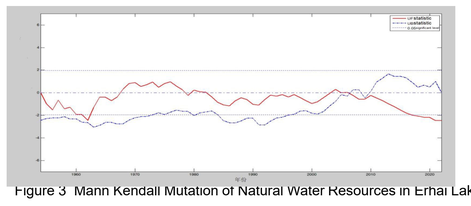
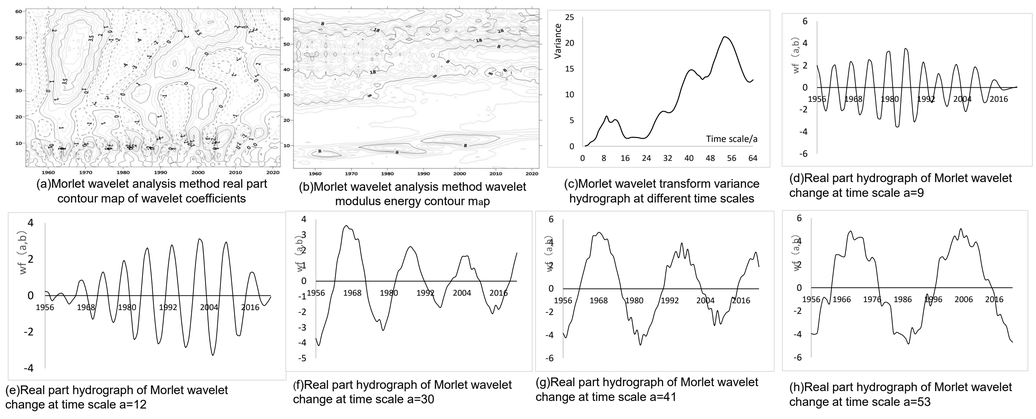


Figure 3 Mann Kendall Mutation of Natural Water Resources in Erhai Lake



(a)Morlet wavelet analysis method real part contour map of wavelet coefficients

(b)Morlet wavelet analysis method wavelet modulus energy contour map

(c)Morlet wavelet transform variance hydrograph at different time scales

(d)Real part hydrograph of Morlet wavelet change at time scale a=9

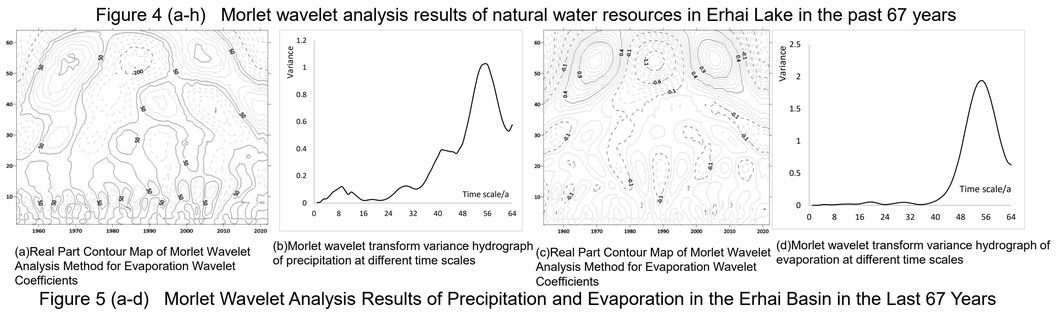
(e)Real part hydrograph of Morlet wavelet change at time scale a=12

(f)Real part hydrograph of Morlet wavelet change at time scale a=30

(g)Real part hydrograph of Morlet wavelet change at time scale a=41

(h)Real part hydrograph of Morlet wavelet change at time scale a=53

Figure 4 (a-h) Morlet wavelet analysis results of natural water resources in Erhai Lake in the past 67 years



(a)Real Part Contour Map of Morlet Wavelet Analysis Method for Evaporation Wavelet Coefficients

(b)Morlet wavelet transform variance hydrograph of precipitation at different time scales

(c)Real Part Contour Map of Morlet Wavelet Analysis Method for Evaporation Wavelet Coefficients

(d)Morlet wavelet transform variance hydrograph of evaporation at different time scales

Figure 5 (a-d) Morlet Wavelet Analysis Results of Precipitation and Evaporation in the Erhai Basin in the Last 67 Years

Discuss： (1) Since 2017, numerous engineering measures such as ecological reservoirs, ponds, wetlands and ecological storage zones have been implemented in the Erhai Lake basin to meet the needs of protection and transformation of the lake and its surrounding areas. These measures have shifted land evaporation to water evaporation, but their impact on seawater resources in Erhai Lake requires further investigation. (2) The construction of a sewage interception project around the lake has affected the amount of water resources entering Erhai Lake area due to changes in water cycle caused by sewage and rainwater entering sewage pipelines. This presents new challenges for studying seawater resources in Erhai Lake.(3) The evaporation loss in Erhai Lake area is large, and different regions. At present, the change of evaporation loss of large water bodies in the lake area is not known. (4)Due to the limited technical ability of individuals, at present, we have not fully grasped the information of land use and underlying surface change, which makes the research angle have a certain impact on the results, and scholars and experts need to conduct research and discussion in the future.

Conclusions： Based on 67 years of monitoring hydrometeorological factors, including river flow, precipitation, evaporation, water level and outflow of Erhai Lake from 1956 to 2022, the natural water resources of Erhai Lake were calculated using hydrological analogy and water balance methods, the trend and periodicity of natural water resources in Erhai Lake have been investigated using the Manner-Kendall method and Morlet wavelet analysis method, and the factors that impact Erhai Lake's water resources, including precipitation, evaporation, and human activities. (2)The natural water resources of Erhai Lake exhibit a significant decreasing trend over time, with an average decrease of 52 million cubic meters every decade. The Mann-Kendall method was employed to calculate that the annual water resources display a significant downward trend over time, while the water resources in the four seasons only show a significant increasing trend over time.(3) Wavelet analysis and calculations reveal periodic variations in seawater resources in Er over the past 67 years at different scales, which significantly influence the trends of abundant and dry seawater resources in Er. The first major cycle occurs approximately every 53 years, followed by a second major period of around 41 years. Additionally, there is a third main period of about 30 years, while the fourth and fifth main periods occur approximately every 9 and 12 years respectively.(4) Through correlation analysis of precipitation, evaporation, human activities and other factors affecting the amount of seawater resources in Erhai Lake, it was observed that the changing trend and fluctuation period of annual precipitation in the Erhai Lake basin are positively correlated with those of annual water resources. The annual evaporation is sometimes positively correlated with the annual water resources, and sometimes negatively correlated, indicating that the annual evaporation has a variety of combinations on the annual water resources in Erhai Lake. The population and water consumption in the Erhai Lake Basin have been steadily increasing with the progress of human society, while human activities continue to exert a profound impact on the underlying surface conditions. The current decline in seawater resources in Erhai Lake is the result of a combination of precipitation and human activities. Initially, the impact of reduced precipitation outweighs that of human activities, but subsequently, the influence of human activities becomes more significant than that of precipitation.

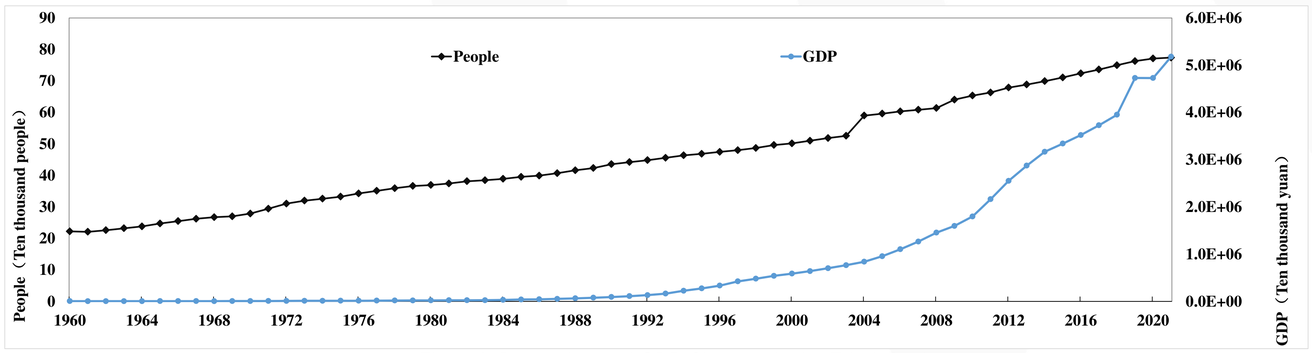


Figure6 Population and GDP Changes in the Erhai Basin