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The Change of Ostracods and Biosilicon from Lake Lugu Sediment Record and the Cause Analysis in Last Hundred Years

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Numerous palaeoclimatic and modern instrumental data indicated that the climate of Yunnan-Guizhou Plateau has undergone a significant warming during the past century. In this research, biological silicon, ostracods, physicochemical proxies of Lake Lugu sediment core were analyzed to illuminate the change on the lake ecosystem and their cause analysis in the past century. The correlations between those proxies and the temperature and precipitation data of the Lijiang region during 1951-2010 AD were analyzed. The results showed that: biosilicon, ostracods and physicochemical proxies changed greatly with the depth of the sediment, especially 14.5 cm which represent for the past 70 years. The results of ostracods combination showed that since 1990, the relative abundance of cold water species reduced, such as *Cyclocypris* and *Candona*, while the relative abundance of the warm water species increased, like *Eucypris* and *Cypris*. *Limnocythere* was the dorminant species in the core. The absolute abundance of ostracoda increased sharply from the end of last century and reduced rapidly in recent years. The content of biological silicon maintained at a relative higher level since 1990, which indicated that the primary productivity was relatively high in Lake Lugu during this period and phytoplankton containing silicon (e.g. Diatoms) increased. Therefore climate change in this region led to the increase of primary productivity in lake Lugu over the last 20 years.

Key words: lake Lugu; ostracods; biosilicon; geochemical proxies.

It is reported from IPCC (2007) that the mean global annual temperature has raised about 0.74 °C during the past 100 years from 1906 AD to 2005 AD. In the background of global warming, the mean annual temperature of the earth's surface in China increased obviously by about 0.5 to 0.8 °Cÿa bit higher than that in the global world, which is 0.6°C ± 02°C [1-2]. Yunnan, a province in low latitude plateau, which issignificantly affected by the monsoon, has an evident warming tendency during the past 50 years[3].

Lake ecosystem, proven to be sensitive to environment changes, can comprehensively reflect the response of entire watershed to climate change[4]. Remote alpine lakes have continuous sediments and can record their area's climate and environment in higher resolution during the past period, so they are widely used to study the history of global change[5-6]. Lugu Lake, in the city of Lijiang, Yunnan province, is located at the Yunnan-Guizhou Plateau, a subtropical region which is affected by southeast and southwest monsoon. As a remote, alpines, semi-closed, deep and oligotrophic freshwater lake, Lugu, which is far away from industries, is an ideal place to study aquatic ecosystem response to climate change[10]. It has low

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population density, low anthropogenic interference and large vegetation coverage. And its water is in accordance with national water quality standard I[7-9].

In the biological records of lake sediments, ostracoda fossil and biogenic silica are widely used in the study of paleoecological and paleoenvironmental research. Compared with gastropods and copepods, ostracodas are a kind of micro arthropod which have long geological history, large production and is widely distributed in the world. Their classification system is relatively perfect. What's more, they have definite source and can be stable in geological time, which makes them good indices to reveal paleoenvironmental and paleoclimate change, so they can be used to reconstruct the past water environment and ecology[11]. At present, the main research is to infer changes (of lake area, climate, etc.) in the region's environment by analyzing ostracods' ecological characteristics, combination, abundance, differentiation degree and so on[12-14], but there are few researches about climate changes for nearly 200 years. Li Yuanfang *et al*. probed into environmental changes of Nanhongshan Lake in 150 years by analyzing ecological characteristics and combination of Ostracods[11]. Compared with plankton and fish, few studies about benthos' response to climate changes are conducted[15-17]. In addition, there have been only a few documents and reports concerned with effects of climate warming on biogenic silica content in lakes during the past 200 years. In foreign countries, researchers mainly study about changes of silicon content of marine organisms, space distribution, and the relationship between biogenic silica and environmental factors such as water chlorophyll, nutrients, water flow, etc[18] And domestic studies mainly take sea (Yellow Sea, East China Sea, etc.) as research object, to infer changes of biogenic silica content for some time in the region, thus to speculate conditions of marine primary productivity in this period of time[19-20]. With the climate warming more and more obvious, lakes as natural reservoirs play an important role in regulating climate and the yield of river water. So, biogenic silica, indicator of primary productivity in lakes and seas is significant to strengthen research[18].

Through investigating and analyzing the record of sediments such as biogenic silica, ostracods and physical and chemical indices in Lugu Lake, this research is aimed at revealing the response of climate change and other environmental factors to the sediment records of lakes in southeast China for nearly 200 years since the industrial revolution, especially over the past century. Besides, this research can also provide some theoretical basis for the effect of regional climate change on inland water environment and water ecosystems, for the effect of global warming on lake ecosystems, and for the prediction of the effect of global warming in the future.

MATERIALS AND METHODS

Study site description

Lugu lake (N: 27°412 ~27°452 , E: 100°452 ~100°502), is located in Yongning township, north of Ninglang county, and in the mountains, left of Yanyuan county, Sichuan province. Its altitude is approximately 2690.75 m, while its area is about 48.45 km^2 (Fig. 1), and it is in a low latitude plateau monsoon region. The total area and volume of the waters is 50.1 km^2 and 20.41×10^8 m^3 respectively. Its average depth is 40.3 m, and the maximum water depth is 93.5 m. The maximum transparency of the lake can be up to 12m, but most are between 6.0 ~ 11.5 m. Its nutrient level is relatively stable, as its water quality has been maintained for class I[7-9]. The main water supply of Lugu lake is rainfall, and the input and output water is mainly balanced. The annual average amplitude of water level is about 1.5 m. The only exit of Lugu lake, Gaizu river, is in the east coast[21]. As a semi-closed lake, its recharge coefficient is only 3.4, so the boarding time is up to 18.5a. The lake is in the monsoon region of southwest and the low latitude plateau, which brings it warm climate with mountain monsoon. It is controlled by the dry Continent Monsoon Climate in winter and Wet Marine climate in summer, with wet and dry season, clearly. The annual average temperature is 12.8!, the average annual precipitation is 920mm, and almost 85% of the annual precipitation concentrates in the rainy season. During January and February, there is a small amount of rain and snowÿwhile the annual relative humidity is 70%. The sunshine hours throughout the year are 2260h, with percentage of sunshine of 57%. Most of the peaks which are over 3000m around the lake are covered by forest or shrub vegetation, and the forest coverage reaches 47.6%[22].

Lugu Lake is the highest lake in Yunnan, and is also one of the deepest freshwater lakes in China. Far away from cities and industries and less disturbed by human being, the lake has high forest coverage rate and low level of contamination. In November, 2009, Lugu lake was assessed as AAAA level scenic spot, which is a precious region of studying lake evolution and climate change.

Field and laboratory methods

A 25 cm long sediment core (LGH-5) was collected at a water depth of 42.0 m using a UWITEC gravity corer in August 20, 2010 near the central part of the southern Lugu Lake (N: 27° 402 10.03 ÿE: 100° 472 51.03 , Figure 1). The core was sectioned at 0.5 cm contiguous intervals in the field, and the collected subsamples were sealed in plastic bags with consecutive numbering and immediately transported to the laboratory, and then kept in a refrigerator at -20 °C.

^{210}Pb dating was measured in the State Key Laboratory of Lake Science and Environment (SKLLSE), Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences. The upper frozen-dry subsamples were analyzed for ^{210}Pb and ^{226}Ra by direct gamma spectrometry using the Ortec HPGe GWL series of well-type, coaxial, low background, intrinsic germanium detectors[23]. ^{210}Pb activity was determined via its direct gamma emissions at 46.5 keV and ^{226}Ra via the 295.2 and 351.9 keV ^{3}-rays emitted by its daughter isotope ^{214}Pb following 3-week storage in sealed containers to allow secular equilibration to be established. Supported ^{210}Pb in each sample was assumed to be in equilibrium with in situ ^{226}Ra. Unsupported ^{210}Pb activity at each depth was calculated by subtracting ^{226}Ra activity from the total ^{210}Pb activity[24]. The standard error of replicate analyses does not exceed 10%.

The dry bulk density of the sediments was measured using a density determination kit for Excellence XP/XS analytical balances (Mettler-Toledo AG, Switzerland). The wet sediments were analyzed for water content by drying for 24 h at 105 °C, and then combusted at 550 °C for 3-4 h to determine the percentage loss on ignition (LOI)[25]. The CE-440 elemental analyzer (EAI Company) was used for the determination of total organic carbon (TOC) and total nitrogen (TN) content of the samples, and calculated TOC/TN ratios (i.e. C/N). Persulfate digestion method was used to measure total phosphorus (TP).

Biogenic silica (BSi) analyses were performed using the standard method of colorimetric determination of the blue silica molybdate complex[26], namely using 2 M Na_2CO_3 solution extraction at 85°C for 8 h, and determinate by molybdenum blue spectrophotometry at 812nm. The standard error of replicate analyses does not exceed 2.5%.

The species identification of ostracods was based on the system of Wang and Sha (2009), Meisch (2000), Hou (1982, 2007), Iedqpa and Nigp (1988), Jiang et al. (2007)[11,27-31]. In order to isolate the ostracods from the sediments, we took 5-10 g wet sediments from each sample and oven-dried

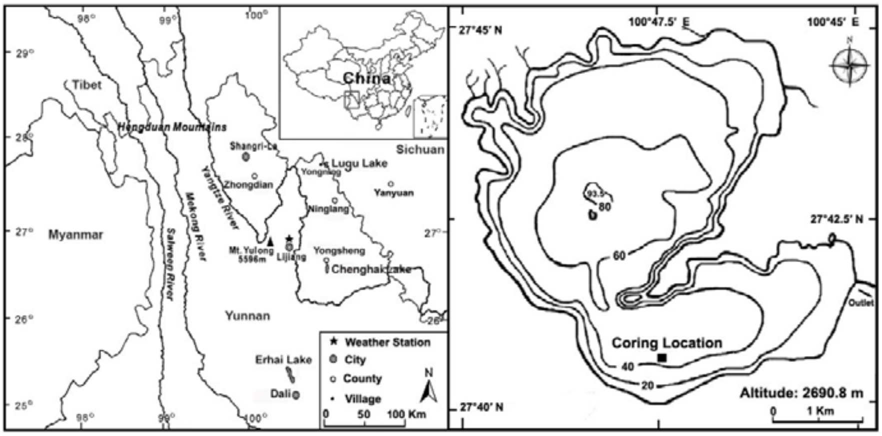

Fig. 1. The location of lake Lugu and the sampling site

them for 24 h at 65°C to obtain their dry weights. The samples were put in a plastic container and mixed with 10% hydrogen peroxide (H_2O_2) to remove organic matter. Then 0.1N HCl was added to remove carbonate. The processed samples were sieved, washed and dried at 65°C. Ostracod valves left in the sieves were picked out from dried residues by brush under a binocular microscope (Olympus 272729).

Climate data

The daily temperature and precipitation meteorological data from 1951 to 2010 at Lijiang weather station (2392.4 m a.s.l., ca. 101.2 km straight line distance from Lugu Lake), were got from the China Meteorological Data Sharing Service Platform (http://cdc.cma.gov.cn). The monthly, seasonal and annual temperature and precipitation were then established from the collected data. This article selects monthly precipitation and temperature data to analyze regional climate characters of annual and seasonal. The time series of annual and seasonal temperature anomaly and precipitation departure were constructed. For depiction of temperature and precipitation data, 5 year running mean of temperature and precipitation were calculated to reflect the trend of climate and precipitation change[3,32].

Data treatment and analysis

Descriptive statistics and Pearson and Spearman correlations for environmental variables and biologic variations about ostracods were calculated using SPSS version 16.0. The significance of ostracod-based biostratigraphic zones was calculated by using the constrained incremental sum of squares (CONISS) facility within the computer programs TILIA and TILIAGRAPH[33], and the statistical analyses of diatom assemblages were based on percent abundances and included 16 diatom taxa with ≤2% abundance at least one sample. The geochemical and biological indicators (ostracods, BSi and physicochemical proxies) was plotted using the computer program C2[34].

RESULTS

Dating (core chronology)

Due to the non-monotonic variation in unsupported ^{210}Pb activity, the date were calculated using the constant rate of supply (CRS) model[35]. ^{210}Pbtot activity decreased exponentially with increasing depth and equilibrated with ^{226}Ra at 22 cm (quality depth at 11.22g/cm^2) (Figure 2a). The resulting ^{210}Pb chronology indicated an earliest date of 1830 AD ± 14 at a depth of 22 cm (Figure 2b). Results indicated that the average deposition rate was 0.15 g cm^{-2} yr^{-1}. However, the deposition rate calculated according to the CRS model at different depth is various. The deposition rate and the sediment accumulation rate generally increased from top to bottom. The average deposition rate and the sediment accumulation rate were 0.14 g cm^{-2} yr^{-1} in the upper 6.0 cm, and 0.18 g cm-2 yr^{-1} from 6.0 cm to 22 cm, repectively. The age-depth plot suggests that LGH-5 spans a period of approximately 100 years, dating back to ca. 1910 AD.

Physicochemical characteristics of the sediment and and BSi proxies

Physicochemical characteristics of the sediment and BSi proxies versus depth in the LGH-5 core was showed in Figure 3. The correlation analysis between the data (the mean annual daily

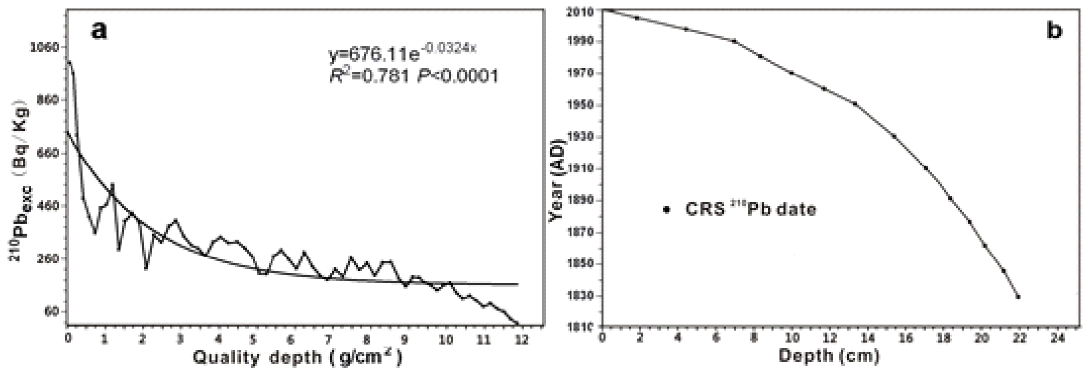

Fig. 2. $^{210}Pb_{exc}$ activty of quality depth (a) and age-depth plot for LGH-5 core (b)

temperature and precipitation meteorological data from 1951 to 2010 AD at Lijiang weather station) and the content of TOC, TN, C/N ratio (TOC/TN), $CaCO_3$ was carried out. The results showed that the mean annual temperature were significantly positively correlated with TOC in the twenty seven collected subsamples (R=0.497, p =0.0009, N =27), but no significant correlation with the content of C/N (TOC/TN) and $CaCO_3$. In addition, the statistically significant correlations were found between the precipitation and the content of TOC, C/N and $CaCO_3$ concentration (R=0.445, p =0.018; R=0.548, p =0.003; R=0.482, p =0.007, N=27, respectively). From the results recorded in the sediment cores of Lugu lake during the last 200 years, a low value in TOC was found between 9 and 12 cm (ca. 1962–1978 AD), which was due to the low temperature and the few precipitation in the region in the period. The content of TOC was followed by increasing trends from 9cm to the top of core, with an average value of 4.1%, and the findings were in accordance with the rising temperatures since 1992 AD.

The linear correlation between the content of TN and TOC in sediments was significantly positive (P<0.01, N=27). The ratio of C/N in the sediment was used as an indicator of the relative contributions of organic matter from terrestrial versus aquatic sources. Generally speaking, terrestrial organic matter typically possesses C/N values >22 [36], whereas algal organic matter generally displays C/N values from ca. 4 to 10 [37]. C/N ratio of sediment core LGH-5 was in a range of 7.68~16.52 (C/N mean 11.77), which indicated that the sedimentary organic matter in Lugu lake was mainly a result from autochthonous production [36, 37].

The C/N ratio in sediment core LGH-5 was gradually declined with a relatively low value (C/N mean 11.77) during two periods (from ca. 1970 to 1980 AD and 2005 to 2010 AD). This maybe attribute to the contributions of organic matter from terrestrial were relatively lower because of the less precipitation in the two periods. In addition, the results were accelerated by the contributions from the terrestrial organic matter which was positively correlated with the regional climate warming since 2005 AD. The findings confirmed the Lugu Lake' primary productivity increase was driven by rising temperatures and human activities in recent fifty years, especially for nearly 20 years. The content change of $CaCO_3$ was similar to the variation of C/N values. The smaller contributions from the terrestrial organic matter, the lower contents of terrestrial $CaCO_3$ were from sediment organic matter.

BSi concentrations of LGH-5 were

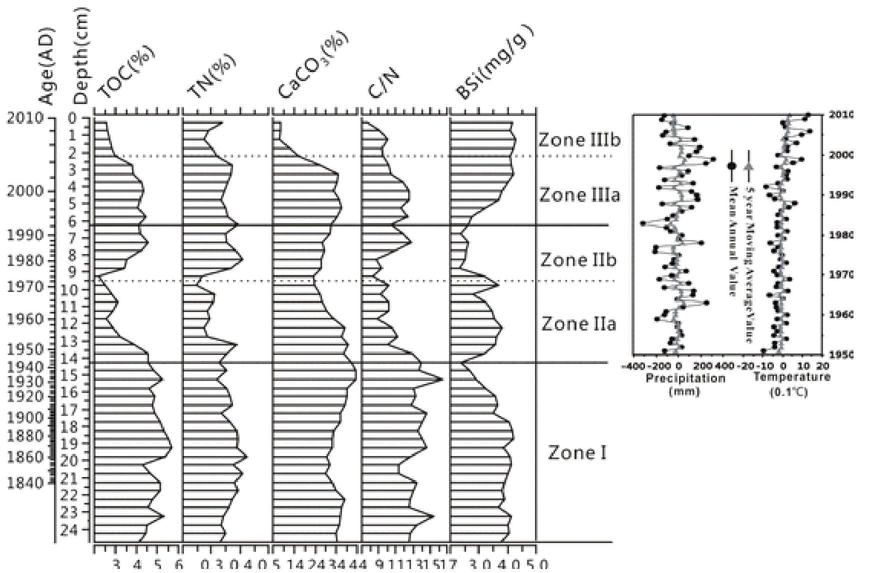

Fig. 3. Geochemical and BSi proxies versus depth in the LGH-5 core (Note: The mean annual temperature and precipitation departure from 1951-2010 from LiJiang weather station, data from China Meteorological Data Sharing Service System http://cdc.cma.gov.cn) (right figure)

relatively low at 14.5 cm (ca. 1945 AD), 10.5 cm (ca. 1965 AD) and from 6 cm to 9.5 cm (ca. 1986 - 1992 AD).Since ca. 1992 AD to 2010 AD (0~6cm), the contents of BSi showed increasing trends in Lugu Lake, which may indicated the increase in primary productivity. Therefore, it suggested that as result of the climate warming in recent 60 years, the changes of BSi and C/N content increased in the Lugu Lake region.

Species composition

Species composition of fossil ostracods for LGH-5 was shown in Figure 4. The sediment samples contained ostracod shells of six genera in total. These are *Limnocythere*, *Eucypris*, *Cypris*, *Darwlnula*, *Candona*, *Cyclocypris*. The fossil ostracod assemblages were dominated by *Limnocythere,* while *Cyclocypris* and *Limnocythere* were the most frequent and abundant taxa before 1970s. Three ostracode zones were identified based on changes in major taxa abundance of LGH-5.

Zone I (ca. 1840-1940 AD) was dominated by *Limnocythere*, *Cyclocypris* and *Candona*. The total abundance and simple diversities of ostracod fossil in Zone I was relatively lower than in Zone III.

Zone II (ca. 1940–1992 AD) was split into two subzones. The total abundance and simple diversities of ostracodes fossil in Zone II was lower than in Zone III. The abundance of genera *Candona* was low, but other two ostracode taxa abundance (*Candona* and *Cyclocypris*) maintained increasing trends in zone II a. In contrast, the percentage of *Limnocythere* increased rapidly and the percentage of *Candona* and *Cyclocypris* significantly reduced in zone II b, and *Candona* disappeared.

Zone III (ca. 1992–2009 AD) was divided into two subzones, Zone IIIa and Zone IIIb. The abundance and diversity of ostracodes in Zone IIIa was high with the average abundance of 50 per layer, which were dominated by *Limnocythere*. In Zone IIIb, the abundance and diversity of ostracodes decreased significantly, but the percentage of *Limnocythere* was also predominant in ostracode assemblages.

DISCUSSION

Causes of BSi record

BSi, known as phytolith or opal, can be comprised of different components mainly of biological origin such as diatoms phytoliths, radiolarians, silicoflagellates and sponge spicules. The contents of BSi in sediments were often used as proxy indicators of productivity of lake and its basin [25,38-39]. In recent 60 years (ca. 1951-2010 AD), BSi contents were highly significantly positively correlated with the annual temperature mean (Spearman r = 0.497, p =0.007, n =27), and not

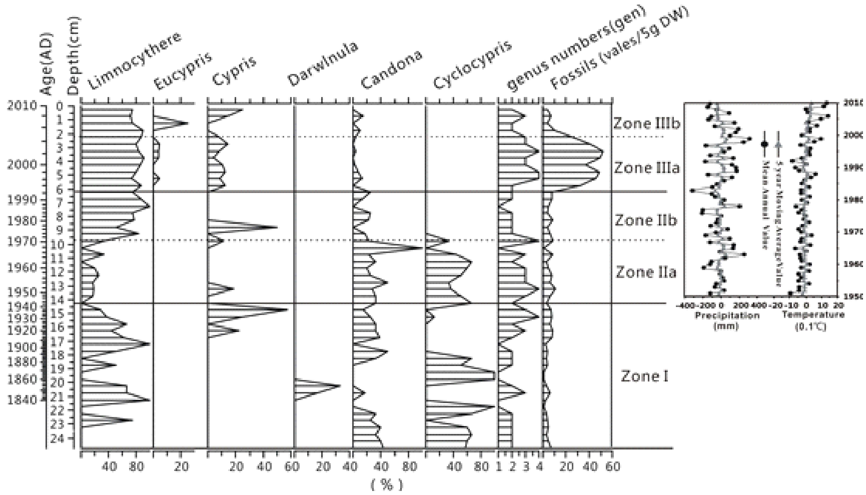

Fig. 4. Species composition of fossil ostracods versus depth in the LGH-5 core (Note: The mean annual temperature and precipitation departure from 1951-2010 from LiJiang weather station, data from China Meteorological Data Sharing Service System http://cdc.cma.gov.cn) (right figure)

correlated with annual rainfall (p >0.05, n =27). The results suggested that BSi concentration was closely correlated with the change of climate in the region. Based on the analysis of C/N values, the increase in lake primary productivity became contribution to sedimentary organic matter in sediment, and BSi was mainly a result from autochthonous lake production.

Cause of ostracod record remains from Lugu lake

Ostracods are small bivalved crustaceans, which shells are typically 0.3-3mm long. They live in a broad range of aquatic habitats (such as lakes, ponds, springs, streams, rivers, estuaries, and oceans) and known to be sensitive to changes in temperature[40], salinity[41], ionic composition[42], and nutrient status[43]. They are also intensely affected by a range of other habitat variables such as water depth, volume, retention time, water transparency, and the degree of aquatic macrophyte cover[44]. As a result of world-wide distribution and long historical records, ostracods can act as an useful indicator to reconstruct paleoenvironments[46,47].

ZoneI from ca. 1840 to 1940 AD, the number of Ostracod were several to more than ten shells per layer, related with climate and nutrition. On the other hand, Ostracod was destroyed by sedimentology and biological factors, such as mechanical damage, compaction, chemical corrosion, and recrystallization.

From ca. 1940 to 1992 AD (Zonea!), the temperature and rainfall data from lijiang city weather station indicated that the environmenntal conditions turned into a cold-arid phase. The results of ostracods composition showed that the cold water species such as *Cyclocypris* and *Candona* increased while the warm water species like *Eucypris* and *Cypris* reduced in the relative abundance. This might indicate a adaption to changes in temperature.

From ca. 1940 to 1992 AD (Zone b!), temperature and rainfall data suggested the warm-wet and warm-dry periods in 1951-2010 AD. Temperature played a vital role in the ostracod compositional assemblages. *Cypris, Eucypris and Limnocythere* have significant positive correlation with temperature (R=0.489, P=0.006; R=0.506, P=0.016; R=0.493, P=0.005, N=27). From ca. 1990 to 2005 AD, the ostracod abundance markedly increased and the number reached to fifty in per layer. Since ca. 2005 AD, ostracod abundance rapidly decreased with the organic matter content reduced, reflected ostracod abundance was significantly positively correlated with TOC

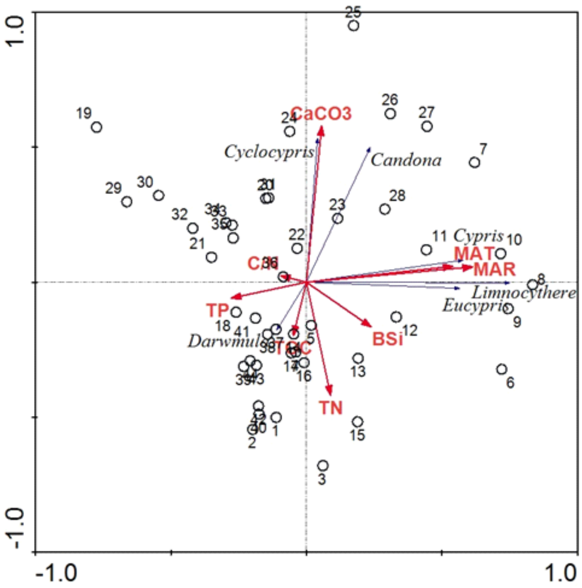

Fig. 5. CCA biplot of species and environmental variables

contentÿ*R*=0.487, *P*=0.023, *N*=27. Furthermore, the ostracod differentiation has increased. Similar results have been found, and the increase in abundance and differentiation were positively correlation with climate warming. *Limnocythere*, was often associated with warm conditions, has been observed to increase in the abundance and become dominant species. On the other hand, *Cyclocypris* has significant negative correlationwith temperature (*R*=-0.470, *P*=0.012, *N*=27), even disappeared resulted from climate warming. Cold-water species *Candona*, living conditions was similar to *Cyclocypris*, the abundance obviously decreased.

Species–environment relationships

CCA identified seven environmental variables ($CaCO_3$, TP, TN, C/N, MAT, MAR, BSi) that significantly explained the variation in the ostracod assemblages (Figure 5). Canonical analyses of the presented calibration dataset revealed TEMP as the main environmental variable, which controls ostracod distribution in the studied lake. The biplot clearly illustrated that *Cyclocypris* and *Candona* were affected by increased $CaCO_3$-levels. *Eucypris*, *Cypris* and *Limnocythere* were influenced by MAT, MAR and BSi. The group of species *Darwmula sp.* was distinguished, which prefer relatively higher TOC. In addition, we found the composition of ostracod was similar to the neighboring layer.

Lugu Lake, which is a remote alpine oligotrophic temperate lake, it is suggested that the changes in BSi, ostracod abundance and differentiation was mainly result from the climate warming in the Lugu Lake region in recent 100 years. In addition, TOC concentration in sediment was another important factor in ostracod abundance.

CONCLUSION

Phytoplankton containing silicon (e.g. Diatoms) increase and the region climate change over the last 20 years lead to the increase of lake primary productivity in Lake Lugu. Since 1992ÿincrease in the abundance and differentiation of ostracod was consistent with the climate warming in the period, which sugguested ostracod species were sensitive to temperature change and can be used as paleoenvironmental indicators. *Limnocythere* was the dominant ostracod taxa in the LGH-5, but before 1970s the ostracod were dominated by *Cyclocypris* and *Limnocythere* in LGH-5. Changes in BSi, ostracod abundance and differentiation were mainly result from the climate warming in the Lugu Lake region in recent 100 years. Moreover, TOC concentration was the other important factor influencing ostracods abundance.

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REFERENCES

1. IPCC 'Climate change: report of working group of the intergovernmental panel on climate change', *Cambridge: Cambridge University Press*, 2007; pp.16-72.
2. The second national assessment report editorial committee of climate change 'The second national assessment of climate change', *Peking: Science Press*, 2011; pp. 28-53. (in chinese)
3. Cheng, J.G. and Xie, M.E. 'The Analysis of Regional Climate Change Features over Yunnan in Recent 50 Years', *Progressin Geography*, 2008; **27**(5): pp.19-27. (in chinese)
4. Adrian, R., O'Reilly, C.M., Zagarese, H., Baines, S.B., Hessen, D.O., Keller, W., Livingstone, D.M., Sommaruga, R., Straile, D., Donk, E.V., Weyhenmeyer, G.A. and Winder, M. 'Lakes as sentinels of climate change. Limnology and Oceanography', *Limnol. Oceanogr.*, 2009; **54**(6): pp. 2283-2297.
5. Battarbee, R.W., Grytnes, J.A., Thompson, R., Appleby, G., Catalan, J., Korhola, A., Birks, H.J.B., Heegaard, E. and Lami, A. 'Comparing palaeolimnological and instrumental evidence of climate change for remote mountain lakes over the last 200 years', *J. Paleolimnol.*, 2002; **28**(1): pp. 161-179.
6. Brancelj, A., ŠiŠko, M., Lami, A., Appleby, P., Livingstone, D.M., Brancelj, L.R. and Ogrin, D. 'Changes in the trophic level of an alpine lake, Jezero v Ledvici (NW Slovenia), induced by earthquakes and climate change', *J. Limnol.*, 2000; **59**: Nos. Suppl.1, pp. 29-42.
7. Wu, G., Zhang, Q.X., Zheng, X.X., Mu, L.F.

and Dai, L.M. 'Water quality of Lugu Lake: changes, causes and measurements', *Int. J. Sust. Dev. World*, 2008; **15**(1): pp. 10-17.
8. Yunnan Province water conservancy station (2000-2010) 'Yunnan Province water resources bulletin', http://lj.xxgk.yn.gov.cn/canton_model24/newslist.aspx?classid=143398.
9. Yu, Y., Zhang, M., Qian, S., Li, D. and Kong F.X. 'Current status and development of water quality of lakes in Yunnan-Guizhou Plateau', *Journal of Lake Sciences*, 2010; **22**(6): pp. 820-828. (in chinese)
10. Chen, Y.F. and Wan, G.J. 'The sediment extraction of 0cellulose and preliminary research of stable carbon isotope in LuGu Lake', *Geology-Geochemistry*, 1999; **27**4: pp. 72-76. (in chinese)
11. Wang, Y.Q. and Sha, J.G. 'Morphology of Ostracods and its Significance of Environment, Function and Taxonomy', *Acta Micropalaeontologica Sinica*, 2009; **26**(3): pp. 283-290. (in chinese)
12. Li, Y.F. and Li, B.Y. 'Ostracoda and environmental changes of South Hongshan Lake on Tibetan Plateau during the past 150 years', *Geographical Research*, 2001; **20**(2): 199-205. (in chinese)
13. Zhang, J.W. and He, J. 'Applications of Non-marine Ostracods in Quaternary Paleoenvironment ——Advances and Problems in Fossil Assemblages', *Advancesin Earth Science*, 2009; **24**(11): 1229-1237. (in chinese)
14. Mischke, S. and Zhang, C.J. 'Ostracod distribution in Ulungur Lake (Xinjiang, China) and a reassessed Holocene record', *Ecol. Res.*, 2011; **26**(1), : 133-145.
15. Ozawa, H. 'Okhotsk Sea ostracods in surface sediments: depth distribution of cryophilic species relative to oceanic environment', *Mar. Micropaleontol.*, 2004; **53**(3-4): 245-260.
16. Ozawa, H. and Kamiya, T. 'Ecological analysis of benthic ostracods in the northern Japan Sea, based on water properties of modem habitats and late Cenozoic fossil records', *Mar. Micropaleontol.*, 2005a; **55**(3-4): 255-276.
17. Ozawa, H. and Kamiya, T. 'The effects of glacio-eustatic sea-level change on Pleistocene cold-water ostracod assemblages from the Japan Sea', *Mar. Micropaleontol.*, 2005b; **54**(3-4): 167-189.
18. Lu, C.W., He, J., Liang, Y., Mao, H.F., Liu, H.L. and Wang, F.J. 'Temporal and spatial distribution of biogenic silica and its significance in the Wuliangsuhai Lake and Daihai Lake', *Acta Ecologica Sinica*, 2010; **30**: 100-105.
19. Ye, X.W. and Zhang, J. 'Ditermination of biogenic opal in sediment of the Huanghai and Bohai Sea and questions in the method', *AHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-hyxb.aspx"ctaHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-hyxb.aspx" OHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-hyxb.aspx"ceanologicaHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-hyxb.aspx" SHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-hyxb.aspx"inica*, 2002; **24**(1): 129-134. (in chinese)
20. Ye, X.W., Zhao, Y.F. and Zhang, J. 'The distribution of biogenic silica in the sediments of the East China Sea and the Yellow Sea and its environmental signification', *Science*, 2004; **24**(3): 265-269. (in chinese)
21. Wang, S.M. and Dou, H.S. 'The lakes of Chinese', *Peking: Science Press*, 1998; 378-379. (in chinese)
22. Bai, X., Ma, K.M., Yang, L. and Zhang, X.L. 'Simulating the impacts of land-use changes on non-point source pollution in Lugu Lake watershed', *Int. J. Sust. Dev. World*, 2008; **15**(1): pp. 18-27.
23. Appleby, P.G. 'Chronostratigraphic techniques in recent sediments Tracking Environmental Change Using Lake Sediments, Basin Analysis, Coring and Chronological Techniques', *Kluwer Academic Publishers Dordrecht***,** 2001; **1**: 171-203.
24. Wu, J., Michael, K.G., Jiang, X., Xia, W., and Wang, S. 'Sedimentary geochemical evidence for recent eutrophication of Lake Chenghai, Yunnan, China', *J. Paleolimnol.* 2004; **32**: 85-94.
25. Heiri, O., Lotter, A.F. and Lemcke, G. 'Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results', *J. Paleolimnol.*, 2001; **25**: 101-110.
26. Mortlock, R.A. and Froelich, P.N. 'A simple method for the rapid determination of biogenic opal in pelagic marine sediments', *Oceanographic Research*, 1989; **36**(9): 1415-1426.
27. Meisch, C 'Freshwater Ostracoda of western and central Europe', *Berlin: spektrum akademischer verlag, Heidelberg* 2000.
28. Hou, Y.T., Chen, D.Q. and Yang, H.R. 'The Ostracod Fauna of Jiangsu Province between Cretaceous and Quaternary', *Beijing: Geological Publishing House*, 1982; 48-205. (in Chinese)
29. Hou, Y.T. and Gou, Y.X. 'Fossils Ostracodes of China (Vol. 2): Superfamilies Cytheracea and Cytherellidae', *Beijing: Science Press*. (in Chinese) 2007
30. IEDQPA and NIGP (Institute of Exploration

and Development of Qinghai Petroleum Administration, Nanjing Institute of Geology and Palaeontology of AcademiaSinica) (1988) 'Tertiary Ostracode Fauna from Qaidam Basin, NW China', *Nanjing: Nanjing University Press*, pp. 22-30 (in Chinese).
31. Jiang, Q.F., Shen, J., Liu, X.Q. and Zhang, E.L. 'Holocene climate reconstruction of Ulungur Lake (XinJiang, China) inferred from Ostracod species assemblages and stable isotopes', *QuaternaryHYPERLINK "http://c.g.wanfangdata.com.cn/Periodical-dsjyj.aspx" Sciences*, 2007; **27**(3): 382-391.
32. You, W.H., Fu, B.P. and Lin, Z.S. (1997) 'The temperature change in the past century and the low-temperature chilling damage in August in Yunnan province', *Plateau Meteorology*, **16**(1): 63-72.
33. Grimm, E.C. 'TILIA, version 1.11. TILIAGRAPH, version 1.18. In: Gear A (eds) A users notebook', State Museum, *Springfield*, IL (1991).
34. Juggins, S. 'Software for ecological and palaeoecological data analysis and visualisation C2 Version 1.5 User guide', Newcastle upon Tyne, *UK: Newcastle University*, 2007; 1-73.
35. Appleby, P.G. 'Chronostratigraphic techniques in recent sediments. In: Last WM, Smol JP (eds) Tracking environmental change using lake sediments', Vol. 1: basin analysis, coring and chronological techniques, *Kluwer, Dordrecht*, 2001; **1**: 171-203.
36. McGlynn, G., Mackay, A.W., Rose, N.L., Taylor, R.G., Leng, M.J. and Engstrom, D.R. 'Palaeolimnological evidence of environmental change over the last 400 years in the Rwenzori Mountains of Uganda', *Hydrobiologia*, 2010; **648**(1), pp. 109-122.
37. Meyers, P.A. 'Preservation of elemental and isotopic source identification of sedimentary organic matter', *Chem. Geol.*, 1994; **114**: 289-302.
38. Swann, G.E.A. and Mackay, A.W. 'Potential limitations of biogenic silica as an indicator of abrupt climate change in Lake Baikal, Russia', *J. Paleolimnol.*, 2006; **36**: 81-89.
39. Lami, A., Turner, S., Musazzi, S., Gerli, S., Guilizzoni, P., Rose, N.L.,Yang, H., Wu, G. and Yang, R. 'Sedimentary evidence for recent increases in production in Tibetan Plateau lakes', *Hydrobiologia*, 2010a; **648**: 175-187.
40. Huang, B. R. 'Ostracods of Pliocene and Early Pleistocenein Gonghe Basin, Qinghai, In Collections of Nanjing Institute of Geology and Palaeontology, CAS (19)', *Beijing*: *Science Press*, 1984; pp. 1-12. (in Chinese)
41. De Deckker, P. 'Ostracods of athalassic saline lakes', *Hydrobiologia*, 1981; **81**: pp. 131-144.
42. Bhatia, S.B., Batra, R.S., and Kotlia, B.S. 'Ostracods and palaeoecology of the karewa formation of Hirpur and Romushi Sections, Kashmir, India', *Current Trends in Geology 6 (Climate and Geology of Kashmir)*, 1985; pp. 45-52.
43. Danielopol, D.L., Handl, M. and Yin, Y. 'Benthic ostracods in the prealpine deep Lake Mondsee. Notes on their origin and distribution', In McKenzie, K. G. & J. P. Jones (eds.), Ostracoda in the Earth and Life Science. *Balkema, Rotterdam*, 1993; pp. 465-479.
44. Carbonel, P., Colin, J.P., Danielopol, D.L., Löffler, H. and Neustrueva, I. 'Paleoecology of limnic ostracodes: A review of some major topics', *Palaeogeogr. Palaeocl.*, 1988; **62**: pp. 418-461.
45. Peng, J.L. 'Abundance and diversity of ostracods in lacustrine sediments are sensitive proxies of environment', *Quaternary Sciences*, 2000; **20**(3): 296.
46. Anadon, P., Gliozzi, E. and Mazzini, I. 'Paleoenvironmental reconstruction of marginal marine environments from combined paleoecological and geochemical analyses on ostracods', In: Holmes J, Chivas A (eds.), The Ostracoda: Applications in Quaternary Research, *Geophysical Monograph*, 2002; **131**: 227-247.
47. Reeves, J.M., Chivas, A.R., Garcia, A. and de Deckker, P. 'Palaeoenvironmental change in the Gulf of Carpentaria (Australia)since the last interglacial based on Ostracoda', *Palaeogeogr. Palaeocl.*, 2007; **246**(2-4): 163-187.