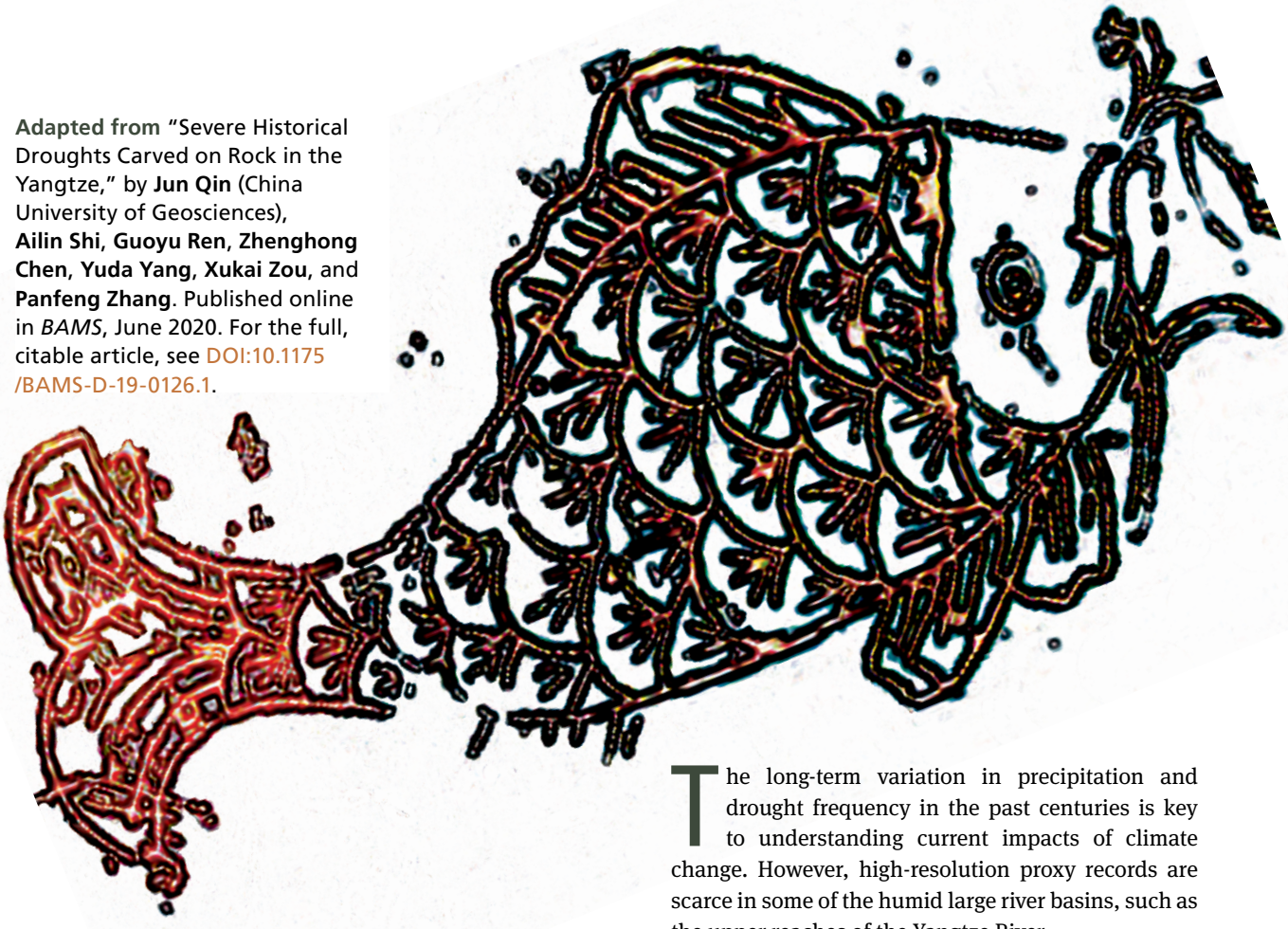
# Carved in Stone

## *What Yangtze Rock Fish Tell of China's Climate*

**Adapted from** "Severe Historical Droughts Carved on Rock in the Yangtze," by **Jun Qin** (China University of Geosciences), **Ailin Shi**, **Guoyu Ren**, **Zhenghong Chen**, **Yuda Yang**, **Xukai Zou**, and **Panfeng Zhang**. Published online in *BAMS*, June 2020. For the full, citable article, see DOI:10.1175/BAMS-D-19-0126.1.



**The Rock Fish at White Crane Ridge record extreme low water levels of the Yangtze, showing more droughts in the Medieval Climate Anomaly, fewer droughts during the Little Ice Age, and once again more droughts in the last century.**

The long-term variation in precipitation and drought frequency in the past centuries is key to understanding current impacts of climate change. However, high-resolution proxy records are scarce in some of the humid large river basins, such as the upper reaches of the Yangtze River.

Near the Three Gorges, close to the boundary between the upper and middle Yangtze, an enormous rock, the White Crane Ridge (WCR), or Baiheliang, lies below the surface of the river. The 1,600-m-long and 15-m-wide ridge was exposed to air only during the middle winter to early spring seasons of drier years. Its emergence from the waters has had special significance in this area of China; early drought in the upper Yangtze was most likely followed by favorable weather and a bumper harvest in the following growing season in the WCR area.

**(left) The surface appearance of WCR before the submergence beneath the water by the Three Gorges Dam and (right) the rubbing of the carved double fish images and inscriptions on WCR. The double Rock Fish were recarved in the Qing Dynasty, which are a little bit different from those originally carved in the Tang Dynasty.**

At least 1,200 years ago people inscribed characters and images of fish [known as Rock Fish (RF)] on the sandstone surface of the ridge when it was exposed. While more than 170 areas of inscriptions with more than 100,000 words have been found, only 18 are identifiable on the upper part of the ridge. The earliest readable inscriptions were carved in AD 764, and the latest ones dated to AD 1963. The inscriptions and images document extremely low water levels in more than 72 individual years, and some clearly record the depths of the water level from two reference RFs in chi (Chinese unit of length).

Based on the inscriptions at WCR, we present an updated drought chronology of the upper Yangtze River and analyze changes in the frequency of severe drought over the last thousand years.

## Physiographical features

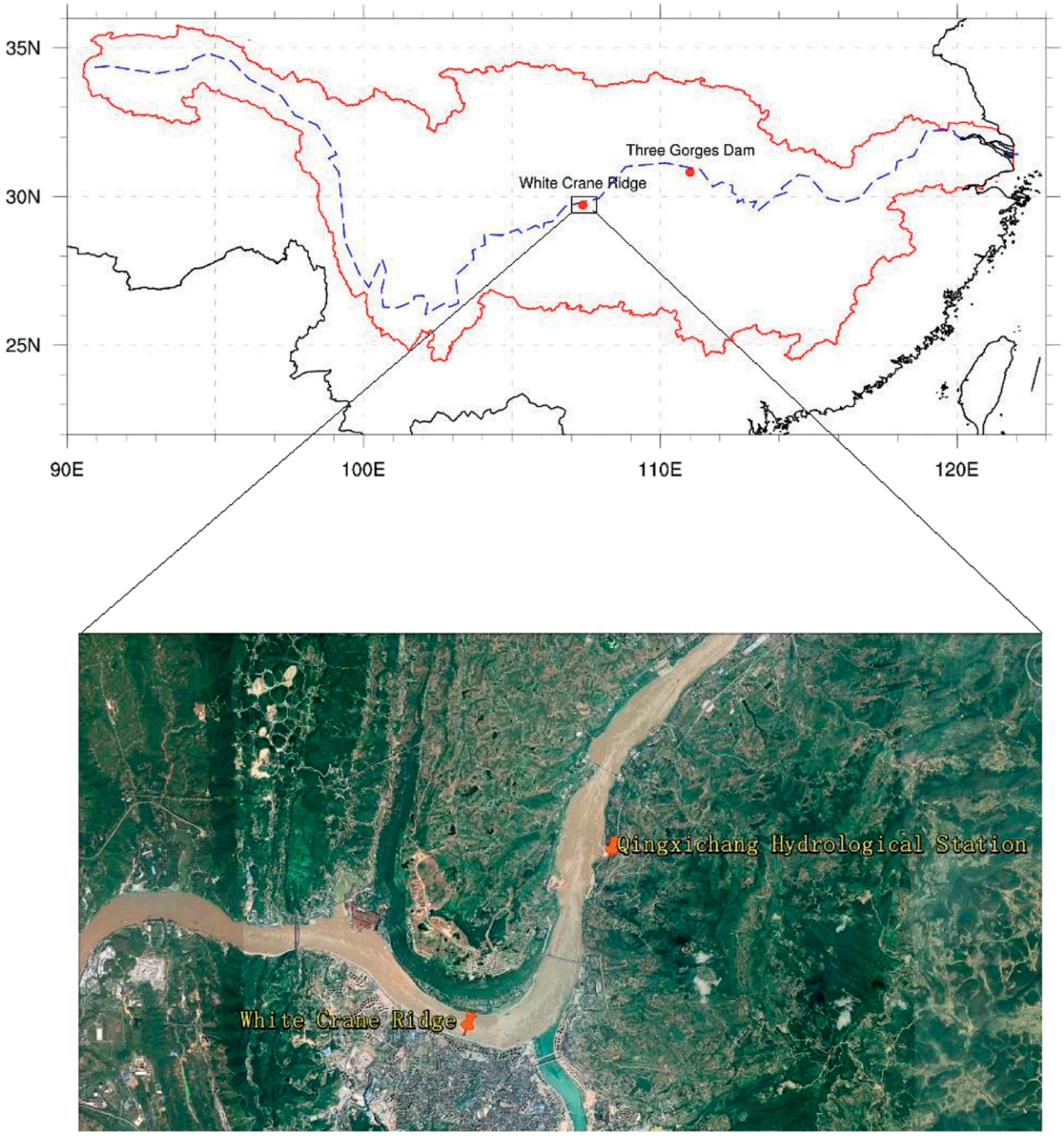
WCR is located in Chongqing City where the Yangtze flows eastward through the Sichuan Basin. WCR and all of the inscriptions and RF images carved on it have been impounded in backwater by the Three Gorges Dam since 2003, but the Baiheliang Underwater Museum was constructed over the inscriptions to preserve the valuable underwater cultural site.

With hot and humid summers and cool and dry winters, this area has an annual precipitation of around 1,200 mm. The highest water level of the Yangtze here is reached in July–August, and the lowest level in December–March. Runoff is mainly supplied by rainfall in the upper reaches of the river, and the glacial snowmelt in the Qinghai–Tibetan Plateau supplies only about 13% of runoff.

## Establishment of drought chronology

Some of the inscriptions and RF images on WCR were copied, kept as rubbings, and published in historical documents, while some were kept intact at the scene. In a 1974 chronology of the extreme droughts of 27 separate years (later updated and corrected), the RFs emerged from AD 764 to AD 1963, with the simultaneous water levels below the reference RFs for some of the years. We updated the chronology by including the estimated RF emergence years after 1963 based on instrumental records of the river water level at the Qingxichang Hydrologic Station (QHS), 12.1 km downstream from WCR.

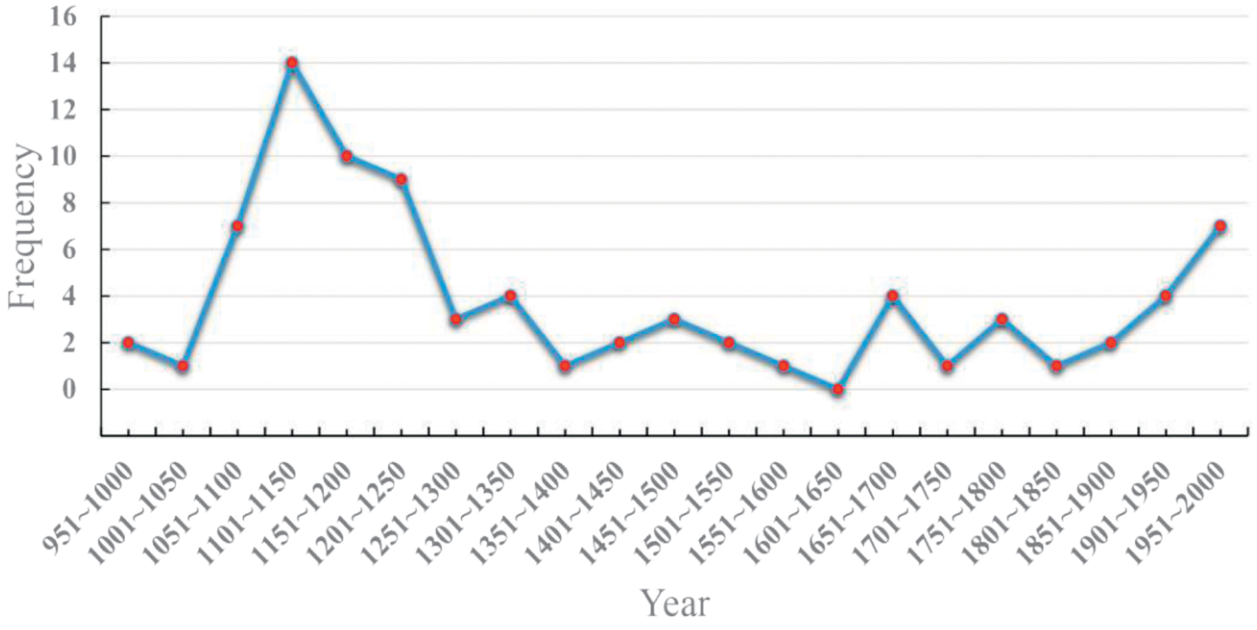
Over the period of instrumental records (1941–2003), RF emergence has only been conclusively documented in 1941, 1963, and 1973. We have found that a consecutive 7-day minimum water level of 136.34 m at QHS constitutes a good threshold for RF emergence at WCR. This is confirmed by the dry season (January–March) mean water level of 136.82 m at QHS. Using the threshold from QHS, we reassessed the period prior to 2003 and added five RF emergence years (1960, 1974, 1978, 1979, and 1987) to the chronology.




**The location of WCR (Baiheliang), QHS, and the Three Gorges Dam in the Yangtze River. (top) The Yangtze River basin, with dashed blue lines indicating the main stream, and solid red lines the boundary of the basin and (bottom) locations of WCR and QHS.**

## Verification of drought occurrence

To confirm the modern association between the hydrologic and climatic droughts, we compared the recent years of RF emergence with the dry season (January–March) mean climatic drought index (CI) series of the upper reaches of the Yangtze River (above the Three Gorges Dam). The CI, developed by the CMA, has long been used in the operational monitoring of meteorological drought. It incorporates accumulated daily precipitation data from CMA over the previous 30 and 90 days. The Penman–Monteith formula is used to calculate evaporation to obtain a wetness




**Frequency (occurrences per 50 yr) of RF emergences for 50-yr intervals since AD 951 at White Crane Ridge. Zero value is registered during AD 1601–50. North China experienced unprecedented droughts during this period, particularly during 1627–43, which may have triggered peasant uprisings, leading to the replacement of the Ming Dynasty by the Qing Dynasty. Furthermore, according to modern research, the spatial pattern of drought in the north and flooding in the south is usually accompanied by a weakening of the East Asian Summer Monsoon.**

term for the last 30 days. The larger the absolute negative values of the index, the more severe the meteorological drought. An annual mean CI ≤ –1.8 indicates drought. We calculate the regional averaged dry season mean CI of the upper Yangtze (223 stations) for 1951–2002. Latitude–longitude grids of 1° × 1° are used to calculate the annual area-weighted values of CI. The correlation coefficient of CI anomalies and the water level at QHS is 0.66, which is significant at the 99% confidence level, indicating a significant influence of meteorological droughts on the water level near WCR.

In the years of RF emergence, the CIs are almost all large negative values, indicating that severe droughts occurred in the preceding months in the region. These results show that large-scale and severe droughts indeed occurred in the years when the river water level dropped at WCR during recent decades, and the historical records at this site reflect past climatic droughts of the upper Yangtze.

## A preliminary analysis of historical droughts

In the 84 years that RF emerged since AD 764, 26 years have records of water level below the reference RF. Allowing that RFs may have varied throughout history due to the succession of dynasties and corresponding changes to society, the RFs do show a relatively high emergence frequency during 1051–1250—the Medieval Climate Anomaly or Medieval Warm Period in the Northern Hemisphere. There is a relatively low emergence frequency during the Little Ice Age (1501–1900). The highest frequency of low water levels for a 50-year period was 14 times in 1101–1150, and the lowest frequency was none during 1601–1650, during the peak of the Little Ice Age.

The unusual lack of RF emergence in this peak half-century of the Little Ice Age may have been caused by more frequent floods and fewer droughts related to generally wetter conditions in the mid- and upper-Yangtze and a weakening of the East Asian Summer Monsoon (EASM). The lowest historical water level indicated by the RF was approximately 0.6 m lower than the

average annual consecutive 7-day minimum water level before the impoundment of the Three Gorges Reservoir. A severe drought event would enormously impact agriculture and society of the upper Yangtze; today such a drought would severely affect operation of the Three Gorges Reservoir.

There is a new increasing trend of low water level events since the mid-nineteenth century, which needs to be further investigated. Reliable precipitation records of more than 100 years are lacking for the upper reaches of the Yangtze River. Also, it may be difficult to associate the modern low water events with variation of the EASM, because the weakened EASM of the last decades might have been caused by a different mechanism from that of the preindustrial era. Natural variability, greenhouse gas–induced global warming, and the aerosol-induced regional cooling have all likely played a part in the recent trend.

## Conclusion

WCR is one of the most valuable ancient hydrologic archives in the world. Our updated historical drought chronology based on the WCR inscriptions could be used in future studies of historical climatic and hydrologic droughts.

It is important to uncover additional records to complete the chronology with other proxy records to confirm the occurrence of major historical droughts and to examine the mechanisms and the social impacts of extreme droughts.

## METADATA

**BAMS:** What would you like readers to learn from this article?

***Guoyu Ren (China University of Geosciences):*** *The White Crane Ridge Rock Fish emergence chronology in Fuling, Chongqing, China, is probably the world's oldest hydrological record and one of the longest chronologies of extreme low water level in any of the world's large rivers. We present an updated chronology of the ancient and modern extreme low water level events that could be highly valuable for further studies of hydrological and climatic variation in the upper Yangtze River Basin.*

**BAMS:** How did you become interested in the rock fish and inscriptions?

***GR:*** *Zhenghong Chen (a coauthor) and I jointly applied for funding to investigate application of the rock fish records in 1996. In 2017, the first author, Jun Qin, Zhenghong Chen, and I suggested an update to the chronology and further examination of its climatic implication. We then discussed the issue many times, and we all realized the great significance of studying the multidecadal-to-century–scale climate and hydrological variability. Ailin Shi, Qin's student, was very interested in this topic, and she has made a great effort to collect data in Chongqing and Wuhan, and to analyze the data.*

**BAMS:** What surprised you about this long record?

***GR:*** *The ancient people in Fuling had a keen ability to observe natural phenomena. They made full use of favorable natural conditions by carving rock fish and inscriptions on the giant rock ridge in the Yangtze River to record the low water level. The rock fish and inscriptions are so vivid, diverse, and exquisite, that's amazing!*

**BAMS:** How do you explain such persistence in this record over so many centuries?

***GR:*** *According to the inscription, the ancient people believed that "rock fish emergence augurs well"; that is, people used the low water level in winter and spring to predict the harvest of crops in next summer and autumn. These applications all surprised us, and we admire the wisdom and perseverance of these ordinary peoples.*

**BAMS:** What was the biggest challenge you encountered while doing this work?

***GR:*** *It is a challenging task to use as much other reliable information, including instrumental data, as possible to interpolate and extend the chronology of rock fish emergence records up to 2003, when the Three Gorge Reservoir was impounded.*

**BAMS:** What's next?

***GR:*** *The reason for the real impact of water level in winter and spring on grain production in the Fuling area the following summer and autumn needs to be investigated. Also, the possible causes of the long-term change in extreme low water level over the last 1,000 years.*