Water security of Sameura dam project under the influence of global climate changes in the western part of Japan

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Abstract This study examine the vulnerability of water resources under the influence global climate changes in the western part of Japan since 1970s when the sea surface water temperature along the pacific coast of Kochi prefecture has started to increase by steps. Many dams in the region are under the fear of creeping return period of the occurrence of extreme drought and floods. SAMEURA dam, which is the largest dam in Shikoku region in Japan, is a typical case of the trouble to suffer from frequent droughts and floods immediately after the completion of dam project in 1973. This study aims to evaluate the influence of global climate change on the water security of SAMEURA dam project and fishery eco-security in Kochi to take into account the correlation of long-term changes between rainfall and sea surface water temperature since mid 1970s. It is estimated that the sea surface water temperature has been increasing by 2 ^{0}C in the past 25 years since 1975, of which the irregular cyclic fluctuation pattern of sea surface water temperature has a relation with El-Nino and La-Nina in the western rim of Pacific Ocean.

Key worlds climate change, rainfall, water resources, vulnerability,

INTRODUCTION

Vulnerability assessment of water resources under the influence of global climate changes is a new agenda for the integrated water resources management policy to forecast the future natural disasters.

Atmospheric general circulation model (MRI-AGCM), which has just been developed by Japan meteorological agency in 1997, suggests the significant influence of global warming on the long-term changes in regional rainfall patterns and intensity up to the middle of 21st century (2050). Historical long term trend of annual average rainfall in the past 100 years is decreasing even after 1970s. While the temporal result of long-term forecasting by MRI-AGCM is alarming with irregular extreme events of droughts and floods to fear the sustainable water use in the western part of Japan(Kitoh 2006, 2008).

Many large scale dam development projects in Japan had been carried out since 1960s to support the growing economy and demand of water for either domestic or industry. The effective storage capacity of dam was designed to use the long-term rainfall data set before the 1960s when the climate system of Japanese island had been rather stable with higher average annual rainfall. When the construction work of many large dams had completed to

supply water in 1970s, the climate system of Japanese island was unlikely started to change by steps with irregular extreme events. The SAMEURA dam, which is the largest dam in Shikoku region in Japan, is a typical case of the trouble to suffer from frequent droughts and floods immediately after completion of dam project in 1973 (Fig.1).

Why the climate in Kochi has changed with irregular extreme events of droughts and floods since 1970s? Correlation between the changes in rainfall and sea surface water temperature along the offshore of Pacific coast in Kochi is analyzed to examine the long-term monitoring data of sea surface water temperature since the mid of 1970s. It is estimated that the sea surface water temperature has been increasing by 2 ^{0}C in the past 25 years since 1975, of which the irregular cyclic fluctuation pattern of sea surface water temperature has a relation with El-Nino and La-Nina in the western rim of Pacific Ocean (Imamura *et.al.* 2001).

This study aims to examine the influence of global climate change on the water security of SAMEURA dam project and fishery eco-security in Kochi to take into account the correlation of long-term changes between rainfall and sea surface water temperature since mid 1970s.

Fig.1 Location map of the study area

HISTORICAL CLIMATE CHANGE AND RAINFALL IN JAPAN

Nowhere are the effects of climate change as visible in Japan as well as monsoon Asia. The increasing frequency of droughts and floods and catastrophic climate events are already hitting after 1980s in accordance with the global warming.

The precipitation is decreasing in the long run, but it seems that the fluctuations have gradually become

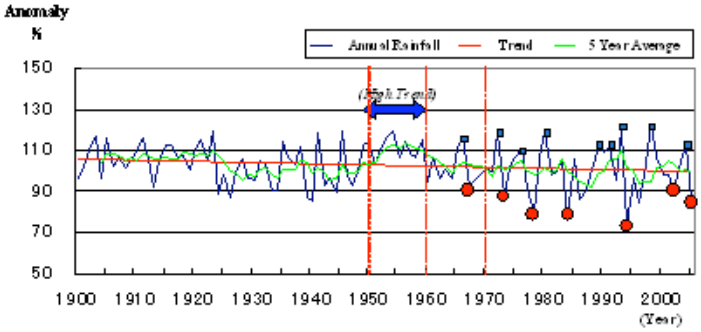

Fig.2 Anomaly of annual rainfall in Japan (1900–2000)

larger (Figs.2).While, Japan received relatively large amount of rainfall till 1920s and around 1950. The climate system of Japan was unlikely started to change by steps with irregular extreme events of droughts and floods after 1970s within the long-term trend of decreasing annual average rainfall in the past 100 years.

The trend of long-term annual average rainfall is different in the regions. The average annual rainfall at Sameura is three times as high as 1,149 mm of Takamatsu. It is likely to increase in the wet region and decrease in the dry region such as at rainfall gauging station of Sameura and Takamatsu, respectively. (Figs. 3,4). This local trend with the effect of significant difference of altitude is also simulated in the fine grid (25km x 25km) MRI-AGCM.

Fig.3 Anomaly of annual rainfall in Takamatsu

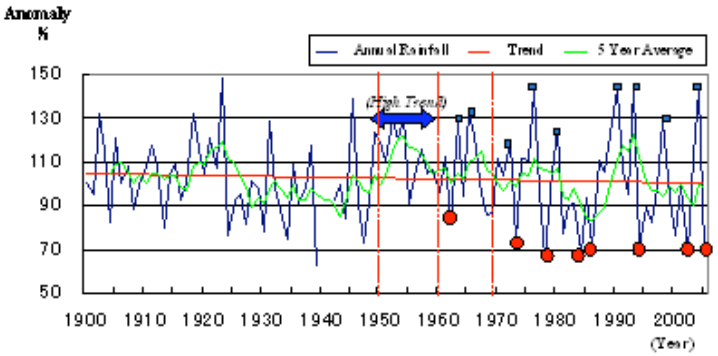

Fig.4 Anomaly of annual rainfall in Sameura

SAMEURA DAM AND KAGAWA MAIN CANAL

Sameura dam, which is the largest multipurpose dam in the island of Shikoku, was constructed in upper reaches of Yoshino river system in 1973. The dam, which receives highest annual average rainfall between 2,200mm and 5,500 mm in the watershed in Kochi prefecture (Fig.4), has an effective storage volume of 280 x 10^6 m^3 to supply 863 x 10^6 m^3 of freshwater to downstream users including Ehime, Kagawa and Tokushima governorates.

The Kagawa prefecture, which had long been suffering from the serious droughts, decided to depend on the trans-boundary water source from Sameura dam in Kochi prefecture in the early 1960s. The construction work of Kagawa main canal system, which diverts Sameura water at Ikeda weir in the middle reaches of Yoshino river by long conduit tunnel, had started in 1968 and completed in 1981 to solve the long-standing water shortage problems in the history. Many decision makers as well as people in the Takamatsu felt deep satisfaction to escape from the long-standing fear of serious droughts. It is somewhat ironic that the droughts came again many times after the completion of the main frame of integrated Yoshino river basin development plan in 1981.

IRONY OF CLIMATE CHANGE AND LARGE DAM

Why unexpected drought affected the Sameura dam in Shikoku after 1970s? The basic planning and detailed design of Sameura dam were prepared in the early 1960s to adopt the hydrologic data set in the 1950s, of which the period was very unique decade with stable and high annual average rainfall throughout 20th century. The effective storage volume of 280 x 10^6 m^3 was too large to store the effective runoff from the catchment after 1980s. The estimated return period for drought in the basic design is decreased about 50% or less if the hydrological data set of up to the year 2000 is taken into account in the probability analysis.

Many large dams in the western part of Japanese island along the Pacific ocean, which were constructed in the period of 1960-1970s, are not satisfying the original safety design criteria owing to the influence of global climate changes after 1970s including the effect of El-Nino and La-Nina.

GLOBAL CLIMATE CHANGE AND SEA SURFACE WATER TEMPERATURE IN KOCHI

Why climate is changing in Kochi after 1980s to correspond with the global warming? Kochi prefecture is located along the Pacific sea coast where *bonito* ride the warm Kuroshio or Black Current from spring to summer (Takahashi 1999).

The prefectural government started to measure the sea surface water temperature at 50 different locations along the off-shore of Pacific Ocean to monitor the fish (*Bonito*) ecology since 1975 (Fig.5).

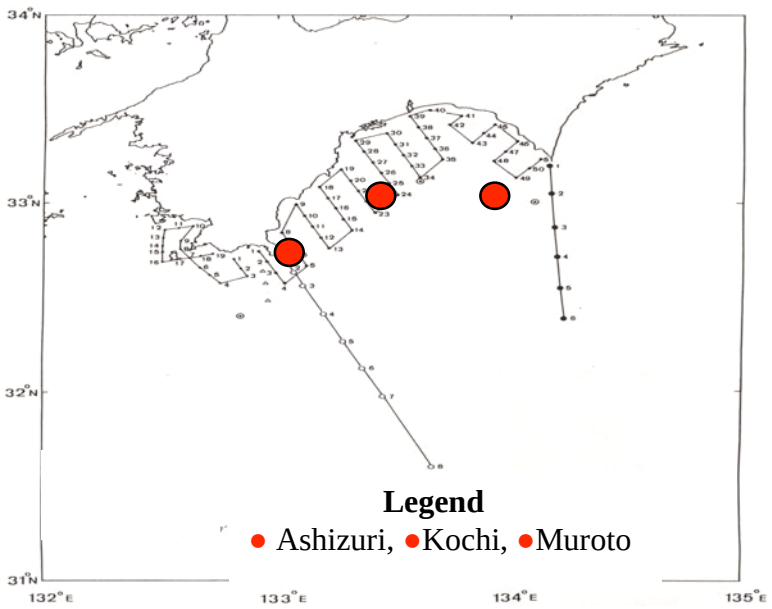

Fig. 5 Monitoring points of sea surface water temperature

Yearly changes of sea surface water temperature are shown in Figs 6. The sea surface water temperature has been increasing by 2.0 ℃ in total during 25 years since 1975. The sea surface water temperature increase is significant after the summer season such as September to December as shown in Fig. 7. The increasing trend of sea surface water temperature is not only observed at surface but in depth. Kochi is a hot spot of increasing sea surface water temperature along the coast of Japan. Fig.7 shows the time series of sea surface water temperature changes at Asizuri. Other two points also show the same trend as of the case atf

Ashizuri. It is found that significant deviations of extreme increase or decrease in sea surface water temperature are observed in the typical year of El-Nino or La-Nina.

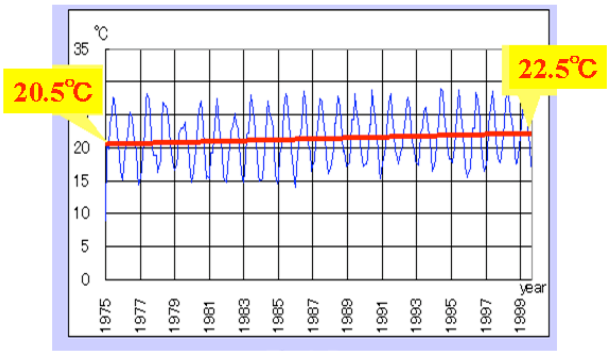

Fig.6 Annual change of sea surfaced water temperature from 1975 to 2000

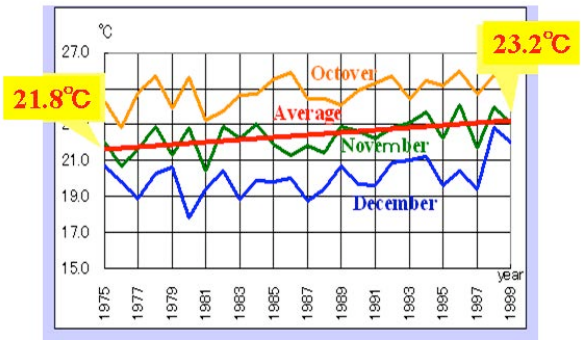

Fig.7 Monthly change of sea surfaced water temperature from 1975 to 2000

THE EFFECT OF LA-NINA ON THE SEA SURFACE WATER TEMPERATURE AND ECO-SYSTEM

The amount of Ayu (*Plecoglossus altuvelis*) catch in the rivers of Kochi prefecture has been significantly decreasing by steps since 1980 corresponding to the increase in sea surface water temperature. Higher sea surface water temperature give an adverse effect on the growth of fries of *Ayu* which stay in the shallow sea along the offshore of the Shimanto river mouth.

The higher sea surface water temperature from summer to autumn in Japan island along the Pacific coast is largely influenced by the La-Nina, which also give an adverse effect on the life environment of the migratory fish of Ayu fry (*Plecoglossus altuvelis*) in the offshore at the river mouth of Shimanto river by decreasing the fish production for the next year. as shown in Fig.8.

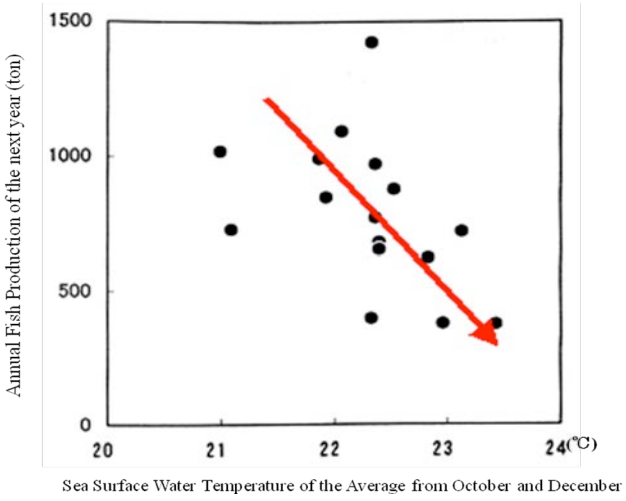

Fig. 8 Correlation between annual fish production of *Ayu* (*Plecoglossus altuvelis*) and sea surface water temperature from October to December

CONCLUSIONS

Many large dams in the western part of Japan island along the Pacific ocean, which were constructed in the period of 1960-1970s, are not satisfying the original safety design criteria owing to the influence of global climate changes after 1970s. Sameura dam is a typical case of creeping return period problem in Japan. The increasing sea surface water temperature along the offshore of Pacific ocean in Kochi gives a significant influence on the changes in regional rainfall as well as the fish ecology and eco-security.

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