QUANTITATIVE EVALUATION OF WATER TEMPERATURE CHANGE ON COLD WATER FISH HABITAT IN SNOWY COLD RIVER

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ABSTRACT

The water environment has been strongly affected by climate change in snowy cold regions. The effects of climate change are inevitable, even if mitigation plans for greenhouse gas reduction are implemented. It is necessary to evaluate quantitatively the effects of climate change on water environment to formulate adaptation plans in snowy cold regions. Therefore, we quantitatively evaluated the future change of water temperature and the impact on cold water fish habitat in snowy cold river by adopting estimated high-resolution data, which can predict meteorological characteristics with climate change in snowy cold regions by using MRI-NHRCM20, which is climate change data based on RCP emission scenario adopted by the IPCC's Fifth Assessment Report. Sorachi River, which is snowy cold river in Hokkaido, has suitable habitat for salmonid fish, such as *Hucho perryi*. *Hucho perryi* is designated as an endangered fish and the impact of raising water temperature with climate change is concerned. For the river water temperature simulation with climate change, the analysis model was constructed that based on heat and water balance model (LoHAS), tank model and channel tracking of heat flux.

Keywords: Climate change, water temperature, cold water fish habitat, MRI-NHRCM20, LoHAS

1. INTRODUCTION

The IPCC Fifth Assessment Report concluded that there is no doubt about the warming of the climate system. In the future, there is a concern that in-water fisheries and ecosystems will be affected by rising water temperatures, which may be caused by rising temperatures and the increase of oxygen consumption due to decomposition of organic matter in river.

The possibility of loss of habitat of cold water fish due to water temperature rise with climate change is reported by evaluating water temperature dependence of fish (Amano *et.al.*,1989). Also, it is reported that there is potential risk of reduced spawning opportunities for salmonid fish with climate change in Fraser River in British Columbia, Canada (Morrison *et.al.*,2002).

Salmonid fish are representative species and valuable fishery resource that supports the local economy in snowy cold regions, such as Hokkaido. In the future, habitat for salmonid fish and the local economy of Hokkaido may be affected by climate change. Therefore, it will be necessary to evaluate quantitatively the effects on climate change.

We focused on regional characteristics of snowy cold regions, which is scale of approximately 10km or less. This paper aims to consider adaptation measures to climate change and evaluate quantitatively the effects on river water temperature and habitat for salmonid fish, by using climate change prediction data.

2. MATERIALS AND METHODS

2.1 The studied basins

Our study addressed Kanayama Dam basin (catchment area: 470km^2), which is at the upper reaches of Sorachi River (catchment area: 2,618km^2), a Class-A river in Hokkaido. Kanayama Dam is under direct control completed in 1967 and managed by Hokkaido Development Bureau of the Ministry of Land, Infrastructure and Transport. Kanayama Dam supplies water to water intake facilities located at the lower reaches of Sorachi River, controls the flood and provides power generation to surrounding areas. In Kanayama Dam basin, cold-water fish species such as *Hucho perryi*, which are extremely at high risk of extinction in Hokkaido in the near future, have been identified. Figure 1 shows the location of Kanayama Dam basin.

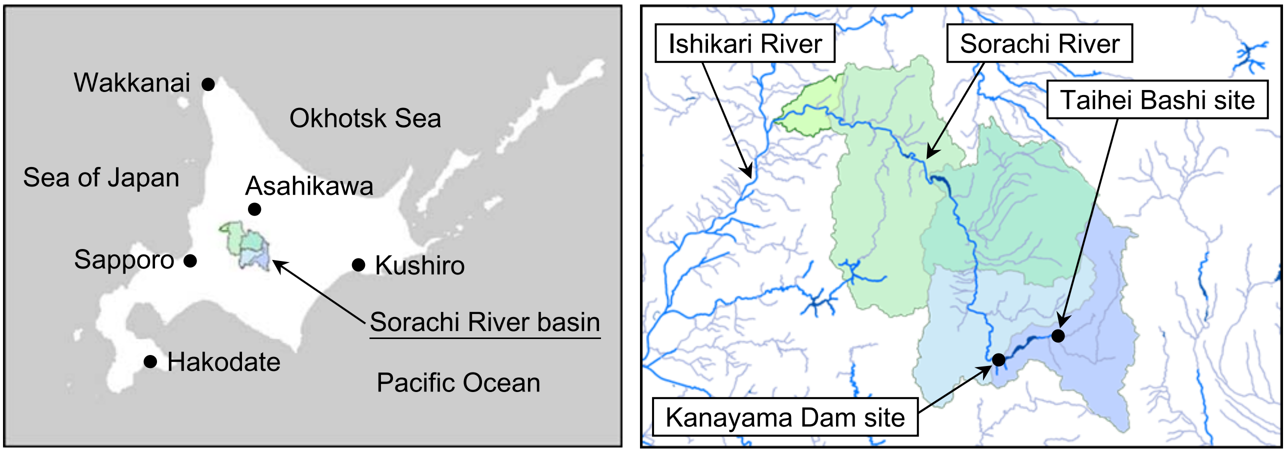


Figure 1. Location of Sorachi River and Kanayama Dam basin

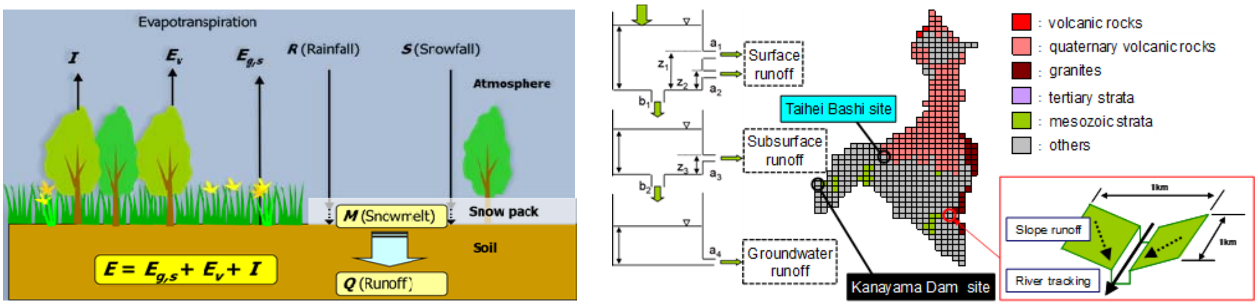
2.2 Analytical methods

Table 1 shows the analysis case of climate change data based on RCP emission scenario in this study. We adopted climate change data (MRI-NHRCM20), which is regional climate model provided by Japan Meteorological Agency and based on RCP emission scenario, and chose Yoshimura scheme from three kinds of the cumulus cloud convection scheme as the same condition, which has good reproducibility of the present cumulus cloud convection around Japan. In this study, we adopted climate change forecast data of 1km mesh size for Sorachi River basin, which is estimated by statistical downscaling that is adopted 55 year analysis model of Japan Meteorological Agency (DS-JRA55).

Table 1. Analysis case of climate change data based on RCP emission scenario

Case no.	Analysis period	RCP emission scenario	Sea surface water temperature
Case-1	9/1/1984～8/31/2004	—	HadISST
Case-2	9/1/2080～8/31/2099	RCP8.5	CMIP5-SST1
Case-3			CMIP5-SST2
Case-4			CMIP5-SST3

Secondly, we calculated runoff by adopting 1km mesh climate change forecast data to the analysis model was constructed that based on heat and water balance model (LoHAS) and tank model. About the parameters of intermediary discharge and groundwater discharge of tank model related to geology, we extracted from surface data of Kanayama Dam basin, such as volcanic rocks, quaternary volcanic rocks, granites, tertiary strata, mesozoic strata, and others with reference to previous study (Usutani *et.al.*,2014). And we set the parameters each mesh by using a regression equation based on the surface geological area ratio of Kanayama Dam basin. Figure 2 shows the conceptual diagram of LoHAS and tank model.



(a) LoHAS (b) tank model

Figure 2. Conceptual diagram of LoHAS and tank model

In this study, in order to find the possibility of water temperature prediction using various hydrological data estimated by LoHAS, we built the analytical model to calculate river water temperature by dividing flux on the arbitrary mesh upstream of Taihei Bashi site by runoff and performed river flow tracking calculation of flux upstream of Taihei Bashi site. As for the analytical model, we considered the shielding rate of solar radiation by riparian trees based on LAI with reference to previous study (Nakamura *et.al.*,1989). And, in order to evaluate the effects of changes in river water temperature with climate change on habitats of cold water fish, we examined the optimal water temperature days and range during the spawning period (from

April to May) of *Hucho perryi*. The optimum water temperature was set at 6-7 °C with reference to previous study (Kasai *et.al.*,2006). Figure 3 shows the conceptual diagram of the analytical model to calculate river water temperature.

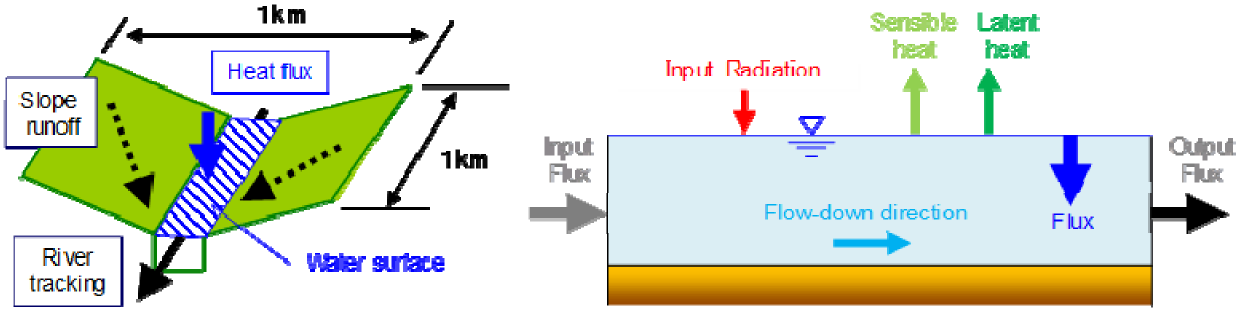


Figure 3. Conceptual diagram of the analytical model to calculate river water temperature

3. RESULTS AND DISCUSSION

Figure 4 shows monthly changes of inflow of Kanayama dam site and river temperature of Taihei Bashi site with climate change. The analysis results were clarified that monthly average water temperature might increase by approximately 4.7 ℃ in March and by approximately 3.6 ℃ in July with climate change in the future. Compared to seasonal fluctuation of inflow of Kanayama Dam in March, both inflow of Kanayama dam and river water temperature of Taihei Bashi site show drastic change in the future climate from the current climate. The change of hydraulic characteristics becomes remarkable. In snowy cold regions, river water temperature is closely related to snowmelt, so snowmelt flood has significant effect on habitat of cold water fish, such as *Hucho perryi*. Therefore, the changes of snowmelt with climate change will affect the life history of cold water fish, such as run-up, spawning and hatching in the future.

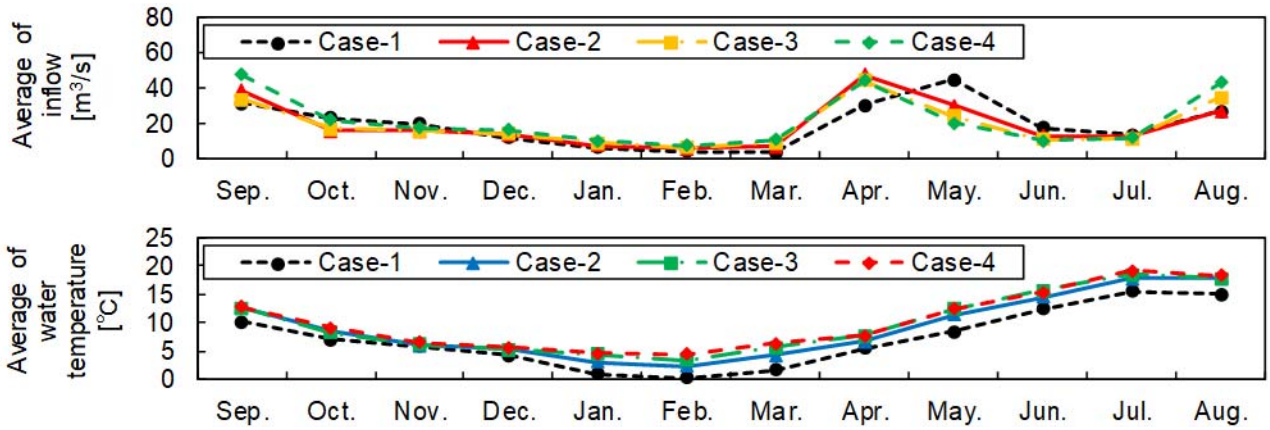


Figure 4. Monthly changes of inflow of Kanayama dam site and river temperature of Taihei Bashi site

Figure 5 shows changes in river water temperature and optimal water temperature days during the spawning period of *Hucho perryi* in the upper Taihei Bashi site. The analysis results were clarified that river water temperature might rise to approximately 8.1 °C and exceed the optimum water temperature during the spawning season with climate change, also number of days in optimum water temperature range might decrease.

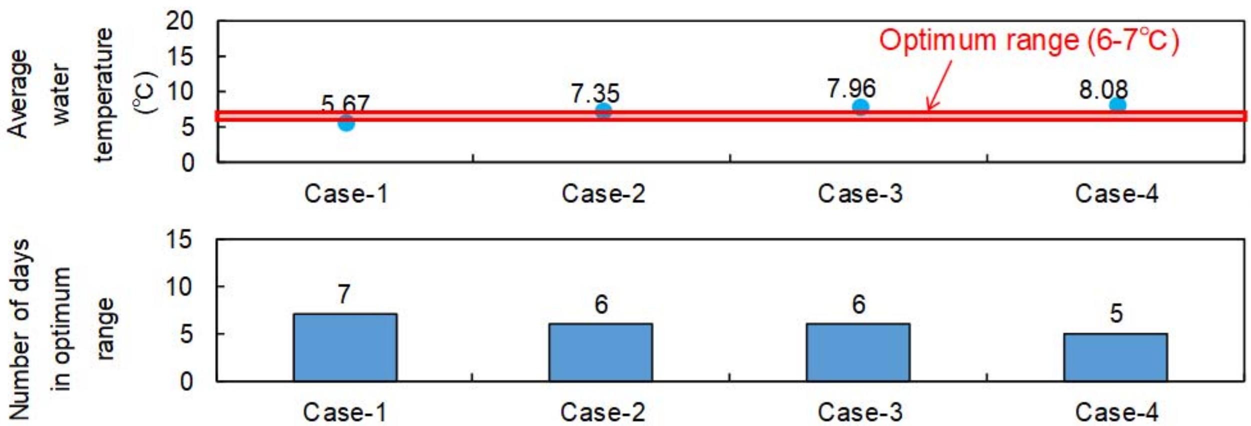
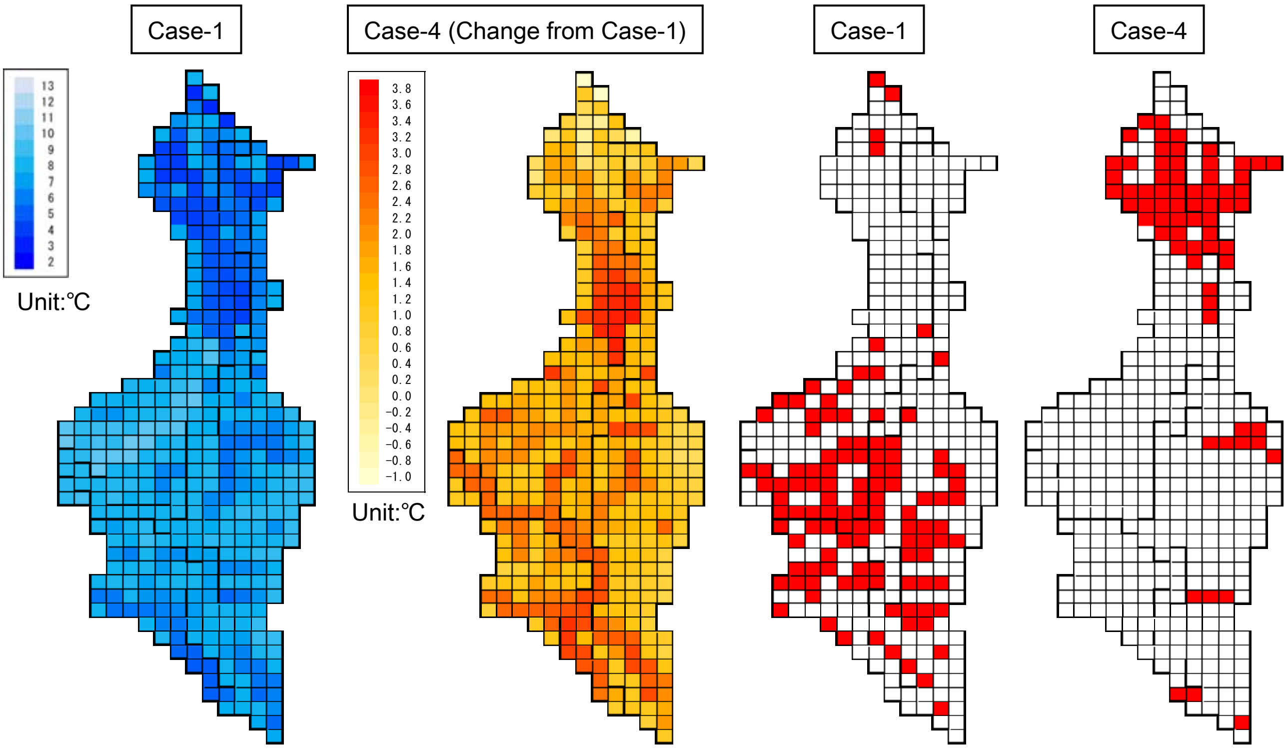


Figure 5. Changes in river water temperature and optimal water temperature days during the spawning period

Figure 6 shows river water temperature distribution and the area of optimal water temperature range during the spawning period of *Hucho perryi* in the upper Taihei Bashi site. The analysis results were clarified that the range of optimum river water temperature area suitable for spawning of *Hucho perryi* scattered in the middle reaches of Taihei Bashi site might move near the upper reaches.



(a) Water temperature distribution (b) Optimal area suitable for spawning

Figure 6. River water temperature distribution and the area of optimal water temperature range

Water environment suitable for spawning of *Hucho perryi* will be significantly impaired and natural reproduction will be difficult due to the loss of spawning opportunities. And, it is necessary that river crossing structure hinder the movement of cold water fish at the upper reaches of Sorachi River can be removed.

4. CONCLUSIONS

In this paper, it was shown that the results of river water temperature simulation indicated that climate change is expected to raise river water temperature in March, also river water temperature area suitable for spawning of *Hucho perryi* might be limited. In the future, the quantitative evaluation method will be used for formulating effective and efficient adaptation plans based on characteristics of snowy cold regions, such as Hokkaido. The analysis model will be further developed for evaluating the influence of climate change accurately and the water environmental management.

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