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Development of a spatially distributed model of fish population density for habitat assessment of rivers

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Flow conditions play an important role in sustaining biodiversity of river ecosystem. However, their relations to freshwater fishes, especially to fish population density, have not been clearly described. This study, therefore, aimed to propose a new methodology to quantitatively link habitat conditions, including flow conditions and other physical conditions, to population density of fish species. We developed a basin-scale fish distribution model by integrating the concept of habitat suitability assessment with a distributed hydrological model (DHM) in order to estimate fish population density with particular attention to flow conditions.

Generalized linear model (GLM) was employed to evaluate the relationship between population density of fish species and major environmental factors. The target basin was Sagami River in central Japan, where the river reach was divided into 10 sections by estuary, confluences of tributaries, and river-crossing structures (dams, weirs). The DHM was employed to simulate river discharge from 1998 to 2005, which was used to calculate 10 flow indices including mean discharge, 25th and 75th percentile discharge, duration of low and high flows, number of floods. In addition, 5 water quality parameters and 13 other physical conditions (such as basin area, river width, mean diameter of riverbed material, and number of river-crossing structures upstream and downstream) of each river section were considered as environmental variables. In case of Sagami River, 10 habitat variables among them were then selected based on their correlations to avoid multicollinearity. Finally, the best GLM was developed for each species based on Akaike's information criterion.

As results, population densities of 16 fish species in Sagami River were modelled, and correlation coefficients between observed and calculated population densities for 10 species were more than 0.70. The key habitat factors for population density varied among fish species. Minimum discharge (MID) was found to be positively correlated to 9 among 16 fish species. For duration of high and low flows (DHF and DLF), longer DHF/DLF was corresponded to lower population density for 7/6 fish species, respectively, such as Rhinogobius kurodai and Plecoglossus altivelis altivelis. Among physical habitat conditions, sinuosity index (SI, the ratio between actual river section length and straight line length) seems to be the most important parameter for fish population density in Sagami River basin, since it affects 12 out of 16 fish species, followed by mean longitudinal slope (S) and number of downstream dams (NLD). Above results demonstrated the applicability of fish distribution model to provide quantitative information on flow conditions required to maintain fish population, which enabled us to evaluate and project ecological consequences of water resource management policy, such as flood management and water withdrawal.