RISK ASSESSMENT AND FISH HABITAT WITH THE STAGE OF RIVER IMPROVEMENT

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ABSTRACT

River improvement of the Yura river is based on the idea of flood control until now, and it surely improves the flood control benefits. This study is to estimate the flood control benefit based on the river improvement history of the midstream part of the Yura river. In addition, this paper examines the possibility of offering in the present river environment. The analysis of floods was carried out using DioVISTA/Flood Professional and the inundation risk map were made for the result of flood simulation analysis. From the analysis result, it was confirmed that the flood control benefit appeared. On the other hand, it was found that the area along the tributary river was flooded with high frequency. Furthermore, it was found that the space which fish can choose as refuge is along a tributary river. It can be said that the inundation area with high frequency is a favorable space for the river environment.

Keywords: River Basin Disaster Resilience and Sustainability, river environment, inundation risk map, fish refuge and habitat

1. INTRODUCTION

Flood control has been based on collecting rainfall in rivers. Therefore, various flood control measures have been implemented, such as channel dredge, continuous levees, sluice gates, and flume. The river maintenance of the Yura River, a first-class river, is based on the concept of flood control and prevention concepts. However, the frequent occurrence of typhoons and heavy rainfalls due to climate change has reached the limits of conventional measures. In recent years, therefore, river improvement has not been able to keep pace with the increasing frequency of typhoons and frontal rainfall. Flood damage has occured in areas with low improvement. This has led to the River Basin Disaster Resilience and Sustainability as a new flood control measure.

River Basin Disaster Resilience and Sustainability differs from the conventional flood control concept. Based on the concept of the River Basin Disaster Resilience and Sustainability, the parties concerned in a basin are supposed to take comprehensive and multilayered measures to prevent flooding as much as possible, reduce and mitigate the damage, and restore/reconstruct the area (Council for Social Infrastructure Development, 2020). When introducing River Basin Disaster Resilience and Sustainability into a river basin, it is essential to understand the effects of flood control based on the history of river improvement. In addition, that the river improvement history has not always taken the river environment into consideration. The closure of the tributary junction section due to channel excavation and continuous levee construction may have contributed to the deterioration of biological habitats in rivers. Therefore, from the perspective of restoration and conservation of ecosystem services, we would like to understand the impact on the river environment.

The purpose of this study is to understand the effects of flood control on the middle reaches of the Yura River shown in Figure 1, based on the history of river improvement. Furthermore, based on the concept of the River Basin Disaster Resilience and Sustainability, the study examines how the facilities

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should be in flood control and the river environment. The paper also presents a method for considering the concept of risk in residential areas and its countermeasures, based on the evolution of risk in the landside areas in the context of flood control measures. Furthermore, in evaluating the biological habitat in the landside area, areas that fish can choose as evacuation centers were considered.

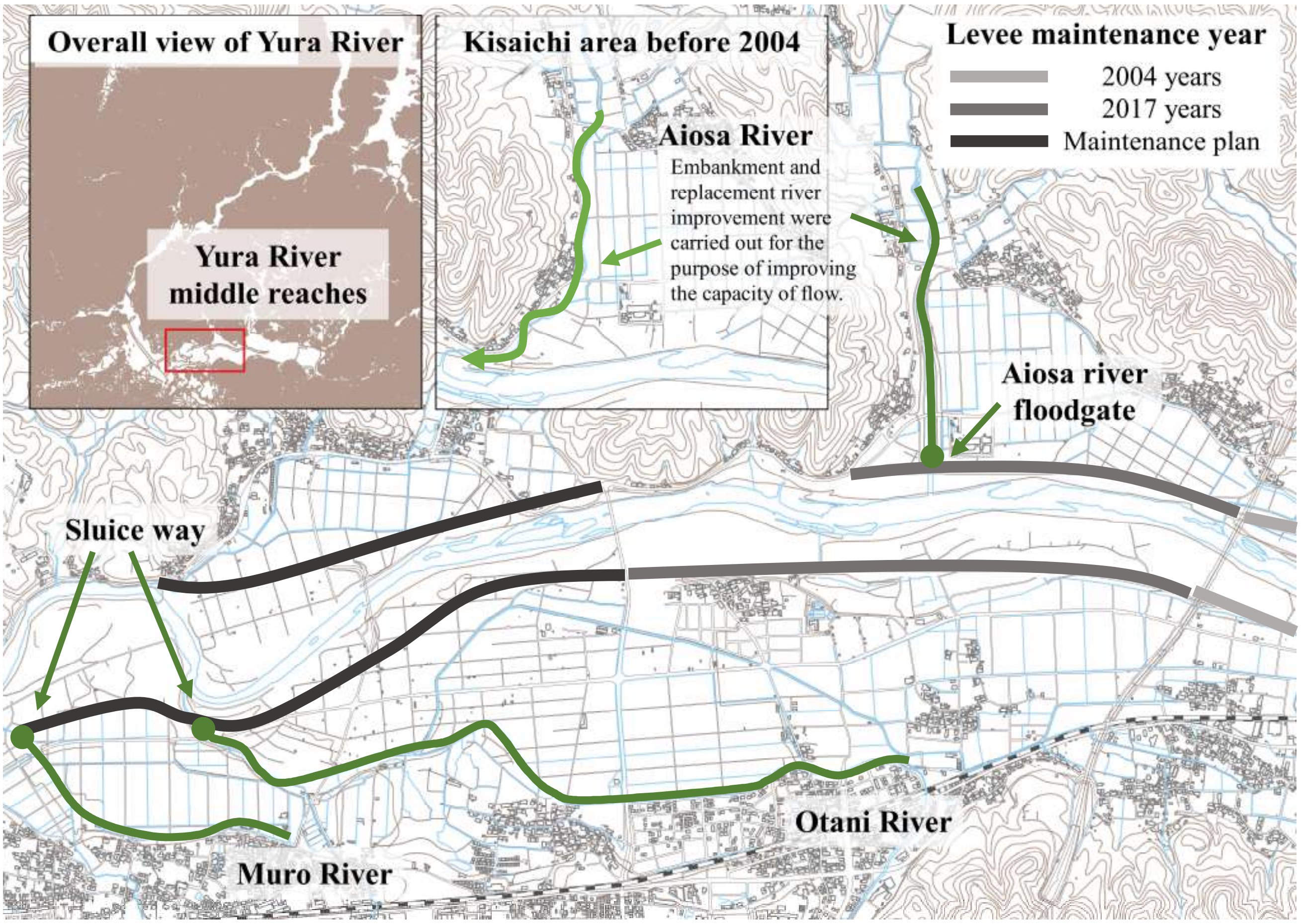

Figure 1. Detailed map of the middle reaches of the Yura River

2. RESEARCH METHODS

2.1 Of Numerical Analysis Model Overview

The analysis of flooding flow in this study was conducted using the DioVISTA/Flood Professional, which is provided by Hitachi Power Solutions, Ltd. The software represents a series of hydrological processes from rainfall to overflow by connecting them to three mathematical models (runoff model, flooding flow in river model, and other model in the inundation). This allows the software to handle inland and outland flooding without distinction.

2.2 Setting cross-section model conditions

In order to reproduce the flooding patterns due to changes in river improvement, an analysis of the flood model was constructed considering the four time periods. The first inundation model was constructed incorporate the cross-section at 1961's, when no channel dredge or embankment improvement had been made. This model incorporates the condition of continuity between the main river channel, tributary, and wetland and flooded area because of the lack of river improvement. Second, the model was updated to incorporate the cross section in 2004, when the river channel was dredged and a portion of the upstream levees was updated. Since the midstream section in 2004 was before the embankment improvement was updated, it was considered to be continuous and functioned as a refuge and habitat for fish, as it did in 1961.Third, a model was updated to the cross-section after 2017, in which some areas of the middle reaches were left in place and treated with tributary river treatments such as embankment improvement, sluices, and flumes. The model was the loss of continuity between the main river channel, tributary and wetland and flooded area, as embankment improvements have been updated in almost all areas. On the other hand, flood safety has improved compared to 1961 and the current condition, as the levees prevent external flooding. Fourth, the model was updated to incorporate the completed cross-section of the river infrastructure development project. However, it is highly likely that the continuity of biological habitats in the main and tributary rivers has been largely lost due to the division of the river by levees and the construction of sluice gates and flumes. The runoff, flooding, and inundation processes were analyzed by subjecting these four models to rainfall events with reproduction periods of 5, 10, 30, 50, 100, and 200 years as the evaluated external forces. Other specific calculation conditions are shown in the Table 1. Note that levee breaking was not considered in this study.

Table 1. Calculation conditions

Item	Setting details
Targeted Floods	2004 Typhoon No.23 2013 Typhoon No.18 Heavy rainfall in July 2018
Exceedance probability	1/5, 10, 30, 50, 100, 200
River channel data	Parts of the Yura river and Haze River are laser survey results provided by the river administrator. Other tributary rivers and canals were prepared from field surveys.
Land use, roughness coefficient, etc.	Flood Risk-area Map Creation Manual (4th ed.) Compliance
Runoff model	Distributed runoff model (Tachikawa Y, et al 2004)
River model	1D unsteady flow
Flood model	2D unsteady flow

2.3 How to evaluate flood control benefits using flood risk maps

Flood control benefits based on river improvement were evaluated from inundation risk maps. The inundation risk map is color-coded according to the condition of whether or not inundation will occur for a given exceedance probability. In other words, it means the likelihood of inundation. The risk map was created based on the method of Taki et al (Taki K, 2010). The maximum envelope value obtained from the analysis was used as the inundation depth. Then, using GIS, the maximum inundation depths for each mesh were superimposed on each probability scale. The legend is colored darker for more likely inundation and lighter for less likely inundation.

2.4 Methods for estimating fish refuge and habitat areas

Refuge and habitat areas estimated from inundation conditions were evaluated based on Denda et al (Denda M, 2009). In general, fishes have two swimming behavioral abilities. One is the cruising speed at which they can swim for a long time, and the other is the rush speed at which they can swim for a short time instantaneously. Therefore, fish are thought to be unable to swim against current velocities greater than the rush velocity. On the other hand, the space where fishes can act is the space where the flow velocity is less than the rush velocity. Therefore, in this study, the rush velocity of fish was used as one threshold value. The space below the rush velocity was defined as a fish refuge space and was visualized and evaluated at each probability scale.

The fish burst speed is defined by Equation (1) (Tsukamoto K, 1983).

$$BS = 10BL \tag{1}$$

where BS: fish burst speed (m/s), BL: body length (m).

Average body lengths of small and medium-sized species were extracted from the results of the census of riparian areas in 2020 and 2021. As a result, the average length of the collected fish community was about 5.8 cm. Based on this, the burst speed was calculated as approximately 0.58 m/s and used as the threshold value. For the fish refuge estimation map, spaces below the threshold were extracted using GIS and overlaid at each probability scale. This is used to estimate fish refuge areas that can ensure continuity between the main river channel, tributary, and wetland and flooded area while maintaining flood safety.

3. ANALYSIS RESULTS

3.1 Flood control benefits from risk maps

The risk map for the middle part of the Yura River based on river improvement is shown in Figure 2 using Typhoon No. 18 in 2013. Risk map 1961’s cross-section shows that the entire midstream area is exposed to high frequency (return period 1/5-1/10) inundation risk. Housing areas far from the main river show a medium-high frequency (return period 1/5-50) inundation risk, which also confirms that the entire area was flooded at a high frequency in 1961 due to the levee-free section of the river. Risk map considered in the 2004's cross-section shows a lower risk of inundation as a result of river channel dredge and partial upstream embankment improvement. Furthermore, it is confirmed that the inundation area has been reduced due to partial embankment upstream. This is because the main river is now taking over the volume of floodwaters that overflowed during the period of no levees. However, the no-levee section is still long, and the high-frequency inundation area is as large as in the 1961 analysis. In the 2017 risk map, the inundation area on the left bank side has been reduced due to the extension of the levee section. However, the Maeda area, which has a low level of maintenance, is inundated at a high frequency due to the no levee section. On the other hand, in the Kisaichi area on the right bank side, there is a medium-to-high frequency of inundation risk, and there is no change in the inundation area compared to 2004. Since 2004, the Aiosa River, a tributary river that runs through the Kisaichi area, has been repaired by river channel dredge and levee maintenance, and an Aiosagawa sluice gate was updated at the confluence of the main river. It can be inferred from the risk map that the flood safety level in the surrounding area has increased due to the improved capacity of the flow. On the other hand, the risk of waterlogging increased with the construction of the embankment and sluice gate. Therefore, the effect of flood control was not significantly improved compared to 2004, when there was no levee and the old Aiosa River was in place. Finally, Figure 3 shows the risk map at the completion of the river improvements in the river infrastructure development project. The Toda and Maeda areas showed a reduction in inundation area and inundation risk in all target flood events. However, the risk of inundation is higher along the tributary rivers. The Kisaichi area experienced internal flooding in 2017. The Otani and Muro Rivers flowing through the Toda and Maeda areas have been improved with the construction of the Otanigawa and Murogawa flumes at their confluence with the main river, in addition to the improvement of their capacity of the flow. With these river improvements and the construction of levees on the main river, external flooding can be prevented. On the other hand, the risk of internal flooding has increased. However, flood damage is limited to agricultural lands such as rice paddies and fields due to river improvement, confirming that flood safety has been realized.

3.2 Function as fish refuge and habitat areas

Along the tributary rivers joining the main river were found to be at high risk of inundation. The results were similar for all target flood events. Therefore, areas along the tributary rivers have the potential to reproduce the continuity between the main river channel, tributary, and wetland and flooded area while maintaining flood safety. Figure 4 visualizes areas that can be used as refuge and habitat area for fish. Figure 4 shows that the space that fish can choose as a refuge with high frequency is located in the inner area of the bank along the tributary river. Compared to the risk map in Figure, the areas that are frequently inundated are areas where fish can act on their own volition. Furthermore, they can also be considered areas that can be selected as evacuation sites at high frequency. Flood plains along and around tributary rivers can be considered favorable spaces for the riverine environment. Therefore, it may be possible to maintain the level of flood safety while taking the river environment into consideration by devising the operation of existing sluice gates and flumes.

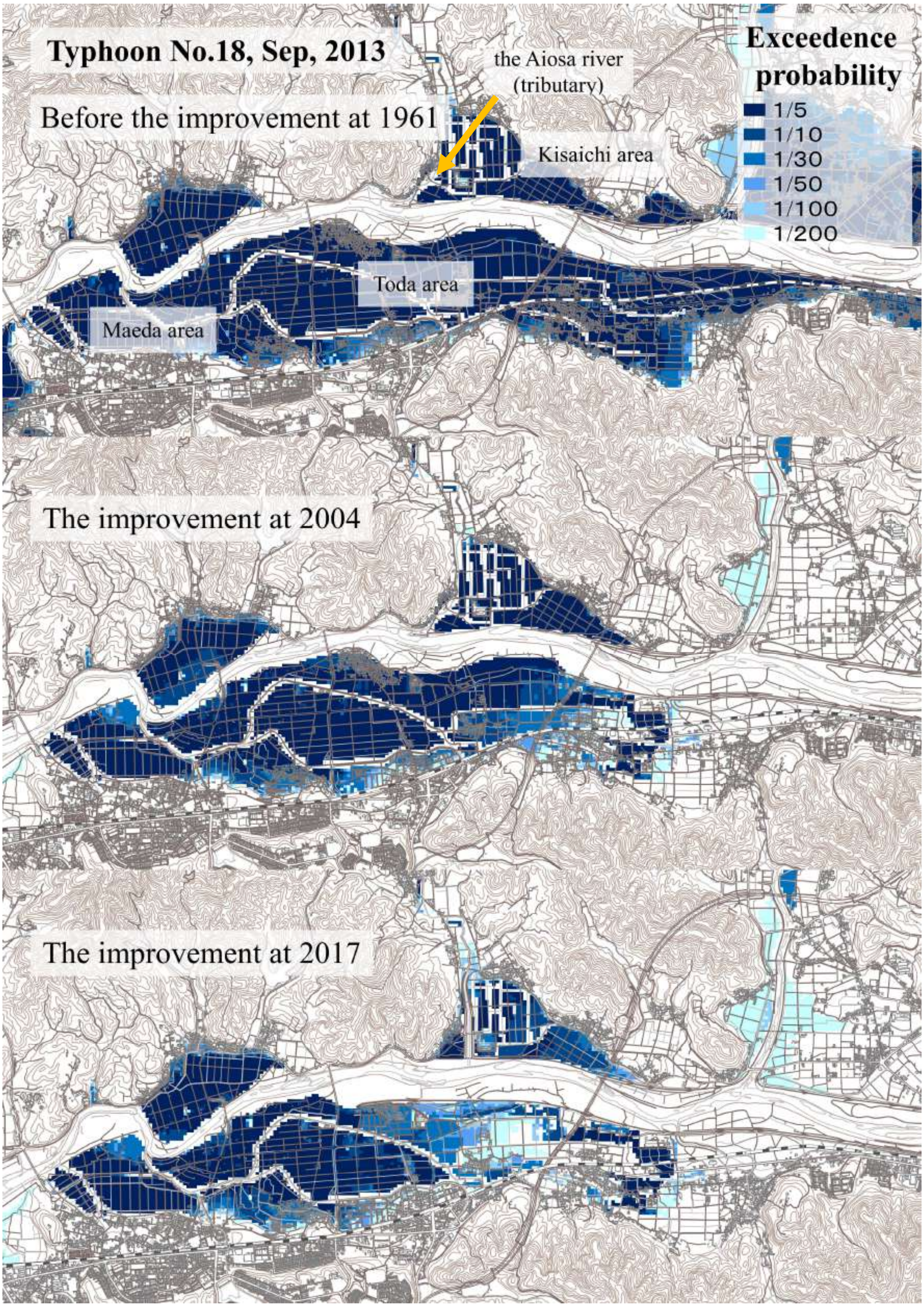

Figure 2. Flood Risk Map for the inundation model of the improved cross-section at each stages (Typhoon No.18, Sep, 2013)

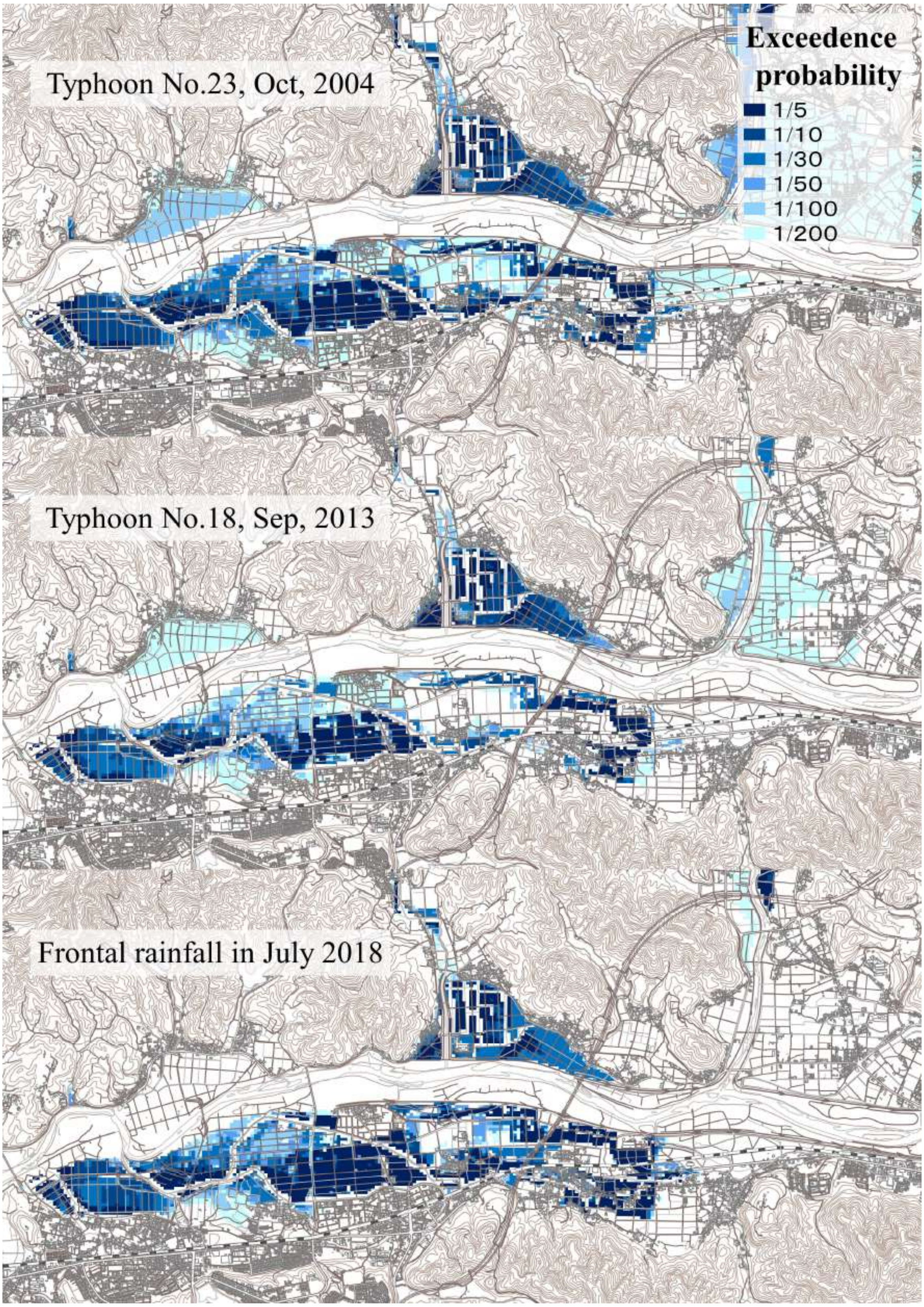

Figure 3. Flood Risk Map of each flood events

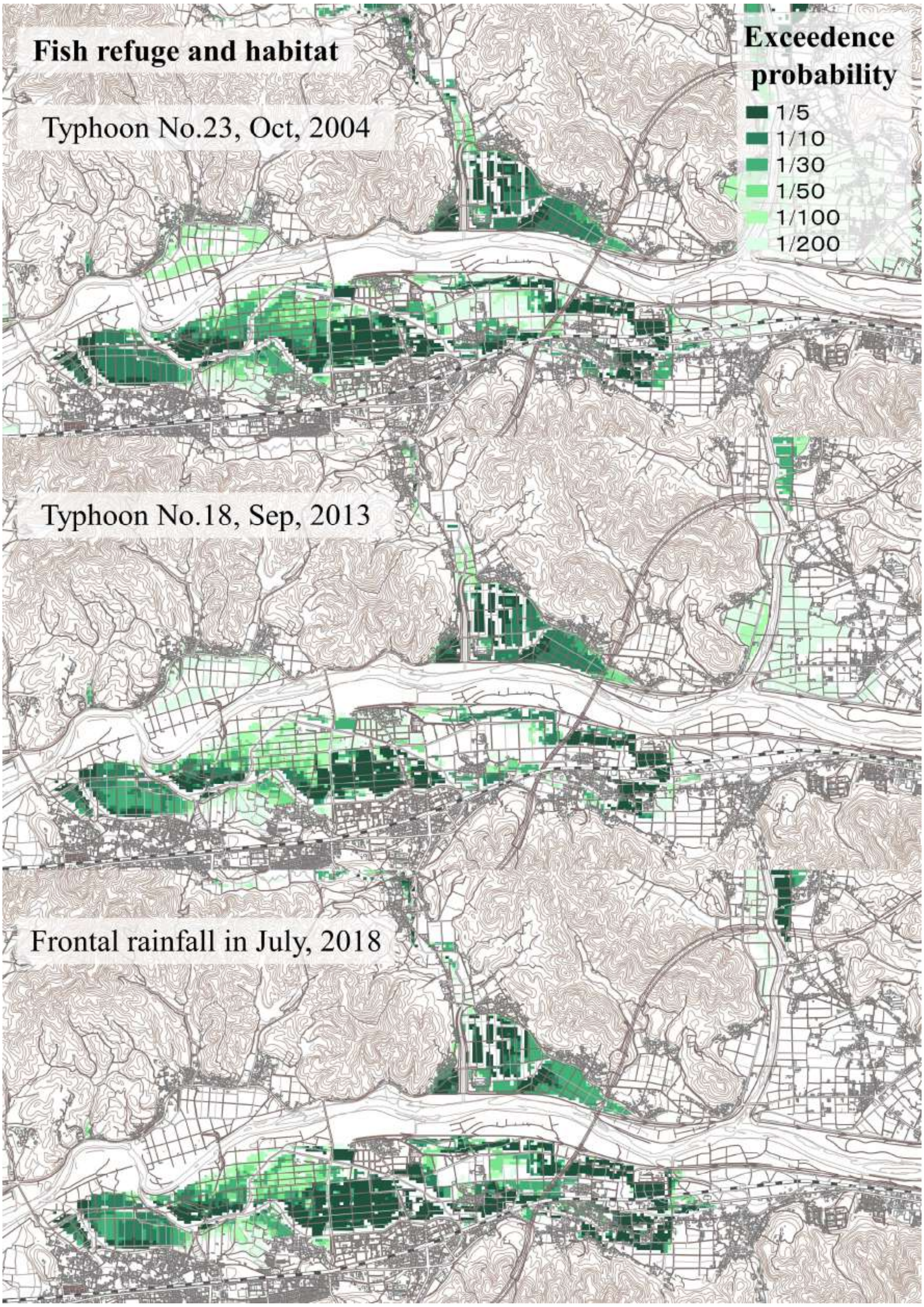

Figure 4. Assumed map of fish refuge areas for the inundation model with each flood events

4. CONCLUSIONS

It was obtained from the results of the analysis that flood control benefits are being manifested. However, the loss of connectivity between the main river and the inner levee area is not necessarily favorable for the ecosystem. Securing areas that are inundated with medium to high frequency is important to ensure the continuity of wetland and flooded area between the main river channel, tributary, and the levee interior, according to the concept of River Basin Disaster Resilience and Sustainability. The risk map confirms that the areas where this can be ensured are along the tributary rivers. Furthermore, it was also confirmed that the area is a space that can be selected as a refuge and habitat for fish. In the future steady, it is necessary to consider how to operate sluice gates and flumes in consideration of the river environment to ensure connectivity between the main and tributary rivers while maintaining flood safety in the event of possible flooding or heavy rainfall. For this purpose, field surveys will be conducted before and after the passage of typhoons to confirm the current habitat conditions, and to examine the methods of operation as well.

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