Change Analysis of flow regime and aquatic habitat in Fushinogawa River by aerial photo and GIS

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1. Introduce

The habitat requirements of a species are the abiotic components of the environment necessary for survival (Rosenfeld, 2003) [1]. Loss of habitat and degeneration are a major factor contributing to the decline of fisheries in both marine and freshwater systems around the world (Langton et al., 1996) [2].

Fushinogawa River, a second degree river in Japan, with a catchment area of 344 km^2, there are some towns distributed around different reaches of it. Its insteam environment has degenerated in past several ten years. The change results in the decrease of the amount of fishes. For example, the amount of Manila clam (*Ruditapes philippinarum*) around Fushinogawa river mouth area has decreased and the amount of Ayu fish (*Plecoglossus altivelis altivelis*) has generally decreased. (fig. 1).

Previous study results showed that the changes from both the flow regime and the flow transport ability have significant impact on the living condition of the above species [3] [5] [6]. Simula- tion of the Fushinogawa River in flow regime and transport ability in the past periods were done in order to explore the causes of those changes and to establish an estimation of the habitat suitability of the species. Through those estimation and analysis, an optimization plan of improving Fushinogawa in stream can be made. However, the lack of relating data is a quite obstacle to the research of this kind type. So exploring out a way for carrying out the kind of a deducing on instream environment has also significance.

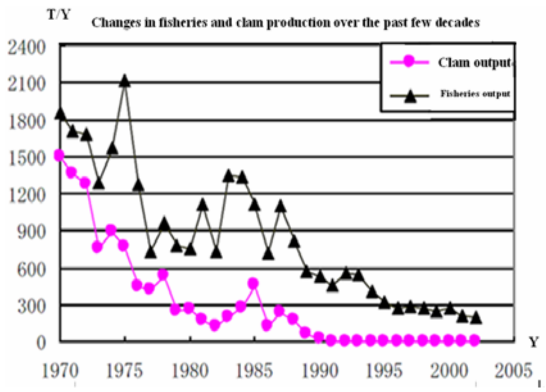

fig. 1

2. Basic Data and Methods

2.1 Basic Data Collection

History white-black aero photos of Fushinogawa basin in 1947 and 2003 came from the official website of the Geospatial Information Authority of Japan (GSI) [4]. The eighteen group characteristics hydrological data at the year 2003 come from suit measurement points and many presumed points of 84 cross sections located upstream-middle reach-downstream based on the shape of cross section, roughness coefficient and flow rate[5 [6]. Specifically, they are below:

1) The water depth data at 365th date, 355th, 275th, 185th, 95th, 1st date. All of date-water depth values in a year are sorted according to their size is a precondition. They are expressed separately by used d_1, d_2, d_3, d_4, d_5 and d_6 symbols, $0 \le d_1 < d_2 < d_3 < d_4 < d_5 < d_6$. ($d_1$ the lowest water level, d_2 –-the droughty water level, d_3 –low water level, d_4—ordinary water level, d_5—ninety-five-date water level, d_6—highest water level, they are characteristics hydrological data);

2) The instream width data that correspond to above depth data: w_1, w_2, w_3, w_4, w_5 and w_6;

3) The flow velocity data that correspond to above depth data: v_1, v_2, v_3, v_4, v_5 and v_6;

Above data and aero photos are the bases and the start points in deducing to the river regimes in 1947 and 2003.

2.2 Image processing of aero photo

On ArcGIS platform, by registration of geographical coordinates process with utilizing rectify tool of ArcGIS software, the selected aero photos were rectified and some ortho images that covers Fushinogawa River were generated.

2.3 Extracting the instream width data from the ortho images of 1947's and 2003's, and estimating the width belonging

Water surface polygons and water route lines of the river were drawn in ArcGIS from the ortho images in 1947 and 2003.

Cross section lines were created every 10m along the water route lines using VBA programming in ArcGIS, and were intersected with the water surface polygons. In this way, the instream widths of Fushinogawa river were obtained at every 10m for 1947 and 2003.

Based on the precipitation records of both years at Shimonoseki station [7], the water level at the date of air photo acquisitions are estimated to be around the droughty water level (w_2) for both years.

2.4 Building a relationship among river width (w), depth (d), and velocity (v) at the year 2003

The regression equation set groups for the year 2003 were constructed by using the characteristics hydrological data of the eighteen groups in 2.1 as sample data.

$w = \{\{w_1 | w_1 = 0.9951\ w_2 - 0.5315, w_2>0\}, \{w_3 | w_3 = 1.0066\ w_2 + 2.3291, w_2>0\}, \{w_4 | w_4 = 0.9907\ w_3 + 3.2185, w_3>0\}, \{w_5 | w_5 = 0.9819 w_4 + 8.5335, w_4>0\}, \{w_6 | w_6 = 1.0019\ w_5 + 20.399, w_5>0\}\ | w_6 > w_5 > w_4 > w_3 > w_2 > w_1\}$;

$d = \{\{d_1 | d_1 = 0.01049145 w_2 + 0.70746680, w_2>0\}, \{d_2 | d_2 = 0.01039758 w_2 + 0.74197480, w_2>0\}, \{d_3 | d_3 = 0.01002501 w_2 + 0.87517972, w_2>0\}, \{d_4 | d_4 = 0.00956331 w_2 + 1.01561072, w_2>0\}, \{d_5 | d_5 = 0.00836016 w_2 + 1.28606880, w_2>0\}, \{d_6 | d_6 = 0.00471962\ w_2 + 2.86256649, w_2>0\} | 0 \le d_1 < d_2 < d_3 < d_4 < d_5 < d_6\}$;

$v = \{\{v_1 | v_1 = 52.38211072 w_2^{(-1.29038511)}, w_2>0\}, \{v_2 | v_2 = 51.18106968 w_2^{(-1.27652844)}, w_2>0\}, \{v_3 | v_3 = 41.12414369 w_2^{(-1.19373340)}, w_2>0\}, \{v_4 | v_4 = 34.05681485 w_2^{(-1.11907260)}, w_2>0\}, \{v_5 | v_5 = 22.46851792\ w_2^{(-0.98367141)}, w_2>0\}, \{v_6 | v_6 = 9.02684199\ w_2^{(-0.53895046)}, w_2>0\} | 0 \le v_1 < v_2 < v_3 < v_4 < v_5 < v_6\}$

where $w_1, w_2, w_3, w_4, w_5, w_6, d_1, d_2, d_3, d_4, d_5, d_6, v_1, v_2, v_3, v_4, v_5$ and v_6 are the same with the relating description in 2.1.

2.5 River regime and sand transporting ability for the year 2003

By using the regression equations in 2.4, the instream width (w), water depth (d), and flow velocity (v) values were calculated for every 10 meter at the cross section along the water route lines of 2003.

With the equation $u_c = v\ \mathbf{n}\ \mathrm{sqrt}(g) / R^{1/6}$, the friction velocity values corresponding to different flow velocity values were calculated. In this equation, u_c is friction velocity (m/s), $\mathbf{n}$ is Manning's roughness coefficient (0.03), g is acceleration of gravity, $g = 9.80665\mathrm{m/s}^2$, R is hydraulic radius. $R = A / P$ where A is instream cross-sectional area of flow (m²), P is wetted perimeter (m). Here $R \approx d$ because of great difference between the instream water depth and the water surface width.

By using following Iwagaki formula, the critical particle size were transported by the flow at the different firection velocity (u_c).

For bed load: $d_b = u_c^2/80.9$, when $25.02 \le u_c^2$; $d_b = (u_c^2/134.6)^{22/31}$, when $6.490 \le u_c^2 \le 25.02$; $d_b = u_c^2/55.0$, when $3.32 \le u_c^2 \le 6.490$; $d_b = (u_c^2/8.41)^{32/11}$, when $1.469 \le u_c^2 \le 3.132$; $d_b = u_c^2/226$, when $0.00 \le u_c^2 \le 1.469$, where d_b is bed load size value variable.

For suspended load: $ds = (u_c^2+17)/1020$, when $85.0 \le u_c^2$; $ds = (u_c^2+15)/1000$, when $0.00 \le u_c^2 \le 85.0$; In which d_s is suspended load size value variable.

For wash load: $d_w = (u_c^2+81)/6478$, when $166.0 \le u_c^2$; $d_w = (u_c^2+76)/6050$, when $45.00 \le u_c^2 \le 166.0$; $d_w = (u_c^2+95)/7500$, when $0.00 \le u_c^2 \le 45.00$. In which d_w is wash load size value variable.

2.6 River regime and sand transporting ability in 1947

2.6.1 Estimating change possibility concerning the shape type of the instream cross section comparing with the year 2003

It is well known that the A (cross section area) in Manning formula is a variable which has different calculation expressions. i.e., the different cross-section objects that are of the same type have the same calculation formula. Therefore, the possibility that there is an instream cross section type difference between the general cross sections in 1947 and in 2003 should be considered. However, considering the endogenic geological process and the exogenic geological process, the analysis results of the whole catchment revealed no evidence in a difference of the cross section shape type in both years. Therefore, the relationship equations among width, depth and velocity on 2003 are also applicable to the statistics in 1947.

2.6.2 Inversing the river regime and sand transporting ability for the year 1947

Using the instream width data (***w***$_2$) from aero photos of the year 1947 as the deducing start point, we deduced the river regime and its sand transportation ability at the year 1947 with manning formula and Iwagaki formula in 2.4.

2.7 Inversion of habitat suitability to Ayu fish and Pale chub in 1947 and 2003 and their comparisons

Based on above inversion results on the river regime in 1947 and 2003, the depth-HIS (HSI_{spd}, HSI_{ad}) values and velocity-HIS (HSI_{spv}, HSI_{av}) values for the spawning and the adult fish living for Ayu fish were calculated by using model 1(Abu-Ishida, 1967), model 2(Akikiwa-Sima, 1991), model 3((JFRCA, 1994) and model 4(JFRCA, 1995); by using model 5, model 6, model 7 and model 8, the depth-HSI ($HSI_{spd)}$, $HSI_{ad)}$ values and velocity-HIS (HSI_{spv}, HSI_{av}) values for the spawning to Pale chub were calculated, separately. The results from above were compared to find the different and similar points.

3. Result and Analysis

3.1. The river regime and sand transporting ability in 1947 and 2003 and their comparison

3.1.1 Instream width

Ther river width in 1947 and 2003 are shown in fig. 3.1.1-1 and fig. 3.1.1-2.

River width in 2003 is generally larger than that of 1947 except in a few river reaches (upstream). The difference of general average river width(***w***), ***w***$_1$, ***w***$_2$, ***w***$_3$, ***w***$_4$, ***w***$_5$ and ***w***$_6$ are respectively 4.56 meter, 13.95meter, 15.913 meter, 15.86 meter, 20.43 meter, 36.16 meter, 78.81 meter (pairwise difference).

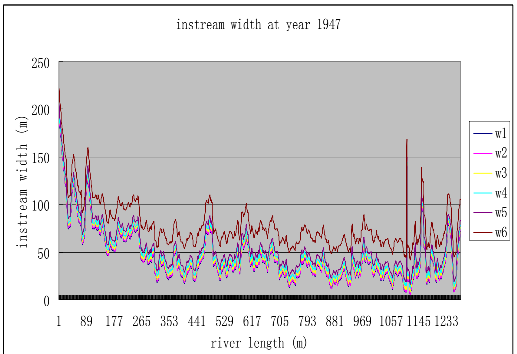

fig.3.1.1-1

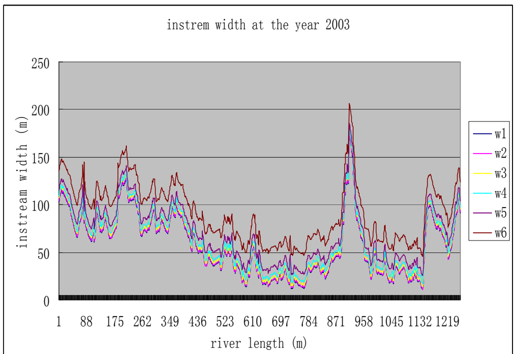

fig.3.1.1-2

3.1.2 Instream water depth

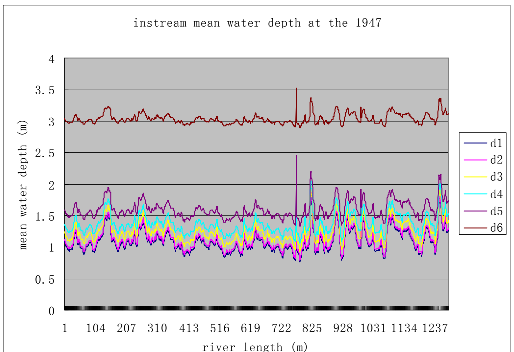

fig.3.1.2-1

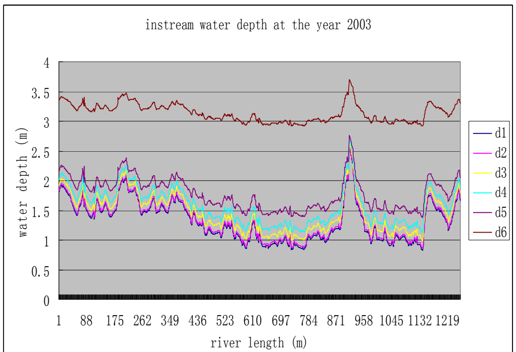

fig.3.1.2-2

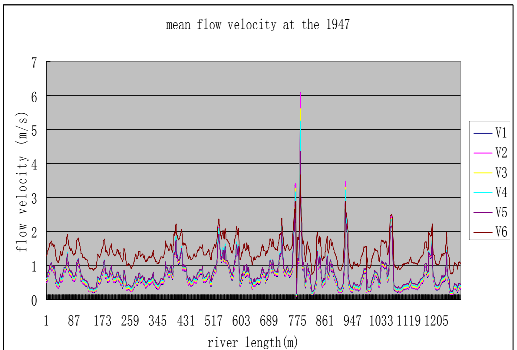

fig. 3.1.3-1

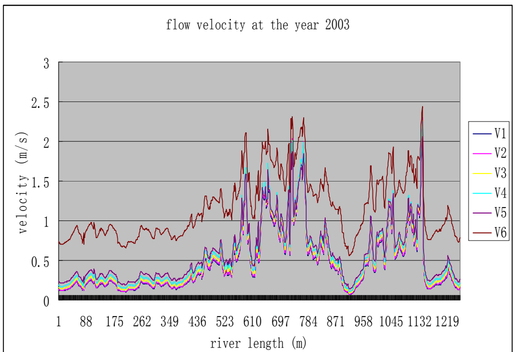

fig.3.1.3-2

The instream water depth in 1947 and 2003 are shown in fig. 3.1.2-1 and fig.3.1.2-2. The instream water depth in 2003 is generally larger then that of 1947, and their difference values of general instream water depth, ***d***$_1$, ***d***$_2$, ***d***$_3$, ***d***$_4$ ***d***$_5$ and ***d***$_6$ are respectively 0.19 meter, 0.23 meter, 0.22 meter, 0.22 meter, 0.21 meter, 0.18 meter and 0.08 meter(pairwise difference).

3.1.3 Flow velocity

The flow velocity in 1947 and in 2003 is shown in fig. 3.1.3-1 and fig.3.1.3-2.

The calculation results of velocity shows that flow velocity values in 1947 are bigger than that of the year 2003. The differences (***v***) between general river flow velocity, ***v***$_1$, ***v***$_2$, ***v***$_3$, ***v***$_4$, ***v***$_5$ and ***v***$_6$ are separately 0.21 m/s, 0.21 m/s, 0.21 m/s, 0.20 m/s, 0.22 m/s, 0.20 m/s, 0.23 m/s.

3.1.4 The river sand transporting capability

From the data generated from above, the calculation results of sand transporting capability show that the river sand transporting capability in many reaches in 1947 is bigger than that of 2003 (fig.3.1.4-1 and fig.3.1.4-2).

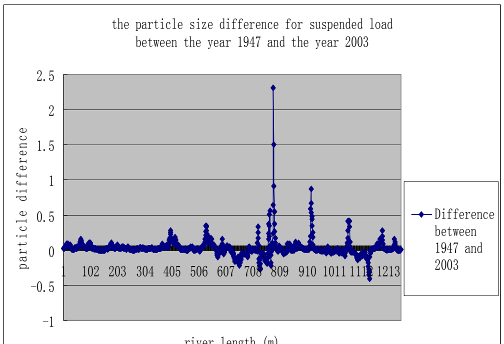

fig.3.1.4-1)

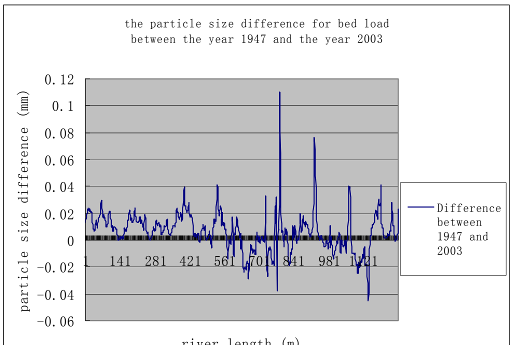

fig.3.1.4-2

3.2 Habitat suitability of Ayu and Pale chub at the year 1947 and the year 2003

The results of calculation shows that, in 1947, there were many suitable habitats at different river segments for spawning and living for Ayu fish, in 2003, the amount of the river segments that are suitability habitats (containing spawning and adult fish) have decreased. Especially, many spawning places have loosed. However, there is not a big change for the Pale chub spawning and adult fish living with regards to the instream environment.

4. Conclusion

For the river regime of Fushinogawa River in 2007, the instream width, instream water depth increased compared with that of 1947, while velocity and sediment transporting ability reduced, whose causes may involve the improvement from the vegetation covering and building of the amount of dams.

The reduction on the velocity and sediment transporting ability contributes to the decrease in sediment size and the amount of bed load. Those deductions can have a negative impact to ecological suitability on some aquatic species such as Ayu fish. This also brings out the changes in depositional environment at the river mouth (i.e. the decreasing size of sediment particle). All those changes can produce impact in the living condition of species in the intertidal zone and leading to the disappearing of species such as original Manila Clam.

Acknowledgements

We thank all people that their data become one of based for carrying out this research.

Reference

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