Impacts of spur dikes on the habitat of *Cyprinidate* and *Homalopteridae*- a case study of Lanyang Estuary

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ABSTRACT

A quasi-two-dimensional numerical model (NETSTARS) and a horizontal two-dimensional model (TABS-2) were used to simulate the hydraulic characteristics, such as water depth, flow velocity and sediment transport capability of Lan-Yan Estuary with and without spur dikes construction. These informations were used to calculate the weighted usable area (WUA) of *Cyprinidate* and *Homalopteridae*.

Both fixed bed and mobile bed conditions were investigated. In the fixed bed case, the maximum WUA of *Cyprinidate* occurs when the dimensionless spur dike length D/L is between 3 to 3.4. The WUA of *Homalopteridae* increases as D/L increases. Taking the effects of sediment transport into account, i.e. the mobile case, the comparing with the results of fixed bed simulation, WUA of Cyprinidate and Homalopteridae decrease 8.42% and 7.17%, respectively. Sediment deposition will decrease fish habitat and is very important in long-term habitat management

Key Words: Spur dikes, weighted usable area (WUA), fish habitat, numerical model, dimensional analysis

1. Introduction

Lanyang Creek lies in the northern part of Nan-Hu Mountain. It includes the main streams of Ilan River, Luotung Creek and Da-Hu Creek, eventually meets the Ilan and Don-San River and empties into the Pacific Ocean. Fig. 1 maps the location of the creek. The estuary is also an ideal habitat for many species, including waterfowl, fish and insects. Over 236 species of birds have been reported to live in the Lanyang Estuary. Consequently, the Ilan County government has marked this estuary as a waterfowl protection zone since 1996.

This study considers the region between Ger-Ma-Lan Bridge and Lanyang Bridge and the impact of spur dikes on the habitat of *Cyprinidate* and *Homalopteridae*. Following the storm damage by Nari typhoon in 2001, eight spur dikes were designed by the Water Resources Agency of the Ministry of Economic Affairs in order to protect the river bank. Not only can the spur dikes protect the river bank, but they can establish different flow conditions and thereby increase fish habitat diversity.

The spur dike is a hydraulic structure intended to protect the river bank by diverting the existing flow direction. It can be used to control the direction of the main stream and subsequently increase sediment deposition on the river bank. River width is thus influenced by spur dikes. The slower velocity zone that is generated around the spur dikes has been provided to benefit the surrounding ecosystem (Hu et al. 2003). Proper utilization of spur dikes can also create near-natural flow conditions in both rivers and lakes (Shubun Fukudome et al. 2002)

2. Methods and Materials

1. Numerical models

A quasi-two-dimensional numerical model, NETSTARS (Lee et al., 1997), and a horizontal two-dimensional model, TABS-2 (SMS 7.0 Users Manual, 2000), were used to simulate the hydraulic characteristics. Water depth, flow velocity and the sediment transport capability were among the Lanyang Estuary characteristics studied in both spur dikes and natural conditions. The results were applied to calculate the weighted usable area (WUA) of

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Cyprinidate and *Homalopteridae*.

2. Analysis of weighted usable area (WUA)

Usable fish habitat area is affected by various factors, such as water depth, flow velocity, turbidity, temperature, dissolved oxygen and substrate types of river bed. In this study, water depth and flow velocity are utilized to quantify the total fish habitat area.

The habitat suitability curve can be derived from the recorded catch per unit of effort (CPUE). The CPUE is established form sampling and experimental results. The water depth and flow velocity suitability curves of *Cyprinidate* and *Homalopteridae* are considered in this study, and are plotted in Figs. 2 and 3, respectively. (Ya et al., 2000).

The weighted usable area (WUA) in a stream is evaluated as:

（1）

Where A_i is the stream area of element i and $f(V_i, D_i)$ is the combined suitability factor (CSF) for A_i. Several methods have been proposed to determine CSF, but the most prevalent technique calculates the product of the corresponding suitability weights for flow velocity, depth and channel characteristics (Mihous, 1999). The flow velocity and the depth in element i (i.e. V_i and D_i) are obtained from the hydraulic simulation result and both vary with discharge. The suitability weights that correspond to these two hydraulic variables are dynamically adjusted as the flow conditions change.

4. Dimensional analysis

The parameters that influence the WUA include the study area A, the water depth H, the length of spur dikes L, the distance between spur dikes D, the grain size of the streambed D_m, the bed shear stress τ_0, the density of substrate ρ_s, the density of the water ρ_w and the gravitational acceleration g. Thus, WUA can be expressed as:

$$PUA = f3\left(Fr, \Theta, \frac{D}{L}\right) \quad (2)$$

where $PUA = \frac{100 \times WUA}{study \quad area\ (A)}$ is the percentage of usable fish habitat area, $Fr = \frac{V}{\sqrt{gH}}$ is the Froude number; $\frac{D}{L}$ is the dimensionless distance of the spur dikes and $\Theta = \rho_w U_*^2 / G_s D_m$ is the dimensionless sediment transport capacity.

Under fixed-bed conditions, the dimensionless sediment transport capacity can be neglected. Eq. 4 is simplified as:

$$PUA = f4\left(Fr, \frac{D}{L}\right) \quad (3)$$

3. Results and Discussion

WUA under fixed-bed condition

Twenty-four combinations of spur dikes layouts, including three different lengths and eight different distances between spur dikes. Additionally, ten different upstream discharges, varying from Q0.1 to Q1.0, were also considered in the simulation. A total of 240 cases were simulated. Table 1 provides the corresponding discharges are provided. Using these results, the regression equation for PUA can be obtained.

Results with a Froude number over1.2 in Fig. 4, which combines a 20% spur dikes length increase, indicate that an increase in the number of spur dikes will actually decrease PUA. Conversely, Fig. 5 shows no Froude number limitations and spur dikes length reduction. Yet the results still indicate that an increase spur dikes do not benefit *Cyprinidate*, regardless of length or Froude number.

WUA under mobile-bed simulations

Six different particle sizes, or diameters - 0.26mm (original specific size), 0.34mm (plus 30%), 0.39mm (plus 50%), 0.52mm (plus 100%), 0.20mm (minus 25%) and 0.18mm (minus 30%) - were considered to examined the substrate influence of the channel bed. Tables 2 and 3 show not only the results, but also include the sediment transport strength and WUA of *Cyprinidate* and *Homalopteridae*. The deposition behind the spur dikes causes the value of WUA to decline over long-term management. This finding is illustrated by the 8.42% and 7.17% of the *Cyprinidate* and *Homalopteridae* decreased WUA, respectively.

4. Conclusions

1. The appropriate flow velocity of *Cyprinidate* is between 0.15 and 0.25 m/s. The WUA of *Cyprinidate* is optimum when the dimensionless spur dikes distance is between 3 and 3.4.
2. The appropriate flow velocity of *Homalopteridae* is between 0.6 and 1.4 m/s. This higher velocity range induces insensitivity of spur dikes distance. Besides, WUA increases with the dimensionless distance of the spur dikes.
3. Buckingham's π method of dimensional analysis was applied in this study to quantify the effect of the habitat parameter. Accordingly, ten variables were reduced to two independent parameters $(Fr, \frac{D}{L})$ and three independent parameters $(Fr, \frac{D}{L}, \Theta)$ in fixed-bed and mobile-bed simulations, respectively, to facilitate the analysis of the weighted usable area.
4. The WUA of *Cyprinidate* and *Homalopteridae* in this area thus decrease 8.42% and 7.17%, respectively. Furthermore, the decrease in WUA became significant as particles became smaller, W UA decreased at an increasing rate.

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6.Figure & Table

Fig.1 The location of Lanyang Creek and Estuary

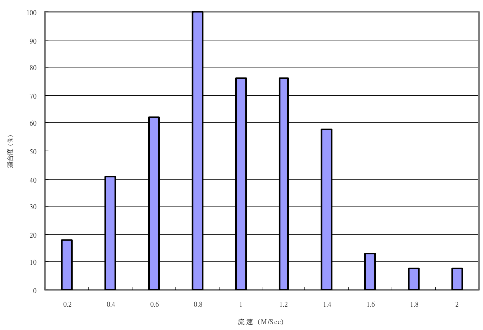

Fig.2 The flow velocity suitability curve of *Homalopteridae* (Ya et. al, 2000)

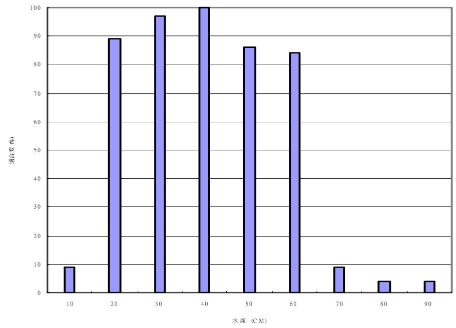

Fig.3 The water depth suitability curve of *Homalopteridae* (Ya et. al, 2000)

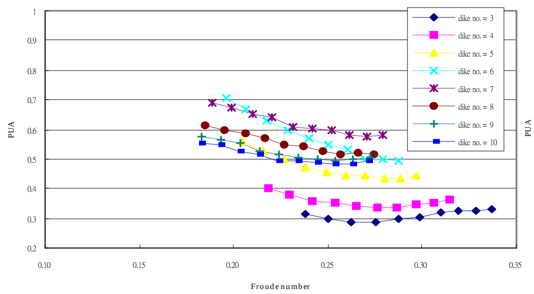

Fig.4 The PUAs-Froude numbers variation of *Cyprinidate* with the installation of decreasing 20% spur dikes length

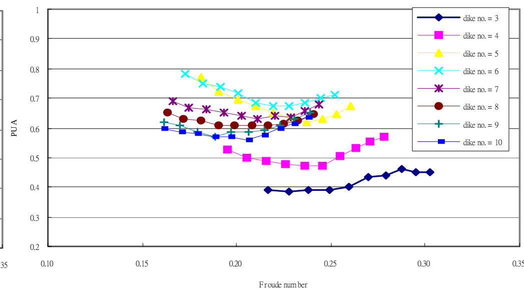

Fig.5 The PUAs-Froude numbers variation of *Homalopteridae* with the installation of original spur dikes length

Table 1 The upstream discharges of Lanyang Creek

Return period(yr)	Code of discharge	Discharge(cms)
1.0	$Q_{1.0}$	1049
1.1	$Q_{0.9}$	1171
5.0	$Q_{0.2}$	2540
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10.0	$Q_{0.1}$	2837

Table2 The variations of WUAs of *Cyprinidate* in mobile-bed conditions

Time of simulations（hr）	10			50		
Particle diameter (mm)	Θ	Fr	WUA	Θ	Fr	WUA
0.343	2.17	0.24	1028.82	1.98	0.24	944.08
0.262 (original size)	**2.84**	**0.24**	**1028.46**	**2.59**	**0.23**	**941.84**
0.197	3.78	0.24	1025.85	3.45	0.23	930.52

Table3 The variations of WUAs of *Homalopteridae* in mobile-bed conditions

Time of simulations（hr）	10			50		
Particle diameter (mm)	Θ	Fr	WUA	Θ	Fr	WUA
0.343	2.17	0.24	3089.17	1.98	0.24	2884.03
0.262 (original size)	**2.84**	**0.24**	**3086.29**	**2.59**	**0.23**	**2865.10**
0.197	3.78	0.24	3074.46	3.45	0.23	2795.73