Using groyne to improve fish habitat diversity in tidal estuary

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ABSTRACT

By selecting fish as the indicator specie, the variations of fish habitat area ad diversity between flooding and normal discharge period were investigated in this study. Meanwhile a quasi-two-dimensional model, NETSTARS, and a horizontal two-dimensional model, TABS-2, were employed to simulate the hydraulic characteristics of the Lan-yang Estuary in the presence and absence of the groyne. Both fixed-bed and mobile-bed conditions were investigated. WUA method was also used to evaluate the fish habitat improvement efficiency by combining the numerical modeling results and fish suitability curve.

In the flooding period, installing groyne will increase the slow-velocity area that can enlarge the refuge area for fish. The effects of sediment transport in the mobile case show that increased sediment deposition would reduce fish habitat area, a finding that is integral to effective long-term habitat management. Adversely, the results in the normal discharge period show that the fish habitat area will increase without groyne. If the flooding risks are not taken into account, the simulation provided the fish habitat area will expand with the less number and the shorter length of groyne.

Key Words: numerical model, groyne, WUA, fish habitat improvement, sediment transport

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. The huge sediment capacity is associated with Lanyang estuary's abundant ecosystem and natural resources. 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 *Gobiidae and Cyprinidae*. 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. Dikes construction was completed in June 2002. Not only can the spur dikes protect the river bank, but they can establish different flow conditions and thereby increase fish habitat diversity.

2. 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.

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The results were applied to calculate the weighted usable area (WUA) of *Gobiidae and Cyprinidae*. The flood discharge which exceeds the return period of one year was selected during five years (1992~1996) as the upstream boundary condition, while the corresponding water surface elevation of the river mouth was selected as the downstream boundary condition. The concentration of the suspended sediments in the upstream boundary is estimated using the discharge-and-sediment concentration rating curve of the Lanyang Bridge, as established by Limin Consultant Company in 2000.

3. Analysis of weighted usable area (WUA; Mihous, 1998)

The water depth and flow velocity suitability curves of *Gobiidae and Cyprinidae* are considered in this study. Because the fish must have the most proper velocity and water depth to perch, this study depend on the value of measure to assume the suitability curves are triangles, and are plotted in Figs. 1,2,3 and 4, respectively. (Hu et al. 2002, Ya et al. 2000).

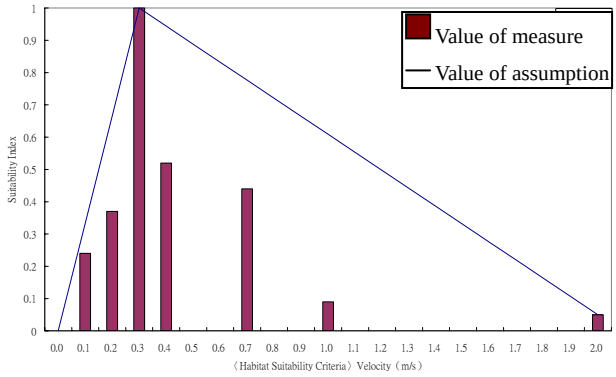

Fig.1 The flow velocity suitability curve of *Gobiidae*

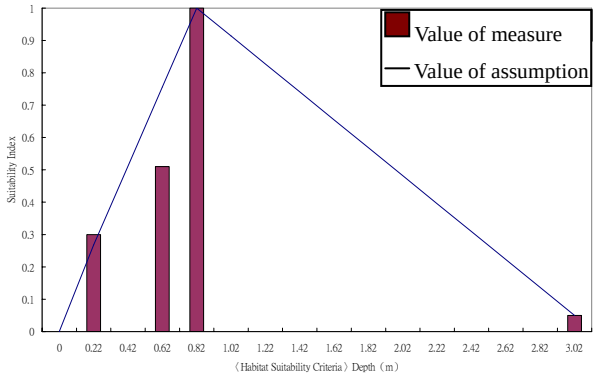

Fig.2 The water depth suitability curve of *Gobiidae*

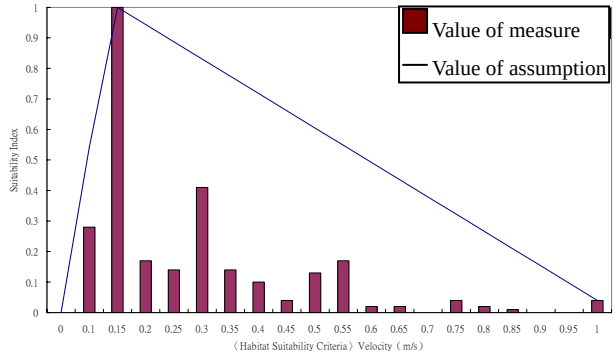

Fig.3 The flow velocity suitability curve of *Cyprinidae*

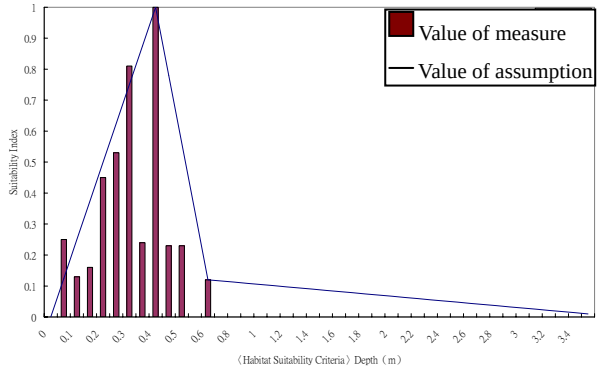

Fig.4 The water depth suitability curve of *Cyprinidae*

5. Results and Discussion

Flooding period

a. Analysis of the habitat umder mobile-bed condition

Mobile-bed simulations were performed using the TABS-2 model. The slow velocity zone, located behind the spur dikes and near the right bank, yields increased sediment deposition and also reduces the conveyance of river and may eventually increase the average velocity of rivers. Thus, WUA will be reduced during long-term management. In the area around spur

dikes, the decrease in WUA became significant as particles became smaller, WUA decreased at an increasing rate. According to the results above, this study was trying to find out the significant relationship between WUA and sediment transport capacity. 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. Three different dikes length, which decreases 20%, maintain original and increase 20% spur dikes length, and four different dikes number, which were four dikes, six dikes, eight dikes, and ten dikes were taken to examined the D/L influence of the WUA. However, the number of spur dikes will influence the habitat of fish and it will affect the decision maker when he builds the dikes. Further details are presented in Tables 1and 2.

Table 1 The maximum PUA of *Gobiidae* under different length of dikes.

Length of dikes	Maximum PUA	
	D/L	Number of spur dikes
increase 20%	4.42	4
original	5.23	4
decreases 20%	3.76	6

Table 2 The maximum PUA of *Cyprinidate* under different length of dikes.

Length of dikes	Maximum PUA	
	D/L	Number of spur dikes
increase 20%	2.60	6
original	3.08	6
decreases 20%	3.76	6

Normal discharge period

The daily discharge and daily water surface elevation of 1990 were taken as the upstream and the downstream boundary conditions, respectively. In this part, we also simulate three kinds of spur dikes length and four dikes number under fixed-bed condition, and six particle sizes under mobile-bed condition.

The results of simulations reveal the fish habitat area will increase without the build of spur dikes. The spur dikes are not beneficial for increasing the fish habitat area but may be helpful for the immature fishes. The influence about the build of spur dikes for *Gobiidae* and *Cyprinidate* were listed in Fig.5 and Fig.6.

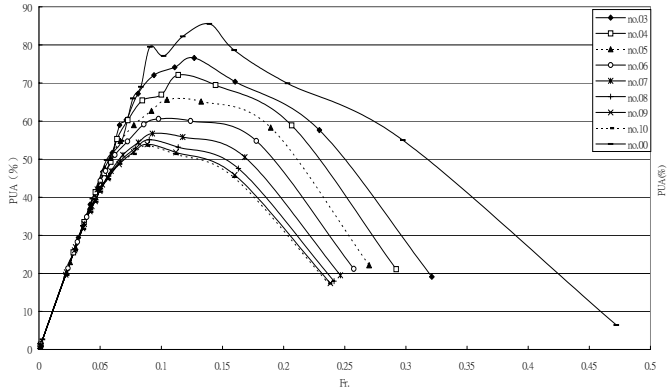

Fig.5 The PUA of *Gobiidae* under different spur dikes

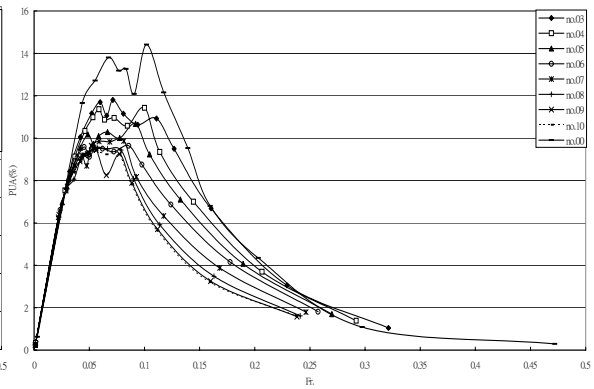

Fig.6 The PUA of *Cyprinidate* under different spur dikes

The PUA difference of *Gobiidae* without spur dikes and with spur dikes reaches up to 30%. The difference of Cyprinidate is smaller but it still decreases after building spur dikes. Finer sands allow for increased sediment capacity, but in turn decrease fish habitat area. And the WUA would decrease as the number of dikes rising. The influences of Froude number in two period (flooding period and normal discharge period) are not alike .In normal discharge period, the WUA would be growing with the Froude number, nevertheless the WUA would reduce as the Froude number increasing. As far as fish is concerned, the water depths and the velocities in the flooding period are over the suitable range of them to subsist. Some of the regressing results are not well. The correlation coefficients are too small, it probably because the influential factors are numerous and complex. In some fluid situations, the dimensionless parameters can't show the relationship between WUA and the influential factor clearly.

6. Reference

Hu, T.J., S.S. Shih and H.Y. Lee, 2003, On hydraulic modeling research of Ecological Engineering method－take Dou-Wang stream for example, *Journal of Chinese soil and water conservation*，34(1):95-100.(in Chinese)

Lee, H.Y., H.M. Hsieh, J.C.Yang and C.T.Yang, 1997, Quasi Two-Dimensional Simulation of Scour and Deposition in an Alluvial Channel, *ASCE Journal of Hydraulic Engineering*, 123(7):600-609.

Mihous RT, 1998, Modeling of instream flow needs: The link between sediment and aquatic habitat. Regulated Rivers: Research and Management, 14: 79-94.

Ouillon and Dartus, 1997, Three-Dimensional Computation of Flow around Groyne, Journal of Hydraulic Engineering, ASCE, 123(HY11):962-971.

SMS 7.0 Users Manual, 2000, *Open-Channel Flow and Sedimentation*, Environmental Modeling Research Laboratory, Brigham Young University.

Ya, M.F., S.H. Lee and S.C. Chang, 2000, The swimming ability of *Varicorhinus alticorpus* and *Lissocheilichthys paradoxus* in Taiwan, Taiwan Endemic Species Research Center (TESRC)，project no. 89.(in Chinese)