行政院國家科學委員會專題研究計畫 成果報告

水環境因子與溪流棲地生態評估之研究
研究成果報告(精簡版)

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行政院國家科學委員會補助專題研究計畫成果報告

（水環境因子與溪流棲地生態評估之研究）

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中文摘要

近來政府推動生態工法希望維護生態系統與完整性，因此拋石丁壩是最常被用來保護河岸的工法之一。傳統上，丁壩是用來防止水流沖刷或促進凹岸的穩定性，同時可以在流況激烈的情況下，促進水生生物的權重可用面積(WUA)。本研究利用中台灣上游淺水溪流為案例，以二維河川水理模式(River2D)結合棲地歧異度模組進行分析。同時利用底質、水深、流速為棲地適合度指數 (HSI)，並配合現地的電格採集法(PAE)資料，以鯉科魚類為指標魚種進行模擬。未設站的洪水分析，係採用數值高程模型進行集水區自動劃分，並以水土保持技術規範計算洪水頻率年。本研究分析之成果指出，現有丁壩工在洪水事件下仍有改善空間。

關鍵詞： 權重可用面積、河川二維水理模式、棲地歧異度、棲地適合度指數、電格採集法

Abstract

Recent years, Taiwan government has strongly promoted the concept of ecological engineering in the hope of maintaining the ecosystem and its integrity. As a result, the riprap spur dike is one of the most commonly used measures for protecting stream banks. Traditionally, a spur dike is used to prevent flow scouring and/or increase stabilization at a concave bank. In the meantime, a deflector structure may increase weighted usable area (WUA) for aquatic life survival during difficult flow regimes. A two dimensional river habitat simulation program (River2D) coupled with a developed shallow water habitat units diversity module was used for the case study at headwater stream in central Taiwan. The habitat suitability index (HSI) are established using substrate, depth and velocity from field surveys for fish family Cyprinidae

by prepositioned area electrofisher (PAE). The ungauged flood conditions are calculated using digital elevation models (DEMs) within a watershed delineation and hydrological modeling system according to local regulations. The simulated results indicate that the spur dikes need be improved from WUA in a flood event viewpoint.

Keywords: weighted usable area (WUA); River2D; habitat unit diversity; habitat suitability index (HSI); prepositioned area electrofisher (PAE)

1. Introduction

The Taiwan island, laying between tropical and subtropical zones, consists of abundant flora and fauna. Within a small area of 3.6×10^4 km^2, it is elevated from sea level to almost 4,000 m height. As a result, the average lengths and slopes for main reaches of most Taiwan's streams are from 46.94 to 186.40 km and from 1/15 to 1/295, respectively. These may cause the stream with a short headwater and torrential flow. Meanwhile, the rain seasons are mainly concentrated from June to October. The average annual precipitation is around 2,500 mm and may be releasing more than 70% in a couples storm and typhoon events. Based on the difficult scenarios, stream habitat may be suffered in the peak flow with unstable channel bed and severe scouring for full-bank or even over-bank discharge.

In this study, in order to establish the hydrological conditions, normal flow rates are from field surveys and peak discharge are calculated based on the Taiwan's Soil and Water Conservation Technical Regulations for ungauged stations using WinBasin (Lin et al., 2007). The habitat suitability index (HSI) for target fish, *Varicorhinus barbatulus*, are calculated based on another investigation project using prepositioned area electrofisher (PAE). The survey data are used to define required channel geometry from AutoCAD® file and transferred into a two dimensional depth averaged finite element hydrodynamic model, River2D (Steffler and Blackburn, 2002). This model is used to simulate the weighted usable area (WUA) for target species before, after and modified spur dikes. Meanwhile, the Simpson diversity of typical channel habitat units is developed in this study to discuss the relationship between the habitat diversity and fish assemblage.

2. Materials and Methods

2.1 Materials

The study area (Fig. 1), Sanlin Stream, is a first-order stream and located at one of the headwaters of Chuoshui River, the longest river in Taiwan with 186.4 km. The studied reach, about 174 m, is in the Sanlin Stream Forest Recreational Area near Joujou Suspension Bridge along the main hiking trail. For preventing flow scouring and maintaining the hiking trail, the first riprap spur dike was established in October 2005 to protect stream bank as a current deflector, meanwhile, enhance the fish habitat. The spur dike is implemented following the training course handout by Fukudome (2003). Since it well protected for the concave bank and avoided the revetment further collapse, another spur dike had been built in the following year at 15 m downstream location.

The study watershed is with a small area of 0.52 km^2, the average slope is 42.6%, and the total stream length is 1.18 km from the studied outlet to stream source. With such a small watershed, this stream like other forest streams in Taiwan is categorized into intermittent stream, which flows during the wet season and may dry out during the season of severe drought depending on groundwater storage. In the time, when the groundwater table of some reaches is below the average channel bed of the stream, the pool quantities and quality are critical for aquatic wildlife to survive. From our field fish investigation, there is only one dominant fish species, *Varicorhinus barbatulus*, is observed and therefore used as the target fish for habitat evaluation. There is a check dam built decades ago at the downstream to moderate the channel slope and scouring, however, it blocks the fish migration upstream. Since the available reach is limited, habitat enhancement becomes one of the most important assignments for current stage. Anyway, there are necessities to understand the habitat benefits from these two spur dikes using numerical simulation.

In this study, abiotic data include digital elevation models (DEMs) for simulating flood events, bathymetry for establishing channel physical geometry, substrate, depth and velocity for establishing HSI and biological data include fish investigation for selecting target fish species and habitat criteria. A developed computer model in this study is used for calculating habitat units diversity. A two-dimensional habitat model (River2D) is used to simulate the WUA. Finally, the spur dikes for habitat benefits are discussed and suggested. The detailed flowchart is shown in Fig. 2.

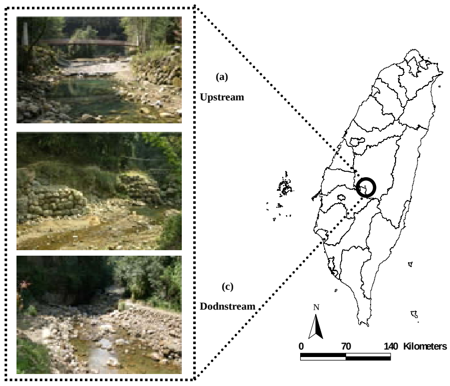

Fig. 1

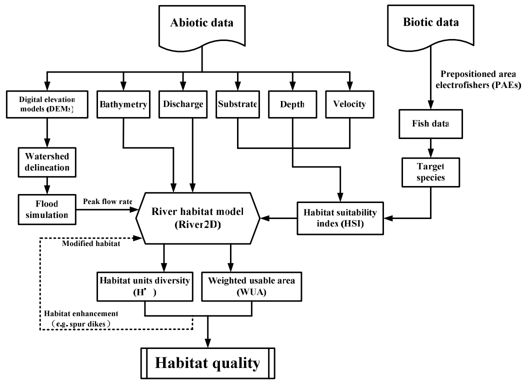

Fig. 2

2.2 Weighted Usable Area (WUA)

USFWS (1981) defined WUA is 'the product of the total surface area of the sampled unit of a stream (i.e., representative reach) and a composite weighting factor which represents the combination of hydraulic conditions. WUA can be predicted by the established CHSI for stream environments under expected flow discharges for evaluated target species at specific life stage. The WUA formula is stated as:

$$WUA = \sum_{i=1}^{n} CHSI_i \times A_i$$

where $CHSI_i$ is the CHSI value for evaluated cell i, A_i is the area for evaluated cell i, n is the total number of evaluated cells (i.e., $\sum_{i=1}^{n} A_i$ is the total evaluated area). The weighted values for all cells are summed, it is thus termed weighted usable area. The WUA provides as index of the overall habitat suitability in a reach of the river for a proposed discharge (Gillenwater et al., 2006).

The fundamentals of hydraulic and habitat modelling remain the same, with different flow scenarios such as regular stream discharge and peak discharge, resulting in a WUA versus discharge relationship (Bartholow et al., 2005). Normally, under natural flow regimes, the WUA increases with regular discharge increased (Gortázar et al., 2004.). Furthermore, flood events with higher discharges, the WUA decreases with flood discharge increased (Gillenwater et al., 2006). Microhabitat values derived from WUA calculations serve as input to an assessment of alternative stream flow management proposals leading to negotiation of flow regimes. These values may also used in establishment of mitigation strategies and for spatial niche analysis (Waddle, 2001).

2.3 River Habitat Simulation

Hydraulic-habitat models, or so called eco-hydraulic models, such as one-dimensional PHABSIM (Waddle, 2001), two-dimensional River2D (Steffler and Blackburn, 2002), and other numerical habitat models (see Parasiewicz and Dunbar, 2001 for review), can be used to predict weighted usable area (WUA) based on habitat suitability index (HSI) calculations for different flow regimes, furthermore, to determine the optimal instream flow requirement and water allocation issues. Normally, each of these models has three major components: hydraulic modelling system, HSI/WUA calculation routines for life stage-specific habitat requirements, and mapping software.

2.6 Habitat Diversity

Midwest Biodiversity Institute (2006) indicates primary channel habitat units are classified as four types including riffle, run, glide, and pool. According to American Fisheries Society (Armantrout, 1998) and Taiwan's Water Resources Agency (2005) definitions, these four habitat units are illustrated in Fig. 3.

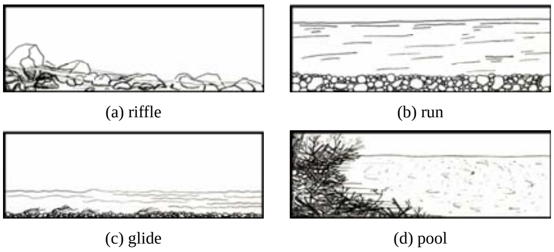

Fig. 3

In this study, a physical habitat unit diversity index adopted Simpson's concept (Simpson, 1949) was developed to assess the physical habitat structure. The used Simpson's index of diversity (1-D) is calculated as:

$$1-D=1-\sum_{i=1}^{S}\frac{n_i(n_i-1)}{N(N-1)}$$

where S is the total umber of habitat unit categories (here in this case S =4, representing riffle, run, glide, and pool), N is the total number of evaluating grids, and n is the subtotal number of each habitat unit. The Simpson's index of diversity measures the probability that two individuals randomly selected from a sample will belong to the same habitat unit category. The value of this index ranges between 0 and 1 with the greater the value, the greater the sample diversity.

3. Results and discussion

The target species is Taiwan shoveljaw carp (*Varicorhinus barbatulus*), because this is the only one fish species had been found during the field investigation implemented by Taiwan's Endemic Species Research Institute. It is a cylindrical-shaped, slippery, and omnivorous fish that feed on the algae clinging to rocks in the water and aquatic insects. Adults are usually 15-25 cm long (Shen, 1993). Taiwan shoveljaw carp is mainly distributed in smaller stream sections, such as small tributaries and headwaters in Taiwan. With increasing numbers these stream reaches being channelized and cemented over for various reasons, mainly flood control, faster currents and fewer pool habitats will appear within these lotic waters and may quickly diminish in these artificially straightened channels (Chuang et al., 2006). Those scenarios for simulated study cases are numbered and listed in Table 1. Simulated results for different stream flows with and without spur dikes, and different sizes for the second spur dike are discussed as follows.

Table 1

	Without spur dike	Only the first spur dike	With two spur dikes	Second spur dike + 1 m	Second spur dike + 2 m	Second spur dike + 3 m	Second spur dike + 4 m	Second spur dike + 5 m
Q_r	Case 1	Case 2	Case 3	Case 13	Case 14	Case 15	Case 16	Case 17
Q_{10}	Case 4	Case 5	Case 6	Case 18	Case 19	Case 20	Case 21	Case 22
Q_{25}	Case 7	Case 8	Case 9	Case 23	Case 24	Case 25	Case 26	Case 27
Q_{50}	Case 10	Case 11	Case 12	Case 28	Case 29	Case 30	Case 31	Case 32

3.1 Simulated results for different stream flows with and without spur dikes (Case 1~12)

For regular stream flow simulations, the predicted WUA for without spur dikes scenario is 152.21 m^2. This WUA value is better than the first spur dike established for 151.90 m^2. However, the predicted WUA for two spur dikes scenario is the best among Q_r simulations with 154.04 m^2. The increased WUA is found between the first spur dike and the second spur dike for creating more suitable velocity. For Q_{10}, Q_{25}, and Q_{50} peak flow simulations, the predicted WUAs for two spur dikes are the best following by with one spur dike and without spur dike. The different part with Q_r is flood creating more suitable habitat near the first spur dike for peak flow simulations. From the results, only one spur dike may deflect flow directions, two spur dikes may provide more WUA comparing without spur dike channel. Supposedly, a series of spur dikes may result in better results, however, the number of spur dikes need consider budgets and revetment stabilization design not only fish habitat.

3.2 Simulated results for different sizes of the second spur dike (Case 13~36)

The WUA simulations for the original sizes of the second spur dike are Case 9~12 and the predicted results for extended 1 m, 2 m, 3 m, 4 m, and 5 m are Case 13~36. The best WUA result, 160.404 m^2 for increasing 8.20 m^2, is the scenario for extending 1 m of the second spur dike for regular stream flow condition. For Q_{10} flood, the best WUA is obtained for extending 2 m for increasing 11.37 m^2. However, for Q_{25} and Q_{50} floods, the best scenarios are extending 3 m for the second spur dike for increasing 11.17 and 13.07 m^2, respectively. From the results, the best WUA conditions may be received by different spur dike sizes under different stream flows. An appropriate spur dike size such as a longer spur dike may cause poor WUA result or even worse than without spur dike. In this study case, extending the second spur dike with 2 to 3 m may provide a better shelter for target fishes during flood periods.

4. Conclusion

Numerical eco-hydraulic modelling systems have been widely used to predict the effects of stream flow on fish habitat. A good spur dike design may result in reducing flow scouring and increasing stabilization at a concave bank. In the meantime, an appropriate deflector structure may increase WUA and habitat diversity for aquatic wildlife survival during flood regimes. The geomorphologic and hydrologic characteristics for an ungauged watershed can be obtained from DEMs and used to predict the flood scenarios and simulate the WUA and habitat diversity. From two dimensional river habitat simulations for the shallow forested headwater stream case, the current spur dikes need be improved by extending the second spur dike for 2 m to 3 m for better results. However, the link between WUA and population parameters such as abundance, growth, survival, or recruitment still need more efforts in the future studies to connect fish assemblage and habitat condition and improve the weakness of numerical habitat models.

計畫成果自評

研究成果提出現地改善意見與提供棲地預測模式，可作為未來河川規劃的基礎。

研究尚未納入其他棲地因子，例如水質參數，可再進一步進行研究。

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