Hydrology Days 2003, 104-116

Habitat Improvement Techniques for Aquatic Fishery: Application Experiences at Ta-Chia River in Taiwan

Bing-Shyan, Lin[1]

PHD student, Department of Hydraulics, Feng Chia University, Taichung, Taiwan

Chao-Hsien Yeh[2]

Associate Professor, Department of Hydraulics, Feng Chia University, Taiwan

Hui-Pang Lien[2]

Associate Professor, Department of Hydraulics, Feng Chia University, Taiwan

Ching-Hao Tuan[3]

Professor, Department of Soil and Water Conservation, National Chung Hsing University, Taiwan

Abstract. With characteristics of river continuum, stream ecosystems have diverse components and environments from upstream channel to estuarine area. Therefore, the habitat requirements and composition of conservative object should be well understood before applying any improvement measure. In this paper, the causes of stream habitat changes were first illustrated with the categories and principles of habitat restoration methods. The structural restoration techniques of fish habitat improvement, including dam partial-removal, utilized by the authors for two research projects during last dozen years were then presented. Through the introductions on the project background, planning guidelines, structure design, and ecological evaluation, this paper tried to provide some effective examples of ecological engineering that ecological experts were invited for cooperation and advising.

Keywords: Fish habitat improvement, Structural restoration, Dam partial-removal

1. Introduction

With functions of water supply, waste cleaning, trade, transportation, and agriculture irrigation, rivers have been seen both in ancient cultures and modern cities along with the problems of flow quantity, water quality, and

[1] PHD student & Correspondence author, Department of Hydraulics

Feng Chi University, Feng Chia University, P.O. Box. 25-123, Taichung 400, Taiwan

[2] Associate Professor, Department of Hydraulics, Feng Chia University, Taiwan

[3] Professor, Department of Soil and Water Conservation, National Chung Hsing University, Taiwan

ecology environment. To protect and support the increasing population along the rivers, various hydraulic structures (such as revetments, dams, and reservoirs) had been widely constructed such that the formations and characteristics of river habitats had changed greatly at the downstream area. In the past, people consider flood prevention and nature conservation in river management are often two inter-conflict targets. But with the development of river rehabilitation, the design principles and application practices have been progressively developed to meet the goals of maintaining channel morphological change, flood prevention, ensuring stream substantial value (Downs & Thorne, 2000). Besides, The Committee on Restoration of Aquatic Ecosystems (National Science Council, 1992) suggested that decreasing the stresses of stream and river can directly improve stream ecological environment and achieve the objective of stream rehabilitation.

Techniques of habitat improvement are widely found recently in various cases, including fishway facilities, vegetation methods, natural materials (i.e., log, rock, net, and lure) habitat improvement facilities, and other management/control policies. Hey (1996) divided the measures of habitat rehabilitation and river habitat improvement into two main categories, structural and nonstructural methods. Nonstructural methods are ways of reconstructing the natural condition in certain part of a river. These recovering construction of river meanderings, pools, shallow area, vertical stream banks, and dead zones are often applied to lowland rivers. The structural restoration methods uses different artificial instream structures to create ponded reaches and bars form and prevent siltation to maintain substrate condition through various kinds of structures, such as weirs/dams, deflectors, and vanes (Figure 1).

In this paper, two stream restoration projects with similar concepts described previously applied at the Ta-chia River of Taiwan are introduced. With various techniques and their ecological effects, the authors report the efforts and the experiences on river fishery rehabilitation.

2. Habitat Improvement At Downstream Area Of Ta-Chia River

At the central part of Taiwan, Ta-chia River is a well-known natural scenic and fish habitat area for it’s convenient transportation, beautiful scenery, and plentiful water resources. Due to limited natural resources for electricity generation, waterpower has become one of the main power resources in Taiwan for decades. Therefore, several reservoirs and dams were constructed on Ta-chia River for its waterpower resource, while the impact on stream habitats has also increased. To meet the water demands for waterpower generation and fishery habitat, a research project of three and half years was initiated at 1990 to resolve the water-use conflict problem under the pressure from local environmental organization at downstream area of Ta-chia River.

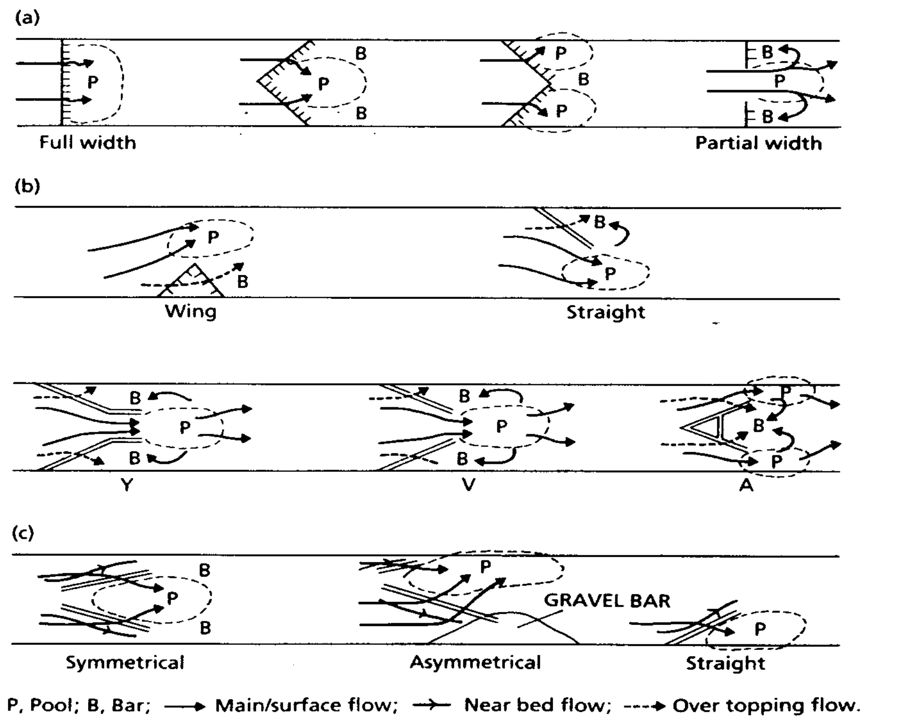

Figure 1. River habitat improvement using structural methods: (a) weirs/dams; (b) deflectors; (c) submerged vanes (Hey, 1992).

2.1 Habitat improvement principles and Techniques

With the experiences of field investigations and visits of advanced countries in this field, four planning and construction principles for downstream fishery habitat improvement were concluded as (Ho and Tuan, 1991): (1) maintain the natural stream landscape as natural as possible; (2) management, design, and construction of improvement techniques should be based on the trails of bed-load and stream channel; (3) emphasis should be on the persistency of artificial pools; and (4) efficiently utilize of limited budgets.

Various structural techniques, including rock weir of partial width, rock deflector, tire weir with opening, channel dredge, concrete deflector with rock pavement, and riverine recreation zone, were designed and applied based on the restoration functions of techniques and social-economic considerations of construction sites (Figure 2). The pictures of different types of techniques were shown as follows.

2.2 Comparisons on the environmental and ecological effects

To verify the environmental and ecological effects of these channel improvement techniques, series investigations of habitat condition and surveys of fishery population were applied at the same time from 1990 to

1993. The analysis results indicated that only partial and mild change on stream hydrology and water quality was discovered after the construction of these measures (Wang, 1996). In general, the reaches with rock deflectors or rock weirs of partial width not only had lower landscape impacts but also had better overall improvements on fishery community and habitat complexity (Table 1).

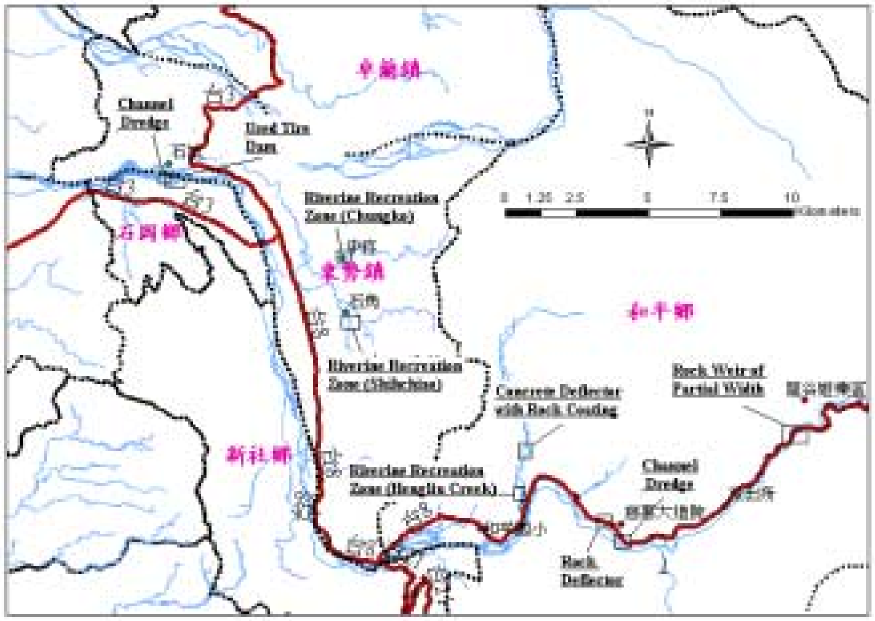

Figure 2. Locations and techniques of habitat improvement applied at downstream area of Ta-Chia River

Table 1. Habitat analysis of habitat improvement sites at downstream Ta-Chia River

	Rock weir of partial width	Rock Reflector	Used Tire Weir	Riverine recreation zone #1	Riverine recreation zone #2
Landscape Environment	Harmony	Harmony	Not Harmony	Not Harmony	Harmony
Channel Environment	Mild changes	Mild changes	Huge changes	Mild changes	Huge changes
Flow Regime	Increase of pools, riffles, & backwaters	Increase of pools, riffles, & backwaters	Increase of pools, deep flows, & backwaters	Increase of pools, riffles, & backwaters	Increase of bank slow runs & deep flows
Habitat Complexity	Increase Obviously	Increase Obviously	Increase	Increase Obviously	Increase
Catch Per Under Effort	Increase 3~14 times	Increase 1~15 times	Increase 5~19 times	Increase 0.6~2.3 times	Increase 2~8 times
Catch Density	Increase 11~48 times	Increase 4~68 times	Increase 15~38 times	Increase 1.6~4.7 times	Increase 18~35 times

Photo 1. Rock weir of partial width

Photo 2. Rock deflector

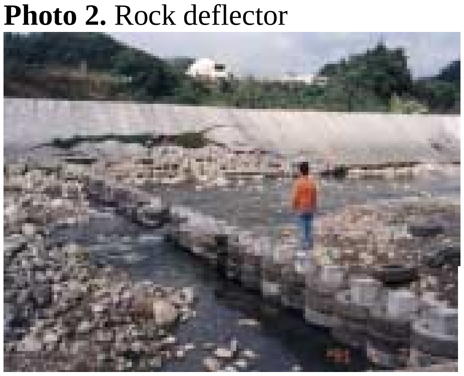

Photo 3. Tire weir with opening

Photo 4. Channel excavation

Photo 5. Concrete deflector with rock pavement

Photo 6. Riverine recreation zone #1

Photo 7. Riverine recreation zone #2

Photo 8. Riverine recreation zone #3

3. Habitat Improvement At Upstream Area Of Ta-Chia River

Identified as land-locked salmon, Formosan Landlocked Salmon (Oncorhynchus masu formosanum) had been recognized as natural monument for its biological importance by Japan government at 1938 during its colonization of Taiwan. At 1940s, several high altitude streams in central Taiwan, including Chi-Chia-Wan Creek, were their main habitat regions (Shei-Pa National Park, 1998). However, Formosan Landlocked Salmon right now only can be found in the Chi-Chia-Wan Creek and its tributary channels (Figure 1). According to the research of Lin & Liang (1990), appropriate habitat condition for salmon and trout should include several key environmental elements. In Taiwan, these elements are low water temperature (below 16°C), high dissolved oxygen in the water (above 6ppm), sufficient flow discharge, well cover of plantation shade over channel, adequate food source from invertebrate, and non-polluted channel bed for eggs' spawn, hatch, and protection. However, increasing human activities (i.e., wild fire, deforestation, over-cultivation, pollution, mining, flood and drought, and changes in channel formation and characteristics) around their habitat often effect these key elements and become as threats for their survival. Chang (1990) further classified the changes of habitation environmental factors into physical, chemical and biological changes. In his definition, construction of dams or weirs across channel, development activities, and deforestation of watershed or channel banks are the major physical changes for channel habitat. For Formosan Landlocked Salmon, major changes in habitat result from physical changes, especially from increase of water temperature and isolation of population. While climate irregular alteration, channel development, deforestation, and reservoirs are the causes for temperature increasing (Lin & Liang, 1990), check dams in the channel separate entire population in to groups without gateway for exchange for this special salmon. According to the field investigation of Tzeng et. al. (2000) since 1997, check dams in Chi-Chia-Wan Creek not only increase water temperature in the downstream channel （below Dam No. 2） and cause high fatal rate of zygote during mating periods, but also lead to the situation of gene homogeneity for each population within one section. With high concentration of sedimentation during flood periods, fishways to over-pass check dams were found infeasible for sediments blocking in the fishways. Therefore, searching for appropriate approach to enhance channel habitat of Formosan Landlocked Salmon has been the major objective for Shei-Pa National Park since 1990s.

To resolve the problem of existing for Formosan Landlocked Salmon, Shei-Pa National Park have implemented several conservation works simultaneously, including dam partial-removals at Gau-Shan Creek. Without any previous experience on dam removal/remodeling for ecological conservation purpose in Taiwan, this study first confirmed the idea of dam-removal based on the results of related research and literature mentioned previously. Field investigation, channel survey, and hydrological analysis were then processed before conducting model experiments. The main objective of flume experiment is to observe the channel reactions regarding to various combinations of opening shapes and dam partial-removal procedures. Suggestions on channel habitat enhancement for Formosan Landlocked Salmon were then concluded from experimental findings. After necessary administration procedures in several related management agencies, implementation of dam removal was finally taken into action while follow-up investigations on the change of channel morphology were scheduled to monitor and record the whole process of habitat restoration in the study reach. Consequently, the research methodology for this study was assembled by these components and illustrated as Figure 3.

3.1 Implementation of dam partial-removal and follow-up investigation

Being one of the upstream branches of Ta-Chia River, Gau-Shan Creek is one of few creeks without other human activities except four serial check dams constructed during the 70’s to prevent massive riverbank landslides and sedimentation into downstream reservoirs. With support from model experiments, the implementations of removal for each dam were separated with certain observation periods in between (Table 2).

According to recent field investigation (Yeh, 2002), each reach has different geomorphologic condition directly related to the implementation time of its downstream dam. For example, from longitude profile changes, reaches above dam No.3 and No.4 are gradually stabilized (Figure 5), while the reach between dam No.1 and No.3 is still under transition period (Figure 6). The gradients of these reaches before and after dam removals are listed in Table 3 along with brief description about the flush chute connected to each dam.

Table 2. Partial Dam removals implemented at Gau-Shan Creek

Implementation Time	April, 1999	October, 2000	September, 2001	December, 2001
Dam	No.4	No.3	No.1 and 2	Enlarged the opening of No.1

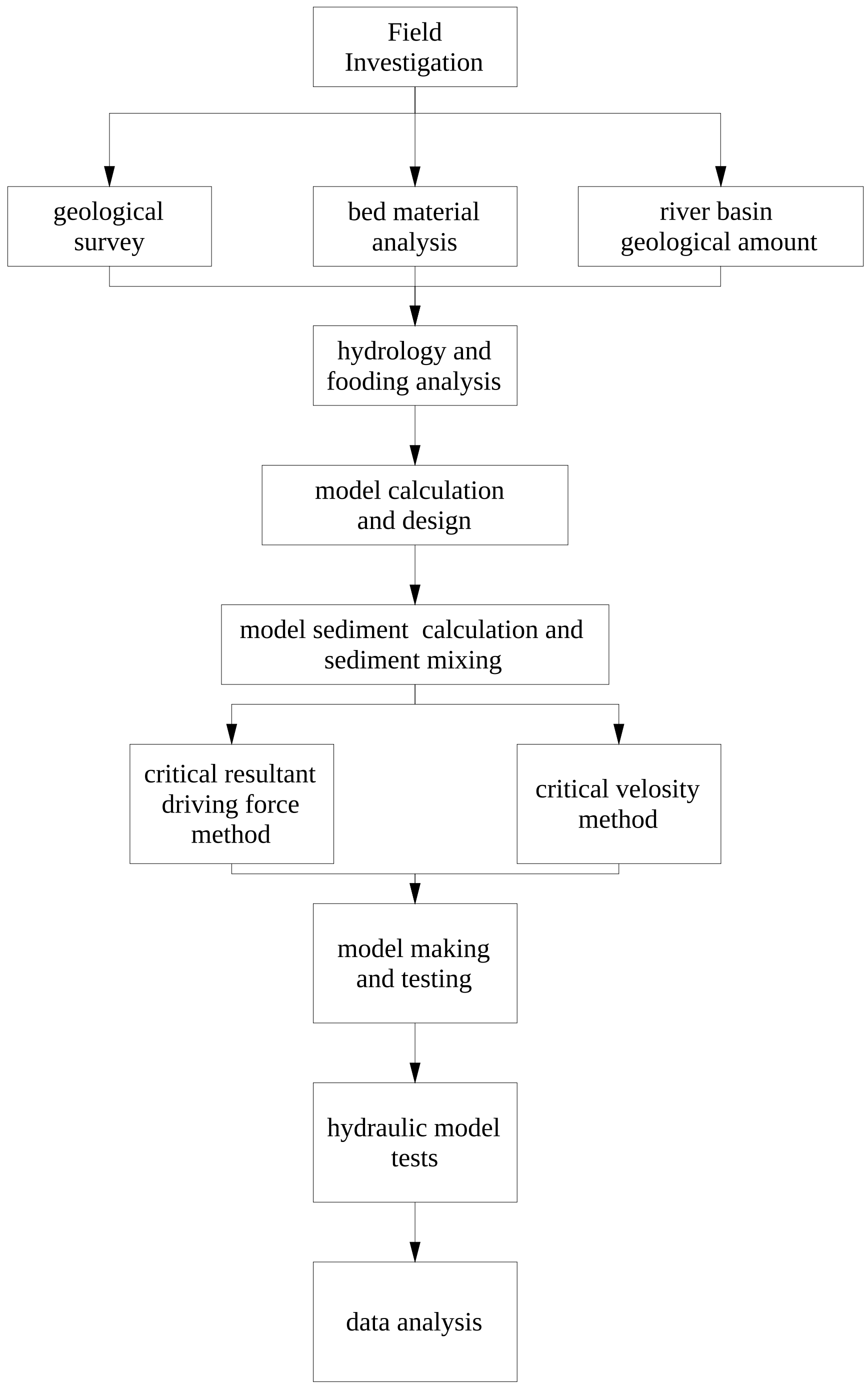

Figure 3. Flowchart of dam removal model experiments

Table 3. Investigations results on channel morphology for each reach

Reach	Average Gradient %		Flush chute connected to each dam
	Origin	2001/10	
Upstream of Dam No.4	3.86	6.68	90m long, forming step pools, and gradually stabilized.
Dam No.3 to Dam No.4	3.08	4.13	100m long, forming step pools, and gradually stabilized.
Dam No.2 to Dam No.3	2.07	3.33	150m long, thalweg deflecting to right bank.
Dam No.1 to Dam No.2	2.00	3.67	250m long, thalweg deflecting to right bank

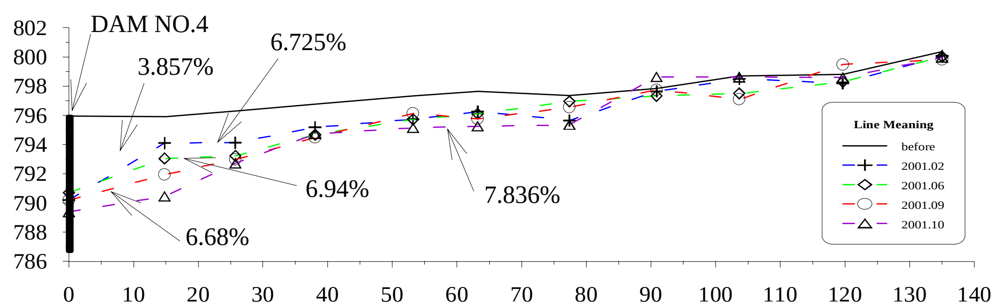

Figure 5. Upstream longitude profile of Dam No.4

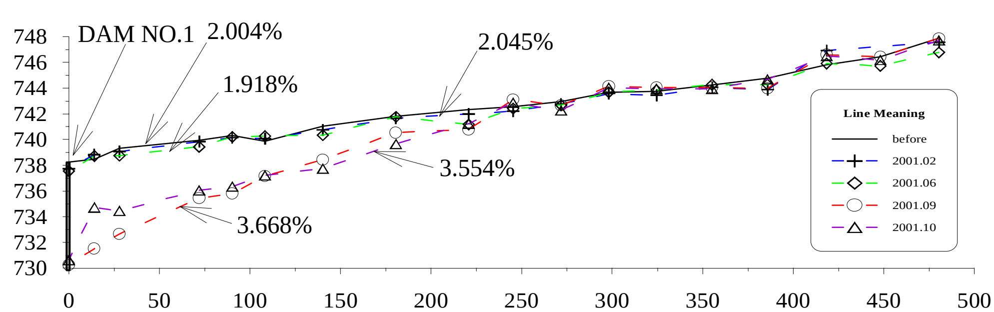

Figure 6. Upstream longitude profile of Dam No.1

3.2 Habitat changes before and after partial dam removal

To understand the effect of check dam partial removal, semi-annual population survey Formosa Landlocked Salmon in these reaches has been conducted since 1997. The investigation results (Tzen 2000, 2001, 2002) not only show spatial distribution of the population in the creek and also displays the effect of dam removal on channel continuity. The total numbers of salmon found within each reach are tabulated as follow (Table 4). However, the analysis results on the compositions of channel habitats, i.e., riffles, runs, deep runs, and pools, indicated that there is no statistical difference for the conditions before and after partial dam removals in the reach between Dam No.3 and No.4 (Lin et. al, 2001).

Table 4. Number of Formosa Landlocked Salmon found in Gau-Shan Creek

Reach	Fall 1998	Summer 1999	Fall 1999	Summer 2000	Fall 2000l	Summer 2001	Fall 200l	Spring, 2002
Downstream of Dam No.1	84	31	77	39	68	3	NA	6
Dam No.1 to Dam No.2	28	61	95	28	3	5	NA	0
Dam No.2 to Dam No.3	3	2	0	1	0	3	10	2
Dam No.3 to Dam No.4	3	1	0	43	28	3	14	46
Upstream of Dam No.4	NA	NA	17	37	50	25	33	55
Total	118	95	189	148	149	39	57	109

Photo 9. Dam No.4 in construction (April, 1999)

Photo 10. Dam No.4 recent condition (Oct., 2001)

Photo 11. Dam No.3 before construction (Oct., 1997)

Photo 12. Dam No.3 recent condition (Nov., 2000)

Photo 13. Dam No.2 before construction (Oct., 1997)

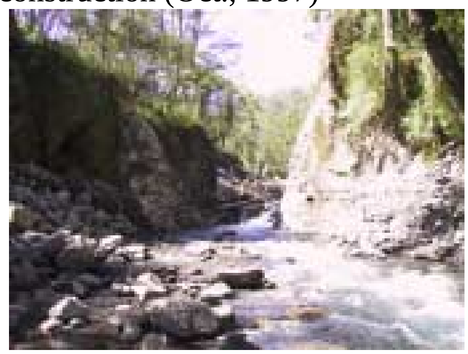

Photo 14. Dam No.2 recent condition (Oct., 2001)

Photo 15. Dam No.1 before construction (April, 2001)

Photo 16. Dam No.1 recent condition (Dec., 2001)

4. Conclusion

In general, the major objectives of river basin habitat improvement project could be protection of specific species, maintaining biological diversity for river habitats, and landscape esthetics and riverbed stability (Shen & Chen, 1998). In this paper, two different projects demonstrated the application techniques and their conservation concepts behind, when one project aimed to provide diverse habitat patterns under the constraint of limited channel flow at the downstream area of Ta-Chia River, the other project focused on the restoration of channel continuity at the upstream creek. Although differed in aims and approaches, these two projects were advised to make necessary modifications with the opinions from ecologists who conducted investigation at studies sites. In the case of dam removal of Gau-Shan Creek, ecologist suggested that the dam opening should be extended downward to decrease the water level difference at the site of dam No.3 after 10 months of implementation such that Formosa landlocked salmon can jump over the dam.

Reference

Abrahams, A.D. & J.F. Atkinson. 1995. Step-pool streams: Adjustment to maximum flow resistance. *Water Resources Research*, 31(10) pp. 2593-2602.

Chang, K.S. 1990. Fish Ecology. pp. 15-22. In: *Proceedings of Aquatic Fishes Conservation in Forest Rivers*, National Taiwan University, Taipei, Taiwan. (In Chinese)

Chiou, G.G. 1990. Habitat Investigation and Improvement for the Aquatic Fishes in Forest Rivers. pp. 139-188. In: *Proceedings of Aquatic Fishes Conservation in Forest Rivers*, National Taiwan University, Taipei, Taiwan. (In Chinese)

Hey, R.D. 1996. Environmentally Sensitive River Engineering. pp. 80-105. In: Petts, G. et al (ed.), *River Restoration: Selected Extracts from the Rivers Handbook*, , Blackwell Science Ltd. Oxford, UK.

Lin, Y.S. & S.S. Liang. 1990. Ecology of Salmon and Trout. pp. 33-52. In: *Proceedings of Aquatic Fishes Conservation in Forest Rivers*, National Taiwan University, Taipei, Taiwan. (In Chinese)

Ouyang, C. F. et al, 1997, Chapter 2: Hydrologic Cycle. pp. 13-26. In: *Use and Conservation of Water Resources*, National Open University, Taipei, Taiwan. (In Chinese)

Shei-Pa National Park. 1996. *Shei-Pa National Park*, pp. 37-38, Taichung, Taiwan.

Tuan, C.H. 1993. A Study of Excavation and Scouring-Depositing for Pools and Channel of Tachia River, Research Report, Graduate Institute of Soil and Water Conservation, National Chung Hsing University, Taichung, Taiwan. (In Chinese)

Tzeng, C.S., C.M. Yu & C.H. Yang. 2000. Studies on Population Ecology of the Formosan Landlocked Salmon. pp.115-135. In: *Proceedings of The Workshop on Conservation of the Taiwan Masou Salmon*, Taiwan Endemic Species Research Institute, Nantou, Taiwan. (In Chinese)

Wang, C.M. 1998. Ecological Assessment for the Fish Habitat Improvement Project Conducted in Tachia River of Taiwan. pp. 151-186. In: *Proceedings of Chinese-Japanese Symposium on Ecological Conservation of Streams*, National Taiwan Normal University, Taipei, Taiwan.

Yeh, C.H. & C.H. Tuan. 1994. Hydrological and Hydraulic Characteristics of Flood-Detention Dam. *Journal of Chinese Soil and Water Conservation*, **25**(4), pp.181-189. (In Chinese)

Yeh, C.H., P.H. Ling, & C.H. Tuan. 2001. A Study of Effects of Check Dam Remodeling on the Changes of Channel Morphology and Habitat Formations for Gau-Shan Creek, *Journal of National Park*, 11(1) pp. 71-85. (In Chinese)

Yeh, C.H. & H.P. Lien. 2001. An Experimental Study of Channel Habitat Improvement for Formosan Landlocked Salmon. pp. 255-263. In: *Proceedings of 21st Annual American Geophysical Union "HYDROLOGY DAYS"*, Colorado State University, Fort Collins, USA.