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The Ecohydraulic of Fish Habitats in Engineered Streams

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Abstract

This paper is intended to establish a mechanism by using Froude number to associate the relationship between flow conditions and fish habitats. In open channel hydraulics, Froude number, which contains two variables: water depth and water velocity, is extensively applied to describe flow type. Utilizing single hydraulic variable such as Froude number to define flow type simplifies two variables, water depth and water velocity, in describing the differences of flow types. The study site is in the Dago Stream, Taipei City, Taiwan, with aim to find the confident intervals of fish habitat occurrence proportion and Froude number distribution during regular flow. After fieldwork in the Dago stream, there are nine aboriginal fishes, however the *Scaphesthes barbatulus* and *Gambusia affinis* are excluded from this statistic due to the little amount. The *Hemibarbus labeo* habitat was most likely to occur at lower Froude number class ranging from 0.3 to 0.4. But the *Monopterus albus* habitat was most likely to occur at higher Froude number class ranging from 0.4 to 0.8. *Zacco pachycephalus*, *Acrossocheilus paradoxus*, *Rhinogobius brunneus* and *Candidia barbata* were extensively existed in the range of Froude number between 0.3 to 1, but the optimum habitats of *Rhinogobius brunneus* and *Candidia barbata* appear from 0.8 to 1.1. This information can be applied to torrent control, depending on changes of channel morphology to create an Environment of habitat heterogeneity and biodiversity.

Keywords: Ecohydraulic; Froude number; Fish habitat; Ordinary flow

Introduction

It is easily to see the mitigation of flood hazard after so many years' hard work on river management in Taiwan. Instead of ignoring stream ecological environment, ecological infrastructure, and landscape planning, the early works of hydraulic engineering only focused upon flood control. The flood control project including forecasting models, costly levees and bank protection works that can reduce the frequency of inundation, mitigate losses by flood damages, and safeguard lives and properties. Owing to lack study of the stream ecology, the hydraulic structures can only be designed to meet the beauty of artificial environment. The ecological systems in those managed steams were almost damaged. From the concept of sustaining development, it is time to introduce the ecological engineering to the hydraulic engineering. Thus the raising consciousness in natural resources and environment protection make the ecological engineering become popular in a short period in Taiwan. Comparing with the conventional methods applied and improved continuously for thousands year, people in Taiwan still do not give their confidence to the methods developed by the ecological engineering in the last decades. Lack of the basic research of steam ecological system, methods has often been chosen for the sake of ecological engineering. Moreover the design and construction were processed without the understanding of the environment of the fish habitat.

The concept of ecological engineering has originated in the West that started with a similar concept of natural dredging in channels and based on traditional river dredging work. It is possible to reach a dredging solution not just similar to the nature itself and cost-efficient, but also preserving the landscape. Odum (1962) indicated the ecological engineering concept of self-organizing activities to apply the ecological engineering to wastewater treatment in salt lakes and wetlands areas. Mitsch (1989) indicated an ecological engineering concept based on self-design capacity of ecological system. The emphasis was to meet the both-benefit purpose through the interaction between artificial environment and natural environment.

The classification definition is shown in Table 1. The flow type is defined by velocity and water depth. The relationship between velocity and water depth can be used to identify the flow type for riffle, run, and pool (Jowett, 1993); Furthermore, Froude number has been applied to describe the flow type. It can be used to sort out clearly eight flow types, including riffle, run, and pool (Wadeson and Rowntree, 1998). To analyze the flow types, it is necessary to take streambed into consideration for ecological habitat. Since streambed serves the ecological functions, such as spawning, feeding and sheltering. Investigations on the relationship between particle size distribution in streambed and Froude number still keep going. The results suggested that sediment was influenced by Froude number range (Kemp et al., 2000), shown in Table 2. Fine sediment occurred more often when Froude number range was lower. Thus it is possible to apply Froude number to establish the relationship between water depth, velocity, and particle size of streambed. Besides Froude number can be used to describe the habitat of water plants (Kemp et al., 2000).

Table 1. The relation of flow condition and Froude number

Flow Type	F_r
Backwater Pool	0.00005~0.004
Pool	0.00033~0.066
Run	0.108~0.161
Riffle	0.108~0.312
Rapid	0.102~0.306
Cascade	0.097~0.392
Glide	0.330~0.635
Chute	0.189~0.581

Note：Remarkable Interval is the occurrence probability between 25%~75%

Table 2. The relation of streambed particle size and the Froude number

	Particle Size (mm)	Fr
Rocks	Above 256	0.35~0.4
Cobbles	64~2	0.1~0.55
Gravel	2~0.125	0.05~0.4
Sand	256~64	0.05~0.25
Silt	under 0.125	under 0.05

Usually there are several typhoons coming with heavy rain which will affect Taiwan. Dredging channels become the key hydraulic work. Currently, the major work of dredging channels is not only for flood control, but also considering the protection of stream ecological system. The design and construction of hydraulic structure have to follow the ecological system. However, most of the hydraulic engineers are lack of ecological concept. The existence of a gap between the ecological system and hydraulic engineering is great and difficult to pass. This study is trying to establish the relationship between the Froude number of habitat and the fishes to bridge the gap. Froude number can be utilizing to describe the flow type, to analyze the proportion range of the aquatic's appearance, and to simply the judgment on hydraulic parameters, in order to provide ecological habitat created by engineering practices.

Methodology

The data of fish and discharge is collected in ordinary flow. Therefore flow condition is assumed to be the steady flow. It is impossible to measure the velocity and depth alone the stream. In order to obtain the Froude number in different cross-sections, HEC-RAS is a good tool. HEC-RAS, developed by the Hydrologic Engineering Center of US Army Corps of Engineers, is a river analytic system. It has been applying to the hydraulic calculation for natural river courses or artificial channels with one-dimensional steady flow. It can simulate water level, rating curve and parameters with only the inputs of river geometrical data and steady boundary current. The reasons to choose HEC-RAS are as follows: (1) It can be applied to the water surface calculation of artificial channels with one-dimensional steady flow. The data input has been simplified and the output includes hydraulic parameters, indicating velocity, water depth and Froude number. (2) HEC-RAS is popular and reliable. (3) The characteristics of flow analysis, from upstream to downstream sections, as well as from low to high discharge, were used to calculate in sequences to establish a relationship-table with hydraulic parameters-simulated discharge. The data can be used as sequential and logical coordination for this research. (4) It is more available, and with more sample demonstration.

The water surfaces and Froude number are computed form one cross section to the next by solving the energy equation as follows (Hydrologic Engineering Center, 2001):

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad (1)$$

Where Y_1 and Y_2 are depth of water at cross sections 1 and 2; Z_1 and Z_2 are elevation of the main channel inverts; V_1 and V_2 are average velocities of cross sections 1 and 2; α_1 and α_2

are velocity weighting coefficients; g is gravitational acceleration; h_e is energy head loss.

HEC-RAS design has been utilized interactively under the environment of friendly interface as one-dimensional river simulation system. This system can be operated under the environment of Windows. In addition, it can be used to calculate the steady-state flow cross-section of river network covering sub-critical flow, supercritical flow or mixed flow. This program has been developed into all geometric data simulations of a single river. Mouse can be used to depict diagrams of different sections from upstream to downstream to input the river network. While river sections are connected, then the program will form connected points automatically. After network was input, the data of river section and connected points can be input. It also provides additional function options; including inputs from data swap files and digitalized three dimensional river section and cross-section data.

Flow is determined by the weight of the fluid flowing downhill in response to gravity. Froude number is a dimensionless parameter for the related characteristics between gravity and inertial velocity, represented as follows:

$$Fr = \frac{v}{\sqrt{gD}} \tag{2}$$

In which v is mean velocity; D is water depth.

In open-channel hydraulics, when $F_r < 1$, it is subcritical flow；while $F_r=1$, critical flow; $F_r > 1$, supercritical flow. Generally, the higher value of Froude number is, representing the flow type more rapid and violent. The category of flow type has been simplified to three forms in this research: (1) Pool: $0.011<F_r<0.066$; (2) Run: $F_r < 0.4$; (3) Riffle and Glide: $F_r > 0.4$. The investigation results have been utilized to list the species and quantities of fish found in Froude number ranges, to reveal the frequency of different kind of fish existing. The corresponding table was made for the quantities and Froude number range of every fish species. Then the existing probability was calculated according to fish and corresponding Froude number.

$$p = \frac{X}{N_T} \tag{3}$$

In which p is the probability; X=frequency of habitat X in Froude number class y; N_T is total number of observations.

To establish the relationship between Froude number and Fish habitat, the individual probability has been calculated with statistics. Within the 95% confidence interval, the probability of upper and lower confidence is given by (Zar, 1984):

$$L_1 = \frac{X}{X + (n - X + 1)F_{\alpha(2),v_1,v_2}} \tag{4}$$

In which: L_1=lower confidence limit; n=frequency of Froude number class y; $v_1=2(n-X+1)$; $v_2=2X$ 。$F_{\alpha(2),v1,v2}$ can be obtained from the F-distribution with degrees of freedom v_1 an v_2. The upper confidence limit in which $v_1=2(X+1)$；$v_2=2(n-X)$.

$$L_2 = \frac{(X+1)F_{\alpha(2),v_1,v_2}}{n - X + (X+1)F_{\alpha(2),v_1,v_2}} \tag{5}$$

It is possible to depict the similar fish existing probability diagram and similar habitat suitability curve from above calculated results. It can tell the suitable Froude number range for every fish species from the calculation.

Description of study area Data

This study has taken at the Dago Upstream that locates in Taipei City as the study area, shown in Figure 1. The Dago Stream, which is a tributary of the Keelong River, has originated from Bai-Hsiu-Hu Hill with altitude in 485 m, and watershed area in 340 hectare. The Dago Stream drains into a pool with closed conduits under the road, then confuses into Keelong River by a regulation outlet. Although the downstream section is close to residence area, the whole stream section remains as a nature stream. The watershed of the upstream is covered by the secondary forest; while along downstream, the land utility is concentrated on agriculture. Due to upstream development and intense farming activities, it caused serious deposition on streambed.

Figure 1. Study site

After urban land consolidation, downstream area of the Dago Stream has been developing into highly concentrated residence community. Due to the needs for roadway, original open-channel was replaced by closed conduits. The result to fight the nature for land came with typhoon Winnie on Aug. 19, 1997. In communities along downstream, the conduit is too narrow to drain water in time. Torrential rain became over-flooded, causing serious disaster. In view of erosion damage on the farms along stream banks caused by torrential rain the Taipei City Government undertook the dredging works on the upstream of the Dago Stream to mitigate the downstream residents' property and life loss.

The work of dredging the Dago Stream extended for 660 m, mainly divided by river mile 0k+300 meander, according to stream functionality. The section from 0k+000 to 0k+300 has been planning for recreational water activities and stream ecological preservation. To coordinate with scenic spots and track exits nearby, there are tracks established to connect the road and original tracks to provide the public with recreational mountain-climbing routes. It also promotes the water functionalities by appropriately leading people's activity area into nature stream areas.

The cross-section data was collected when the Dago Stream is dredged. The work of dredging channel has been divided into two stages. The first stage was finished in December 1999; the second stage was finished in February 2001. The blueprint included cross-section, vertical section, and detail design.

The total length for the dredged channel was 660 m. The stream is divided into 34 cells to form the flow net. The hydraulic structures in the channel included energy dissipaters. The average channel slope is 0.01. Manning's roughness coefficient n is 0.03. Figure 2 shows the locations of stations whose geometric data is entered for the calculation of Froude numbers. The distance between the adjacent cross-sections is 20 m. After that, according to the riverbank protection of each section, the required parameters such as friction coefficient were input.

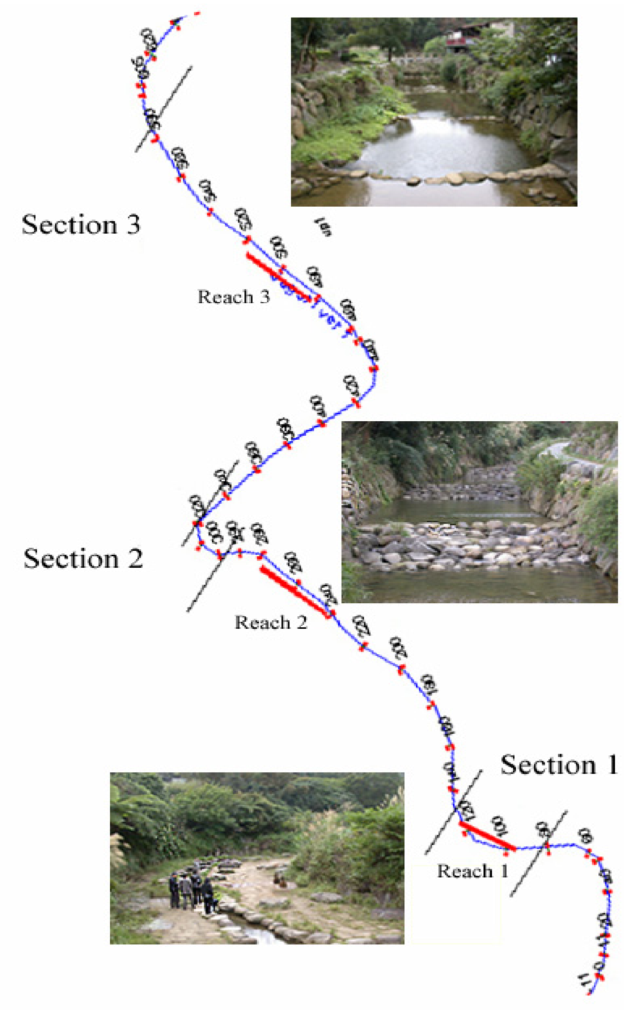


Figure 2. Location of stations in the Dago Stream

During dry season, habitat spaces in the water would decrease substantially that will affect on the shelter and reproduction of aquatics. The characteristics of mountain rivers in Taiwan are high altitude and short flow path. Rainfall has concentrated in a short period and cause great variations in water-stage. Therefore, it is very important if it is sufficient to meet the aquatics' basic needs of shelter and reproduction for river ecological system during dry season. This study has put the emphasis on the flow type in ordinary flow to observe the relevant aquatics' sheltering condition.

The Dago Stream is a nature stream from a small watershed, without gauging station to measure the discharge. The discharge measurement was taken at the site with straight steam. The discharge is measured at both 0 k+080 m to 0 k+120 m. The mean-section method was used to calculate the discharge.

In the water ecological system, fishes are the higher consumers in river food chain. If the fish distribution is intact, it can reflect the group situation of consumers in lower level or producers. Fish's life cycle is long; while existing in the rivers, it can completely reflect the physical, chemical, and ecological characteristics of rivers. Thus, this research has chosen fishes as the indicators for ecological survey.

Due to lack of relevant research on ecological distribution in the Dago Stream, it is determined to take samples at the spot. The sampling method, electro-fishing method, has been used to conduct three fish samplings. They were May 08, 2003; December 21, 2002; and May 04, 2003, respectively. Sampling sections were located at downstream, mid-stream and upstream along the Dago Stream. The three sampling sections on December 21, 2002 and May 04, 2003, were located at 0 k+100 m to 0 k+120 m, 0 k+240 m to 0 k+280 m, 0 k+480 m to 0 k+520 m, respectively.

To observe entire ecological environment via the water temperature, it can determine the vegetation quality in surrounding environment according to changes of water temperature. There were 9 survey spots for water temperature from downstream to upstream. Table 3 revealed the temperature from each cross-section along the Dago Stream on May 4, 2002. In artificial channel, the water temperature taken from downstream section, 0 k+080 m to 0 k+135 m was 29℃; 27 or 28℃ from Section 2, 0 k+140 m to 0 k+300 m; 24~26.5℃ from upstream 0 k+340 m to 0 k+580 m. Survey point I was the un-dredged section in upstream, preserving the original vegetation and water temperature was 23℃. Within only a short distance of 600 m, the temperature increased 6 ℃. It revealed that the vegetation in surrounding environment along the dredged section in the Dago Stream was not in a good condition.

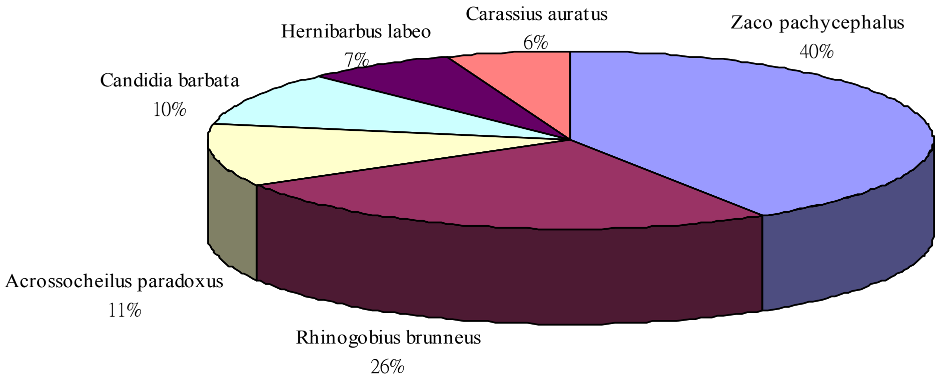
Table 3. Water temperature variations along the Dago Stream on May 4, 2002

	Downstream	Midstream	Upstream
Station	0k+080~0k+135	0k+140~0k+300	0k+340~0k+580
Main channel width (m)	1.2	6.2	8.6
Water temperature (℃)	29	27~28	24~26.5

Results

The Dago Stream is composed of cross-sections in three sizes. Therefore, the study area is divided into three sections. The channel width of Section 1, 0 k+0 m to 0 k+135 m, is 1.2 m; Section 2, 0 k+140 m to 0 k+300 m, 6.2 m; and Section 3, 0 k+340 m to 0 k+580 m, 8.6 m. According to the data taken from the site, the ordinary flow was about 0.03~0.05 m3/s. The ordinary flow is the input of HEC-RAS, the results were as follows: for Section 1, Froude number was about 0.85~1.1; Section 2 was 0.8~1.05; Section 3 was 0.3~0.5. After hydrological analysis, it found that the flow type in Section 1 and Section 2 were Glide or Riffle; while Section 3 was run. According to the site survey in the Dago Stream, it ascertained that Section 1 exists a main channel; it flowed only in main channel under ordinary flow, and a glide being formed; the channel type in Section 2 was more a serial submerged dam, caused riffle or chute to be formed; Section 3 has a wider channel cross-section, forming a flow type of run or pool.

Backpack shocker was utilized to take fish samples. Fish samples from the first investigation were 98; the second samplings were 176; and 111 fishes from the third time. In the first investigation, the reach of sampling site was not recorded; therefore, it failed to determine clearly the flow type in sampling site. It led to un-completed statistic calculation. The second and third investigations took sampling at Reachs a, b, and c, shown Fig. 2. The investigated results of fish populations are shown in Figure 3. From those two investigations, there were 12 kinds of fish found in the Dago Stream; in which, 9 of them were native species, while the alien species including *Shubunkin*、*Tilapia*, and *Hypostomus spp*, with limited quantities. In second sampling, only one *Scaphesthes barbatulus* was found. There was one *Gambusia affinis* found respectively from the second and third investigations. Those two species were excluded from this statistics, due to limited quantity. *Carassius auratus*, *Monopterus albus*, *Hemibarbus labeo* have existed along the Dago Stream, but not in big quantity. Alien species such as *Tilapia* and *Hypostomus spp* were not in big quantity either; both were found in upstream sampling site, with slow flow. *Gambusia affinis* was excluded from this statistics due to very limited quantity; it existed in downstream, with Glide flow type.



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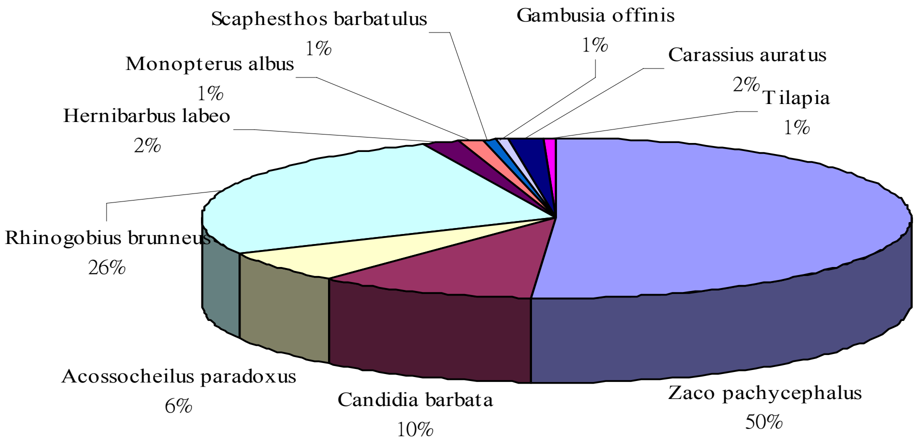

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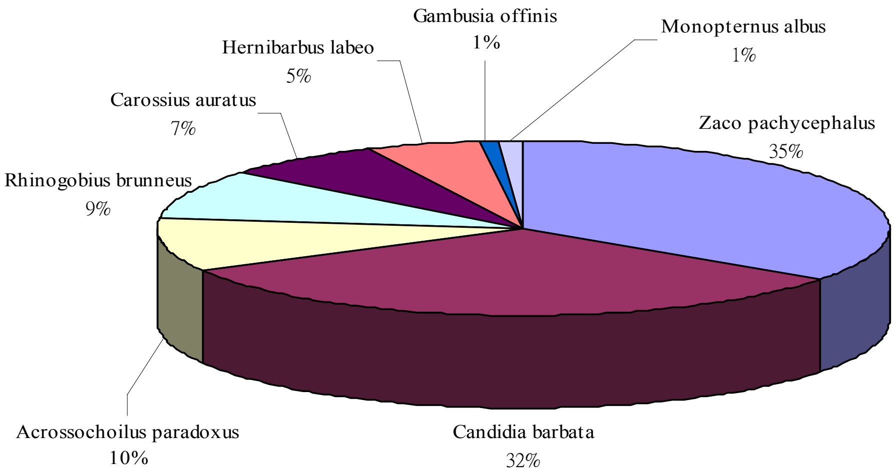


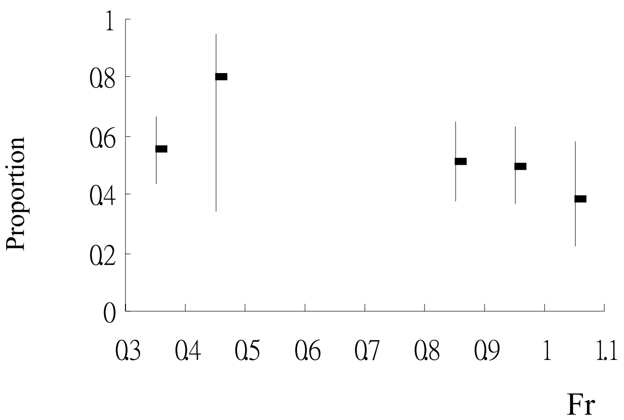
(c)

Figure 3. Fish population in the Dago Stream; (a)May 8, 2002; (b) Dec. 21, 2002; (c) May 4, 2003

By the Froude numbers of fish habitats and sampled fishes, it is possible to obtain the probability for each fish, as well as upper and lower limits of probability. It could depict the interval graph for Fraud number vs. fish occurrence probability. In Fig. 4, the horizontal axis is Froude number and vertical axis is occurrence probability. Taking *Zacco pachycephalus* from Figure 4.(a) as an example, under the flow type with Froude number in 0.3~0.4, the upper limit for actual occurrence probability was 0.55, being represented by black dots in the lines. The upper limit for possible occurrence probability would be 0.66, with 0.43 for lower limit; i.e. the highest and lowest dots in the lines. Synthetically, the occurrence probability of *Zacco pachycephalus* was high in each flow type, being wide-spread in all flow types. *Acrossocheilus paradoxus* were found in each flow type, but with steady probability in rapid flow. *Candidia barbata* and *Rhinogobius brunneus* were found in each flow type, but with higher occurrence probability in Froude numbers between 0.8~1.1. *Hemibarbus labeo* occurred more often in Froude numbera 0.3~0.4. *Monopterus albus* only was found in Froude numbers 0.8~1. *Carassius auratus* has occurred in Froude numbers 0.3~0.4 and 0.9~1. They show that (1) *Hemibarbus labeo has* occurred in the flow type with lower Froude numbers 0.3~0.4; (2) *Monopterus albus* has occurred in the flow type with higher Froude numbers 0.8~1.05; (3) *Zacco pachycephalus, Acrossocheilus paradoxus, Rhinogobius brunneus*, and *Candidia barbata* could be found in Froude numbers 0.3~1, with wide-spread flow type; in which, *Rhinogobius brunneus* and *Candidia barbata* have occurred most often in the flow type with Froude numbers 0.8~1.1. Fig. 5 was obtained from the above-integrated data. It shows the relationship between Froude number (flow type) and fish species.

Before the hydraulic structure is constructed, it is necessary to investigate the fish species distribution in this stream and then refers to the data from Table 4. Based on Froude number suitable for different fish species, it's possible to design the proper flood-drainage channels. It's also possible to plan and install proper engineering structures, to build a physical habitat environment or preserve the original habitat. The so-built diversified water would benefit the survival and reproduction of aboriginal fish species. Taking *Hemibarbus labeo* for example, when it's found in dredging wild stream, then it should be possible for the regular flow from designed channel to form a slow flow, such as constructing a pool, reducing the slope of a channel, and widening waterway. It could make the hydrological condition to meet the requirement of Froude numbers in 0.3~0.4, and to preserve the living environment for *Hemibarbus labeo*.

The Dago Stream does provide a bio-habitat during ordinary flow; however, whether the flood peak discharge caused by flood can provide shelter as well, to prevent the biological havoc from over-flooded. It still remains an issue to probe into in-depth. Taking flood frequency from the flood discharge designed for the Dago Stream for 50 years, the flood peak discharge is about 95 m^3/s. Under this flow, it's possible to utilize hydro-engineering structures in even flood discharge channel, to build a habitat with bio-diversity, and to shelter aquatics.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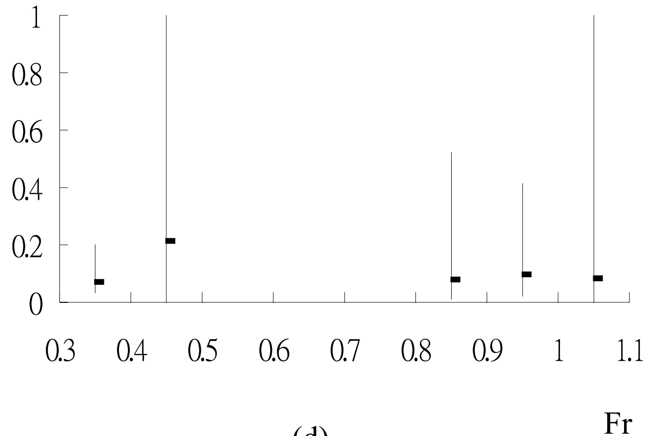
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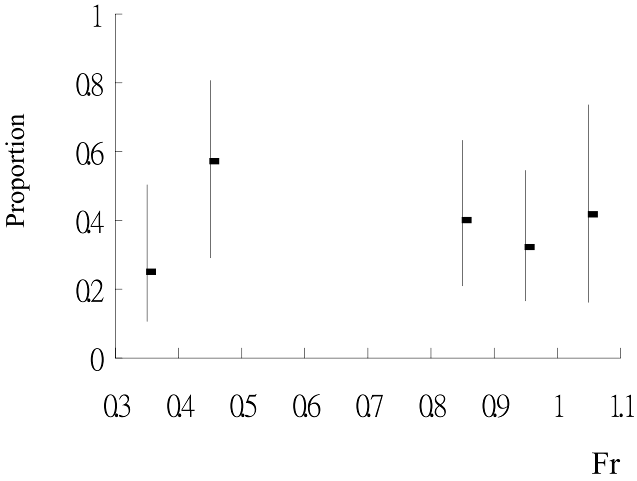
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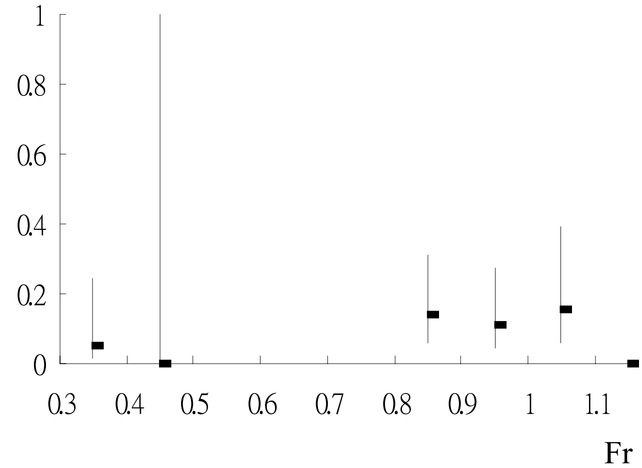
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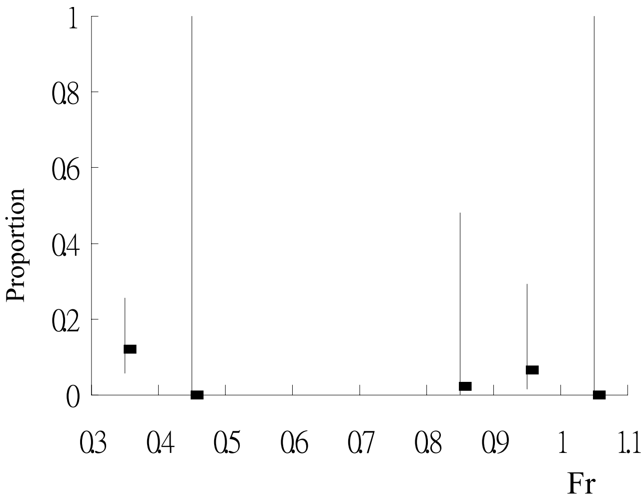
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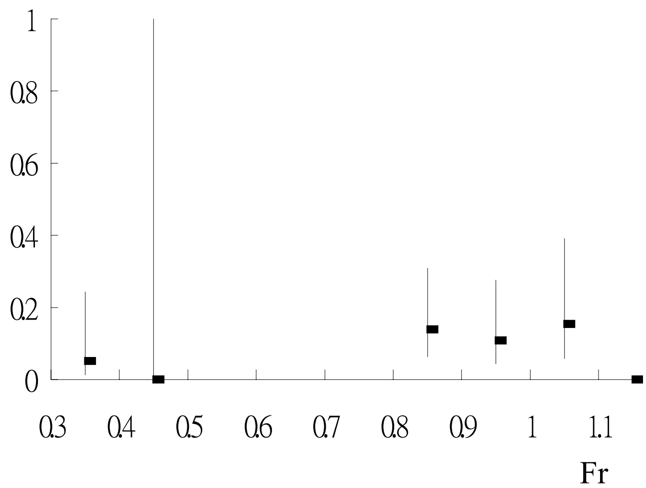
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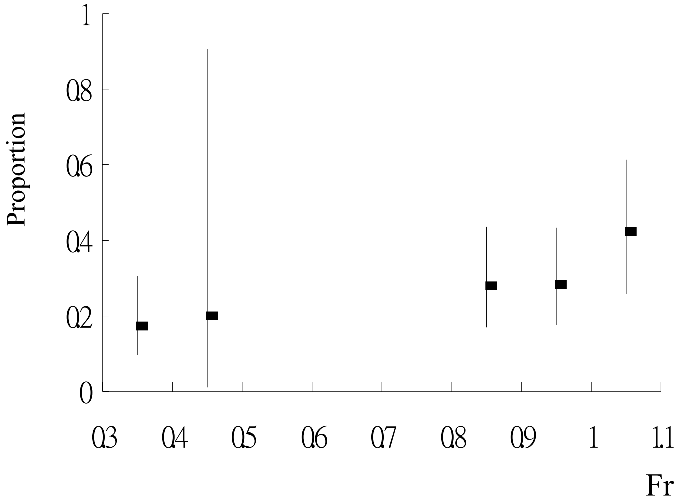
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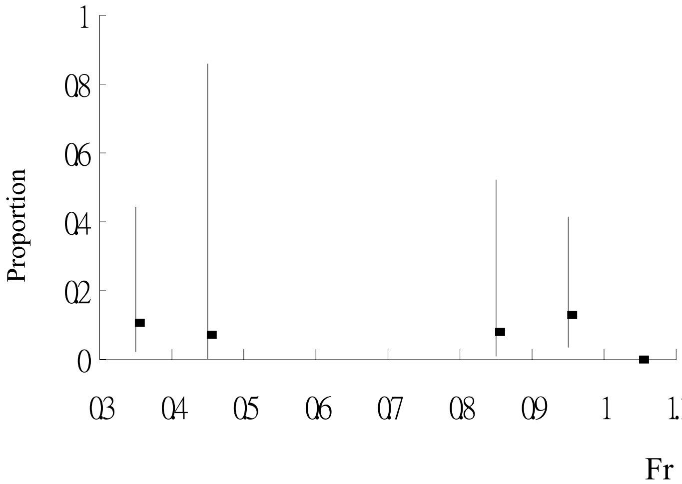
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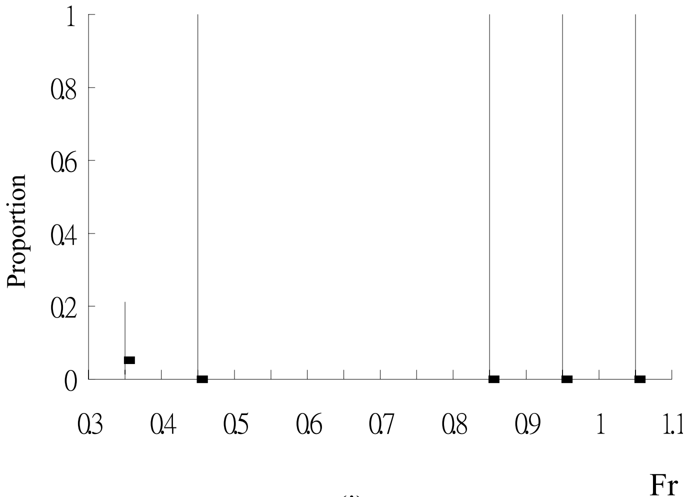
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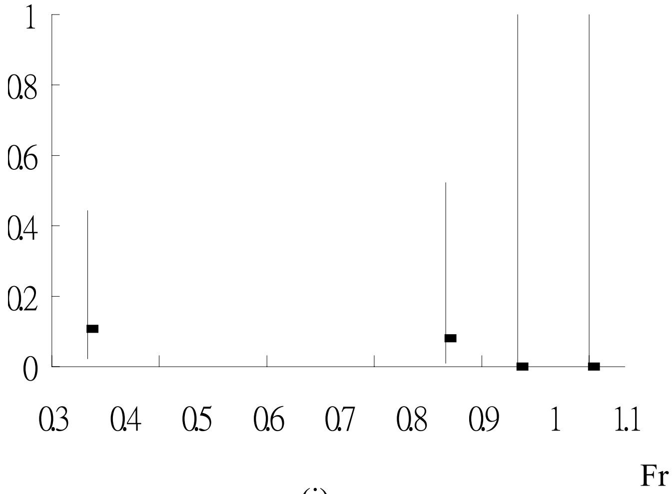
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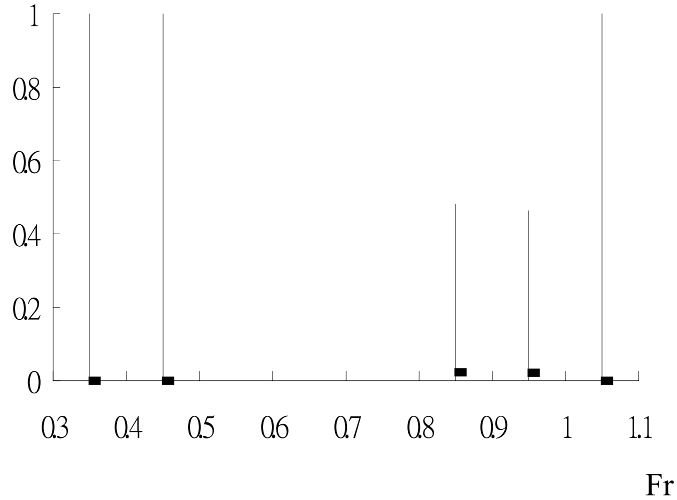
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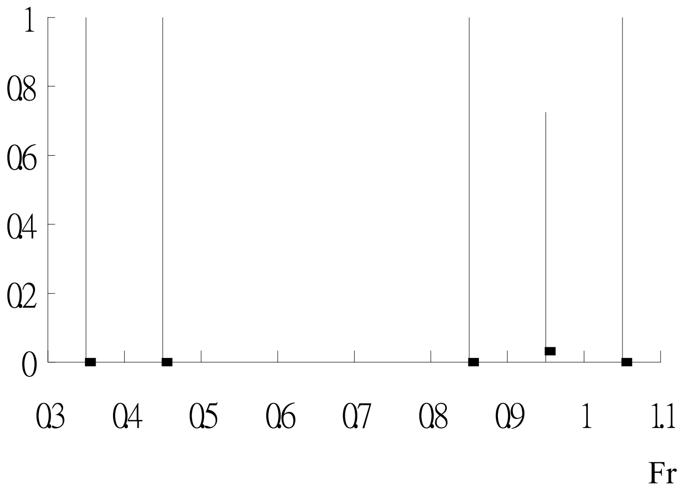
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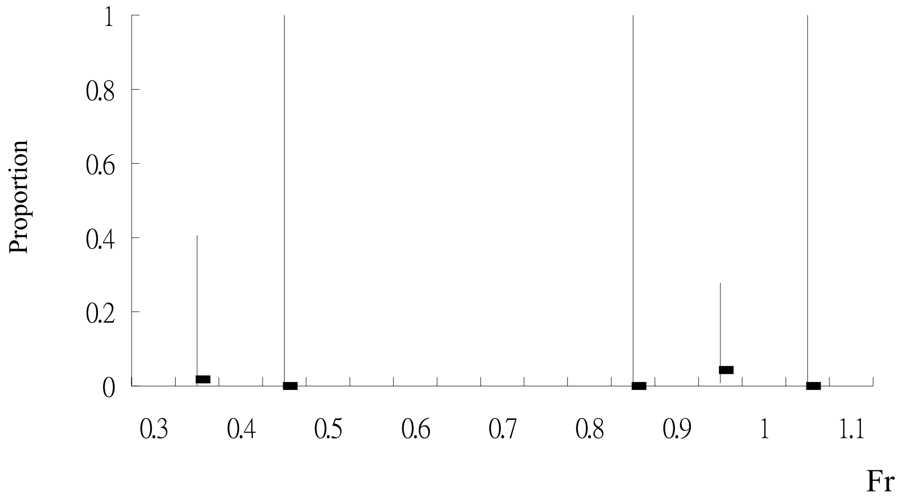

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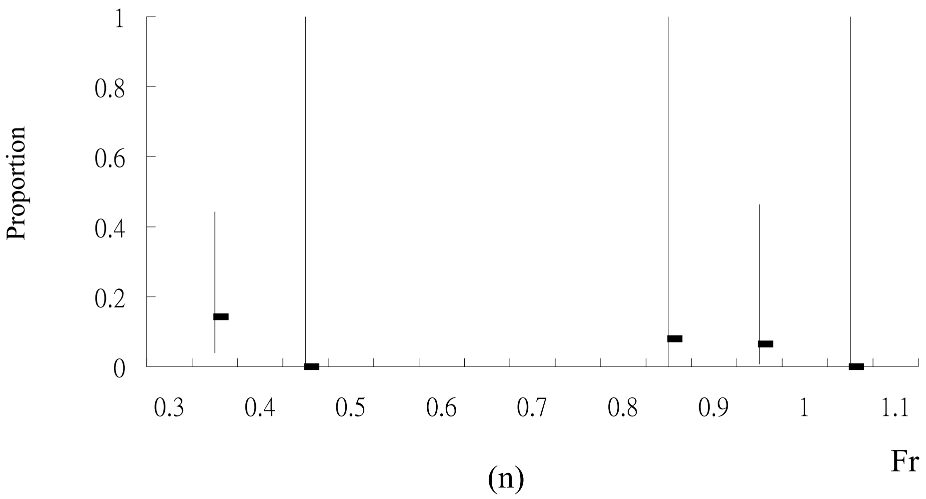

(n)

Figure 4. The relation of Fr and fish; (a) *Zaco pachycephalus*, 12/21/02; (b) *Zaco pachycephalus*, 5/4/03; (c) *Acrosscheilus paradoxus*, 12/21/02; (d) *Acrosscheilus paradoxus*, 5/4/03; (e) *Candidia barbata*, 12/21/02; (f) *Candidia barbata*, 5/4/03; (g) *Rhinogobius brunneus*, 12/21/02; (h) *Rhinogobius brunneus*, 5/4/03; (i) *Hernibarbus labeo*, 12/21/02; (j) *Hernibarbus labeo*, 5/4/03; (k) *Monopteus albus*, 12/21/02; (l) *Hernibarbus labeo*, 5/4/03; (m) *Carassius auratus*, 12/21/02; (n) *Carassius auratus*, 5/4/03

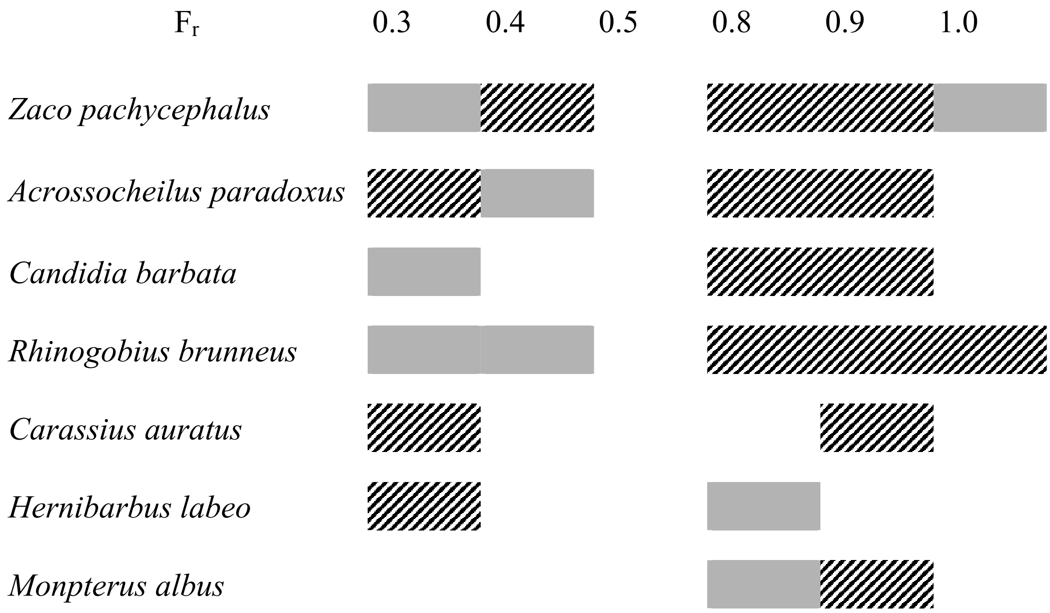

Figure 5. The association between functional habitat occurrence and F_r

Table 4. Summary of flow conditions and fish habitats in the Dago Stream

	Downstream	Midstream	Upstream
Flow type	Riffle, Glide	Riffle, Glide	Run
F_r	0.85~1.1	0.8~1.05	0.3~0.4
Hydraulic structure	Energy dissipater, boulder cluster	Energy dissipater, boulder cluster	Riverbed protection
Fish	*Zacco pachycephalus, Candidia barbata, Acrossocheilus paradoxus, Rhinogobius brunneus, Hemibarbus labeo*	*Zacco pachycephalus, Candidia barbata, Acrossocheilus paradoxus, Rhinogobius brunneus, Carassius auratus*	*Zacco pachycephalus, Candidia barbata, Scaphesthes barbatulus, Acrossocheilus paradoxus, Rhinogobius brunneus, Hemibarbus labeo, Carassius auratus*

Note: Discharge is between 0.03 and 0.05 m^3/s

Conclusions

This study has analyzed the fish habitat by flow type described by Froude number in the Dago Stream. The results are as follows:

(1) *Hemibarbus labeo* occurred in the flow type with lower Froude number, ranging from 0.3 to 0.4.

(2) *Monopterus albus* occurred in the flow type with higher Froude number, ranging from 0.8to 1.05.

(3) *Zacco* pachycephalus, *Acrossocheilus paradoxus*, *Rhinogobius brunneus*, and *Candidia barbata* occurred in wide-spread Froude number ranging from 0.3 to 1; *Rhinogobius brunneus* and *Candidia barbata* occurred most in the flow type with Froude number ranging from 0.8 to 1.1.

Froude number is composed of water velocity and water depth; and can be used to describe fish habitat environment. It is even possible to relate Froude number to particle size of streambed, to simply the determining parameters for hydrological analysis. By this mechanism, it is possible to relate water conservancy project to biological habitat. This information can be used as references for nature conservancy and stream habitat preservation.

This study was focus only on ordinary flow in the Dago Stream. It is very difficult to measure discharge during high water, and unable to record the fish distribution survey as well. Thus, the flow variation during flood can be simulated by some models to speculate the biological effects. As to the fish distribution during high water level, it is possible to study from biological aspect. Besides, the relevant issues worthy to probe into, are including the poor vegetation on artificial sections in the Dago Stream, as well as increasing water temperature in construction sections, due to intense sunshine.

Acknowledgements

The authors are grateful to Dr. Eric H. Tsao for his generosity in providing the valuable data.

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Strategies for Restoration and Management of Constructed Wetlands

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Abstract

This concept paper reviewed compressive approaches briefly of wetland restoration developed as goals setting, indicator identification, reference site selection, variation calibration, and life-cycle monitoring. Since there are no nationally recognized protocols for assessing the ecological conditions of wetland areas in Taiwan, this short paper provided proper approaches to satisfy assessments at scales ranging from individual restoration sites to riparian areas from research-driven analysis to model building. Scales issues were clearly identified and some recommendations are supported to solve both issues of natural and anthropogenic influences.

Keywords: wetland, restoration

Introduction

Wetland restoration has been suggested to use a smooth path, named for "trajectory", to predict the matching goals from target sites to a reference site (Simenstad and Thom, 1996) (Figure 1.). It is dependent on ecosystem structure and function, representing by the historic wetland condition (Lewis, 1990). The restoration of degraded wetland areas often indicates a scientific and social challenge (Bedford and Preston, 1988; National Research Council, 1992.). In some cases, the natural conditions of a particular wetland may no longer exist or may not be known with certainty. In addition, multiple causes of degradation may have occurred over long periods of time, thus, cause-and effect re- lationships may not be well known at landscape scale (Bradshaw, 1996). Studies indicated that many models have similar problems in assessing restoration progress, such as: (1) no clear goals were established to determine progress; (2) indicators of desired wetland functions have not been developed, (3) no natural site was used for reference; (4) spatial and temporal variability of reference sites was too high; and (5) assessment periods only covered a short term (Aronson and Le Floc, 1996; Bradshaw, 1996; Hobbs and Norton, 1996; Zedler 1996a). To resolve these problems aforementioned, compressive approaches to wetland restoration will be developed as goals setting, indicator identification, reference site selection, variation calibration, and life-cycle monitoring as follows.

Goals Setting

The goal of wetland restoration is to return a damaged ecosystem to a more natural condition. It is to facilitate self-sustaining occurrences of natural processes and linkages among terrestrial, riparian, and aquatic ecosystems. Rather than a single objective, the goals will be considered essential components: (1) maintaining biological diversity, (2) ensuring ecological persistence and resilience through time, and (3) sustaining ecological functions and structures. Aber and Melillo (1991) argued that ecosystem responses to a disturbing effect. While persistence and resilience are mechanisms of recovery, the response of nature reflects a long-term result through restoration efforts (see Figure 2.). Here, disturbance is a change in conditions, which interferes biological structure and function. For a purpose of wetland restoration, reference sites have to be defined a place whether a disturbed wetland is being restored or remains in a degraded state. The major challenges facing here are: how to assess restoration state to meet functional and structural equivalency with natural reference sites? How much progress they make changes toward sustainability? Since the start lines are different in each degraded pond in my study areas, thus, the ending points of restoration trajectories are including single points or alternative outcomes. The shape of pathway could be straight, curved, or plateaus depending on the progress made by restoration sites in a long-term period. The terms "success and failure" will be replaced with "progress", thus, a comparable range will be set and measured in degrees (excellent, good, fair, poor, very poor) in relation to a reference site. Compliance by seasonal monitoring will be used to indicate that mitigation criteria have been met so that the restoration goals can be achieved over time.

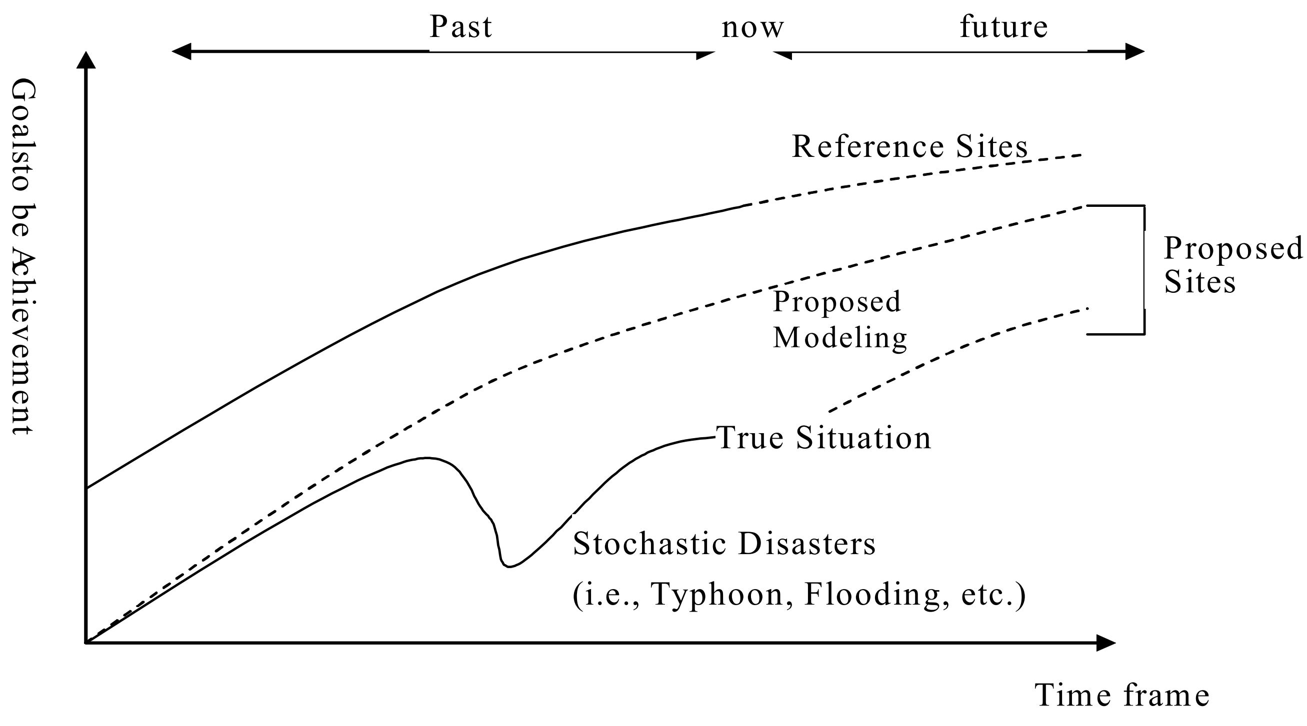

Figure 1. Trajectory lines of wetland restoration. Modified after Simenstad and Thom (1996).

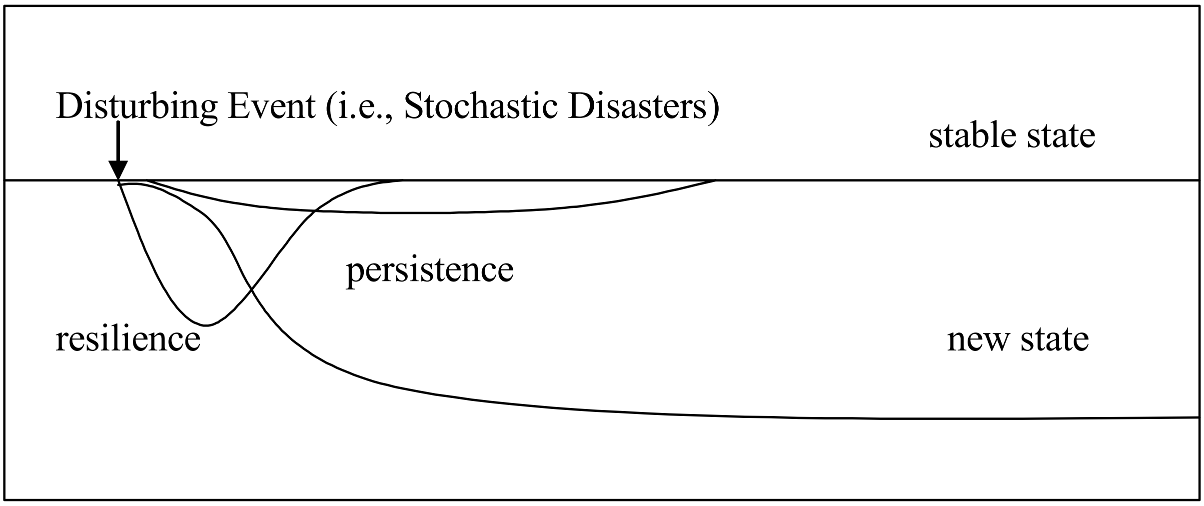

Figure 2. Ecosystem responses to a disturbing event (Aber and Melillo, 1991)

Indicator Identification

Indicator identification should consider abiotic and biotic factors to meet mitigation criteria. Since most farm ponds have been degraded and stressed, thus, it is important to find indicators that appear sensitive to that degradation and stress. Components of the wetland indicators are considered both structural (topography, hydrology, soils, floral, and faunal communities) and functional (nutrient cycling, productivity, salinity, and disturbance). I will select topography, hydrology, soil, flora, and fauna to be my indicators. Topography studies concern slope, elevation, pond configuration (i.e., area, edge, clustering, and shape). Hydrological studies focus on the upland-wetland interface, assessing the hydrologic budgets at various stages of succession (Brinson, 1993; Bedford, 1996). Soil studies investigated soil carbon storage, organic matter content, and soil texture (Childers and Day Jr., 1988). Floral studies centered on both current and potential terrestrial vegetation and aquatic vegetation. Vegetation cover, plant height, density, biomass, and species number will be measured (Connor et al., 1981). The change in area of different vegetation types and vegetation classes will also be considered. Faunal community studies assess invertebrates (i.e., benthic invertebrates and natant macro fauna) and fish. They will be surveyed by their abundances, richness, dominance, distributions within specific habitat types. The general criteria to select regional biota are (1) attracting the desired species, and (2) resisting invasion by exotics (Jackson, et al., 1995). In addition, functional studies will be assessing soil, vegetation, and hydrological data to describe change in energy, productivity, nutrient budgets, and disturbance across the successional and recovery gradients.

Reference Site Selection

Predictions in restored sites will follow trajectories from reference sites. A reference wetland, therefore, serves as a model for planning a restoration project, and later for its evaluation (Andel and Grootjans, 2006). In my study area, I will select reference sites which are self-sustaining and have not been markedly influenced by anthropogenic impacts. Since this study area had been disturbed in the late nineteenth century and in the early twentieth century, very few natural wetlands have found as before perturbation. Therefore, I will use Government Land Office records, historical vegetation surveys, soil maps, aerial photographs, and geomorphic assessments of wetland forms to select reference sites. In addition, topographic characters selected by Geographic Information System (GIS) will be chosen as the criteria for identifying several set of reference sites, too (Figure 3.). These criteria will include size, isolated condition from urban center, and hydrological connectivity with watercourses. This selection of reference sites will be based in part on the assumptions that the larger, more isolated, more hydraulic the site, (1) the more protected the interior areas would be from direct human impact (e.g. road runoff, storm sewer outfalls, road mortality of animals, dumping of trash, etc.); (2) the greater the amount of microhabitat heterogeneity and species pool; (3) the more likely that it has not been substantially altered in the past, since it is still a wetland habitat; (4) the greater the likelihood that animal species with large home ranges could be present; and (5) the more likely that it has flood-pulse duration to keep water level fluctuations. After selecting reference sites, I will use trajectory analysis to interpret large sets of comparative data from restoration sites to reference sites (Simenstad and Thom, 1996).

Variation Calibration

Temporal and spatial variability can be high even among reference sites initially thought to be uniform, so it is crucially important to learn the potential range of variation. Although considerable spatial variability exists among reference sites, and temporal variability within a single reference site, reference sites will be maintained relatively constant rates of providing specific functions over time. In my study area, natural disturbance will be recognized and accounted for by reference sites. The range of variation such as climate, topography, and geomorphology will be assessed. The variation will be calibrated and standardized before measuring the progress of restoration sites.

Life-cycle Monitoring

Life-cycle Monitoring needs to be developed to predict the effectiveness of wetland restoration after implementation. In this strategy, data collected seasonally at the restoration site are plotted to establish response curve to predict functional equivalency. Through the study of restored, disturbed, and reference sites, wetland function response curves will be developed which will vary depending on the indicator evaluated. Reference sites have relatively constant rates of providing specific ecological functions over time. Restored sites may never fully recover or may be returned to a higher level for the long-term or short-term (McIntosh, 1980) (Figure 4.). This monitoring will take aims at: (1) assessing long-term progress of restoration strategies; (2) detecting changes over time and identify their causes; (3) distinguish the effects of natural perturbations and anthropogenic disturbances. In my study area, I project that the integrated progress of recovery time from farm ponds to depression wetlands will be time-consuming approximately within 100 years. Therefore, long-term monitoring is required. For example, the functional and structural recovery time will be estimated from such key components as follows: vegetation growth (starting monitoring time), sediment retention (2 years to monitor), infiltration of root biomass (5 years to monitor), willow reproduction (5 years to monitor), habitat change (10 years to monitor), shade/litter input (10 years to monitor), small wood (25 years to monitor), and large wood (60 years to monitor), respectively.

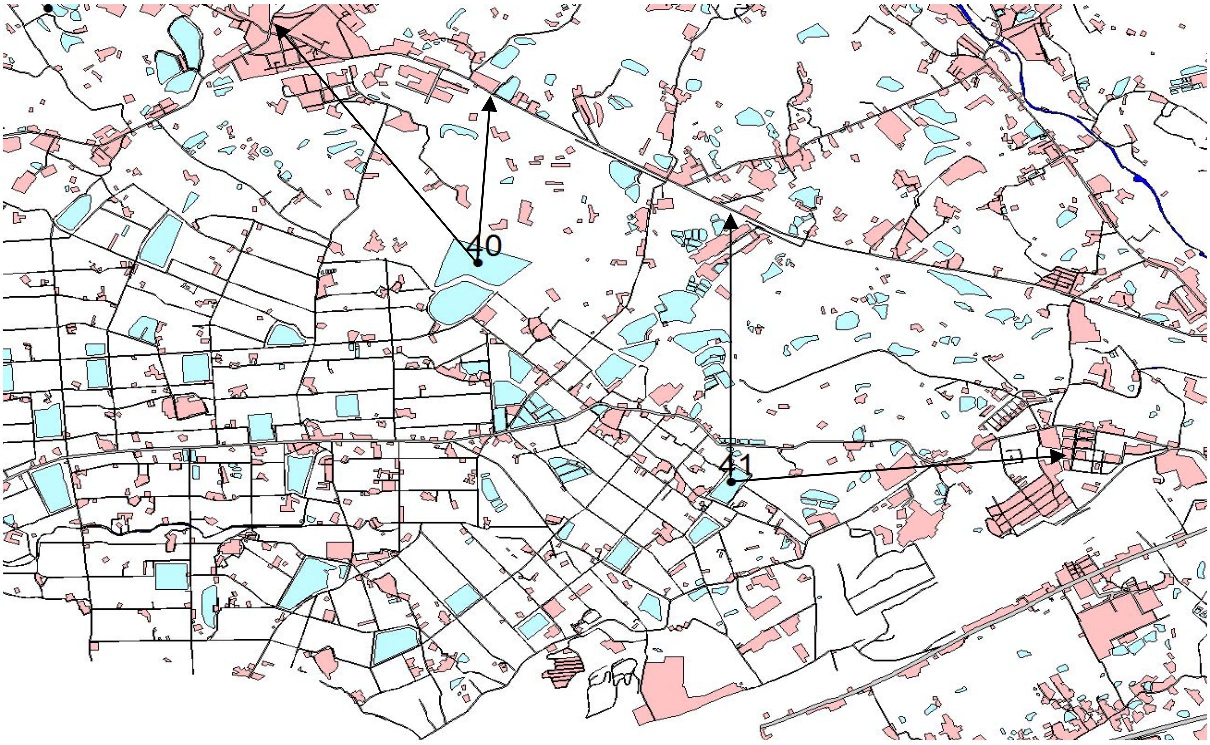

Figure 3. These criteria will include size, isolated condition from urban center, and hydrological connectivity with watercourses from GIS. (case study: Taoyuan, Taiwan)

Figure 4. Restored sites may be returned to a moderate level for a short-term state starting from monitoring time (from left to right side, photographs within short periods detected vegetation growth change during 11 months and more). Photographs taken at Tochen Creek Wetland Project, Sinchu, Taiwan.

Conclusion and Recommendations

Currently, there are no nationally recognized protocols for assessing the ecological conditions of restoration wetland areas in Taiwan. The proper approach is needed to satisfy assessments at scales ranging from individual restoration sites to riparian areas, from research-driven analysis to model building. Because wetland areas are the main connectors of landscapes, evaluation should begin with large-scale analyses that assess the variety, location, and connectivity between original degraded ponds and riparian areas (Zedler, 1996b). In micro-scale, site-specific assessments will be undergone considerable wetland evolution. In mesoscale, landscape methods will be useful in determining restoration needs, goals, and reference sites for future monitoring. There are several recommendations for future developing methods:

(1) Trends at the variability of the restoration sites that lead towards the reference sites confirm that the restoration will be following its intended trajectory.

(2) The concepts underlying tools used for aquatic ponds will be transferable to depression wetland, suggesting that the self-organized concept can be modified to assess the condition of wetland areas.

(3) Tools for wetland restoration will rely from screening specific locations to riparian areas with modeling of structure and function.

(4) These evaluations will be implemented through riparian management that takes into account both natural and anthropogenic influences.

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The Coastal Protection Policy In the South -Eastern United States

—A Review of "HURRICANE KATRINA: IMPLICATIONS FOR BUILDING AND LIVING IN HARM'S WAY"

Yi-ju Liu[1]

"The US government has issued guidelines on rebuilding thousands of homes and businesses in New Orleans, seven months after Hurricane Katrina hit."-from BBC.com

Seven months after New Orleans was hit by Katrina, the disastrous hurricane, there are still many news reports about the disaster. From reading these reports we could easily understand that Hurricane Katrina was certainly "the largest disaster in the U.S. in this century", which made its landfall in Louisiana and Mississippi as a Category 4 or even 5 storm. so stated by Leathermanin his article "HURRICANE KATRINA: IMPLICATIONS FOR BUILDING AND LIVING IN HARM'S WAY", which was published in *Water Resources Impact vol.8 no.1*. The article suggests that federal policies for coastal region protection, especially for tourist areas such as New Orleans, Miami, Mississippi Gulf Coast, etc. need to be re-examined Hurricane Katrina was called "the costliest and one of the deadliest hurricanes in American history", but for what reason? Historically there were other category 4, and even 5, hurricanes hitting the Southeastern United States, but did not cause as much devastation and economic loss as Katrina did. In his article, Leatherman discussed some key causes that led to the disaster. The following sections present these causes, based mainly on Leatherman's article and

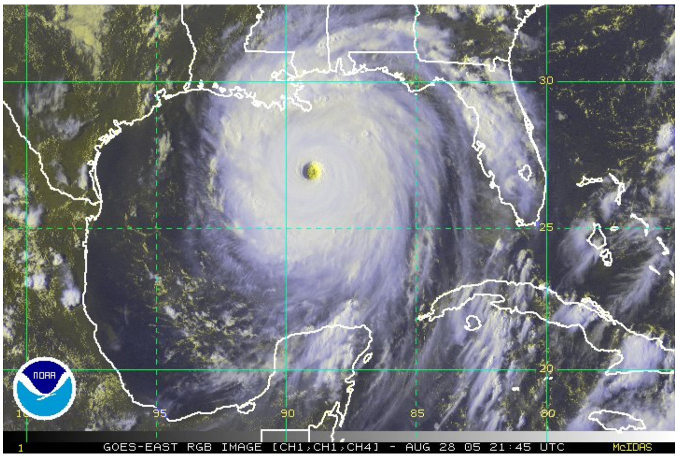

Figure 1 Hurricane Katrina, as pictured in the Gulf of Mexico at 2145 UTC on August 28, 2005.

[1] Engineer, GT International.

some other news articles and reports.

1. Some residents have become complacent and the poor's inability to evacuate aggravated the problem.

Historically, in the south-Eastern region of the U.S. around the Gulf of Mexico, including Taxes, Louisiana, Mississippi, Alabama and Florida State, hurricane occurrence is common due to its geographical location. Local residents who live around the beach along the Gulf of Mexico would have experienced at least several hurricanes in their lifetime. If some residents decided to remain in their homes during lesser hurricanes and escaped safely, they might become insensitive to stronger hurricanes and could suffer serious consequences. Therefore, these residents may lose the ability to make the correct decision regarding evacuation and taking refuge when there is a natural disaster looming. Leatherman's article pointed out that "hundreds of people perished because they remained in their houses that had withstood the seven-meter surge generated by Hurricane Camille in 1969 until Katrina." These people might think that since they could withstand the fury of Hurricane Camille- the last Category 5 hurricane in the U.S. record, they could do the same with Katrina, a similar Category 5 hurricane.

Besides, the news media had reported that there were still around one hundred thousand people -nearly 20% of the population- remained in New Orleans during Hurricane Katrina's stay, even though a forced-order of evacuation was announced by the Mayor twenty-one hours before Katrina's landfall. Most of them were poor people. A disaster-evacuation problem was shown: while the forced-evacuation commend was announced, most citizens would escape by driving to safe locations where friends or relatives lived in, whereas other people who have no private vehicles would be unable to follow the evacuation plan because public transportation such as trains or buses had ceased working due in part to lack of emergency preparedness training and execution; Furthermore, there was not enough public spaces to hold the refugees.

2. The federal government has put more emphasis on economic development, and not enough on coastal area protection.

Because of their geographical locations, beaches along the South-Eastern U. S. coastline are often impacted by hurricanes and storm surges that cause significant beach erosion. Due to this reason, beach nourishment and beach protective engineering work are extremely important and should have the oversight of a federal agency such as the Corps of Engineers. On the other hand, coast areas are important economic regions, which bring enormous economical benefits to many localities. There have been instances that, for economic reasons, beach nourishment would be going on without the Corps of Engineers' involvements.

There have been many unpublished and confidential analyses showing that the high returns associated with the Corp's nourishment projects often make them worth the 65% federal contribution, but the governmental administration has been trying to reverse the cost sharing formula to only 35% federal matching. From this article, there is the Coastal Zone Management Program (CZM) established within NOAA, working on minimizing coastal hazards through some policies and practices, but mostly without the Corps of Engineers' involvement. Instead of the coastal engineering management, the federal government has put more emphasis on economic coastal management. The government sometimes only provide the annual funding but without tangible enforcement authority, e.g., for the Corps of Engineers.

3. Mississippi levee structural flaws

Locating between Lake Pontchartrain and the Mississippi River, New Orleans is a rich city on the Mississippi Delta with fertile land and variable landform. New Orleans is a low-lying city. Because there are rich oil deposits around the Gulf of Mexico, oil wells setting made the ground level sinking in a tiny scale year by year, and nowadays 80% of the city stand below the sea level. On the other hand, due to its great position for convenient transportation and rich land for industry, New Orleans has become an important city as the biggest port and main industrial center in the USA. There are complicated drainage systems in the city, and more than 20 feet high levees around to defend the city from floods or surges in the Mississippi River and Lake Pontchartrain.

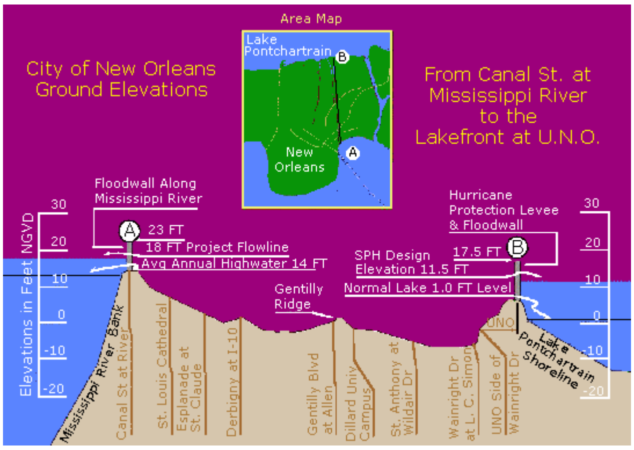

Figure 2. Vertical cross-section of New Orleans, showing maximum levee height of 23 feet

Figure 3. Map of New Orleans City in Louisiana

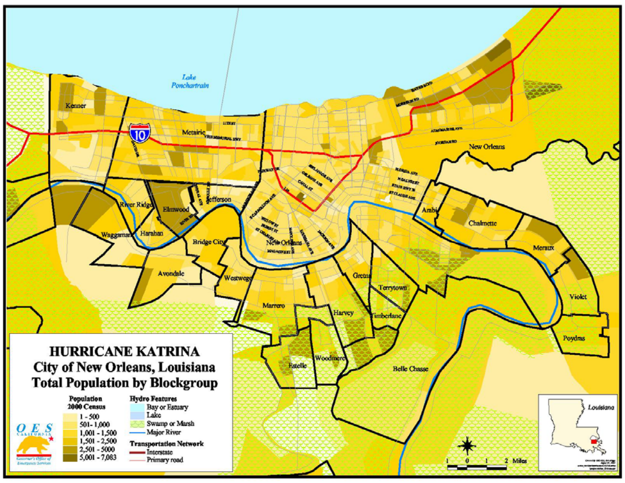

Figure 4. the population distribution of New Orleans

The Corps of Engineers had designed these levees to withstand a Category 3 hurricane, which they deemed to be a 100-year event. With such a design scale, it would be expected that a category 4 or 5- hurricane like Hurricane Katrina or Hurricane Ivan, would cause the levees to fail because the structure was not designed to withstand a category 4 or 5 hurricane. The Corps of Engineers claimed that the cause of the levees' crack was that the certainly-too-high surges overtopped the 17^{th} Street Canal levees, undermining the groundside of the levees' base, and then made them collapsed and broken. However, Leatherman pointed out that , "storm surge modeling by the IHRC researchers indicated that the storm surge in Lake Ponchantrain was only 3 to 4 meters; the 17^{th} Street Canal levees were built to a height exceeding 5 meters." Actually, the 17^{th} Street Levees were upgraded with thick concrete walls sitting on the earthen levees under the water face. The lake's raised levels may have increased water pressure to the point that water flowed through the earthen levees on which the concrete walls sat (Travis, 2005). "The highest wrack lines were well below the height of the unbreached levees", that is, even without a Category 5 hurricane's invasion, whenever the lake level rose up to generate enough hydraulic pressure, the flow-through water would permeate as seepage leading to "cavitations"; and then lead to the potential collapse of levees directly.

Even as the government officials and the research institutions still tried to recover from Hurricane Katrina, the people are casting nervous eyes to the gulf. Hurricane season comes every year around summer. The USA likely has to face other major hurricane strikes. A researcher said, "Who knows what else is on the way?" But we can say,"No matter whatever else is on the way, we have learned our lesson and will prepare to handle it better next time".

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Fig 1 From a NOAA website page http://www.nasa.gov/vision/earth/lookingatearth/h2005_katrina.html

Fig 2 Hurricane & Emergency Information – NGVD Defined – New Orleans District, Corps of Engineers : http://www.mvn.usace.army.mil/pao/response/NGVD.asp

Fig 3 Civil and Hydraulic Engineering (32)5: pp.4

Fig 4 http://www.oes.ca.gov/Operational/OESHome.nsf

International Forum -

The California Rivers Assessment Project

The Editorial

California is a large State. In area it is over 400,000 square kilometers. It has over 27,000 linear kilometers of rivers. If it were a country it would be the 8th largest economy in the world. Seven hundred of California's rivers flow through over 200 cities. In the 1960's, it was recognized that the quality of water in California was becoming degraded. In 1972, the California clean water act was passed by the legislature.

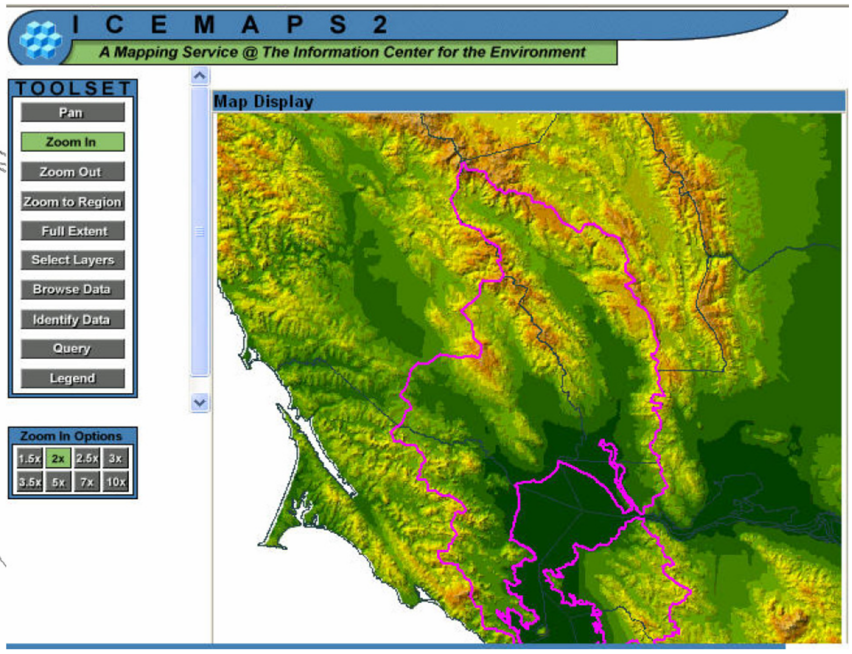


Figure 1. A GIS image of the river systems in California (Prof. Michael McCoy/2006)

California was required to create a better management strategy for its water quality. However, twenty years hence there was still no comprehensive and easily-implemented system for assessing the water quality of California's rivers. The State then commissioned the University (University of California, Davis) to develop an assessment system starting in 1992. The University's Information Center for the Environment began to establish a GIS (Geographic Information Systems) system to address the task. Mike McCoy, the founding director of the Information Center for the Environment, told us the story of how this assessment was done and what came after it as California realized the value of information technology in land use and environmental assessment and planning.

In the Forum, Professor McCoy presented to us his valuable experiences in river and water management. His speech attracted the whole audience's attention on water management policies and various issues. The audience asked some interesting questions and had good discussions with Professor McCoy. Some of the highlights are presented below.

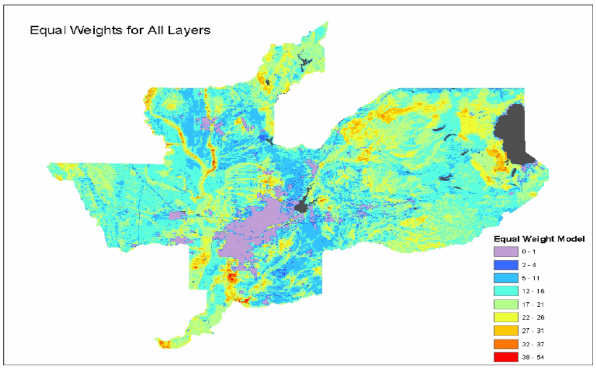


Figure 2. Result of Equal Weight analysis for California. (Prof. Michael McCoy/2006)

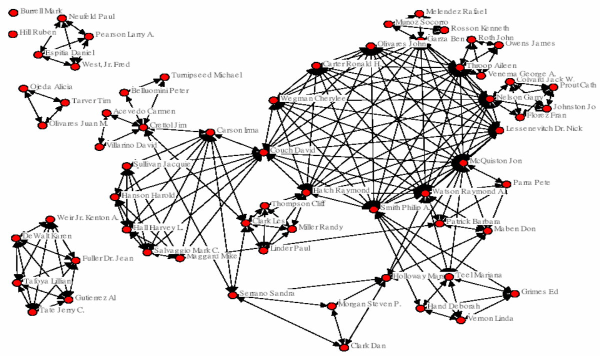


Figure 3. The connection system between localities and the government and other organizations. (Prof. Michael McCoy/2006)

Q1:

The wastewater collection and treatment system is not available in many parts of Taiwan, therefore in some areas domestic and industrial sewage flow directly into the rivers without treatment. How is the situation in California? And what is the main pollution going into your rivers?

Ans:

There are 525 cities in the State. We have laws that require the construction of sewage systems in cities with population 100 thousand people or more. These sewage systems were constructed during 1970 to 1980, and even the smaller towns have also completed their wastewater systems in later years. Since most of the treatment systems are at least secondary, we find that major pollutants of concern entering our water bodies in recent years are those that are not removed by secondary treatment such as nutrients, and those coming from non-point sources such as nutrients, metals, oil/grease and other non-conventional pollutants.

Q2:

As for river restoration, if you mean that river renovation work is all about engineering involving concrete con- struction, would the same approach fit the river environment in Taiwan?

Ans:

In fact, there are three effective methods for regenerating rivers. First, expanding the river's flood plain could be an effective measure instead of channelization with concrete. By this way the larger flood plain would pass more floodwater and therefore lower the peak flow of floods.

Second, install some barriers along the riverbanks, like some wood stems or sticks, or some natural rocks or stones, to lower the velocity, and also to supply some habitats for animals.

Third, planting vegetation. Set aside a certain area along the river as a buffer zone, which can help to slow down the surface run-off to avoid bank-erosion and lower the peak flow. Furthermore, planting areas in the buffer zone could provide recreational benefits.

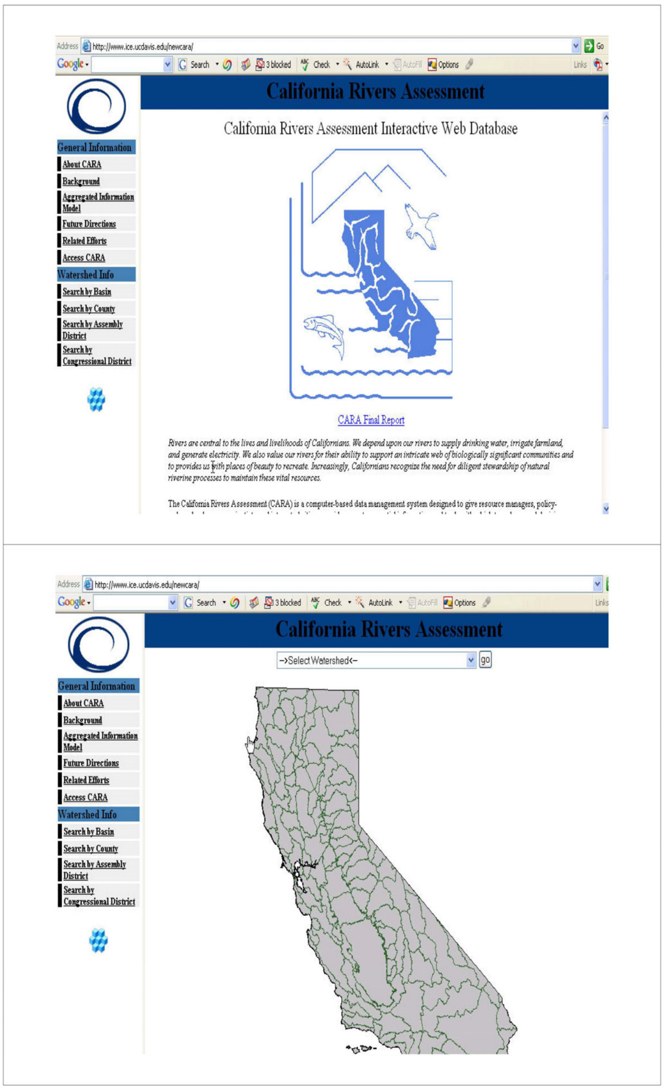


Figure 4 The website pages showing California Rivers Assessment Interactive Web. (Prof. Michael McCoy/2006)

Q3:

Among your slides, we saw that one-third of those who download the watershed information from the internet are from Non-government Organization. Does it mean the NGOs, and the local residents in California have more sense of environmental protection?

Ans:

They do have more senses of environmental protection. There are many reasons. In California, we have plenty of natural resources, all of our people are aware of these values. These natural resources also bring us the benefit of tourism. When commercial businesses are linked to environmental resources, of course, environmental protection should attract people's attention. The natural resources of California thus attract more and more the attention of environmental groups and researchers, who are very concerned about the environmental problems in California. So in California, I can say, we do have a deep awareness of where we lived and its ecology.

Q4:

The model you presented seems to be an excellent model. These investigation and information might be lacked several decades ago, but now we can regenerate rivers according to this information and this management model. If we compare the differences from the two conditions, with and without this model, what are the differences? And can you tell us about your experience during the improvement.

Ans:

For the first question, the difference between doing with and without this model is about policy, about institution, even more so, about politics, instead of technical or scientific aspects. After the model was developed and tested successfully, we spread the information about its capabilities and usefulness to all sectors of the society, particularly the responsible governmental agencies and people having a direct interest in certain rivers. This helps to create a strong motivational force for all people and power them to be concerned of the situation of our rivers and work on solving the problem of the rivers. In my experience, I think if we want our academic knowledge to be applicable in the real world, we need to take the professors and researches out of their schools. We need to open our minds and let the interested public at large to come to participate in theriver restoration and protection projects.

Q5:

We also have had significant river quantity and quality problems due to excessive -development around the urban areas and in the watersheds. Recently the Executive Yuan has proposed to spend 80 Billion NTD in 8 years to help with river protection and restoration projects in Taiwan. We understand the advantages of using the model you described, so if now this model can be applied to the river engineering in Taiwan, do you think the application will be successful? Do you have any suggestions from your experiences for promoting the use of this model?

Ans:

I believe in gradualism. I will make the advancement one river at a time, from a branch first and then gradually to the whole basin. I can’t be sure if this policy, which is to work on all the rivers at the same time, is the best policy. In my experience, we picked only 13 basins for experimentation first. According to the results of the 13-basin experiment, and then of other 14 basin sites for further experiments, we could find the best method for river protection and restoration. Only after the successful experimentation with a few rivers, we then proceed to apply the model to larger river watersheds.

Forum Information:

Date & Time： January, 11th, 2006 (Wednesday)
pm 3：30～5：00

Location： Conference Hall, 5th F of Civil Engineering building, National Taipei University of Technology

Speaker：Professor Michael McCoy

Education：B.S. California State University, Sacramento, 1968
M.A. University of Illinois, Urbana, 1969

Professional：Biopopulation distribution; Water body and quality reduction; Land use and infrastructure policy; Investigation of constructive information integration and distribution.

Experience：1981-1996 Director, Land Use and Natural Resource Programs, UC Davis Extension
1993-Present Co-Director, Information Center for the Environment, UC Davis (http：//ice.ucdavis.edu)
Acad. Admin V, ENVIRONMENTAL SCIENCE AND POLICY, UC Davis

Translator：Professor Shyh-Chyang Lin

Education：B.S. Chung Yuan Christian University, Taiwan, 1983
M.A. Civil Engineering, National Taiwan University, Taiwan, 1985
Ph.D. Civil Engineering, Northwestern University, USA, 1993

Professional：Structural mechanics; Materials of civil engineering; Technique of concrete; Ecological engineering.

Experience：1998-Present Assistant Professor, Department of Construction Engineering, National Kinmen Institution of Technology.

J. of Ecotechnology, 2006 (2) 1

Interview with Modern Ecological Engineering

—Report on a Book and Its Author

The Editorial

Having been involved with the field of "ecological engineering" for some years, I've come to the realization that there is still a key problem which has not been fully resolved. So far, scientists and engineers are still unable to fully bridge the GAP between ecology and engineering. Dr. –Ing Hein van Bohemen, who has been the Head of the *Environmental Research Department of the Road and Hydraulic Engineering Institute of the Ministry of Transport*, *Public Works and Water Management* in the Netherlands. He also works as a lecturer on Ecological Engineering at the *University of Technology in Delft, the Netherlands*. Moreover, he was a founding member of the IEES (*International Ecological Engineering Society*), and has a deep interest in the relationship between ecology and civil engineering. The book, "*Ecological Engineering – bridging between ecology and civil engineering*", is the latest publication edited by Dr. Bohemen last year. He focuses on the potential role of ecological technology as a bridge between a sustainable development of the built environment and infrastructure. In a report in "*EcoEng Newsletter No. 11*", which is published by the IEES, Andreas Schoenborn-Schaller wrote a comprehensive review of this book and presented an interesting interview with Dr. Bohemen. The following is a brief description of Schoenborn-Schaller's report, entitled "Modern Viewpoint of Ecological Engineering".

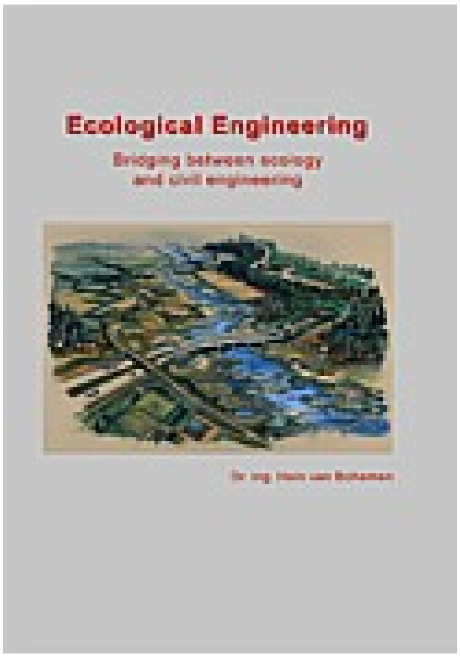


Figure 1. cover of the book

Many researchers and engineers who are in the field of ecological engineering would probably agree with Bergen *et al.,* who describe ecological engineering as " *the deign of sustainable system* *consistent with ecological principles that integrates human society with its natural environment for the benefit of both*". On the other hand, many practitioners in ecological engineering seem to feel that "*ecological engineering is engineering with an attitude*". But what is the attitude? Since by nature ecological engineering is a science, which integrates knowledge from many different fields such as ecology, humanities, landscape architecture, and civil and environmental engineering, etc., there are undoable many different attitudes and – sometimes with conflicts among them.

Of special interest to me is the "conflict" between ecology and civil engineering, which is elegantly explored in the book "Ecological Engineering – Bridging between Ecology and Civil Engineering", written as a textbook by H. v. Bohemen. Blows are some excerpts from a review of the book written by Andreas Schoenborn-Schaller:

Hein van Bohemen writes: "*This book addresses the construction of both environmentally friendly and people-friendly roads and the surroundings of these roads*" (p.13). This is the basis on which the book is built upon. Netherlands has one of the world's densest road networks; Netherlands has also a large number of researches in the area of road ecology and fauna corridors. In Netherlands, we can see the evidence that road traffic and the associated noise, exhaust fumes and other types of pollution are main factors in landscaping and ecological considerations. As the human population worldwide keeps increasing, there will be more and more infrastructures and amounts of traffic. If we want the developing areas to remain habitats for animals – actually, for the whole ecosystem including human ourselves – we have to deal with the impact of roads and railways and work to have their effects eliminated or mitigated.

The following are the contents of the book:

1. Justification
2. The objective of this book
3. Introduction
4. Another model of thinking to reach ecological sustainability
5. Ecological Engineering
6. The concept of nature and the significance of biological diversity
7. Overview of goods and services that can be supplied by natural systems
8. Construction material, policy and practice
9. Main ecological and landscape ecological principles in road construction and hydraulic engineering
10. (Eco)system thinking and roads as ecosystems
11. Ecological effects of roads and roadside verges

12. Fragmentation of nature by roads and traffic and its defragmentation: Prevention, minimization, mitigation, compensation of effects, and conservation, restoration and ecological values
13. Ecology and economy
14. Infrastructural landscapes: from theory to practice
15. Principles of Ecological Engineering for use in a civil engineering context

Chapters 9 through 12dealing with road management by using ecological engineering approaches, are of special interest to civil engineers. The author introduces the theoretical concepts of landscape ecology, for example, the habitat patch-corridor-matrix model as shown in Figure 2. Also discussed are the importance of boundaries, the concept of connectivity, ecological networks, ecology of scale and so on. Chapter 10 then presents methods to describe, analyze, understand and model ecosystems including theroretical aspects.

Of interest is the reason given by the author for "the gap between ecologists and engineers", and that is: "there has been a continuing lack of communication between ecologists and engineers". The author further states: "It is very probable that (ecologists') suggestions never reached the road engineers who did the actual designs and built the roads." Even today, the same situation still indeed exists.

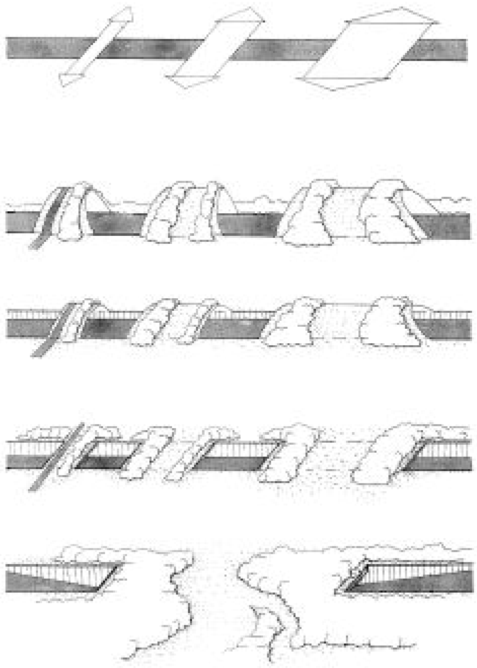


Figure 2. Various types of ecoducts / fauna passages

Figure 3. A "hop-over" for bats: This provides a safe overpass for bats.

Chapter 11 gives a close and detailed look at vegetation and fauna of roadside verges. Here the author goes into great detail. Some of the readers may think that a roadside verge is just a meadow or a lawn alongside the road. A closer look at the specific plant communities found along roads and other associated management practices clearly show that such practices would lead to a higher diversity and ecological value of the roadside verges. The interesting role of roads as migration corridors for plants was discovered. He also introduces an interesting example of roadside verges management: For the barn owl, traffic on the A6 motorway is attributed to more than 50% of the annual mortality in the Dutch province of Flevoland (p.211). Why would owls be attracted to roads? Ecological roadside management provides rodents with more food than the monotonous arable land and grassland in the surroundings. The rodents in turn are prey for the owls. The barn owls also like to use mileage signposts as lookout posts - a high risk place for a bird. In this example, we could see a different verge management practice and even a different design of the mileage posts are used to help improve the situation of the barn owl and in general, to improve the roadside verge ecosystem.

The next chapter focuses on fragmentation and defragmentation, and on concrete measures that can be taken. There is a rich choice of different examples in chapter 12, ranging from fauna tunnels (converts) to ecoducts (fauna passages, fauna bridges), and to special measures for bats (Figure 3).

Other than reviewing the book, Schoenborn-Schaller also did an interesting interview with Dr. H. v. Bohemen. The interview covered many different points of view on ecological engineering. From the excerpts below, readers can find out how the well-respected ecological engineering researcher, Dr. H. v. Bohemen, thinks about modern ecological engineering.

Figure 4. A fauna passage in Banff National Park, Canada. (H.v.B.)

Figure 5. Innovative noise barrier at a resting site on a Dutch motorway, providing both noise protetion and habitat. (H.v.B.)

In the following paragraphs, “AS” refers to Schoenborn-Schaller and “HvB” refers to H. v. Bohemen.

<u>AS</u>:

I believe that our readers will be interested to get some more information here. This is one of the issues that separate the existing "schools" of Ecological Engineering from each other. For example, our flagship journal "Ecological Engineering" has the subtitle "The journal of Ecosystem Restoration". A title that reflects the academic roots of this field, but not necessarily the whole scope of possible applications of this "new ecological paradigm", as Bill Mitsch called it (Mitsch, 1990).
So, can you tell us a bit more about the limitations of the Ecological Engineering approach, from your view? For example, have you encountered fields while writing your book where Ecological Engineering could not be applied?

<u>HvB</u>:

Indeed there are limitations about the understanding of Ecological Engineering in the scientific field. In my view, besides

1. restoration of ecosystems, and
2. development of new sustainable ecosystems, the goals of Ecological Engineering should also include
3. the integration of techno-systems and ecosystems by using mitigation measures.

It means the design and incorporating of mitigation measures that are used to reduce negative effects on nature by all kinds of civil engineering constructions. Facilitating and stimulating ecological patterns and ecological processes can do this. Examples of the last category are: vegetated ('green') roofs, roadside and railway verges, planted buffer zones, defragmentation measures (like fauna passages in the form of ecoducts, fauna tunnels, culverts adapted for fauna passage, ecopipes...). It includes also multifunctional noise barriers, concrete walls with holes for nests of the sand martin [a bird species, AS] or wood blocks with small holes for nesting of wild bees.

This third category is mostly fully omitted in Ecological Engineering textbooks. That was one of the reasons for writing the book 'Ecological Engineering: Bridging between ecology and civil engineering in which Ecological Engineering is presented as a much wider approach.

AS:

If I follow your reasoning, Ecological Engineering would not be applicable in fields where ecosystems are not involved, right? Such as, e.g., in computer science, mechanical engineering and human psychology? Let me drill down some more on this issue: There are some people who limit Ecological Engineering to basically wetlands and similar ecosystems, others who would even include city planning and any kind of systems thinking. Some people even use Ecological Engineering as one of the options for a more ecological crop production (without excluding, e.g., genetic engineering or the use of pesticides). I strongly feel that whoever defines a term will define the perception of it in the future. So understanding where we do not use the term Ecological Engineering, or where we think it can't be used, is crucial for its perception in the public. For example, can a genetically engineered plant be part of an ecologically engineered system? If the system alone would be the focus, why or why not? If however, there is an ethical viewpoint involved, and then excluding this approach would be the way.

HvB:

My central concern is the way we can find a balance between satisfying human needs as well as allowing other species to meet their 'needs'. Are we able to share our options in areas with other species living in the same area? In all areas of decision making we need ethical judgments to find out which impacts human behavior has on other species and ecosystems and how to prevent mitigate or compensate these impacts.

So for me, coming to your question about genetic engineering, I think genetic engineering is not part of Ecological Engineering, but within an ethical framework of Ecological Engineering, we may decide that specific proposals for genetic engineering are acceptable. Here we are touching basic questions about the borders of science. Can we include philosophy and ethical considerations in our way of doing science? I think we should say yes in the case of Ecological Engineering.

AS:

Let us take a closer look at the Netherlands: Is Ecological Engineering going to become a "mainstream" in the next 10 years? How many people are promoting it? Can you name a few and give examples?

HvB:

If you define 'Ecological Engineering' in a wider sense, interesting steps are taking place in civil engineering and in architecture. But Ecological Engineering as a mainstream issue is further away, as economics and politics are very slow in accepting the idea that "free resources" should have a real, real, real price.

In several fields of interest some people are promoting Ecological Engineering, but there is a need for more experience, showcases and real support for ecologically engineered solutions.

Good examples are: recycling of waste, constructed wetlands, mitigation measures for crossing fauna, rehabilitation of old buildings instead of destroying them and the "water harmonica" model (feeding spoonbills on 'wastewater'). There are only two living machines existing in the Netherlands at the moment, a third are going to be implemented. A great deal of experience has been gathered in the field of coastal management, where natural dynamics are used for protecting sandy coast lines against storms. These are all well known applications of Ecological Engineering in the Netherlands.

AS:

What in your view is the main obstacle for the further development of Ecological Engineering in your country?

HvB:

The biggest challenge is the further integration of different scientific fields as well as to get enough interest in the society. More working together can help to formulate hypotheses and theories, which go across the boundaries of their respective scientific fields.

For instance we can look separately at ecosystem health, human health and mental health. But would it be possible to join the different fields all together? We should also look at the economic theories and practices. In principle, economy should not be the origin of deteriorating ecological values and destroying our natural support system, which it does up till now in many, many situations. 'Free goods' are suffering and the generations after us will pay the bill. Is this right?

AS:

I have a last question: Do you personally apply Ecological Engineering in some way? (Some of our boards members have a composting toilet at home ...)

HvB:

We use rainwater for our garden; recycle paper, and glass and organic waste in our compost. Locally we travel by foot and bike as much as possible and use the train for longer distances. And we are now in the process to install a 'green' roof on our carport.

When my parents died, part of the heritage has been used to form a foundation with the name of our parents to prevent using the money for consumption. The goal of the fund is to stimulate peace projects among youth. I think this is also part of sustainability and should be more widely used. It will save money for future generations as well.

Recently I got my early retirement, but I will still work one day a week at the University of Technology in Delft as a lecturer in Ecological Engineering. I hope to have a chance to transform this temporary post into a more permanent one. The Board of Directors of the university has accepted that sustainability should be one of the pillars of the studies of technology. In the building and design faculties it is already fully integrated, but in other faculties there is still a need for a more fundamental basis in the curriculum, but this is now changing. Sustainable construction and recycling of building waste are courses that have been running for years at the Civil Engineering Department. The course I am responsible for is held in the Masters of Science of Civil Engineering program and students can get a sustainability annotation. If they wish they can call themselves engineers in sustainability.
I like to end this interview with some personal wishes...

A more active approach of respecting the diversity of human cultures in their respective natural systems should be a general attitude for humans and institutions.

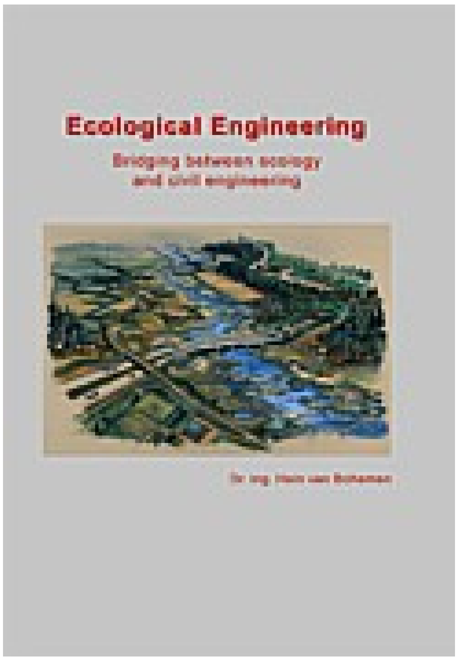
International trade should become more involved in reducing side effects like spreading of exotic species, which in a lot of cases has been harmful to local environments.

The WTO should be more active in stimulating real sustainability, not only in economical terms but also in social and ecological ways. A strategy for local production and selling of food and vegetables are ways to reduce impacts. WTO should defend more the integrity of natural bioregions. Organizations promoting eco-cities, eco-villages, eco-parks and eco-landscapes should work more together.

Basic in all understanding is the ethical role humans should fulfill: finding a balance between their needs as well as satisfying the 'needs' of other species using scientific methods and not by pursuing ideologies or other one sighted visions of our world. The main task will be to conserve the cultural and biological diversity of the Earth, in order to have a mutual relationship with other forms of life, by using local resources, by recycling, including use of waste as a resource and using renewable energy instead of fossil fuels as much as possible.

In all applied fields there should be more attention towards more ecological sound and sustainable living. In the field of architectural design and area planning more ecological design should be realized. There is a need of integration of good places for recycling, safe places for bicycles, separation of urine and feces, composting in a fully integrated system. When talking about safety I'd like to say that any civil engineered or human engineered project or object (houses, bridges and cars) should be safe for the public as well as safe for the environment. This means a harmonious integration of engineered projects or objects within ecosystems at all levels of scale. The construction and the use should be as ecologically embedded as possible. If impacts cannot be prevented, effects should be mitigated as much as possible and if this is not enough the rest should be compensated.

BOOK INFORMATIONS



"Ecological Engineering – Bridging between ecology and civil engineering"

Author: Mr. H.D. van Bohemen, PhD
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Price: € 65.00

(Most contents and figures in this composition are adapted from **Andreas Schoenborn-Schaller 2005, "Review of "Ecological Engineering – bridging between ecology and civil engineering" by Dr. –Ing. Hein van Bohemen" and "Building bridges between ecology and civil engineering",** ***EcoEng Newsletter, No.11***)

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1. **Language**: All manuscripts must be submitted in English. The manuscript title, authors, affiliation, and abstract should also include a Chinese translation.
2. **Format**: Manuscripts shall be typed in Times New Roman, 12-point font, single column format. Please submit both a Document (.DOC) file and a Portable Document Format (.PDF) file for editing purposes.
3. **Figures**: Please do NOT reduce the resolution of illustrations. If illustrations were not included in the text files, please send them separately with at least 300 dpi resolution.

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2. Please submit your manuscript stored in CD-ROM disks by mail if the file size is larger than 10 MB.
   Mail to: Mr. Chi-Chang Liu
   Water Environment Research Center,
   National Taipei University of Technology
   No. 1, Sec. 3, Chung-hsiao E. Rd. Taipei, Taiwan, R.O.C. 10608

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