Habitat Functions of Urban Rivers and their Flood Plains –
A Case Study of the Lower Keelung River in Taipei City, Taiwan

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Abstract

Not only in Europe but also in Taiwan, local and regional planning authorities have begun to focus on the state of urban rivers that are under pressure from many different uses and impacts. Furthermore, society places many demands on the ecosystems of urban rivers. For example, urban rivers and their flood plains must satisfy needs for recreation, drinking water, biodiversity and flood protection. Many rivers are heavily modified and cannot provide these ecosystem services sufficiently. Whereas in Europe methodologies are available for the inventory and assessment of such ecosystem functions as a basis for urban landscape planning, in Taiwan no such methodologies are in place. Especially biodiversity has been neglected in Taiwanese urban river management until now, although this has been identified as one of the most urgent problems in recent environmental policies on a global scale.

The objective of this thesis is to develop and test a methodology for the inventory and assessment of urban river habitat functions in Taiwan that can be used for the planning of rehabilitation measure and nature conservation. This objective presents challenge of developing a state of the art methodology which provides results that are valid and sufficiently specific for planning purposes. Furthermore, these results must be suitable for use in the Taiwanese planning context, i.e. the necessary information and data must be available for Taiwanese cities.

The methodological approach to this task encompassed different scientific steps and methods. The classification, inventory and assessment of river habitats and their components were carried out. The potential impacts on the habitat functions were guided using the theoretical framework of the DPSIR-concepts. The German approach to habitat inventory and assessment was chosen as the starting point for developing a method that is suitable for Taiwanese conditions and needs. This approach was reviewed in the context of the Taiwanese legislation about planning and environmental regulations in order to understand and adapt it to the Taiwanese requirements. The Keelung River in Taipei City and its flood plains were selected as a study area, because they illustrate the typical situation and condition of urban rivers in Taiwan. They also provide a good information base in order to explore the environmental situation, to test the method and to discuss the outcomes with experts.

The working program in this study can be divided into three steps. Firstly, the habitats of the study area were identified and characterized using aerial photographs and additional information about water regime, soil, land use and vegetation. The preliminary classification of habitat types for urban river areas was carried out using an inductive method. Secondly, the habitat classification was verified with field work which led to refinement of the habitat classification and development of qualitative and quantitative parameters. This classification can be used to further develop a

habitat typology. This list of habitat types in urban river areas and their principle value for biodiversity can be applied to other comparable sites in Taiwan in a field survey. A guideline for the required data and how to obtain it was also developed in this step. Further investigation can help to improve the typology until valid supra regional types are identified. Furthermore, the biotope types can be updated with information about the current state and characteristics of the individual habitats. The features, which were mapped but not included in the typology, were reviewed in a second, more place-based assessment, in order to use this as a standard habitat typology in the future.

In a third step, anthropogenic factors that impact the habitats were classified separately and evaluated with regard to their potential impacts on the habitat functions and with respect to water quality, soil, land use, stability of river channel and flood plains. Besides, the biotope condition is evaluated to represent the habitat naturalness, habitat diversity, habitat fragmentation and protected status. The method of evaluation of impacts on the urban river ecosystems and its quality has been tested on the lower Keelung River.

In order to evaluate the validity of the habitat quality, the results of habitat evaluation were considered in combination with bird species and their habitats. The existing data about bird species diversity in habitats represent the species-environment-relationship. The findings from the evaluation results identify the priorities, satisfactory or required actions for rehabilitation. A regular investigation represents as a monitoring tool to show the environmental changes and the context of impacts.

In conclusion, a methodology is presented which has been tested for practicability, adaptation to data availability, validity in representing habitat quality for bird species, and suitability for urban river management planning. The method should be tested and further developed in additional urban areas of Taiwan before it can be introduced as a standard.

Keywords: urban river management, biotope classification, PSR framework, habitat functions

Kurzfassung

Das Management der urbanen Fließgewässer wird in Europa und Taiwan in der Regel interdisziplinär in Zusammenarbeit zwischen lokalen und regionalen Planungsbehörden durchgeführt. Die städtischen Fließgewässer stehen unter besonderem Druck aufgrund verschiedener menschlicher Nutzungen und deren Auswirkungen auf die Umwelt. Die urbanen Fließgewässer sollen einerseits die verschiedenen Bedürfnisse des Menschen (z.B. Freizeit und Erholung, Trinkwasser, Hochwasserschutz usw.) decken und andererseits sollen die Ökosystemfunktionen erhalten werden (z.B. Biodiversität). Viele Fließgewässer sind stark verändert und können die ökologischen Funktionen nicht mehr ausreichend erfüllen. In Europa wurden verschiedene Methoden zur Bewertung von ökologischen Funktionen entwickelt, die in der Landschaftsplanung Verwendung finden. Die Biodiversität spielt eine besondere Rolle bei der Bewertung der ökologischen Funktionen. Dem globalen Problem des Biodiversitätsverlusts wird in verschiedenen Ländern mit Umweltstrategien begegnet. Bisher fehlt eine Methode zur Bewertung der Habitatfunktion für urbane Fließgewässer in Taiwan. Die meisten Projekte im Bereich des Fließgewässermanagements in Taiwan berücksichtigen den Aspekt der Biodiversität noch nicht ausreichend.

Daher ist das Ziel dieser Arbeit, eine Methode zur Kartierung der Biotoptypen und zur Bewertung der Habitatfunktionen für taiwanesische städtische Fließgewässer zu entwickeln. Die Probleme des Forschungsprozesses waren hauptsächlich, dass viele Daten über Biodiversität und Fließgewässermanagement aufgrund von Datenschutzbestimmungen der taiwanesischen Landesverteidigung nicht verfügbar waren. Viele Daten mussten deshalb vor Ort durch Kartierung erhoben werden. Die Ergebnisse der Kartierung und Untersuchung später an den taiwanesischen Planungskontext angepasst werden.

Die Methode basiert auf verschiedenen wissenschaftlichen Theorien. Die Fragestellung sowie die bewerteten Indikatoren der urbanen Fließgewässer beruhen auf dem DPSIR-Konzept. Als Grundlage wurde das niedersächsische Vorgehen zur Inventarisierung der Biotoptypen und deren Bewertung ausgewählt. Bei der Entwicklung der Methode wurden die speziellen taiwanesischen Bedingungen berücksichtigt. Die Ergebnisse der Bewertung können später in der Praxis verwendet werden, da die Methode als naturschutzfachliche Gesetzesgrundlage für das urbane Fließgewässermanagement berücksichtigt werden kann. Der Fluss Keelung und seine Aue wurden als Fallstudie ausgewählt, da er ein typisches Beispiel für städtische Fließgewässer in Taiwan ist. Der Keelung spielt deshalb eine wichtige Rolle als Teststudie für nachhaltiges urbanes Fließgewässermanagement in Megastädten.

Die Biotoptypen des Keelung wurden zuerst mit Hilfe von Luftbildern abgegrenzt und durch vorhandene Daten (z.B. Wasserqualität, Boden und Vegetation) ergänzt. Die Haupteinheit sowie die Funktionen der Biotope wurden im zweiten Schritt vor Ort kartiert und nachgewiesen. Der Schlüssel der Biotoptypen für urbane Fließgewässer wurde in Bezug auf ökologische Funktionen differenziert und soll später als Referenz für andere städtische Fließgewässer dienen. Die Methode der Kartierung soll weiter für andere Projekte genutzt werden. Damit kann eine komplette Liste der Biotoptypen für urbane Fließgewässer erstellt werden.

In der dritten Phase dieser Forschungsarbeit wurde eine Zustandsbewertung der Lebensräume entwickelt. Die Ergebnisse geben Informationen für die Entscheidungsfindung im Bereich des Fließgewässermanagements. Dabei wurden die Ergebnisse der Habitatfunktionen mit vorliegenden avifaunistischen Daten entlang dem Keelung verglichen. Die Ergebnisse zeigen die Problembereiche und die wertvollen Lebensräume der urbanen Fließgewässer, auf denen Maßnahmen und Renaturierungskonzepte aufgebaut werden können.

Schlagworte: urbanes Fließgewässermanagement, Klassifizierung der Biotope, PSR Framework, Funktionen des Habitats

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List of Abbreviations

ASREQ	Assessment system for river ecological quality
BOD	Biochemical Oxygen Demand
CBD	Central Business District
CBD	The Convention on Biological Diversity
CEPD	Council for Economic Planning and Development
CIR	Colour infrared
CR	Critically Endangered
DO	Dissolved Oxygen
DPSIR	Driving-Pressure-State-Impact-Response
EBAs	Endemic Bird Areas
EEA	European Environment Agency
EEIFR	The ecological and environmental instream flow requirements
EF	Ecological Footprint
EN	Endangered
EPA	Taiwanese Environment Protection Administration
EU	European Union
EW	Extinct in the Wild
EX	Extinct
FFH	Fauna-Flora-Habitat
GBIF	Global Biodiversity Information Facility
GE	Google Earth
GIS	Geographic Information System
GIWA	Global International Waters Assessment
HQ	Habitat Quality
IBA	Important Bird Area
IMP	Percentage of impervious area
IRBM	Integrated river basin management
IUCN	The World Conservation Union
IURBM	Integrated urban river basin management
NH_3-H	Ammonia nitrogen
NT	Near Threatened
LC	Least Concern
OECD	Organisation for Economic Co-operation and Development

PM	Fine particulate matter
P/R	primary productivity / total respiration
PSR	Pressure-State-Response
RCC	River Continuum Concept
RPI	River Pollution Index
SERAS	Stream environment rapid assessment system
SIAM	Stream integrity assessment mode
SS	Suspended Solids
SV	Scales of values
SVS	Scales of Values in test sections
TaiBNET	Taiwan Biodiversity National Information Network
TW	Taiwan
UNEP	United Nations Environment Programme
VU	Vulnerable
WBST	Wild Bird Society of Taipei
WWF	World Wide Fund for Nature

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at Schneiderberg, Hannover, June 2011

Yu-Fang Lin

"....Es muss das Herz bei jedem Lebensrufe bereit zum Abschied sein und Neubeginne, um sich in Tapferkeit und ohne Trauern in andre, neue Bindungen zu geben...." (Quote from „Stufen" by Hermann Hesse, 1941)

1. Introduction

1.1 General Background

The concern with urban river management has been growing in the past decade. A considerable number of studies have been made on an integrated concept of river management in Europe and throughout the world, e.g. the Water Framework Directive in EU directs the European countries to establish the objective and strategies of river management. Recently, integrated river basin management (IRBM) is considered as a comprehensive management approach (Evers, 2007), which is an interdisciplinary project in the fields of ecology, transportation, landscape planning, and other environmental planning to achieve many objectives (i.e. society, economics and ecology) simultaneously. The approach of IRBM in the World Wide Fund for Nature (WWF) refers to that “River basins are dynamic over space and time, and any single management intervention has implications for the system as a whole”. In addition, each project of IRBM rests on the principle that naturally functioning river basin ecosystems are the source of freshwater on which people everywhere depend; therefore, the management of river basins must include maintaining ecosystem functioning as a paramount goal (WWF, 2004). The ecological functions can be especially confined to habitat functions, i.e. a suitable place supplies function of breeding, resting and feeding for wildlife (De Groot, 2006). This kind of concepts depends on the multinational cooperation for some important long rivers (like the Rhine). For urban rivers, in general, the same principles and functions are relevant. An “urban river” is defined in this study as “a place where a significant part of the contributing catchment consists of developed areas” (Findlay and Taylor, 2006).

A comprehensive concept of urban river management is expected to cover many issues which are similar to the above mentioned, e.g. flooding prevention, improvement in water pollution, preservation of biodiversity, water resources development, floodplain management and environment impact analysis. However, these issues in urban areas are specially getting worse to serve basic ecological service due to uncertain multi-impacts, like the habitat functions of urban rivers have continually fundamental decreased caused by urbanization.

Impact of Urbanization on Urban Rivers

Paul and Meyer (2001) define “urbanization” as “a pervasive and rapidly growing form of land use change”. One remarkable phenomenon is that people migrant to cities gradually since the industrial revolution; this has evolved into a global trend. The United Nations projected that more than half of the world population live in urban areas at the end of 2008 (UN, 2008). Riparian lands have been therefore modified extensively by human use for urban development, the rivers were subject of intensive river regulation activities which aimed at improving the human uses like flood protection, agriculture, navigation, settlements, power production and recreation (Zinke, 2000). Many environmental problems accompany urbanization, e.g. greenhouse effect, climate change, sprawling development, wrong or overloading land use, increasing pollution, shortage of water supply. They have a great impact on the river basins and their neighbourhoods.

The main impacts on urban rivers are water pollution, rising water temperature, decrement of groundwater storage, change of landscape structure; furthermore, these impacts have secondary damaging effects like flooding, soil erosion, they destroy and disconnect or fragment habitats and wildlife. Many studies underpin that up to now rivers have been managed according to selected human demands and economic benefits (Newson, 1992). Rivers were channelized and regulated by embankments, weirs and sluices for water resource control and flood defences (Nienhuis & Leuven, 2001; Hostmann, 2005). Straightened river channels have been popular strategy for river governance in the 1970s. The main purposes of urban river management have been flood control, water use, reduction of water pollution and recreation (Chibana, 2008).

Taiwan was no exception in this respect. Rivers were modified by dams and other river engineering works for human use and urban development. However, these impacts could not totally prevent flooding or build a safer environment yet. One reason for this is that on floodplains infrastructure (such as riparian parks, bikeways), water supply and other urban developing purposes, the overloading development on riverbanks might rapidly reduce the areas of natural environment (e.g. forests, grasslands, and other natural areas). Many of the man-made features and defence structures on riverbanks were overloading established due to the “levee effect[1]” (Smith and Ward, 1998; Liao, 2006). The works of straightening channel even completely change the hydrology and river ecosystem. The embankments and other man-made infrastructure disconnect or fragment the habitat of wildlife, the monotonous vegetation structure and disconnected habitats cause destruction to biological diversity (Lin et al., 2001). In addition, most rivers in Taiwan are short, and flow rapidly into the ocean. The temporary heavy rainfall raises serious floods and soil erosion due to increase of surface water runoff, which causes much non-point pollution and brings suspended solids into the water bodies. The water quality is getting worse in cities accordingly.

[1] “Levee effect” has been argued by McMaster in his Master’s thesis in 1996 to evaluate the effect on local economic growth of improved flood protection (McMaster, 1996; The Tennessee Valley Authority, 2004). The developed areas logically become protection and protection attracts further flood planning development. When levees do fail losses are greater, and levees can then hold the flood water on the floodplain after river recedes. For the fear of preventing flooding, the government budgets more and more for building levee.

State and Problems of Urban River Biodiversity Management

Urban rivers are permanent or "stopover" habitats for wildlife. The urban streams are 'bio-highways' to transport the nutrients, energy and material. The riparian areas work as conjunction of land and water body, i.e. they act as a natural buffer between upland terrestrial activities and the water (McConnachie, 2002). Importantly they are able to store water and thus mitigate the effects of flooding, recharge ground water, reduce erosion and trap sediment, provide shelter and food for wildlife, and finally they also help to reduce the effects of nonpoint source pollution (Naiman and Décamps, 1990; Oklahoma Conservation Commission, 1998; McConnachie, 2002). However, the man-made riverbanks display monotonous vegetation structure and habitats; the human activities on riverbanks are the reasons for destroying, shrinking and polluting of the habitats, and as well as fragment the landscape. The decrease of biodiversity therefore arises from poor natural environment.

All the above mentioned impacts may worsen in the lower reach in cities which is explained by the River Continuum Concept (Vannote, 1980; detail in Section 2.1.1.1). To maintain biodiversity in urban riparian areas is therefore an especially important goal for spatial planning. This comprises the conservation of wildlife, maintenance of biological resources, ecological rehabilitation, and protection of natural environment. On the one hand, biodiversity conservation means that the diversity on species and subspecies has to be maintained on different spatial scales. On the other hand, biodiversity conservation also aims at maintaining typical composition of different species according to the type of ecosystem. Usually the typical biodiversity of an ecosystem also is the basis for other ecosystem functions and services (like flood protection, recreation, etc.)

Wang (1999) argues that the main causes of decreasing urban river biodiversity in Taiwan are water pollution, lack of ecological instream flows[2], simplex habitats and river flows, disconnection and fragment of habitats, alien species and disturbances from human activities and development. The rivers in mega-city Taipei especially show the worst case. All rivers, flowing through Taipei City, are modified for the purposes of flooding prevention and recreation (Change, 2004). The habitats on floodplains are fragmented by man-made infrastructure, which threaten the diversity of species and their living spaces. Therefore, these rivers can be considered as typical prototypes for a case study on urban rivers in Taiwan.

[2] "Instream flows are essential determinants of channel morphology, riparian and aquatic flora and fauna, water quality estuarine inflow and stream load transport. The ecological and environmental instream flow requirements (EEIFR) should be estimated to make the exploitation and utilization of water resources in a highly efficient and sustainable way and maintain the river ecosystem good health (Song et al., 2007)."

1.2 Research Niche and Study Area

Although a considerable number of researchers has considered the issue of river management over the past few years in Taiwan (e.g. Tang, 1997; Pang, 1999; Lin, 2001; Wong, 2001; Yang, 2002; Chen, 2003; Chang, 2004; Liang, 2004; Lin, 2005; Chu, 2006), very little attention has been given specifically to the lower reaches in cities (urban rivers), due to the dynamic and uncertain changes of urban development. The studies dealing with the downstream mostly attempted to treat flooding management, water quality control or the influence of specific infrastructure. For examining the causes of biodiversity problems of urban rivers and reacting by planning it would be necessary to have an inventory of the urban river ecosystem in its different components, its ecosystem functions, priority areas of conservations and damaged areas. Until now no methodology has been developed for mapping and appraisal of urban river ecosystems and their ecosystem functions. The issues of urban rivers are complicated and puzzling to handle, therefore, it would be difficult to solve these problems without methodological support and knowledge of the basic conditions of biotopes. In European countries, especially in Germany, the mapping of biotope types is usually taken as an important basis for environment planning to show the physical integrity of ecosystems. The understanding of the physical habitat conditions of riparian areas allows for better assessments of the stream ecosystem and human caused effects.

Also a great deal of effort has been made on assessment systems of rivers (e.g. ASREQ[3] by Pang, 1999; SERAS[4] by Liang, 2004; SIAM[5] by Chu, 2006), but most of the studies just focus on the upstream or midstream. For example, the ASREQ evaluated the ecosystem by biological condition. In contrast, it lacks biological data and change of habitats, which can not really judge the real condition. The SIAM surveyed the stream integrity, but only worked for the upper reach; the indicators cannot be simply adapted to the urban areas, because the considerations of the urban ecosystem are much more complicated than in rural areas. The criteria seem to either lack biological data or only deal with rivers in rural areas in Taiwan. The evaluation criteria for ecological services of urban rivers are lacking. In other words, until now no methodology has been developed for biotope mapping and appraisal of urban river ecosystems and their functions in Taiwan. This study aims at developing a methodology for urban river biodiversity inventory. This comprises a typology of biotopes and their evaluation concerning habitat functions. The emphasis of evaluation is on habitat functions (i.e. ecological conditions) rather than societal values (e.g. flooding prevent/mitigation, recreation), because the habitat values apply

[3] ASREQ is abbreviation of Assessment system for river ecological quality.
[4] SERAS is a model named „Stream environment rapid assessment system“.
[5] SIAM is „Stream integrity assessment mode“, which combined with many river assessment models.

the information about conservation for decision-making, which may not only benefit to the ecological environment, but also to the societal environment. The results should be suitable as a basis for urban river planning and as well as for city and regional planning in Taiwan.

The downstream Keelung River in Taipei City (ca. 24.7 km long) is a suitable study area. On the one hand, it flows through the Central Business District (CBD), the impacts from urbanization and human activities are much more obvious than in the other main branches of Danschui Basin[6]. On the other hand, the lower Keelung River covers different biotopes qualities (near-natural to extremely artificial); the results of this study can provide a theoretically sound basis for other projects for river basin management. The research design and analysis framework are shown in Chapter IV (Methodology)

1.3 Research Questions and Research Structure

Figure 1.1 shows the flowchart of study on habitat functions of urban rivers. The first phase of this research was undertaken to describe the background of relevant theories of landscape ecology, integrated urban river basin management and habitat functions by document review (See Chapter II). Based on these theories, the river condition of study areas was firstly reviewed by PSR (Pressure-State-Response) framework, which specified the environmental phenomena in urban river areas and also displayed the human – environment interactions with the relevant information, hence to carry out the research questions and targets of this study. The results of this phase provided the descriptive basis and further contributed to biotope mapping and evaluative criteria.

[6] Danshui Basin is the main river basin in great Taipei areas (Taipei City, Taipei County, Taoyuan County and Hsinchu County) in north Taiwan. It has a length of ca. 159 km and the drainage areas of ca. 2,726 km^2. It is the third biggest River in Taiwan. The main stream is Danshui River; the main three main branches are Keelung River, Xindian River and Tahan River. The lower stream flows through Taipei Basin and empties into the Taiwan Strait.

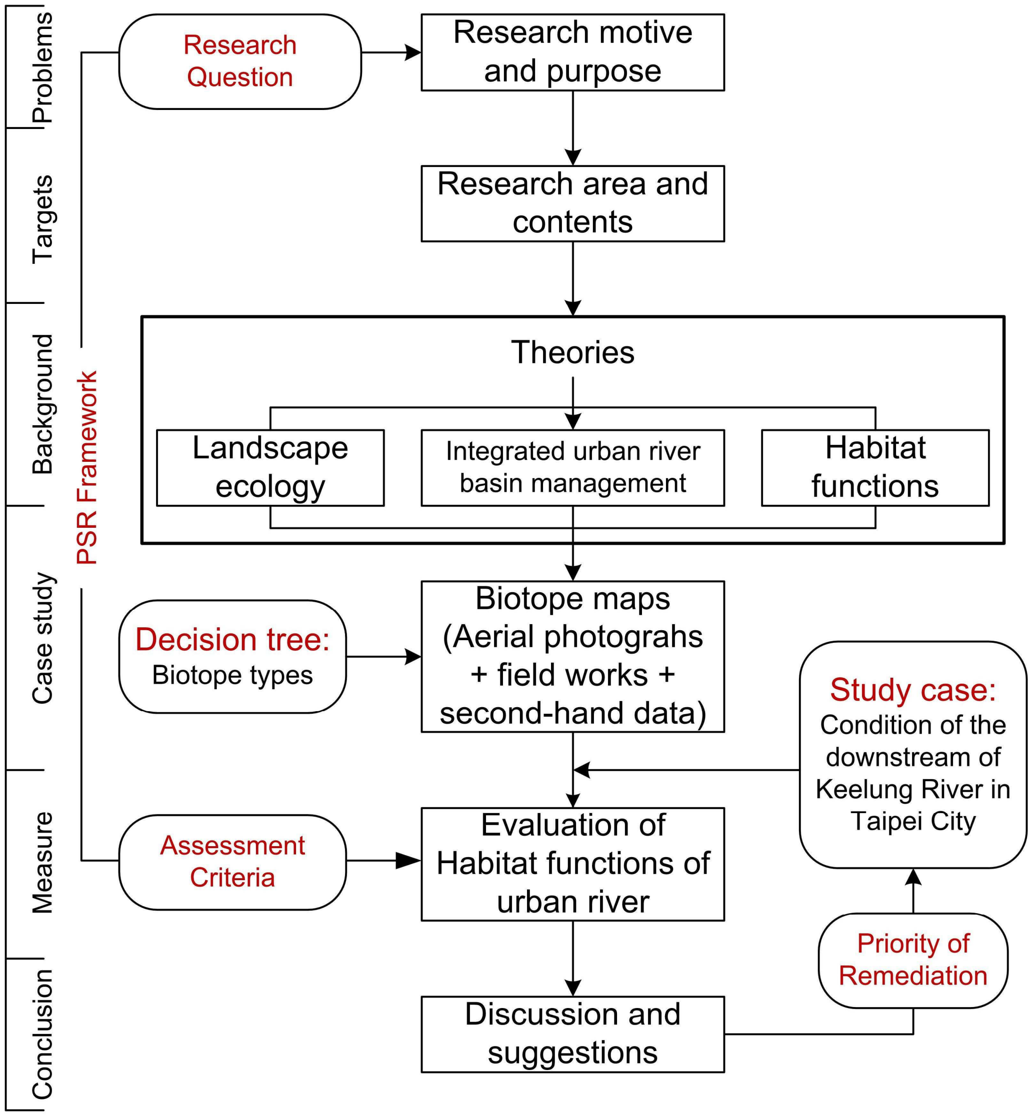


Figure 1.1: Flowchart of evaluation on habitat functions in urban river areas

In Chapter IV has the design of methodology of biotope typology in the field of urban river areas. The concept of biotope classification serves knowledge of physical condition of habitats and their relationship with wildlife. It may further contribute to the basis of evaluation criteria. The biotope classification in this study was carried out based on the German design of biotope mapping, and verified with ground truth by field survey. In order to tackle these challenges, the following research questions have to be worked on:

- Which features of the German classification concepts are suitable as a basis for a Taiwanese classification? How to develop a typology of biotopes for study areas in the lower reach of Keelung River, basing on the German concept but adapted to Taiwanese national and international situation (reference documents in Lower Saxony – Niedersachsen; detail in Chapter IV)?

- Which criteria can be used for assessing habitat functions of urban river? As well as pressures and impacts on the habitat functions?

- How to display the results of evaluation on urban rivers? How to propose the priorities of rehabilitation to decision-maker and planner?

Above all, the research objects in this study can be listed as Table 1.1.

Table 1.1: Research design for habitat functions of urban rivers

Research question	Work packages	Methodology	Database	Result
a. develop a typology of biotope types for Taiwan basin	●Check German typology/classification for transferability ●Check information-data situation in Taiwan ●Mapping of biotope types ●Set up database	●Document review ●Decision tree ●geodata-based analysis compared work ●Field work (ground truth)	●Aerial photo graphs ●Data sources (physical, chemical and biological information about study areas) ●German system of biotope types	Typology of biotope types in lower reach of Keelung River
b. how to set up criteria for habitat functions of urban river?	●Checking existing criteria used in other system concerning specific legal condition, basis ●Compare with preconditions in Taiwan or internet objections ●Establish criteria for habitat functions of urban river ●Evaluation	●Document review ●Statistic analysis ●Test geodata-based analysis	Relevant information (e.g. water quality, climate, bird species, etc.)	Measure of habitat functions of urban river
c. how to propose priorities of special planning?	●Review theories and techniques for urban river rehabilitation ●Suggestions and decision support	●Document review ●Qualitative analysis ●PSR analysis	●Results of evaluation from study case ●Relative data (e.g. laws, policies, etc.)	Suggestions in spatial planning

The German classification of biotope types served as a conceptual basis for a biotope typology in Taiwan. In a first phase of this study, it has been tested whether this concept weight is transferred to Taiwanese conditions. The characteristics of rivers, according to vegetation, landscape and geology, provided a core framework for biotope types. The main biotope types of this study can be grouped into eight types: forest, shrubbery, inland water, wetland, unvegetated habitat, urban green, man-made areas and others. This background was firstly digitized into geodata with aerial photographs and combined with physical, chemical and biological information as database. For the first classification verifying by ground truth data, the field work was undertaken during December 2006 and February 2007. The classification and river habitat survey process provide then an inventory or reference for evidence of river condition and its analysis. These data from the Keelung River can provide the understanding of biotope features and act as a basis for evaluation of habitat functions. The process and results are listed in Chapter IV and Chapter V.

It is difficult to find a comprehensive framework for assessment the habitat values and ecological services of urban river due to the uncertainty and complexity of urban environment. The assessment framework was listed for the purpose of habitat functions of urban river to assess the river conditions by disturbance indicators (pressure) and the state of biotope and species (vulnerability state). The evaluation methodology is listed in Chapter IV, the results of assessment is shown in Chapter VI, which outline the description of river condition and provide the basis for priority of rehabilitation.

Decision making in environment management projects are often multilateral, unique and associated with different objectives and uncertain outcomes (Hostmann, 2005). Many comprehensive projects of river management also pay attention to rehabilitation/remediation as subproject to improve the river ecosystem back to original or resembling natural condition. However, it is hard to list a best priority for rehabilitation projects. The strategies of river management might often argue to require more space for the river dynamics (live with flood), which creates a conflict with current utilization of the riparian areas. Ehrenfeld (2000) refers the major goals of rehabilitation usually to focus on three categories: rehabilitation of species, rehabilitation of whole ecosystems or landscapes and rehabilitation of ecosystem services (such as water supply, water treatment, recreation) According to the biggest benefit and limited budget, the protection of biodiversity hotpots or ecosystem restoration has higher priority (Hostmann, 2005). Hence, the last phase would not propose a comprehensive concept for rehabilitation, but provide the priority and emphasis for decision making of habitat remediation. The ranking is listed after the evaluation in Chapter VII.

With these questions in mind, the research results may help survey the condition of urban rivers in Taiwan, from this establish the typology of biotope types, it is a pilot study for biotope mapping in Taiwan. It may also attempt to contribute to the evaluation methodology of habitat functions for other cases in aspect of urban river. The results of evaluation expect to provide useful information and can propose the priority of decision making for rehabilitation of habitat functions in the lower Keelung River. The entire concept may further contribute to river basin management in Taiwan.

2. Concepts and Methods in the Field of Urban River Ecosystem and its Management

Rivers are open and dynamic ecosystems with constant changes over time and space. The characteristics of urban rivers, which are usually the lower reaches in low-lying densely populated areas, are even influenced by wide range of upstream and the neighbourhoods in natural factors (e.g. local climate and geology) (Schneiderbruber et al., 2004; Haasnoot et al., 2004). Meanwhile, the extreme changes of urban land use reflect the on-going human demands of planning, thus building and raising questions about the ecology of the built environment and river management (Haasnoot et al., 2004; Jarvis and Young, 2005). To investigate the research questions, some concepts regarding urban river ecosystem and its management will be introduced as theoretical background. The definition and concepts of landscape ecology on urban rivers will first be given in Section 2.1 as the basis of research aspect. Based on this aspect, Section 2.2 will further discuss the concepts of urban river management that leads into the need of understanding the causes and consequences of urbanisation on the river ecosystems. In this context, the DPSIR (driving force-pressure-status-impact-response) framework can be a good instrument to understand the integrated urban river management and helps to establish the evaluative indicators (Section 2.3). A database for evaluation and identification of urban river ecosystems will be carried out by biotope classification (Section 2.4).

2.1 Landscape Ecology on Urban Rivers

2.1.1 Components of Urban River Ecosystem and its Influence

Landscape ecology is a study that includes geography and ecology. Troll first brought the ecological theories into spatial planning and designated the term of “landscape ecology” in 1939. Yet this subject was not broadly discussed until 1980’s; nowadays, landscape ecology is applicable to many aspects of environmental planning, such as resource management and preservation, urban planning and nature conservation. In theory and praxis, landscape ecology is taken as “a study of spatial variation in landscapes at a variety of scales. It includes biophysical and societal causes and consequences of landscape heterogeneity, i.e. the relationship between organism and non-organism, integration of the inside functions, spatial structure and developing regulation” (IALE, 2007).

To describe and discuss the dynamic condition of ecosystems, three characteristics of landscape should be mentioned: structure, function and change (Forman and Godron, 1986) (Figure 2.1). “Structure” means the spatial relationships among the distinctive patches or the present elements which can distribute to the energy, materials and configurations of the ecosystems. Different structures of landscape serve different "functions" that denotes the interactions between the spatial elements in ecology (e.g. flows of energy, materials). The component in space, which is altered in structure and functions over time, is the so-called "change". Forman and Godron (1986) further proposed seven planning principles of landscape ecology to show the landscape transformation and dynamic changes by five different processes: perforation, dissection, fragmentation, shrinkage and attrition (Forman, 1995, Table 2.1). Each process has a characteristic signature or effect on attributes of the landscape pattern (Ziperer, 1993; Forman, 1995), which was shaped by the natural influences (e.g. climate, vegetation, geology) and human-environment interactions (e.g. land use, human activities).

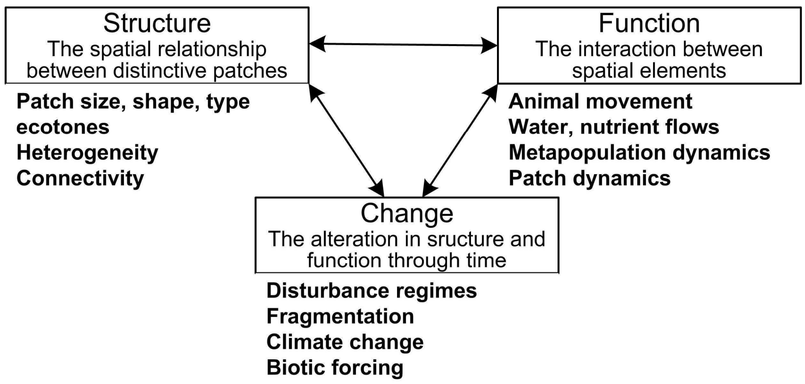


Figure 2.1: Components of landscape ecology (Forman and Godron, 1986; Hobbs, 1997)

Table 2.1: Emerging general principles of landscape ecology (Forman and Godron, 1986)

Principle	Description	Component
Landscape Structure and Function Principle	Landscapes are heterogeneous and differ structurally in the distribution of species, energy and materials among the patches, corridors and matrix present. Consequently, landscapes differ functionally in the flows of species, energy and materials among these structural landscape elements.	Structure
Biotic Diversity Principle	Landscape heterogeneity decreases the abundance of rare interior species, increases the abundance of edge species and animals requiring two or more landscape elements and enhances the potential total species coexistence.	
Species Flow Principle	The expansion and contraction of species among landscape elements has both a major effect on, and is controlled by, landscape heterogeneity.	Function
Nutrient Redistribution Principle	The rate of redistribution of mineral nutrients among landscape elements increases with disturbance intensity in those landscape elements.	
Energy Flow Principle	The flows of heat energy and biomass across boundaries separating the patches, corridors and matrix of a landscape increase with increasing landscape heterogeneity.	
Landscape Change Principle	When undisturbed, horizontal landscape structure tends progressively toward homogeneity; moderate disturbance rapidly decrease heterogeneity.	Change
Landscape Stability Principle	Stability of the landscape mosaic may increase in three distinct ways, toward (a) physical system stability (characterized by the absence of biomass), (b) rapid recovery from disturbance (low biomass present), or (c) high resistance to disturbance (usually high biomass present).	

The landscape ecological principles provide ecologists the insight for conservation, restoration and management of natural ecosystems and cultural landscapes (Forman, 1995; Sukopp, 1998; Farina, 2000; Davis and Stoms, 2001; Ingegnoli, 2002; Hont et al., 2004). However, the traditional principles of landscape ecology as mentioned above mostly pay attention to terrestrial ecosystems. Some studies (e.g. Hansen and di Castri, 1992), which are involved in river areas, have mentioned the important functions of rivers as networks within landscapes, i.e. rivers and their riparian areas were considered as functional parts of landscapes that act as corridors to transport and exchange nutrients, materials, organisms, energy, or information across boundaries or ecotones between adjacent landscape elements. For instance, to review the investigations of European floodplain, they demonstrated how landscape ecology can provide an effective framework to integrate pattern and process in river corridors, to examine environmental dynamics and interactive pathways among landscape elements, and to develop viable strategies for river conservation (Ward et al., 2002). From this perspective, more and more events of "Waterscape" have raised questions about the ecological health and services of water management in the last decades, which especially attracted attention in the complex urban ecosystems (Haasnoot et al., 2004). According to the collective ideas of "urban areas" as a developed environment, the term "urban river" is defined as "a river catchment usually flowing slowly through the highly developed areas, it is well known as the middle to lower stream in cities".

The urban river ecosystem consists of the interactions among physical (e.g. climate), biological (e.g. food chain) and human environment (e.g. human activities, industry and urbanization). These interactions show obviously the components of landscape. Besides, urban rivers act as one part of "green resources" in cities which not only provide areas for life cycle of wildlife, but also let human beings getting close to the natural environment. However, urban rivers seem to be regarded as a resource to be exploited and governed extremely for human demands until recent decades. The changing patterns of urban land use reflect the on-going human processes of development (Jarvis and Young, 2005). The natural habitats of urban rivers are therefore disconnected by human impacts (urbanization e.g. land use, human activities and urban sprawl). Moreover, the influences that human activities bring on these flows normally cause the shrinkage and fragmentation of habitat, the edge effect and the decreasing of biological diversity of riparian habitats.

Besides, urban rivers are not single sections that are altered by natural changes and human activities with longitudinal, lateral and vertical connectivity over time. Therefore, before turning to the issue of habitat functions of urban rivers, the longitudinal (River Continuum Concept, RCC) and latitudinal (interactions with the neighbourhoods) influences of rivers should be discussed in the following section.

2.1.1.1 River Continuum Concept (Longitudinal Connections)

The River Continuum Concept (RCC; Figure 2.2) is a theory based on the concept of "dynamic equilibrium" argued by Curry (1972) to describe physical, chemical and biological changes on a longitudinal gradient from the headwaters to the lower reaches of river systems (Vannote et al., 1980). The RCC attempts to summarise the changes in organic matter processing and biotic communities in response to change in the physical parameters (e.g. width, depth, velocity, sediment loading) (Vannote et al., 1980; Winterbourn et al., 1981; Lake, 1995; Dunn, 2000). Generally speaking, the lower stream is characterized by having slow current velocity, deeper and wider channel with lower slope, warmer water temperature and stronger interactions on floodplains. Thus, in the lower reaches, the food chain and biological communities and production are much more complicated and richer than in the headwaters (Table 2.2). In extended river reaches, biological communities should approach to equilibrium with the dynamic physical conditions of the channel.

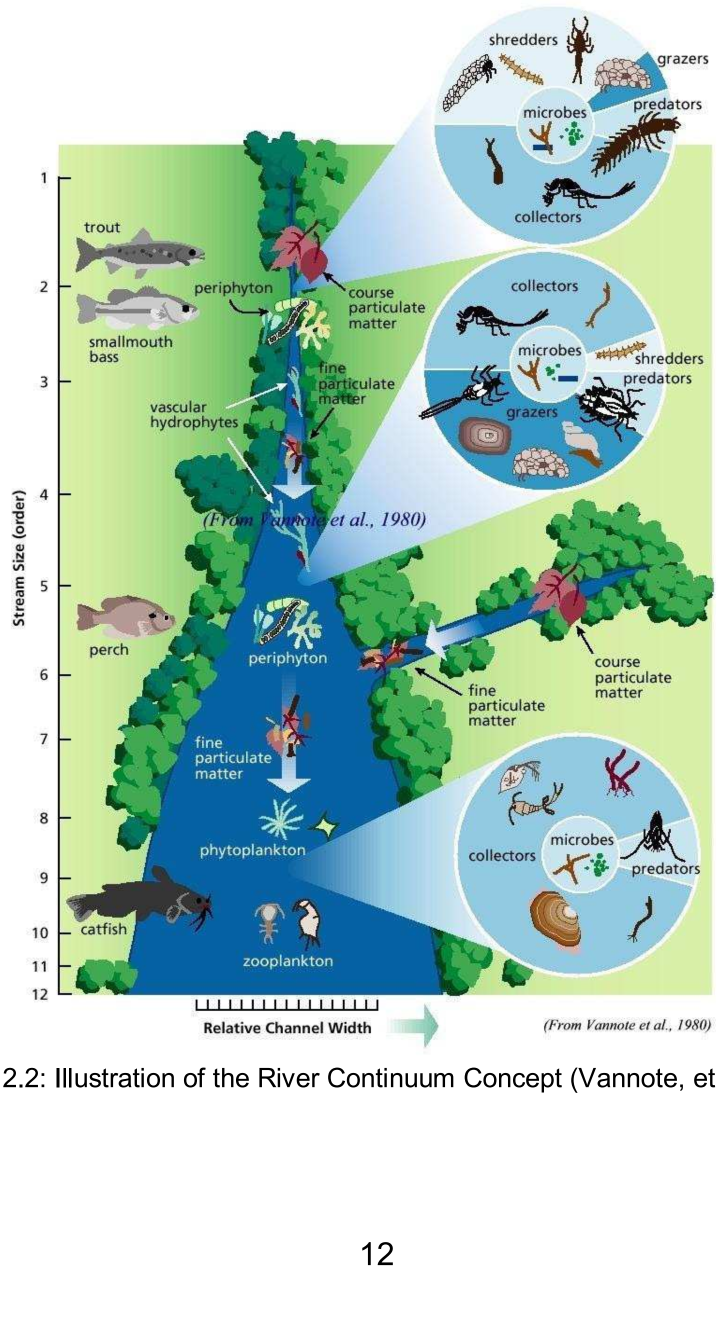


Figure 2.2: Illustration of the River Continuum Concept (Vannote, et al., 1980)

Crosa et al. (2002) argued that the RCC emphasizes on input and fluxes of matter and energy and also contended based on some studies to use the physical condition to show the discrete habitat units as scientific acceptance with some reasons: 1) the short scale applicability and its considerable management potential (e.g. Harper et al., 1995; Armitage and Cannan, 1998; Newson at al., 1998), 2) the physical habitats can be easily recognized on visual basis, 3) habitats provide links between impacts on the natural environment and its inhabitants (Harper et al., 1995), 4) following the pressure for flow regulation schemes with ecological orientation (Petts et al., 1995). Nevertheless, due to the fact that the channelization and water regulation for navigation or hydroelectric development have particularly affected the instream habitats (Linfield, 1985; Copp, 1991) resulting in habitat destruction or changes in flow regime (Bain et al., 1988; Persat and Chessel, 1989; Copp, 1991). Thus, the RCC demonstrates the patch dynamics in biological patterns to develop the need and information for water management in protection and conservation of biodiversity.

Table 2.2: The environment of different reaches (Vannote, et al., 1980; Chen, 2003.)

	Headwater	**Midstream**	**Lower reach**
Water flow	fast	Slow and deep	lower slope, steady flowing
Biological environment	Producers: water plants and advanced plants. Consumers: aquatic insects, Molluscs and small fishes; most fishes feed on invertebrates	Relative stable conditions in water, therefore, the aquatic nutrients and the quantities of fauna and flora are much more than the upper stream. Piscivorous species are also abundant	Producers: water plants, advanced plants and organic detritus. High quantities of products. The food chain is complicated. Planktivorous species may be present
P/R[1] ratio	<1, heterotrophy	>1, autotrophy	<1, heterotrophy
Main type of food production	coarse particulate organic matter, CPOM	fine particulate organic matter, FPOM	fine particulate organic matter, FPOM

2.1.1.2 Interactions between Water and its Neighbourhoods (Latitudinal Link)

An integrated river management should consider the interactions between water and its neighbourhoods. Normally, urban river ecosystems comprise the actual aquatic (in-channel) environment and associated riverbanks or riparian systems (Poff et al., 2002). The instream waterway includes channel, the boundaries of the channel and alluvial soil. The riverbanks normally refer to the floodplains on both sides of channel, riparian vegetation, embankment, hill slopes, strip of upland above the banks and the land-use types in neighbourhoods (Chang, 2004) (illustrated in Figure 2.3). The liner aspect of riparian corridors is often viewed as an important characteristic as these provide a potential to link isolated habitats and populations as passages (Eckstein, 1984; Gardiner, 1991) while simultaneously controlling the movements of water,

[1] P/R ratio was formulated by Pavletic et al. (1976) to check the primary productivity (P) relative to community respiration (R) in the running water. When the P/R ratio is greater than 1, which means autotrophy, and heterotrophy means that the P/R ratio is less than 1.

nutrients, sediment and species (Malanson, 1993; Forman, 1995). The riparian areas, the so-called interface between aquatic and terrestrial ecosystems, was originally referred to as tension zones by Shelford (1913) and then as "ecotones" (e.g. Holland, 1988; Naiman et al., 1988; Copp, 1991). The ecotone is an open space with a maximum of exchanging energy, nutrient and material that offers for organisms. Moreover, species also use ecotone for migration and refuge. From these points of view, the influences on the riparian areas and the interactions with the neighbourhoods are important to indicate the impacts of urbanization and ecosystem functions of urban rivers.

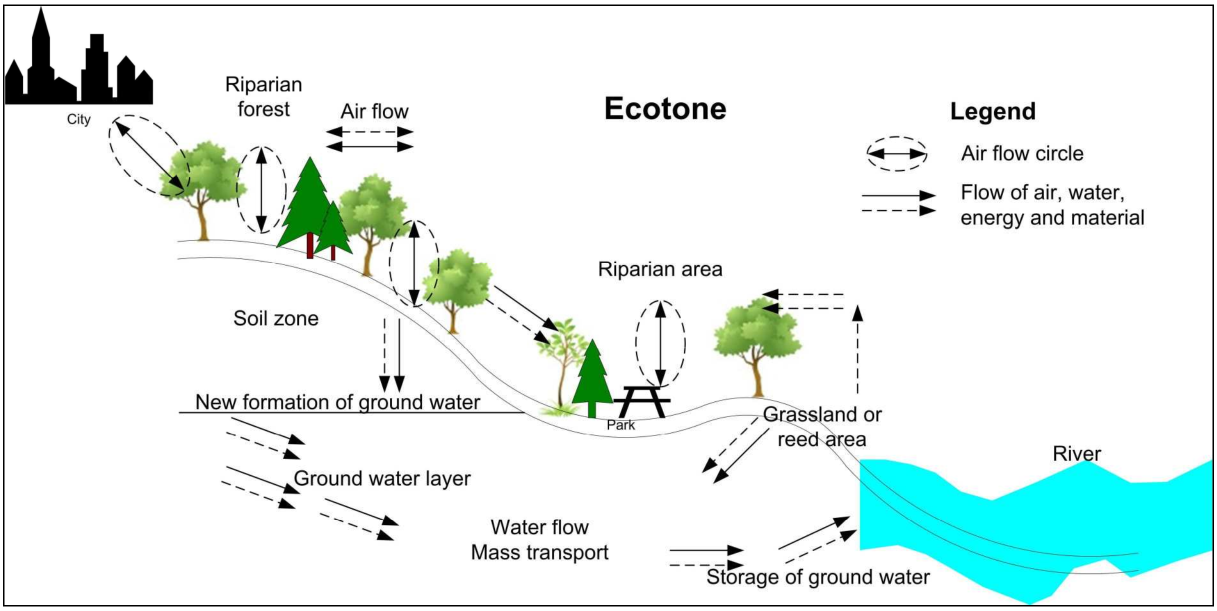


Figure 2.3: Interactions between river and neighbourhoods (Redraw from DVWK, 1996)

Based on the knowledge of landscape ecology in urban river areas, the values and services of urban rivers should be further mentioned to show the ecosystem functions. Moreover, the reasons to emphasise the habitat functions in this study will would be given in the next sections.

2.1.2 Habitat Functions of Urban River

Ecosystem functions are difficultly understood in planning process due to the different definition of "functions", which results in different requirements and targets of planning (Jax, 2005). The ecosystem functions can be the ecosystem processes, the functioning of ecosystem, the role of ecosystem or the ecosystem services (Figure 2.4). Mostly, "functions" refer to the cause-effect-relations underlying the processes or the ecosystem services for human beings in environmental studies (Jax, 2005). To pay attention to the ecosystem processes and the services, de Groot (2006) grouped the ecosystem functions in five categories: regulation, habitat, production, information and carrier. De Groot also explained the progresses and elements of natural and semi-natural ecosystems with these five functions. In which, these functions can be associated with different scales of ecosystems (e.g. the entire river ecosystem or the specific reaches such as urban rivers). For instance, the value to ecological entities like self-regulation of water quality denotes the correlation of urban river and ecosystem functions (process), the value to human beings such as recreation expresses the ecosystem services (service for human demands). Generally speaking, urban rivers have functions as habitat, conduit, source, filter and sink for human demands and ecological entities (Forman, 1995).

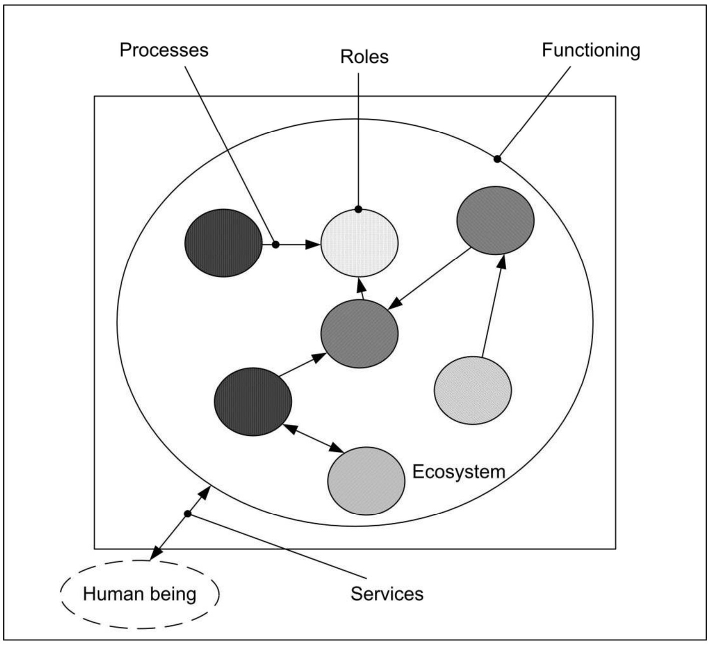


Figure 2.4: Illustration the ecosystem functions in planning process (redraw from Jax, 2000; v. Haaren, 2004)

Urban environment is much more complicated and dynamic. From the perspective of spatial structure, the functions of urban rivers can be divided into water bodies and riparian areas as shown in Table 2.3. The water bodies give ecological functions such as flooding drain, storages of groundwater; river flow contributed by groundwater is generally a constant and dependable water supply (Pellaud, 2007). The riparian areas, which Rosenburg et al. (1997) redefined by calling them "linear patches", play a role as "Ecotone" that provide values and use of corridors for species movement (Rosenburg et al., 1997; Bryand, 2006), adjust the ecosystem (e.g. micro-weather, air condition, water quality), serve as habitat for wildlife, as well as apply places for human beings to close to the natural environment. To review the existing environmental condition and its changes, the urban river functions present by including biodiversity, habitat types, habitat quality and the structure of landscape. These components provide natural sources of the city to enhance the quality of urban health for people, plants and wildlife (Jarvis and Young, 2005). Generally speaking, urban rivers serve for species protection (refuges, dispersal centres, corridors), for recreation, for environmental protection and environmental health (water resources, water hygiene, climate, air hygiene, noise protection) (Sukopp and Weiler, 1988).

In addition, urban rivers are permanent or "stopover" habitats for wildlife. The urban streams are "bio-highways" to transport the nutrient, energy and material. The riparian areas work as conjunction of land and water bodies, i.e. they act as a natural buffer between upland terrestrial activities and the water (McConnachie, 2002). They are importantly able to store water and thus mitigate the effects of flooding, recharge ground water, reduce erosion and trap sediment, provide shelter and food for wildlife, and finally they also help to reduce the effects of nonpoint source pollution (Naiman and Décamps, 1990; Oklahoma Conservation Commission, 1998; McConnachie, 2002).

Table 2.3: Functions of urban river according to spatial structure (Modified from Postel and Carpenter, 1997; Oyang, 2001; Poff et al., 2002)

Spaces	Functioning	Processes / Services
River flow	Water control	1) Floodwater discharge, 2) Surface water discharge, 3) Waste water discharge, 4) Groundwater regulation, 5) Soil conservation
	Water supply	1) Water source for household uses, 2) Transportation, 3) Industrial uses, 4) Energy resource, 5) Irrigation & Aquaculture
Riparian area	Wildlife	1) Activity, 2) Refuge, 3) Breeding, 4) Habitat / resting, 5) Foraging
	Ecology	1) Ecological conservation, 2) Micro-weather adjustment, 3) Groundwater keeping, 4) Purification of air, 5) Water quality self-regulation
	Human demand	1) Landscape, 2) Land use, 3) Recreation, 4) Education

However, urban river areas usually display monotonous vegetation and landscape structure due to rapid urbanization. River modification works and human activities on riverbanks are the main causes of changing the natural course, and to destroy, shrink and fragment the habitats. With a perspective of ecological systems, this study especially emphasizes the habitat functions of urban rivers (i.e. suitable living places with functioning of breeding, resting and foraging for wildlife; de Groot, 2006) rather than other societal values (e.g. flooding prevent/mitigation, recreation); because the ecological value is fundamental to other values (Dunn, 2000). The evaluation of habitat functions demands information about cause-effect-relations, which used to assess the quality of habitat with physical (i.e. vegetation itself and its living environment), biological and environmental states. Moreover, vegetation is important as a food supply and migratory route. The spatial pattern of vegetation may also influence on local ecosystem functions; i.e. vegetation provides many invaluable data to the understanding of wildlife habitat (Forman 1995; Hong et al., 2004), since different physical characteristics control the spatial distribution of the habitats (Kemp et al., 1999; Newson and Newson, 2000). The evaluation results of habitat functions provide important information about relational database for decision-making, which may both benefit to the physical and social environments.

Moreover, the definition of habitat functions of urban rivers in this study are based on the "biotope functions" by Kirsch-Stracke and Reich as "the services and functions of ecosystem as habitats for vegetation and animals and the living spaces with functioning of refuge, foraging, resting and breeding" (Haaren v. (Ed.), 2004). As the definition given above, the word "habitat" itself often has a resonance of implying how the various components of the biotope interact and function (Jarvis and Young, 2005). In many studies (e.g. Sukopp et al., 1984; Sukopp and Weiler, 1988; Lödde et al., 1995), the term "biotope" is synonymous with habitat (Connor et al., 2004; Hiscock and Tyler-Walters, 2003, Olenin and Ducrotoy, 2006). For clarifying the terminology of research design, the terms of **habitat** and **biotope** should be defined before developing the whole research concept.

2.1.3 Terms of habitat and biotope

"Habitat" is used to describe the physical surroundings of plants and animals. Olenin and Ducrotoy (2006) argued that habitat may be considered the place where organism are found (e.g. sandbank) or the area where species occur. For instance, the aquatic habitats can be defined as the local physical, chemical and biological features that provide an environment for the instream biota (Maddocke, 1999), which encompasses the substratum (e.g. rock, sediment), its topography and the conditions of salinity, tidal currents and other water quality characteristics (Connor et al., 2004). Besides, Forman (1995) mentioned that the riparian corridors also obviously provide habitats for terrestrial organisms; the interactions are strong with the surroundings and therefore raise the biological diversity. Accordingly, the habitats of urban river ecosystems contain both the instream and riparian areas.

Since the 1970's, the investigation on habitats is gradually carried out with concepts of "biotope" as basic information to survey the environmental issues throughout Europe that is especially widely used in Germany. "Biotope" is defined as the combination of an abiotic habitat and its associated community of species (Connor et al., 2004), which is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. A biotope is a smallest unit of biosphere and almost synonymous with "habitat". A habitat refers to the space for unique species or population. However, a biotope can be itself an element or many different components of habitats.

Reviewing far back in the past, the concept of biotope was first brought up by a German biologist Ernst Haeckel (1834-1919) in his book "General Morphology" (1866). Haeckel emphasized the importance of habitat as a prerequisite of organism's existence, i.e. it is a space of interaction among the environmental factors and organisms related to ecosystem. The original idea of biotope was closely associated to the evolutional theory. Möbius (1877) then formulated the concept of "biocenosis" to determine the physical-chemical conditions of existence of a biocoenosis as a complex "superorganism" where animals and plants live together in an interdependent biological community. F. Dahl finally denominated this term as "biotope" in 1908 to define the physical condition of existence in a complex of factors (Olenin and Ducrotoy, 2006) that only indicated the abiotic environment. Tansley (1935) later produced the first definition of ecosystem from the biotope (abiotic environment) and the biocenosis (biotic communities) to describe the physical condition and groups of plants and animals living there (Keller and Golley, 2000; Olenin and Ducrotoy, 2006). In brief, a biotope (bios-life and topos-place in Greek) is a secion of terrestrial or water surface with similar abiotic environment with its characteristic plant community (Mirkin and Resenberg, 1983; Ignatieva et al., 2000). Nowadays, a new biotope concept combines both the habitat and its distinctive assemblage of conspicuous species (Hiscock and Tyler-Walters, 2003; Olenin and Ducrotoy, 2006). Accordingly, a recent definition of a biotope was used in the framework of the European programme Biomar-Life as "it combines the concepts of habitat and community[2] for defining geographical units" (Connor, 1995; Connor et al., 2004). In general, a new meaning of "biotope" is distinguished both from the physical environment and plant community (Olenin and Ducrotoy, 2006). Based the new concepts of biotopes, the new understanding of biotope is now widely used in the fields of biodiversity, benthic research, agriculture, landscape ecology and others (Haeupler, 2002; Olenin and Ducrotoy, 2006). Besides, the concept of biotope is scale-dependent and partly species-specific; the large biotopes (several square kilometres) can be included as a landscape (Löfvenhaft et al., 2002).

Accordingly, a database of biotopes in study areas may help to know the physical condition and the biotic communities living there, which will contribute to the further studies on integrated river management and urban ecosystems. Besides, biodiversity is another central issue while discussing habitat functions in this study, because biodiversity denotes the composition, structure and interaction with other species in assemblage. Therefore, before introducing the integrated urban river management, the term of biodiversity in urban river ecosystems should be discussed in the subsequent paragraphs.

2.1.4 Urban Biodiversity and River Ecosystem

The definition of "biodiversity", which combined the ideas of biological and diversity in 1986, is "the diversity of biology, which is included all species and interactions of the ecosystems; the basic ideas are heredity diversity, species diversityand ecosystem diversity" (Harper and Hawksworth, 1995; Sandström et al., 2006). Biodiversity is so-called biological resource that shows a number of different levels of variation in an area. In other words, variability among living organisms from all sources including and the ecological complexes of which they area apart: this includes diversity within

[2] The term community is used to mean an association of species which has particular species, at certain densities, in common (Connor et al., 2004).

species, between species and of ecosystem (Convention on Biological Diversity, 1992). The Convention on Biological Diversity (CBD) defined that biodiversity is an important convention to maintain the global environment. Nowadays, biodiversity and nature conservation are considered as fundamentals to global environment and development strategy. The recent EU regulations and policies present the need for ecological rehabilitation and the conservation of habitats for endangered species (Duel et al., 2003) to maintain and enhance biodiversity.

Many studies represented biological diversity at ecotones or boundaries between patches in the riverine landscape (e.g. Amoros et al., 1993; Ward and Wines, 2001; Ward and Tockner, 2001; Wiens, 2002), because of the multiple factors (e.g. river order, elevation, slope, base of riverbed, water quantity, water quality, energy, biological interactions, human activities). The elements and structure of landscape and their interactions affect the diversity of species in waterscape. Poff et al., (2002) argued that the freshwater ecosystems and coastal wetlands are essential contributors to the diversity and productivity of the biosphere; they also provide the goods and services to human civilization and welfare.

However, biodiversity in the field of urban river is increasingly degraded by human activities and urban development (e.g. recreation, channelization). Thus, the man-made riparian areas display poor vegetation cover and habitats. Human activities on riverbanks often destroy, shrink and pollute the habitats, and also fragment the natural landscape. The decrease in biodiversity therefore arises from poor natural environment. Bryant (2006) surveyed the possible effects of urbanization on biodiversity in some aspects: 1) The disappearance, fragmentation, dissection and impairment of habitats in the entire basin, the landscape and ecosystem are therefore changed. 2) Overusing of natural sources, hence the river corridors cannot act well as habitats for wildlife. 3) Pollution of soil, water and air. The polluted water bodies and riparian areas may reflect on the worse quality of habitats. 4) Change of climate. This influence will represent in the long-term studies, like climate change. 5) Industrialization/urbanisation: The dredging works, channelization, the engineering works on riverbanks (e.g. embankments, infrastructure and riparian parks) as well as pollution from such engineering works, may cause losing biodiversity in waterscape. 6) Importing alien species may change the structure of original ecosystem. In brief, urban development impacts biodiversity through land disturbance and conversion to impervious surfaces, removal of native vegetation, introduction of non-native exotic species, and fragmentation / isolation of remaining natural areas. Therefore, efforts to manage urban biodiversity aim to minimize and mitigate those impacts, protect and connect remaining habitats, and restore damaged natural areas (Bryant and Randolph, 2002; Bryant, 2006).

General speaking, biodiversity is an important issue for protecting most valuable and threatened species, because it refers to the variety of living organisms, interaction among themselves and with their living environment (UNEP, 2010). However, natural disturbance and human impacts threat to biodiversity and the urban landscape, a biodiversity strategy for urban river management is especially important to pay attention to the resilience of habitat management. Accordingly, the spatial planning in urban river areas considers the conservation of wildlife, maintenance of biological resources, ecological rehabilitation and protection of natural environment. The rehabilitation, mitigation or conservation strategies must be quantified in a clear and understandable way in order to enhance the use in spatial management and landscape conservation (Duel et al., 2003). In addition, it engenders the need of assessment to prove the relationship between biodiversity and the abiotic environment, concerning temporal and special aspects (Newson and Newson, 2000). The resulting species/habitat databases provide planners with information for decision making (Crosa et al., 2002). Therefore, the investigation of biodiversity plays a fundamental role for adaptations of ecosystems to their environments, and also for the enhancement of ecosystem resilience against disturbance (Niemelä, 1999).

For investigating the habitat types and the associated species in study areas, biotope mapping is taken as an important instrument to display information about the physical properties (e.g. location, size) and the associated biotic characteristics (species composition) in central Europe (Sukopp and Wittig, 1993: Niemelä, 1999). It especially forms a useful basis for urban planning in Germany. The next section further shows the concepts of biotope classification in urban river areas.

2.2 The Concept of Biotope Classification

2.2.1 Contexts of Biotope Classification

Environmental planning and nature conservation demand a comprehensive frequently updated set of relevant information suited as basis for decision making (Jarivis and Young, 2005). The information about biotope types consists of data about the abiotic environment of biological community, eventually determined for the study areas. Biotopes can be defined at different scales, which may result in a hierarchical classification of types (Connor et al., 2004). Since the late 1980’s, many European Directives have been promulgated in order to being a driving force for protecting ecosystems (Ducrotoy and Elliott, 1997; Elliott et al., 1999; Olenin and Ducrotoy, 2006). For instance, the CORINE biotope classification was carried out to derive a habitat classification on European level to support the requirements of the EU Habitats Directive (EU, 1992; Olenin and Ducrotoy, 2006).

Biotope classification may address the consistent interpretation of data, and also devise as a monitoring tool for planning (e.g. the process-function approach for biotic and abiotic components) (Olenin and Ducrotoy, 2006). It is an instrument to forecast the urbanization impacts on the ecosystems. In addition, Olenin and Ducrotoy (2006) mentioned that the biotope classification is the ecologically sound as the central premise of stream remediation – the ecosystem can be largely managed through manipulation of stream resources. Generally speaking, biotope classification is developed in species-habitat relationships based on the ecosystem concepts and landscape ecology principles. From this viewpoint, biotopes are determined according to the physical and chemical conditions, and associated with community to present the interaction and ecological functions as habitats. Accordingly, biotopes can be considered and protected as landscape components for natural vegetation and animals, where the organisms and ecosystem interact with each other. Therefore, biotope classification helps to divide the networks of interacting populations and the process-functions in biotic and abiotic components. For identifying the complete environmental characteristics, the work of biotope mapping can be used to document dynamics of urban fauna such as the changes in the species composition, and abundance of different types of biotopes (Witt, 1996).

Olenin and Ducrotoy (2006) further mentioned that the concept of biotope classification associated with biodiversity in the ecosystem can model the relationships between biotopes in relation to the overall behaviour of the ecosystem. That is, the qualities of biotopes themselves depend on correlations between biological and physical processes may reflect the environmental conditions and potential problems (Olenin and Ducrotoy, 2006). The well-defined physical structure, potentially varying composition would be robust over time with the information about biological features in the dynamic natural environment (Connor et al., 2004; Olenin and Ducrotoy, 2006). Accordingly, the process and results of biotope classification are carried out for management values (e.g. rehabilitation), particularly in the urban ecosystem. This process of biotope classification not only serves a database of abiotic and biological conditions, but also apply to the conservation analysis (statistics) combined with GIS (Geographic Information System) software. In conclusion, the consideration of biotope classification shows then in different aspects: 1) As the components of the ecosystem and dominant organisms or rare species, 2) The relation to the physical boundaries and their individual characteristics at spatial scale (geodiversity), 3) Showing the temporal condition as well as the changes to the distribution of biotopes within the ecosystem over time, 4) Demonstrating the processes of biotope connections and functions, 5) Display the constraints on the ecosystem behaviour and the translation of biotopes to such changes (Hong et al., 2004; Olenin and Ducrotoy, 2006). Nowadays, the survey biotope mapping process is developed with new technology of geodata-based on the demands and purpose of planning targets (Kuebler et al., 1991).

The methodology of biotope mapping can be divided into two different types due to the research targets and scales: comprehensive biotope mapping (mapping of all biotope types) and selective biotope mapping (Table 2.4). A comprehensive mapping of biotope types is used on small scale and overall classification to interpret the naturalness and condition of vegetation and thermal mapping by reflectance with aerial photographs and satellite images (Crosa et al., 2002). Selective biotope mapping is usually carried out with aerial photograph and survey of ground truth for small or specific study areas. Both methodologies of biotope mapping have increasingly become dependent on GIS software and other tools of pattern analysis for landscape ecology issues (Jarvis and Young, 2005).

Table 2.4: The difference between the biotope type mapping and biotope mapping (Riedel and Lange, 2002; Kim, 2007)

Methodology of mapping	**Comprehensive biotope mapping (Mapping of all biotope types)**	**Selective biotope mapping**
Other identification	• Mapping of real uses • Mapping of biotope types and land use	• Mapping of valuable biotopes • Selective biotope mapping • Mapping for nature conservation, especially in the valuable areas
Basic information	• With predominant regional or areal CIR aerial photographs • Cases of doubt survey with ground truth	• Mapping of biotope types • Investigation of existing data • Survey with ground truth
Spatial collection areas	Comprehensive areas	Only for the selected areas
Scale	1:10,000 or bigger	1:25,000 or smaller
Mapping units	All of the biotope types	Selected biotope would be individually described in detail
Collection units	Biotope would be typed by detect unit	Biotope would be described in individual detail
Collection information	Characteristics of structure, vegetation and land use	Comprehensive information about flora, vegetation and flora, as well as its impacts and measure of preservation and development
Main application	• Local landscape planning • Impact regulation • Assessment of environmental effects • Background of biotope mapping • Background of legal supported biotope mapping	• Regional landscape planning • Planning of protective area • Evaluation of core areas of natural protection for landscape planning and application of impact regulation

Accordingly, the ability of biotope classification in the field of urban river may give values to environmental planners and decision makers the applied information about the landscape elements and structure of river ecosystems, the managed condition for human uses and natural value purposes (e.g. land use, background of habitat ecology) (McLea, 2000; Kim, 2007). The relevant abiotic and biological information supports the need of biotope types and the purposes identified, then the projects of river management can be carried out based on such provisions of river biotope classification (McLea, 2000). As reference, the further concepts of biotope classification are shown with the original design in Germany and the application in Asian countries in the following sections.

2.2.2 Biotope Classification in Germany

The Federal Nature Conservation Act ("Bundesnaturschutzgesetz" in German) was promulgated in 1976 in Germany. This act firstly included the concepts of landscape planning and the impact regulation, in which requires that the wild animals and plants and their community should be protected as parts of the ecosystems in the specific diversity which has grown naturally and historically. The biotopes and other living conditions should be protected, preserved, developed and restored in four aspects: 1) Ecological services and habitat functions, 2) The ability of regeneration and sustainable development of land use, 3) The habitats of fauna and flora, 4) the duration of diversity, characteristics and rehabilitation of nature and landscape (Number 9, Clause 1, Article 2). Accordingly, biotopes serves as the basis for landscape planning in Germany in order to deal with the environmental planning on multifunctionality in consideration of the sustainable development (Haaren v., 2004).

At the beginning, biotope mapping has been carried out determine the inventory of the biotopes requiring protection of endangered plant and animal species in rural areas. The surveys included natural and semi-natural ecosystems (wetland, water bodies, forest, etc.), as well as biotopes which have developed under the influence of agricultural land-use practices (Sukopp and Weiler, 1988). The biotope mapping in developed areas seemed to be superfluous, because people did not pay attention to the nature conservation in cities. Sukopp et al. (1988) argued the importance of nature conservation in cities afterwards, and aimed at preserving wildlife and wild space as the basis for direct contact of urban residents with the natural elements of their environment (Sukopp et al., 1980b; Sukopp and Weiler, 1988).

As shown in the previous section, there are two methods of biotope mapping and species recording in urban areas in Germany. One is comprehensive biotope mapping to survey all biotopes found in the city; for instance the study case in Berlin (by Sukopp et al., 1980b). The other concept is selective biotope mapping, which only focuses on the protection of certain valuable habitats or worthy of conservation. This kind of urban biotope mapping was held in Munich (by Duhme et al., 1983) and the rapid biotope mapping in Düsseldorf (by Witting and Schreiber, 1983). The method of selective biotope mapping presupposes a framework of mapping and criteria for corresponding evaluation (Müller, 1998). Accordingly, a point-scoring system associated with four criteria was used for choosing methodology of developing biotope classification: period of development, areas, rarity and function as habitat (Witting and Shreiber, 1983; Hong et al., 2004). In general, a guideline of biotope classification for urban river areas must be modified with the conditions in developed areas and the special demands of nature conservation in cities (Sukopp and Weiler, 1988).

Besides, Sukopp and Weiler (1988) concluded that the collected data should be used to map at least some of the following features: 1) Areas with rich flora and /or fauna and the occurrence of at least some rare species; 2) Refuges for animal and plant species which have been displaced by intensive land use; 3) Habitats with a high degree of self-regulation; 4) Areas free of polluting emissions; 5) Areas with a high structural diversity; 6) Areas which offer an enriching experience in terms of informal recreation and contact with wildlife for urban citizens (Duhme et al., 1983; Sukopp and Weiler, 1988). In order to determine these features more precisely, they further mentioned that criteria of "rarity of the biotope" and "intensity of land use" should be used. In the end, the distribution maps for individual species or groups of species (e.g. for city-specific species or endangered species) can be displayed for nature conservation (Sukopp and Weiler, 1988; See Figure 2.5).

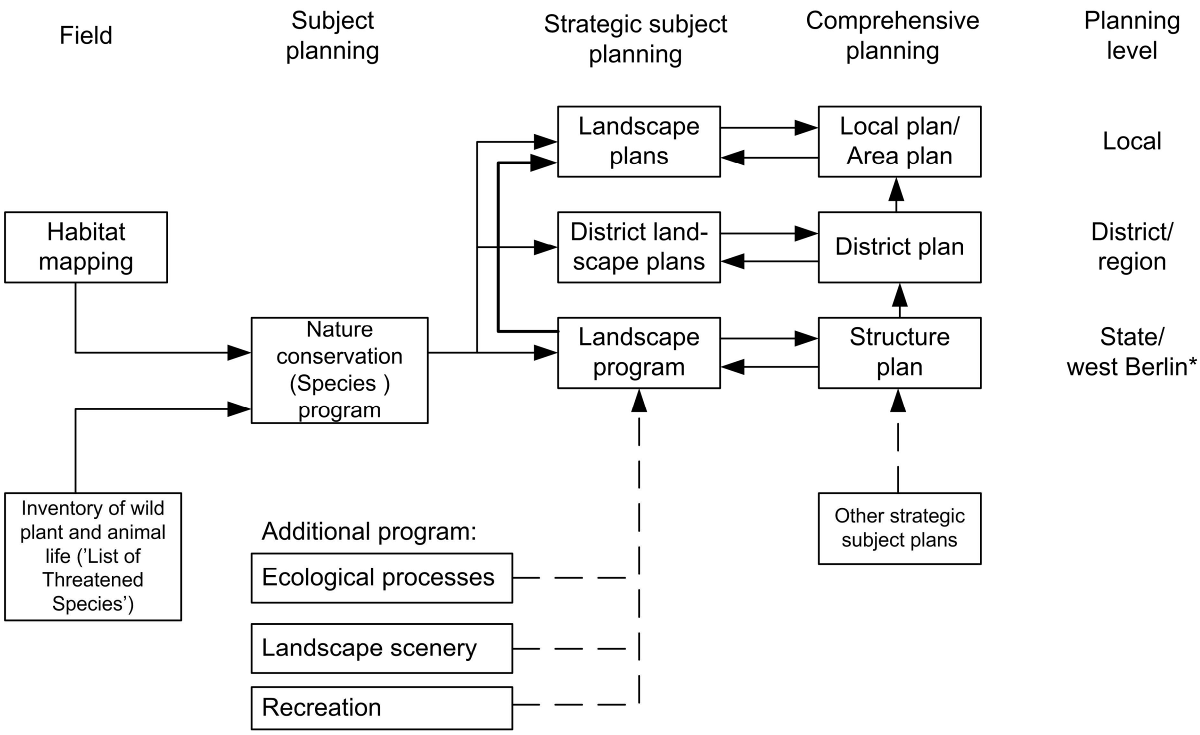


Figure 2.5: Planning system for "Nature Conservation and Landscape Management" (Sukopp and Weiler, 1988) Explanation*: This project was held in the West Berlin before the unity of Germany

Nowadays, more than 200 cities and local municipalities in Germany are using biotope mapping for their urban ecosystem management (Song, 2001; Hong et al., 2005). In general, the biotope mapping serves as a basis for investigation of plants and animals, the results of biotope mapping then contribute to evaluate the nature conservation and environmental protection. These should be conserved as a basis for direct contact between urban dwellers and the natural elements of their surroundings in order to preserve biodiversity and to improve the quality of the environmental media (e.g. air, water and soil) (Müller and Fujiwara, 1998). In other words, the biotope classification benefits such as the certification of environmental changes, the management of nature preservation and the background of impact resilience in planning contexts.

The concept of biotope classification has already applied in planning progress in some Asian counties. The understanding of these cases may help to understand the application in different cultural landscape and different urban developing contexts. Two cases in Japan and Korea are introduced as reference as.

2.2.3 Biotope Classification in Asia

2.2.3.1 Biotope Classification in Japan

In the 1990's, the concepts of urban biotope mapping were brought to Asia. The first project was done during 1996 and 1998 in Tokyo (by Müller). This project was carried out by selective urban biotope mapping and displayed in two study cases in Yokohama city and at Yokohama National University. The study areas were selected for two reasons: 1) Actual data of flora and vegetation already existed for the university campus; and 2) The areas included many different land-use types, which are typical for the agglomeration of Tokyo. For the investigation, a modification of the representative mapping method was used. After the investigation of the land-use types and checking the high-biodiversity areas, an evaluation was done (Müller and Fujiwara, 1998).

In this project, Müller took the actual biological data as basis, such as the detailed data about vegetation which already exist in parts of test areas. The data of land use and high-biodiversity areas were collected by field investigations on the basis of aerial photographs at the scale on 1:4,000. The base maps of the test areas were emerged from the previous studies and the collecting data. Accordingly, Müller evaluated the high-biodiversity areas and provided a priority for nature conservation based on the existing biological data and the results from field work. The targets and application of this pilot study for biotope classification in Yokohama City which can be associated to this study are grouped as follows (Müller and Fujiwara, 1998):

1. Establishment of database: the basic information about biotopes provides the fundamental and useful information for spatial planning (e.g. infrastructure, land use) and green resource management (e.g. landscape planning, green space planning). The results of biotope mapping are best adapted to the different ecological conditions in urban habitats and therefore should be used for environmental planning with consideration of nature conservation. For instance, the traditionally established parks can be expanded by a system of existing high-biodiversity areas, which can be used for non-organised forms of recreation (e.g. walking and viewing in nature). New types

of green spaces can be developed on bare ground by using the natural invasion and succession of wild plants.

2. Suggestion of rehabilitation: it especially refers to the green space management to increase the native flora species and reduce fragmentation of habitats.

3. Legislation for nature conservation: programs for endangered species and fundamental information for developing laws (e.g. for the protection of trees in cities)

4. Bio-indication and ecosystem research: the distribution of vascular plants or animals can be taken as bio-indication and provide database for other studies on urban ecology.

5. Nature education: high-biodiversity areas such as old vacant land and secondary forests can be used for education in schools and also for increasing awareness among adults.

2.2.3.2 Biotope Classification in South Korea

The first project in Korea was held in Seoul in 1999. This case used the concept of comprehensive mapping in Seoul. It was carried out by the city government and executed with a professional advice group from Berlin. In this study, they examined the biotope types in Seoul firstly with the new application of IKONOS and QuickBird satellite remote sensing data (Figure 2.6).

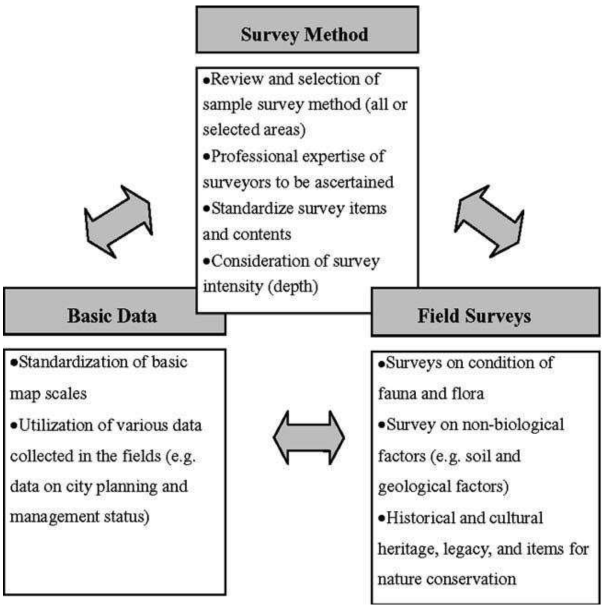


Figure 2.6: Systematic survey processes for biotope mapping (Hong et al., 2005)

This project was developed much more smoothly due to the coherence by the authorities with the annual budgets earmarked for mapping. In addition, the mapping results were also applied into the real spatial planning. There were four important concepts should be mentioned for the further studies through this case (Hong et al., 2005); which are:

1. Standardized the survey method by introducing a uniform standard;

2. Identified the basic category of biotopes; this was taken from outcome of the previous projects;

3. Minimized the differences between the evaluation criteria and the assessment factors;

4. Applied the results of the biotope evaluation to city planning and reflected the results first in the landscape plans.

To compare the methodology of biotope classification among Germany and application in Japan and Korea, the main differences in process and results have been shown in investigating scales and authorities (Table 2.5). The projects in Germany and Korea have been supported by governments, which can be carried out with more detailed database. The colleting information is also related to the targets of evaluation. Accordingly, the pilot study of biotope classification in urban river areas in Taipei has been carried out with information about vegetation types and land use. The main evaluation focuses on the conservation area planning, the maintenance of habitats for bird species and the document and evaluation of habitat condition and landscape structure. More detail will be introduced in Chapter IV.

Table 2.5: Biotope classification in urban areas in Germany, Japan and Korea

Item	Germany	Japan	Korea
Beginning	1978 in west-Berlin	1996 in Tokyo	1999 in Seoul
Spatial survey areas	Comprehensive	Selective study cases	Comprehensive
Scale	1:10,000 or bigger	1:4,000 or bigger	1:5,000 or bigger
Background	CIR-aerial photographs (basically), supplemented by field work	Aerial photographs, supplemented by field work	Terrestrial regional surveys (mainly), supplemented by high quality satellite data
Spatial mapping	Statistical block	Partial developed areas and a university	City block in developed areas
Collective information	Structure characteristics, vegetation characteristics, land use	Vegetation types, land use	Land use, vegetation types
Main evaluation	- regional/overall landscape planning - conservation area planning - intervention rule - environmental compatibility survey	- infrastructure planning - nature conservation - rehabilitation of nature management and land use - green planning	- evaluation of designation of conservation areas - biotope interconnection planning and protection - document and evaluation of 1st condition of nature and landscape in environmental evaluation - evaluation of sustainable land use planning - biotope factors

2.2.4 Products and Applications of Biotope Classification

To summarise the previous processes of biotope classification, a general classification is precondition for comparable mapping results, then a local biotope classification is carried out by on-site mapping. Biotope classification serves an updatable database to show the current condition of study areas, as well as to display the context of environmental changes. The background and mapping results usually apply to the environmental planning. Moreover, the biotope classification presents the key aspects of conservation action and priority management with assessment of biological communities, changes in habitat distribution and extent over time (Connor et al., 2004; more detail in Table 2.6).

Table 2.6: Applications of biotope classification (Modified from Connor et al., 2004)

Aspects of application	**Instances**
Background and database of planning	• to provide a practical system for the consistent description of habitat types • to show the geographical distribution of habitats • to map the extent of habitats • to provide categories for the assessment of the state of biological communities • to indicate the changes in habitat distribution and extent over time, to provide information on quality status, and rate of change in habitat distribution • to identify the protected areas • to present the habitat information at a scale and level of detail
Evaluation and conservation	• to assess the relative importance of particular habitats (i.e. which habitats are rare or of national or regional importance) and the implications of this for priority management and conservation action. Such assessment can lead to the listing of habitats for conservation action (e.g. Red lists) • to enable the nature conservation value of habitats at specific sites to be assessed • to address a variety of biodiversity and management issues

Generally speaking, biotope mapping is a good instrument to serve a basis for assessing the occurrence of various habitat types in order to evaluate the interactions between associated species and the urban landscape (Witting et al., 1993: Niemelä, 1999). It provides comprehensive information about physical, chemical and biological condition as maps and databases for urban environmental planning. The biotope classification in urban river areas is therefore the fundamental requirements for projects of integrated urban river management. The integrated urban river management is then developed t from different perspectives to maintain and enhance the ecosystem functions in cities. The concepts and application of integrated river basin management are then introduced in the next paragraphs.

2.3 Urban River Management

The development of urban river management can be described in some phases. In the 1960s, the main instrument of river management was controlling floods by dams, levees and protecting walls. The flood control works only focused on hazard-based approach to the problems. From the end of 1960s, some scientists started to treat river management with consideration of natural environment; urban ecology was first discussed with river governance. Urban ecology then referred to ecosystem services in the 1990s, urban river management focused on the benefits of nature to human beings, such as flood control, water supply and drainage, waste water treatment. With the development of environmental awareness, the concept of integrated river basin management was progressed in urban planning.

2.3.1 The Concept of Integrated River Basin Management (IRBM)

The spatial paradigms of freshwater ecosystem are currently being debated in an increasingly interdisciplinary research area (Newson and Newson, 2000). Integrated River Basin Management (IRBM) is therefore considered as a comprehensive management approach in Europe and throughout the world over the last years (Evers, 2007), IRBM is an interdisciplinary project in the fields of ecology, hydrology, transportation and landscape planning to simultaneously achieve various preferences of objectives (i.e. society, economics and environment). The beginning of river management focused on the improvement of water quality in the 1950's. In the 1980's, more studies treated river ecosystems and sustainable development as key issues. The emphases were maintenance of biological diversity and rehabilitation of ecological functions. The Rhine 2000 can be taken as an example to represent the development of rehabilitation. Since 1990's, IRBM projects provide a comprehensive vision to manage all relevant risks in a master planning (Schneiderbruber et al., 2004). It is now widely recognised as appropriate approach for delivering sustainable use of limited freshwater resources (Schneiderbruber et al., 2004).

The approach of IRBM in the World Wide Fund for Nature (WWF) refers to the importance of IRBM that "river basins are dynamic over space and time, and any single management intervention has implications for the system as a whole". In addition, each project of IRBM rests on the principle that naturally functioning river basin ecosystems, including accompanying wetland and groundwater systems, are an important source of freshwater on which people everywhere depend, which should also concern with maintaining natural functions as a paramount goal (Schneiderbruber et al., 2004).

Based on the target of maintaining ecosystem functions, the studies by WWF (2004) also denoted that "IRBM is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems." IRBM involves alternative options (e.g. water storage and use, waste water treatment), different states of nature (e.g. climate, soils, hydrology, etc.) to achieve the targets for governing river environments. In other words, the projects of IRBM depend on a multinational cooperation for some important longer rivers (such as the Rhine). In a complicated and dynamic ecosystem as cities, a comprehensive project of urban river management is expected to solve many problems (e.g. flooding prevention, improvement in water pollution, preservation of biodiversity), and also serve strategies for river rehabilitation, water resources development, floodplain management and environment impact analysis. In brief, the main elements of IRBM can be grouped in seven initiatives by WWF (Schneiderbruber et al., 2004):

1. A long-term vision for the river basin, agreed to by all the major stakeholders.

2. Integration of policies, decisions and costs across sectoral interests such as industry, agriculture, urban development, navigation, fisheries management and conservation, including through poverty reduction strategies.

3. Strategic decision-making at the river basin scale, which guides actions at sub-basin or local levels.

4. Effective timing, taking advantage of opportunities as they arise while working within a strategic framework.

5. Active participation by all relevant stakeholders in will-informed and transparent planning and decision-making.

6. Adequate investment by governments, the private sector and civil society organisations in capacity for river basin planning and participation processes.

7. A solid foundation of knowledge of the river basin and the natural and socio-economic forces that influence it.

2.3.2 Possible Design, Issues and Activities of IRBM

The IRBM projects are usually developed to consider some important issues in multiple perspectives (technical, socio-economic and ecological aspects). Some important aspects like water resources development, river and floodplain management and policy analysis are carried out by multi-disciplinary teams. Accordingly, the specialist advices can be listed as “water resources management”, “water supply and demand assessment”, “floodplain management”, “integrated flood control management”, “river master planning and policy development”, “river rehabilitation”, “environmental impact analysis”, as well as “information systems and decision support systems” (WL | Delft Hydraulics, 2001).

As shown in Table 2.7 that all the specialist advices can be combined as an integrated project of river basin management. Besides, each of the sample projects can be one sub-project of an integrated river management, or an independent improvement to solve the existing problems according to the purposes and budget of research. In the last recent decades, water pollution control, ecological rehabilitation and flood risk management of rivers and their floodplains have become important issues for river management (Duel et al., 2003). However, protection of ecological values and landscape quality of rivers is one of the comprehensive topics for river managers and policy makers while making a sustainable water management strategy (Dunn, 2000; Duel et al., 2003). From this viewpoint, the evaluation and determination for measuring the ecological impacts are developed. In this approach, the habitat modelling of rivers should include aquatic habitats, wetland habitats and riparian areas (Duel et al., 2003).

Table 2.7: A sample on specialist advices of IRBM (WL | Delft Hydraulics, 2001)

Specialist advices	Key issue	Key activities
Floodplain management and hydrology	A key issue in sustainable river and floodplain management is matching of divergent uses and functions with the natural capacity of the river system. Besides the primary functions of discharging water and sediment, the most important role involves navigation, the supply of water for drinking and for use in agriculture, industry and hydropower generation, fishing and providing recreational and environmental enjoyment	●floodplain management, ●integrated flood control management, ●river master planning and policy development
River engineering and morphology	The River Engineering and Morphology group is a multi-disciplinary specialist team dedicated to natural water systems, making their use more profitable and limiting their hindrance due to excessive fluctuations in level and flow.	●flood control ●drinking water and industrial water supply ●ecology and environmental control ●irrigation and drainage ●navigation ●hydro power ●fisheries ●recreation
Water quality and ecology	It is carried out based on in-depth knowledge of (bio) chemical and ecological processes combined with detailed knowledge of hydraulic and morphologic processes. With this multi-disciplinary approach, it supports water managers world-wide by analysing their problems, finding solutions, and assessing the effectiveness of proposed solutions.	●strategies for water pollution control in urban water systems ●point and non-point sources of nutrients and contaminants ●water quality in the urban environment (water systems and sewers) ●environmental flow requirements ●eco-hydraulics and bio-geomorphology ●habitat modelling for rivers, tidal (fresh) waters, lakes, reservoirs and wetlands ●environmental and ecological indicator systems
Integrated river basin management	The Integrated River Basin Management group focuses on complex decision-making in river basins. Water resources development, river and flood-plain management and policy analysis projects are carried out by multi-disciplinary teams. Not only the natural systems, but also the related socio-economic and institutional aspects are addressed.	●water resources management studies ●master planning and policy development ●investment planning/feasibility studies ●soil erosion assessment and planning of soil erosion control strategies ●water supply and demand assessment ●water resources system modelling

Table 2.7: Continuance

Specialist advices	Key issue	Key activities
Information and decision support systems	Data base management systems, mathematical models and a user interface are often combined in a Decision Support System (DSS)	●data base development ●design of Decision Support Systems
Integrated river basin management	The Integrated River Basin Management group focuses on complex decision-making in river basins. Water resources development, river and flood-plain management and policy analysis projects are carried out by multi-disciplinary teams. Not only the natural systems, but also the related socio-economic and institutional aspects are addressed.	●water resources management studies ●master planning and policy development ●investment planning/feasibility studies ●soil erosion assessment and planning of soil erosion control strategies ●water supply and demand assessment ●water resources system modelling
Water resources management	The development and sustainable use of water and land resources requires the allocation of these scarce resources among competing human activities. It aims at the generation and evaluation of strategies t meet the management and policy goals in a future situation.	●water resources management studies ●master planning and policy development ●investment planning/feasibility studies ●soil erosion assessment and planning of soil erosion control strategies ●water supply and demand assessment ●water resources system modelling
Regional and urban water management	The Regional and Urban Water Management Group specializes in research and consultancy services for water management on relatively small scale areas following a different approach. By applying an integral, "across the border" looks at urban and rural (both on polder and on regional scales) problems, solutions are offered that are acceptable to the wide range of water users involved. The results offer practical, tailor-made solutions in which ample consideration is given to (long term) sustainable water management.	●Analysis of regional water systems ●Urban water management ●Overland flooding Policy analysis ●Data management ●Development of information systems
Environmental impact analysis	An environmental impact assessment, EIA provides designers and decision makers with information on the environmental feasibility of a project	●environment impact assessment, ●river and floodplain ecology and rehabilitation

Based on the theories of urban ecology and river management, the concepts of integrated river management are apparent to contribute to the design of the integrated urban river management (IURBM), which should concern the healthy and the productive ability of habitats in cities. IURBM is a science of management, not invariably attempted “controlling” the rivers. Furthermore, floodplains are diverse landscapes where various requirements should be observed. Fresh water and the riparian areas are extremely important to display the rich ecosystems with a huge variety of species and functionalities (Evers, 2007).

However, the natural habitats of river basins are extremely influenced by human activities and urban development. Some impacts, like declines in water quantity and degradation of water quality, are the common problems while developing a project of urban river management. An investigation of cause-effect relationships in urban river areas may help to measure the pressure (disturbances from natural environment and impacts from human beings) and state (quality of vulnerability) of habitats, then making responses to the integrated urban river management (strategies). This concept also contributes to assess the stream ecosystems and benefit ecological services to societal economics. Accordingly, DPSIR (Driving Forces-Pressures-State-Impacts-Responses) is often used as an instrument to determine the problems and impacts on urban rivers and then react to the dynamic and complex urban environment with its uncertain sources of disturbances.

2.4 DPSIR Framework

2.4.1 Background of DPSIR Framework

The DPSIR framework is an extended version of the well-known PSR (Pressure – State – Response Framework) framework by OECD (1993) used to comprehensively assess and manage environmental problems (WL | Delft Hydraulics, 2001; EEA, 2003). The European Environmental Agency (1999) developed this model as a standard of environmental indicators in pan-European areas (Figure 2.7). “Driving forces” are usually the socio-economic and socio-cultural forces driving human activities, which increase or mitigate pressures on the environment. “Pressures” are the stresses that human activities place on the environment. “State” shows the condition of the environment changes, and then displays the effects of environmental degradation as “impact” on ecosystems. “Response” refers to the responses by society to the environmental situation through preventive, adaptive or curative solutions (GIWA, 2001; EEA, 2002; Jago-on, et al., 2009).

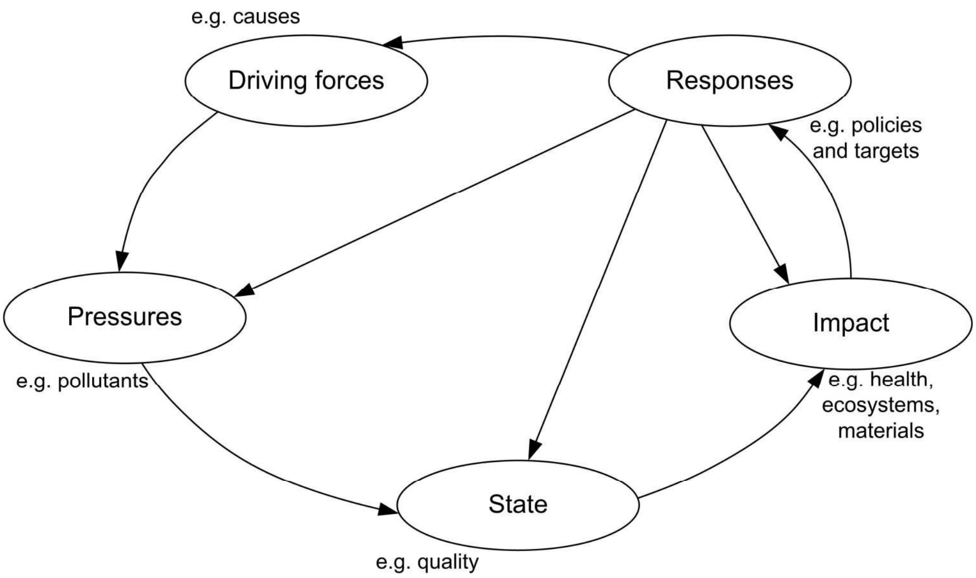


Figure 2.7: The DPSIR framework for reporting on environmental issues by EEA (EEA, 2003)

The previous simple model of DPSIR is introduced as PSR framework, which displays the driving forces in the description of pressure, and represents the impacts with the state of environment. PSR framework was developed by the Organisation of Economic Cooperation and Development (OECD) in the late 1980's for environmental indicator development of monitoring environmental performance. The PSR framework was used for the development of a preliminary set of environmental indicators in 1991 (Bell, 2000). It is a reporting tool now to describe a dynamic situation with attention for the various feedbacks in the system (EEA, 2003), and to lay out the basic relationship among ecological, social and economical environment. The PSR framework shows the pressures that human society put on the environment, and then presents the state of the environment (the result of human activities) and also displays the directions of soothing or preventing the negative impacts from the pressures (Figure 2.8). In relation to policy-making, the PSR framework has been used to develop environmental indicators or modified to show the environmental problems and their causes, in order to develop the policy responses and priority setting on environmental policies (EEA, 2003).

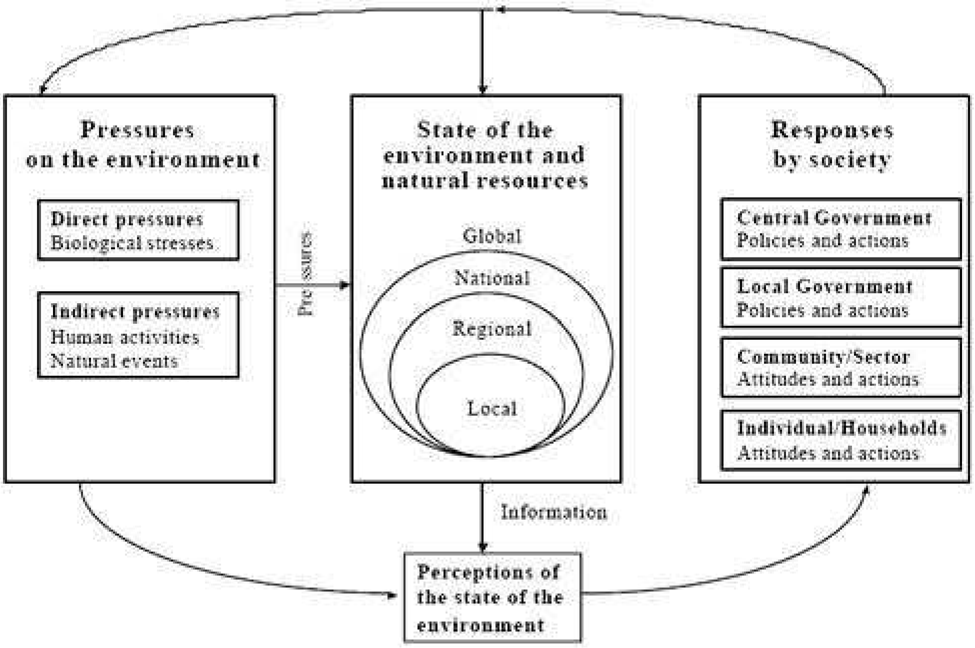


Figure2.8: The OECD Pressure-State-Response Framework (Bell, 2000)

Urban river ecosystem is dynamic and uncertain. Thus, it is practical to analyze the background and establish the targets in projects of urban river management by PSR framework, since the driving forces and the pressure on the environment are not easy to distinguish clearly from each other, also because the impacts on ecosystem can be described with the changes of state. Although the concept of the PSR framework can not show every problem in detail, it can highlight the interactions between human beings and natural environment, which have appeared on the problems and possible responses in complicated urban environment. This concept is flexible to perform the changes and trends of cities as well. Therefore, this study took the PSR framework to simulate the phenomena and problems in the study areas, the research questions and targets are accordingly carried out. The definition and process of the PSR model are shown as following paragraphs.

2.4.2 Pressure

The “pressure” is derived from the human activities, which are social-economic pressures on variety of environment to manifest in changes in its quality and quantity of natural resources (Shah, 2000). The pressure comprises two parts: proximate pressure (directly stress on the environment, which are normally expressed in terms of emissions or consumption of natural resources) and indirect pressure (background reflecting human activities which lead to proximate environmental pressures) (Bell, 2000).

The pressure is often used as a substitute for the measurement of environmental conditions. The factors are shown in accordance with the reasons which influence the environmental condition strongly, like population growth, consumption or poverty.

2.4.3 State

Due to the pressure on environment, the state of the environment changes (EEA, 2003), so the “state” is related to the quality of environment and the quality and quantity of natural resources (Bell, 2000). It presents the conditions and situations of physical phenomena (e.g. temperature), biological phenomena (e.g. bird population) and chemical phenomena (e.g. CO_2-concentration) (EEA, 2003), which result from the pressures and change with the time (e.g. depletion of natural resources, decrease in biodiversity and degradation of environmental quality). Therefore, the state shows the impact of pressures on ecosystem and human health, and what improvement should the planner/government do for the environment with amending laws or policies. However, this part is difficult to show because of the ambiguous performance and measurement of environmental conditions. Some conditions are even more difficult or costly to be measured as usable data. Hence, the impacts on environmental functions (e.g. ecosystem functions, resources availability, biodiversity) help to describe the changes of state.

In the work of the Group on the State of the Environment, four major categories of use are present: 1) measurement of environmental performance; 2) integration of environmental concerns in sector policies; 3) integration of environmental and economic decision-making more generally (e.g. through environmental accounting; 4) reporting on the state of the environment (OECD, 1993).

2.4.4 Response

The "response" normally means only for the societal response (not ecosystem) (EEA, 2003). It shows the responding to environmental changes, concerns by degree, refers to actions to mitigate and adapts to prevent negative impacts by human activities on the environment and to halt or reverse environmental damage already inflicted. The driving forces behind these changes are considered to be a combination of political decisions, technical and economical development (Ihse and Lewan, 1986; Cousins and Ihse, 1998). The response displays the actions taken for the preservation or conservation of the environment and natural resources.

Pintér et al. (2000) argued that the targets of Response include: 1) to be designed to ease or prevent negative environmental impacts, 2) to correct the existing damage and 3) to conserve natural resources (Pintér et al., 2000). The so-call responses can appear in forms like regulatory actions, environmental expenditures, studies, public opinions, consumer preferences, the following changes in management strategies and the provision of environmental information. Therefore, the Response redesigns the performance of pressure and impact as well as the environmental state. It will achieve long-term goals or short-term benefits due to different implementation.

2.4.5 Application of PSR Framework

Generally speaking, the PSR framework represents the environmental policy cycle that includes problem perception, policy formulation, monitoring and policy evaluation (Shah, 2000). The application of PSR framework involves a great deal of information gathering for indicators to reflect the cause-effect relationships between human activities and environmental consequences and the responses to environmental changes (Jago-On et al., 2009). While the PSR framework has the advantage of highlighting these links, it tends to suggest linear relationships in the interaction between human activities and environment. The PSR Framework is therefore the most effective model developed so far for reporting on the condition of the environment (Bell, 2000). For instance, the Environment Australia amended the PSR model to report the state and interactions in the dynamic environment and showed the modified model as Table 2.8 and Figure 2.9.

Table 2.8: The possible application of the PSR framework (Environment Australia, 1997; Bell, 2000; Jago-On et al., 2009).

PSR framework	Pressures	States	Responses
Application	Pressures are defined as human induced; Inappropriate human responses to natural conditions (e.g. variability and natural hazards such as droughts) are also pressures; Lack of action can be a pressure.	Natural conditions are primarily states (e.g. soil salinity, climate variability, soil nutrients, topography and natural hazards); States reflect pressure and the effectiveness of responses.	Responses can be aimed at both pressures and states; Appropriate responses reduce pressures.

Yencken (1996) further reviewed the PSR model for Environment Australia and concluded its benefits as: 1) this model describes the cyclical or multi-dimensional relationship between pressure, state and response in a better way; 2) this model more effectively links the main components of the PSR model; 3) this model is not only useful in decision making, but also workable, meaningful and as simple as possible to use. The Australian work on state of the environment reporting is appears to be starting to put more emphasis on the responses, or what we can do about the condition of the environment (Anzecc, 1997; Bell, 2000). These ideas can be applied to develop evaluation criteria in this study.

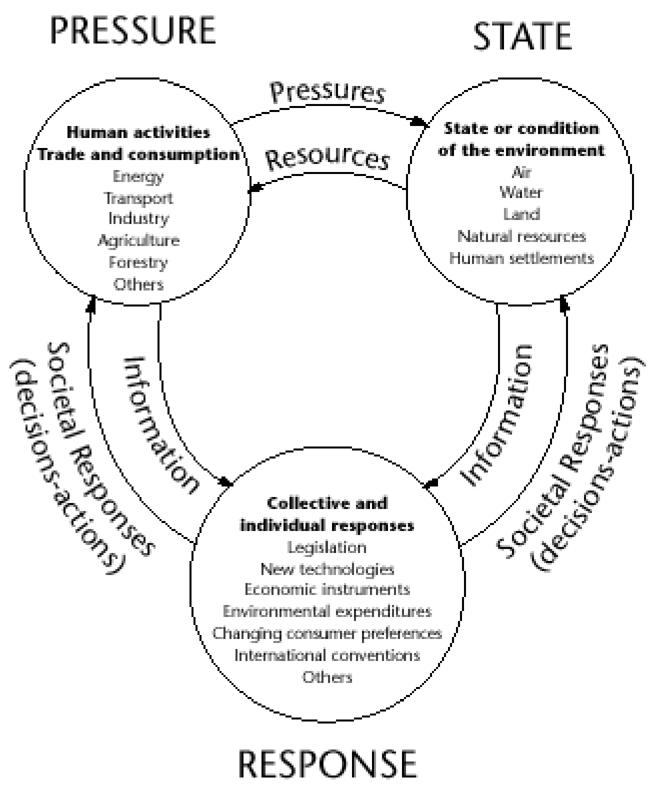


Figure 2.9: The Pressure-State-Response Framework - as adapted for use in Australia (Yencken, 1996; Bell, 2000)

Jago-On et al. (2009) illustrated that the common indicators of pressures include economic, social and demographic changes in societies. The consumption of natural resources exerts alteration in land use. State indicators usually describe the changes in quantity and quality of the physical environment, biological components and chemical concentration, as well as the effects on the social and economic functions of the environment. Response indicators refer to responses in society to prevent the negative consequences, improve the environmental condition, or adapt to changes in the environmental status through policy and legislation (Jago-On, 2009)

Basically, there is no unique framework that generates sets of environmental indicators for every purpose. Also, a framework may change with the time when further scientific understanding on environmental problems and societal values evolving. However, the PSR framework can report on the condition of environment in an understandable way to the lay people and be truly effective in communicating what and why are happening in the environment. In other words, an appropriate set of framework is made for its particular use since different cases have different conditions and different users of environmental indicators have different needs. The application of the PSR framework to this research would be discussed in detail in Section 4.3.2.

2.5 Brief Summary: Problems and Evaluation of Urban River Management

As urban areas have expanded through processes of suburban sprawl, the spatial influence of urbanization has increased (Pickett, S. T.A. et al., 2001). The greatest intensity of causes from urban development on rivers is by land use, population assemblage, transportation expansion, pollution (both of point sources and non-point sources), industrial expansion, and river resource development. All negative feedbacks impact on the ecosystem, and especially sprawl widely by transportation of river corridors. The remarkable changes are showing on habitat structure, hydraulic structure, landscape construction, organism assemblage, ability of self-regulation. The information about the remarkable changes may contribute to show the actual environmental problems and the context of planning.

However, to balance urban expansion and nature conservation is always a challenge for the city planners and decision makers. The multi-problems (e.g. urbanization, impervious surfaces, channelization and storm sewers) and uncertain factors cause frequent flash flooding in the lower regions of the watershed, which especially occur in the raining season. The earlier solution was found in the design and construction of a flooding control channel in the lower reaches. People tried to control the water flow by engineering and change the structures, functions, and direction of river channel, which cause some negative feedbacks, such as “narrow the space of corridors”, “disconnect the habitats”, “change the river structure”, “increase the speed of flow and deposition at the same time”, “decrease the lateral moving of organism” and “reduce the diversity of landscape” (Yang, 2001). The term “urban ecology”, which is one of the main concepts of this study, was therefore defined to design the concepts of urban river management. In theories, urban ecology refers to studies of the distribution and abundance of organisms in and around cities, and on the biogeochemical budgets of urban areas (Sukopp, 1998; Pickett et al., 2001), which refers the pressure and condition of urban river. In praxis of Planning, it has focused on designing the environmental amenities of cities for people, and on reducing environmental impacts of urban regions (Deelstra, 1998; Pickett et al., 2001), which may apply to the concepts of urban river remediation.

Moreover, spatial ecology based on habitat evaluation and conservation through a database of biotope types can serve as a scientific basis for habitat evaluation and conservation of the local fauna and flora in forestry, range management and nature conservation (Hong et al., 2004). Based on the studies of urban river management in above, evaluating the physical and biological condition as habitat functions can help to find the basic solutions for river management, which needs a database of biotope types as fundamental requirement. The PSR framework helps to determine the environmental condition and planning targets for urban river management. Before turning to the methodologies, the background of study areas will be introduced in Chapter III.

3. Background of Study Areas – the Lower Keelung River

The lower Keelung River, which has poor condition as many other urban rivers in mega-cities, has been chosen as investigation areas in this study. The reasons emerged from the location and special biotope types of the lower Keelung River, which provide a potential benefit as habitats for wildlife. This benefit will contribute to the river ecosystem, as well as to the entire urban ecology. The spatial scale of study areas is therefore in relation to the physical boundaries between Taipei City and Taipei County, the confluence of the Keelung River and the Danshui River and embankments on both sides of river basin (Figure 3.1). Based on the background listed in this chapter, the biotope mapping for urban river areas has been carried out according to the broad definition of urban rivers, which refers to the river corridors and the vegetation communities both in the river channel and the both sides of floodplains. The background of study areas is introduced with geographic characteristics, biological features and land-use types as follows.

3.1 General Information

The Keelung River is the longest and biggest tributary of the Danshui River Basin in the north Taiwan. It is also the most important branch of the Danshui River due to its location. The Keelung River rises in Jing-tong Mountain (Height ca. 508 metres) in a rural environment in the Taipei metropolitan and flows into the urban areas from Nanhu Bridge; the so-called downstream goes through the centre of Taipei City[1] into the Danshui River at Guandu (Figure 3.1). The Keelung River has drainage areas of 490.77 km^2 and total length of 86.5 km. The lower reach of Keelung River runs zigzag through the CBD of Taipei City for the length of 24.7 km, the slope goes down to 1:6700 (Table 3.2). The lower stream Keelung River is a typical urban river altered and governed for human demands and city development (e.g. preventing floods, for recreation) over the past few decades, since Taipei City is a highly developed mega-city. Due to the geographic characteristics, flooding occurs in the lower land easily after heavy rainfalls or strong typhoons. Thus, preventing floods is always an important issue in Taipei. However, the opinions on river management in Taipei still focus on building levee system or relative engineering for preventing flooding, which not only destroy the structure of landscape, but also change the urban ecosystem. Besides, the wrong or overloading development on riverbanks of upper stream raises the water pollution and soil erosion. Therefore, the riverine characteristics and floodplain habitats were destroyed or fragmented due to river regulations and the utilisation of floodplains for agriculture and other human activities. The quality of the

[1] Taipei City is the capital of Taiwan, where is located in Taipei Basin in the northern Taiwan. It covers an area of ca. 272 square kilometres and has a population of around 2.6 million (till the end of 2007). The higher population density of 9,674 per square kilometres represents that Taipei City is a highly developed city.

remaining habitats is even deteriorated. For these reason, the Keelung River is gradually losing the functions of transportation, recreation and ecological services over the last years.

Yet the Guandu Wetland (25°07'N, 121°28'E), which is located at the confluence of the Keelung River and the Danshui River, serves assets as habitats for bird species (at a distance from estuary of about 10 kilometres) (green circle in Figure 3.1). It is one of the important hot spot of migrant birds in the world, great quantities of migrant birds come from Siberia, north China, Korea and Japan for rest and recovering in winter a route to south-east Asia, Australasia and South Pacific, or overwinter at this site from September to May on their return. It is not only an important stopover for migratory birds, but also maintains and upgrades the ecosystem of the Keelung River. It is therefore a popular place of bird watching in Taiwan. About 300 bird species have been recorded at this place. The BirdLife International listed Guandu as one of the Important Bird Area (IBA) in Taiwan in the year of 2001 (Code: Kuantu, TW003) (Lin, 2009).

Table 3.1 shows the general information about Keelung River with both natural and cultural environment. More details of study areas are listed with themes of physical, chemical and biological characteristics and land-use types in the next sections.

Table 3.1: Natural and cultural environment along the Keelung River

Characteristic \ Section		**Upper stream** Hotungjiesho Bridge – Dahua Bridge (Pingxi – Rifang)	**Middle stream** Dahua Bridge – Nanhu Bridge (Rifang – Nangang)	**Lower stream** Nanhu Bridge – confluence (Nangang – Guandu)
Natural	Main topography	valley, gorge	river terrace	alluvial plain
	Geology	rock, pebble, pot hole	rock, pot hole, sand and gravel	sand and gravel, peat
	Vegetation	variety	monotony or no vegetation	man-made greensward, simplex and monotony
	Natural vegetation cover	high	low	Low (Middle at confluence)
	Current	shallow flow, rapid, torrent flow	rapid, slowly flow	tidal whirling, slowly flow, still flow
Cultural	Transportation	low	middle	high
	Urbanization	low	middle	high
	Industries of neighbourhood	recreation, agriculture	industry	commerce, industry and entertainment
	Water control works	water intake point	water intake point, reservoir	pumping station
	Flood control works	concrete revetment	concrete embankment	preventing wall, concrete revetment, concrete embankment
				Study area

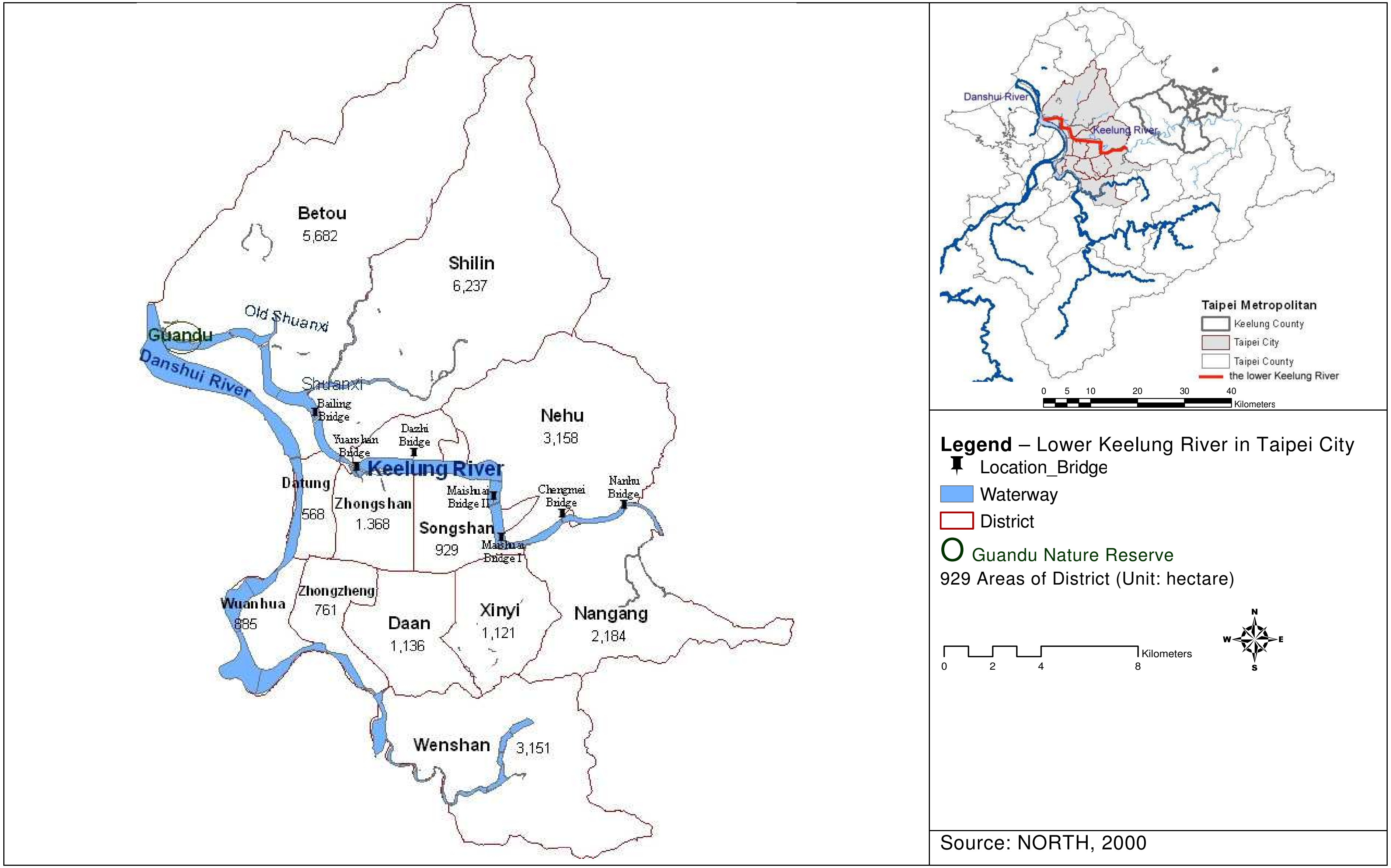


Figure 3.1: Study Scope: location of the lower Keelung River

3.2 Geography, Topography and Soil

Landscape is usually varied depending on different composition of elements. The waterscape is especially shaped by different terrestrial and aquatic geographic-characteristics. Table 3.2 shows the basic geographic characteristics in different reaches of the Keelung River. The geologic characteristic of the upper Keelung River is “Shihti Formation” which included “Sandstone”, “Siltstone”, and “Shale” (Soil and Water Conservation Bureau of Taiwan, 1986; Lin, 2002). The flowing direction follows the geological structure, thus the upper stream is typical rift valley. Moreover, the rapid river flow brings waterfalls, river terraces and pot holes (Wang, 1994). The geology in the middle stream became winding, due to the epeirogeny and the faults formed in the Miocene epoch and the Oligocene epoch. Hence, there are rich resources of coal mine; the mining was the main industry in 19th century and the beginning of 20th century in the areas of middle Keelung River (Chen, 1997; Lin, 2002). The main geographic structures in this section are meander and river terraces, people developed industries and villages on the terraces (Wang, 1994). The flat downstream terrain is shown with characteristics of meander, alluvial plain and estuary wetland.

Table 3.2: Geographic characteristics of the Keelung River (Wang, 1994; Lin, 2002)

Section	**upper - wild brook**	**middle - river valley**	**lower - alluvial plain**
	Hotungjiesho Bridge – Dahua Bridge (Pingxi – Rifang)	Dahua Bridge – Nanhu Bridge (Rifang – Nangang)	Nanhu Bridge – confluence (Nangang – Guandu)
Slope	1:250	1:4,900	1:6,700
Geographic characteristics	River terraces, pot holes, waterfalls, river valley	Digging meander (concave bank), broad meander (convex bank), pot holes, river valley	Meander, alluvial plain, estuary wetland (Guandu)
			Study area

The main soil type of the Keelung Basin is “young yellow earth” (fertile soil) (Soil and Water Conservation Bureau, Council of Agriculture, 1986; Lin, 2002), which displays different types from other reaches, for example “lithosol” in the upper section, “red soil” and “yellow soil” in the middle section (acid, infertile soil types) and certain of “yellow soil” around Nangang and Nehu in the lower section. Down to Nangang, an alluvial plain silted up with mud, sand and gravel lies along the river (Lin, 2002). Moreover, there are some volcanic areas and rapid hills where landslides often occur around the Taipei Basin. If it is defective in Soil and Water Conservation Engineering, soil erosion usually occurs after heavy rainfalls or earthquakes. The sandstone washed into streamway would result in two main problems: water pollution and silting up in the lower stream. Moreover, the ratio of impermeable layer of riverbank is becoming higher since the man-made constructions raise the speed of ground surface runoff, and reduce the natural vegetation cover. For that matter, the soil erosion on riverbanks is becoming worse after heavy precipitation.

3.3 Climate

Taipei City is located in subtropical zone in western Pacific Ocean (Central Position: 121°33’20”E, 25°05’14”N). The weather is typical island climate varied by seasons, also affected by the geological condition. It blows north-easterly wind in winter and southwest wind in summer. It rains all the year round, but the main rainy season is from May to October (Table 3.3). The plum rain brings fine rainfall instead of heavy rainfall around May and sometimes lasts for a long period. The southwest monsoon usually brings showers in summer. Moreover, howling wind and torrential rainfall comes with typhoons bringing rainfall intensity more than 40 mm/hour. The continental cold air-mass comes from northeast and brings orographic rainfall in winter. However, it rains little in winter since 2002 because of global climate change.

Table 3.3: The average of rainfall in Taipei City (measuring station No.: 692) (Central Weather Bureau, Taiwan)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Sum	11-4	5-10
Rainfall (mm)	99.1	109.1	180.9	148.3	221.7	291.5	217.3	326.1	489.3	132.2	70.4	75.2	2361	683	1678
%	4.2	4.6	7.7	6.3	9.4	12.3	9.2	13.8	20.7	5.6	3.0	3.2	100	28.9	71.1

Explain: The average of rainfall was ca. 1910.7 till 2002; it was becoming lower due to climate change.

A flooding disaster often caused by a short-deferred torrential precipitation or a long-deferred rainfall with Typhoons. The former happens, has high rainfall intensity in a small area during a short time, suddenly bring water-flow out of puddles in some areas due to poor drainage. In this case, the river level would not rise suddenly. Comparing with short-deferred torrential precipitation, a typhoon comes from high seas and brings heavy strong rainfall far beyond the carry capacity of river basin; especially the influence of a typhoon would usually last for a few days and overflow the river basin. No matter a torrential rainfall or a typhoon, each of them could be a heavy loading for a short river in a mega-city. Therefore, preventing floods is a big issue for urban planning and river management in Taipei City (Lin et al., 2000).

As mentioned above, flooding caused by torrential precipitation in the typhoon season is the problem in Taipei City. The government adopted many strategies of preventing floods and river regulation in the past decades. The information about regional climate helps to understand the disturbance as well as to adapt to the simulation of river management and rehabilitation of natural habitats. Table 3.4 shows the weather information based on the data of Central Weather Bureau (till 2007). The annual average of rainfall is 2,361 mm, the highest rainfall is in September (489.3 mm, Table 3.3) and the lowest is in November (70.4 mm). The average of Temperature is about 23.3℃, the warmest month is July at 29.9℃, and the lowest temperature is around 16.4℃ in January. The relative humidity is between 73% and 79%.

Table 3.4: Analysis of climate in Taipei City (measuring station No.: 692) (Central Weather Bureau, Taiwan)

	Rainfall	**Rainy day**	**Temperature**	**Relative humidity**	**Highest Temperature**	**Lowest Temperature**
month	mm	day	℃	%	℃	℃
January	99.1	13	16.4	78	26.1	9.1
February	109.1	11	17.5	79	28.1	11.0
March	180.9	15	18.7	78	29.9	11.2
April	148.3	14	22.5	77	32.8	15.2
May	221.7	14	25.7	78	35.0	19.4
June	291.5	15	27.9	77	36.0	21.8
July	217.3	12	29.9	73	37.0	24.7
August	326.1	14	29.6	74	36.8	24.6
September	489.3	15	27.5	77	34.7	23.0
October	132.2	12	24.6	74	32.5	19.5
November	70.4	12	21.7	75	30.4	15.6
December	75.2	11	18.3	76	26.9	11.8
Average	196.8	159	23.3	76	32.1	17.3
Period	1971-2007	1971-2007	1971-2007	1971-2007	1971-2007	1971-2007

3.4 Hydrology and Water Quality

Water quality and water quantity are two important issues to discuss the hydrology of the Keelung River. The average discharge of the Keelung River is about 8.9 million tons, the river flows were influenced by tide and climate. Although the average width of the Keelung River is 180 metres, and the widest section is nearby Bailin Bridge of ca. 500 metres wide; the narrowest channel is from Nanhu Bridge to Dazhi Bridge (breadth is around 80 metres), this section is located in the urban areas, flooding seems to be a serious problem in its neighbourhoods. Pang (1999) represented that the most sections of the lower Keelung River are 4th-order stream, and it is 5th-oder stream section after converging Shuangxi down to the influx into the Danshui River.

The water quality of the Keelung River is usually heavy-polluted in the most sections. The main pollution sources are from drains from housing (ca. 91.3%), pasture drainage and agriculture irrigation. The residents in early days had no sense of environmental protection. They took the river as an open tank for discharging. The riverbanks seemed to be a free waste yard. In addition, the disordered urban development in the middle and upper stream, all result in the water pollution and impacts on cultural landscape. It shows the worst water quality in all branches of the Danshui Basin. The heavy-polluted sections are in the length more than 20 kilometres (around 24 % of the whole Keelung River, and more than 4% of entire Danshui Basin) (EPA, 2007). The statistics from Taiwanese Environment Protection Administration (EPA) showed that the water quality in the upper stream Keelung

River is non-polluted (RPI<2, RPI: River Pollution Index), in middle reach is medium-polluted (3<RPI<6) and heavy-polluted in the lower section (EPA, 2007, Table 3.5).

Table 3.5: Water quality in lower stream the Keelung River (till 2007, Environmental Protection Data in Taiwan and Environmental Protection Administration)

Station	Guandu Bridge (1003)	Bailin Bridge (1012)	Zhongshan Bridge (1280)	Dazhi Bridge (1011)	Minquan Bridge (1010)	Chengmei Bridge (1270)	Nanhu Bridge (1269)
Distance from estuary (km)	6.95	13.91	16.29	20.19	23.48	25.54	29.26
Ave. of DO	1.86	1.39	1.62	2.60	2.98	3.54	4.03
Ave. of BOD_5	4.02	11.90	11.37	10.82	6.08	8.45	5.98
Ave. of SS	41.29	50.98	52.63	62.25	77.70	61.21	64.46
Ave. of NH_3-N	3.74	4.55	4.42	4.23	3.93	3.14	3.25
Ave. of pH	7.3	7.1	7.1	7.2	7.3	7.3	7.7
RPI	**5.5**	**8**	**8**	**7**	**7**	**7**	**7**
state	Medium-polluted	Heavy-polluted	Heavy-polluted	Heavy-polluted	Heavy-polluted	Heavy-polluted	Heavy-polluted

According to the states of climate and hydrology, the ratio of rainfall directly reflects the flow rate of the Keelung River. In other words, the river level is much higher in the rainy season. The discharge in raining seasons is greatly different from that in dry period. The levee systems have been gradually built along the rivers in order to reduce the flooding water caused by the heavy rainfall. The causes of floods can be concluded from some dimensions as follows (Lin et al., 2001):

A. The over-flat lower stream: the landscape in the upper Keelung River is cliffy (slope by 1:250). The river is relatively short and rapidly flows into the lower section (slope by 1:5000) which results in some serious problems such as flood water and soil erosion when the torrential rainfall washes out the channel.

B. Sand and gravel extraction from the riverbank: sand and gravel are extracted from the riverbank as architectural materials in the section between Songshan and Nehu. The over-extraction cases the unstable channel structure.

C. Meanders: the Keelung River runs zigzag from Badu down to the confluence. The flow speed is quite slow in this section; thus the water way cannot quickly drain the water away after torrent.

D. Channelization: the lower Keelung River has been altered for irrigation and preventing floods. The straightened river channel changes the landscape structure and ecosystem along the river. (detail shown in Section 3.7).

E. Sand sediment: in the middle stream, lots of trash and waste soil are discarded on riverbank. Moreover, a wrong development appears in the neighbourhoods, many buildings located on the unstable riverbank procure the worse situation. The soil erosion causes by heavy rainfall that silt up in the downstream.

Yang (2001) argued that the reflection of urban development has “Time-Delay” that appears the effects later on. For instance, the towns near the Keelung River were developed in the 1980's. However, the negative feedbacks appeared obviously in the 1990's. Consequently, the original rural landscape and land use were designed as middle-scale cities. This research supposed that the original impacts were still under the threshold of carry capacity, thus the river ecosystem is not resilient d e to the progressively continuing impacts.

3.5 Vegetation Structure in the lower Keelung River

The vegetation along the Keelung River includes 34 families, 60 genera, and 106 species as listed in Table 3.6. The vegetation structure in the upper streams is different in different sections (Lin, 2002). The diversity of plant species and structure represent better in the upper and middle stream. The urban section covers mostly the man-made construction and lacks for native plant species. The condition of vegetation cover is dull, which often replanted after floods. Although the confluence of the Keelung River and the Danshui River (Guandu Wetland) serves relatively natural condition than the other sections, the poor vegetation cover still seems to be an important perspective to change the structure of vegetation and food-chain.

Table 3.6: Vegetation types of the Keelung River (Lin, 2002; http://databook.fhk.gov.tw/plant)

Section	**Upper stream**	**Middle stream**	**Lower stream**	**confluence**
	Hotungjiesho Bridge – Dahua Bridge (Pingxi – Rifang)	Dahua Bridge – Nanhu Bridge (Rifang – Nangang)	Nanhu Bridge – confluence (Nangang – Guandu)	Guandu wetland
Woody plants	*Machilus zuihoensis, Machilus thunbergii, Ficus fistulosa Reinw. Ex Blume, Machilus japonica Sieb., Smilax china L., Mallotus japonicus, etc.*	*Ricinus communis L., Acacia confusa Merr., Machilus thunbergii, Lagerstroemia subcostata Koehne, Ficus septica Burm. F., etc.*	*Ficus septica Burm. F.*	*Hibiscus tiliaceus L., Kandelia candel.*
Herb	*Paspalum conjugatum, Formosan Raspberry, Miscanthus floridulus, etc.*	*Miscanthus floridulus, Hedychium coronarium, Ipomoea cairica (L.) Sweet, Stephania cephalantha Hay.*	*Bidens pilosa L. var. minor, Wedelia chinensis, Brachiaria mutica (Forsk.) Stapf, Commelina auriculata Blume, Lycianthes biflora (Lour) Bitter., etc.*	*Paspalum distichum L., Phragmites communis (L.)Trin., Cyperus malaccensis Lam, Typha angustifolia L., Miscanthus floridulus*
Fern	*Alsophila spinulosa, Microlepia strigosa (Thunb.) Presl, Asplenium antiquum Makino, Miscanthus floridulus*	*Alsophila spinulosa, Blechnum orientale L., Cyperus pilosus Vahl., Humulus japonicus, Phyllanthus urinaria L., Pennisetum purpureum*		
Aquatic vegeta-tion		*Eichhornia crassipes, Potamogeton malaianus Miq., Hydrilla verticillata*	*Eichhornia crassipes, Potamogeton malaianus Miq., Hydrilla verticillata*	

*Detail in Annex A — **Study areas** (Lower stream and confluence)

The poor vegetation cover along the lower Keelung River was caused by water pollution, the constructions on riverbanks and the straightening works. That is, the diversity of fauna and flora obviously decreases due to urbanization and channelization between the middle stream and the confluence. The human activities and the straightening works also changed the habitats and reduced the biodiversity of the Keelung River. Pang (1998, 1999) referred to the biological status in the lower the Keelung River contrasting with before and after the engineering works (Table 3.7).

Table 3.7: Main species in the lower Keelung River* (Lin, 2001; Huang, 2001; Chen, 2004)

		Before straightening works	**After straightening works**
Vegetation		Alternanthera philoxeroides, Ludwigia epilobioides Maxim., Polygonum sagittatum L., Potamogeton crispus L., Potamogeton malaianus Miq., Hydrilla verticillata	Miscanthus floridulus (Labill.) Warb. ex Schum. & Lauterb., Bidens pilosa L. var. minor, Oxalis corniculata L., Humulus scandens (Lour.) Merr., artificial greensward
Fauna	Birds	Ixobrychus cinnamomeus, *Chrysolophus pictures,* Hirundo tahitica, *Milvus migrans,* Egretta garzetta, Nycticorax nycticorax, Gallinula chloropus, Amaurornis phoenicurus, Casmerodius albus, Ardea cinerea, Charadrius dubius, Anas crecca, Larus ridibundus, Tringa hypoleucos, Motacilla cinerea, Motacilla flava, *Shorebirds, Egretta garzetta,* Family *Laridae,* Family *Anatidae,* Family *Motacillidae*	Ixobrychus cinnamomeus, Hirundo tahitica, *Milvus migrans,* Egretta garzetta, Nycticorax nycticorax, Gallinula chloropus, Amaurornis phoenicurus, *Podiceps ruficollis philippensis,* Hirundo rustica, Passer montanus, Zosterops japonicus, Pycnonotus sinensis
	Fish	Channa sp, Megalops cyrpinoides, Liza macrolepsis, Scatophagus argus, Terapon jarbua, Chenos chanos, Lates angustifrons, Ambassis urotaenia Bleeker, *Eleotris fusca*	Channa sp, Arius thalassinus, Megalops cyrpinoides, Niloticus mouthbrooder, Tilapia mossambica, Tilapia spp, Tilapia zillii, Liza macrolepsis, Mugil tade, *Liza carinata,* Clarias fuscus, Gambusia affinis, Periophthalmus cantonensis

* More information about the fauna and flora is shown in Section 3.6

3.6 Biological Features in the lower Keelung River

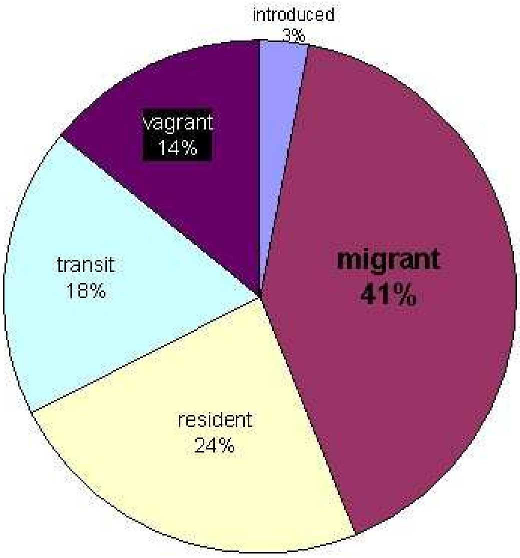
The species in river areas may be divided into four types according to the location of habitats: **surface water species** (e.g. Zooplankton, phytoplankton, *Gambusia affinis*), **sub-base species** (e.g. *Seriola quinqueradiata*), **base species** (e.g. algae, spiral shells, shellfish, loach, etc.) and **riparian species** (e.g. riparian vegetation) (Wang, 1999). The recent studies refer to the lack of fishes in the lower Keelung River due to water pollution. Only very small quantity of fish species can survive in the muddy water (e.g. *Tilapia* and *Megalops cyrpinoides*) in the lower Keelung River (Wang, 1993; Lin, et al., 2000). Some fishes are used as target species for bio-monitoring of water quality. Table 3.8 shows the main biological features with bird species and fish species along the Keelung River. The great biodiversity of the Keelung River displays on bird species that especially appears at the river confluence “Guandu Wetland”. Around 300 types of bird species have been recorded in Guandu Wetland. It is an important stopover for migrant birds, thus this place is one of the Important Bird Area (IBA) of BirdLife International.

Table 3.8: Fauna of the Keelung River (Lin, 2002)

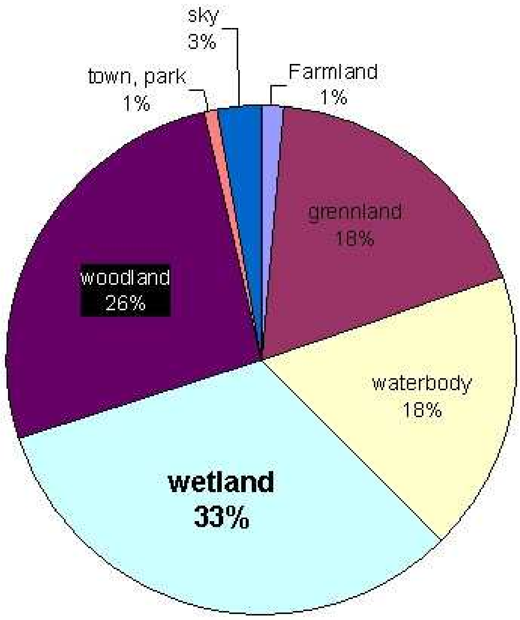
Section	**Upper stream**	**Middle stream**	**Lower stream**	**confluence**
	Hotungjiesho Bridge – Dahua Bridge (Pingxi – Rifang)	Dahua Bridge – Nanhu Bridge (Rifang – Nangang)	Nanhu Bridge – confluence (Nangang – Guandu)	Guandu wetland
Birds	_Myiophonus insularis, Alcedo atthis, Egretta garzetta, Butorides striatus, Spilornis cheela, Urocissa caerulea, Rhyacornis fuliginosus, Motacilla cinerea, Dendrocitta formosae, Hypsipetes leucocephalus, Pomatorhinus ruficollis, Dicrurus macrocercus_	_Alcedo atthis, Motacilla alba_*, _Motacilla cinerea,_* _Egretta garzetta, Butorides striatus, Spilornis cheela, Milvus migrans_, _Pycnonotus sinensis, Megalaima oorti_	_Ixobrychus cinnamomeus, Gallinula chloropus, Amaurornis phoenicurus, Egretta garzetta, Hirundo tahitica, Anas crecca, Phasianus colchicus, Larus ridibundus, Milvus migrans, Podiceps ruficollis, Nycticorax nycticorax, Hirundo rustica_*, _Passer montanus, Zosterops japonicus, Pycnonotus sinensis_	**Raptor** **Family _Ardeidae_** **Family _Phalaropodidae_** **Family _Charadriidae_** **Family _Anatidae_** **Family _Hirundinidae_** **Family _Sylviidae_** **Family _Rallidae_** **Family _Motacillidae_** **Others**: _Ciconia ciconia_*, etc.
Fishes	_Rhinogobius brunneus, Crossostoma lacustre,_ Acrossocheilus paradoxus, _Zacco pachycephalus, Zacco platypus,_ Zacco temmincki, _Microphysogobio brevirostris, Varicorhinus barbatulus,_ Pseudorasbora parva, _Cobitis taenia, Crossostoma,_ etc.	_Rhinogobius brunneus, Zacco pachycephalus, Zacco platypus,_ Zacco temmincki, _Microphysogobio brevirostris, Acrossocheilus paradoxus_, _Carassius auratus auratus, Varicorhinus barbatulus, Hemibarbus labeo, Pseudorasbora parva, Misgurnus anguillicaudatus, Cobitis taenia,_ etc.	_Channa sp., Pangasius sutchi, Megalops cyprinoides, Oreochromis niloticus niloticus, Oreochromis mossambicus, Oreochromis sp, Tilapia zillii, Liza macrolepsis, Mugil tade, Liza carinata, Clarias fuscus, Gambusia affinis, Misgurnus anguillicaudatus, Periophthalmus cantonensis_	_Boleophthalmus chinensis, Periophthalmus cantonensis, Megalops cyprinoides,_ Elops hawaiensis, _Chanos chanos, Liza affinis, Liza macrolepsis_, _Mugil cephalus, Valamugil formosae_, _Terapon jarbua, Acanthopagrus schlegeli, Pangasius sutchi, Liza macrolepsis, Mugil tade_, etc.

Explaination: * means migrant bird; Endemic Species Research Institute, http://www.tesri.gov.tw; Digital Museum of Zoology, National Taiwan University: http://archive.zo.ntu.edu.tw/index1.htm; The fish Database of Taiwan, http://fishdb.sinica.edu.tw/ Detail in Annex A

Moreover, the bird species in this database can be grouped into categories of "migrant", "resident", "vagrant", "transit" and "introduced" according to the database by Digital Museum of Zoology, National Taiwan University and the observation by the volunteers of Wild Bird Society of Taipei (WBST) (Figure 3.2, Detail in Annex B, Part B). The results are displayed as presence-absence maps on grids of 2 km * 2 km. Such maps become particularly valuable if there are opportunities to relate species impacts to the key environmental variables. The degree of explanation can apply to the geodata-based assessment. Furthermore, the main habitats of bird species in the urban section of Keelung River, Figure 3.3 displays the ratio of main habitats in wetland (33%), woodland (26%, included the shrubbery), greenland and water bodies (each 18%). The relationship between the bird species and their habitat may further discuss in Chapter VI.



a. proportion of bird habitual behaviour



b. main habitats of bird species

Figure 3.2: Proportion of bird habitual behaviour (a.) and main habitats of bird species (b.) in the lower Keelung River

3.7 Land use (Based on Urban Planning)

3.7.1 Riparian Areas of the lower Keelung River

The Keelung River has ever played an important role in transportation, irrigation and recreation far back in the past. The aborigines lived on floodplains along the Keelung River for societal functions (e.g. transportation, drinking water, cultivation, fishing and recreation) in the early period. The earliest urban planning in Taipei City was developed during the Japanese colonial period (1895-1945), which was also established the first phase of river government. With the development of urbanization, the Keelung River is under pressure of human activities. The lower reach, namely urban section, has been shortened, straightened, deeply developed on floodplains and embanked for preventing floods. The government used the straightened engendering and levee systems as an only solution to prevent floods. However, these constructions and works have not effectively solved the flooding problems and even caused the degression and destruction of habitats in river areas over time. The natural habitats on floodplains were destroyed or fragmented due to river regulation and the utilisation of floodplains for agriculture and other human demands in the past decades. The quality of the remaining habitats has deteriorated as the other urban rivers. Meanwhile, the cultural landscape in the lower Keelung River was gradually separated from the CBD of Taipei City by embankments and other flood control works. The land use is therefore developed with special projects or regulations for preventing floods. The ecological rehabilitation in river areas has become an important perspective in river management besides flood risk management. In general, the riparian areas of the lower Keelung River have an area around 400 hectares, the main land-use types are divided into four parts according to "*Water Act*", "Regulation *Governing River Management*", "*Regulation Governing Water Recreation Activities*", "*Special Act for Flood Management*" and "*Urban Planning Act*":

A. Agriculture: there were some bamboos and rice fields near Nanhu Bridge and closed to Shezi. These areas are now reused as riparian parks.

B. Recreation: there are twelve riparian parks on both sides along the lower Keelung River (Table 3.9). Most of them are built as playgrounds, sport fields or artificial greensward for sports and recreation reasons.

Table 3.9: Riparian parks along the lower Keelung River (Hydraulic Engineering Office, Taipei City Government, 2007)

Park	District	Area (ha)	Location	Infrastructure	Parking area
Nanhu-left	Nan-gang	6.6	Nanhu Bridge – Chenggung Bridge (L)	Greensward, basketball court, playground	No
Nanhu-right	Nehu	6.6	Nanhu Bridge – Chenggung Bridge (R)	Greensward, croquet court	No
Chengmei - left	Nan-gang	2.2	Chenggung Bridge – Maishai 1st Bridge (L)	Basketball court, playground, greensward	No
Chengmei - right	Nehu	9.9	Chenggung Bridge – Maishai 1st Bridge (R)	Tennis court, basketball court, softball field, skating rink, playground, greensward	No
Guanshan	Shong-shan	27.22	Maishai 1st Bridge – High way (Jiozung) (L)	Basketball court, parking area, greensward	Yes
Rainbow	Nehu	31.27	Maishai 1st Bridge – High way (Jiozung) (R)	Tennis court, badminton court, softball field, parking area, greensward	Yes
Yingfeng	Shong-shan	60	Highway – Dazhi Bridge (Jintai)(L)	Badminton court, in-line skates court, football field, parking area, greensward	Yes
Meiti	Zhong-shan	45.62	Highway – Dazhi Bridge (Jintai)(R)	Tennis court, badminton court, volleyball court, basketball court, in-line skates court, pond, parking area, greensward	Yes
Dajia	Zhong-shan	42	Dazhi Bridge – Zhongshan Bridge	Fountain, parking area, greensward	Yes
Yuanshan	Zhong-shan	1.94	1, Lane 185, Zhongshan Nord Rd., Sec. 3	Playground, skating rink	No
Bailin- left	Shilin	27.34	Chengde Bridge – Shezi 24th Rd.	Tennis court, basketball court, softball / baseball field, skating rink, playground, parking area, greensward	Yes
Bailin-right	Shilin	14.43	Chengde Bridge - Shuangxi	Basketball court, skating rink, parking area, greensward	Yes

C. Nature conservation area: this area is established in 1986 for protecting the Mangrove at the confluence of the Keelung River and the Danshui River (Figure 3.3). The main vegetation cover is *Kandelia candel* (ca. 70%).

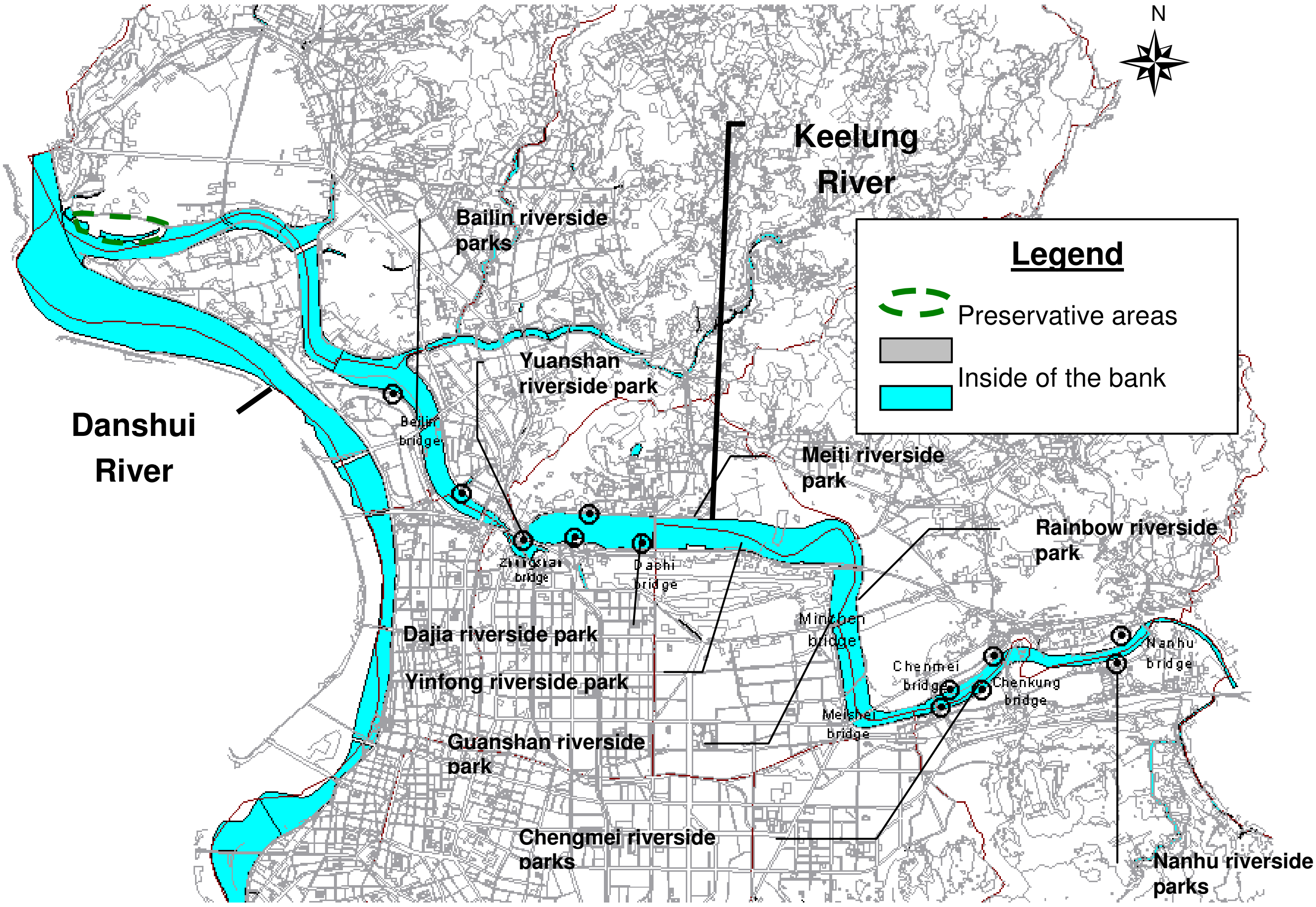


Figure 3.3: Riverside parks along the Keelung River

D. Infrastructure: the functions are included in two main categories – transportation (e.g. parking areas, bikeways) and water control works (e.g. pumping stations, embankments, levee, etc). This section flowed zigzag through the highly developed areas, so the slow drainage speed plus the tidal affection twice a day usually occurs flooding after heavy rainfall (Wang, 1994). The government used to establish embankments and other water control systems and also changed the direction of river flow for preventing floods. The first flood control works of the Keelung River is the levee system in 1960's. The earliest project was delivered from Yuanshan to the confluence of the Keelung River and the Danshui River. Until 2007 the embankments are about 45.7 kilometres in length (ca. 39.2% of whole Taipei City), and the length of revetments are around 30.9 kilometres (ca. 47.7% of whole Taipei City) (Table 3.10, Figure 3.4). Moreover, three important water control works have been done to prevent flood along the Keelung River (Detail see Annex C). These engineering works totally changed the structure of landscape, and affected the ecosystem along the lower Keelung River.


Shezi levee

Dazhi bank

Figure 3.4: Sample photos of embankment along the Keelung River

Table 3.10: Height of Embankment along the lower Keelung River (Hydraulic Engineering Office, Taipei City Government, 2007)

Banks	Length (m)	Beginning and the end point	Height (m)	Note
Guandu levee	4,726	Betou Incinerator to influence	3.50 -9.65	Right side
Shezi levee	5,819	Yianping North Road 6th Section to Influence	6	Left side
Zhomei levee	3,789	Betou Incinerator to Shuangxi	6 - 9.65	Right side
Shezi bank	2,560	Dalong pumping Station to Tonghe street	9.65-9.77	Left side
Shilin bank	3,582	Zhongshan Bridge to Shuangxi	9.65-9.92	Right side
Yuanshan bank	1,191	Zhongshan Bridge to Dalong pumping station	9.77-10.15	Left side
Dazhi bank	2,725	Dazhi Bridge to Zhongshan Bridge	11.15	Right side
Shongshan bank	4,698	Fuyuan street to Zhongshan Bridge	11.15	Left side
Fuyuan retaining wall	2,177	Maishai Bridge to Fuzua street	11.15	Left side
New Nehu bank	8,015	Nanhu Bridge to Dazhi Bridge	12.80	Right side
Yuchen bank	2,426	Chengong Bridge to Maishai Bridge	12.05	Left side
Nangang bank	2,205	Nanhu Bridge to Chenggung Bridge	12.80	Left side
Upper Nanhu Bridge – R	600	City boundary to Nanhu Bridge – right side	12.8	Right side
Upper Nanhu Bridge – L	1,200	City boundary to Nanhu Bridge – lift side	12.8	Left side

3.7.2 Neighbourhood

As mentioned above that the lower Keelung River flows through the highly developed areas of Taipei City. The land-use types along the Keelung River can be roughly listed in Table 3.11. The land-use in surrounding areas includes seven types according to zoning for Taipei City (Lin, et al., 2000):

Table 3.11: Landscape along the Keelung River (Wang, 1994; Lin, 2002)

Section	Upper stream	Middle stream	Lower stream
	Hotungjiesho Bridge – Dahua Bridge (Pingxi – Rifang)	Dahua Bridge – Nanhu Bridge (Rifang – Nangang)	Nanhu Bridge – confluence (Nangang – Guandu)
Natural Landscape	River terrace, pot holes, waterfall, valley, vegetation	Meander, pot holes, valley	Meander, flood plain, wetland (Guandu)→buffer zone of energy flow
Cultural Landscape	Mining factory, railway, riparian town, Bridge/passage, revetment and embankment	Railway, small city, industrial area, Bridge/passage, revetment and embankment	Mega-city, straightening channel, riparian parks, Bridge/passage, revetment and embankment
			Study area

A. **Residential districts**: it is distributed around the middle reach of the lower Keelung River, such as “Chenggung readjustment area” next to Chenggung Bridge, the area from Chengmei Bridge to Minquan Bridge, “Dazhi readjustment area” next to Dazhi Bridge, and Shilin area from Chende Bridge to Bailin Bridge.

B. **Commercial districts**: two main commercial districts are located on the left side of Chengmei Bridge, and the left side of Bailin Bridge. The new developing areas between Minquan Bridge and Dazhi Bridge are scattered some department stores and shopping mall.

C. **Industrial districts**: there is no heavy industry but some electronics industries and car repair factories in the neighbourhoods along the Keelung River. They are located at some places on the left side of the Keelung River, for instance the neighbourhoods next to Chengde Bridge, Shezi and the surrounding areas next to Shilin pumping station. While remarking on Nehu, the industrial section is located on the right side between Nanhu Bridge and Chenggung Bridge.

D. **Agriculture areas**: in addition to the left side near the confluence (Shezi), there are several fragmentary agriculture areas near the lower Keelung River. These areas are mainly used as bamboo fields, farmland and fishpond, which have been found near Nanhu Bridge, Chenggung Bridge, and Chengmei Bridge.

E. **Infrastructures**: the infrastructures next to the Keelung River include Schools, subway stations, sewage treatments, pumping stations, transformer stations and Nehu dump. Moreover, there are some important transportation constructions close to the Keelung River. For example, Shungshan Airport is right by the Keelung River on the left side. Some important passages are also built along the Keelung River or across the river, such as Nanhu Bridge, Chenggung Bridge, Chengmei Bridge, Maishuai 1st Bridge, Maishuai 2nd Bridge, Mingqian Bridge, Dazhi Bridge, Chengde Bridge, Bailin Bridge, and National Freeway No. 1.

F. **Conservation area**: in order to protect the habitats of bird species, many Taiwanese NGOs (non-governmental organization) pushed to improve the environment near the Guandu Nature Reserve (green circle in Figure 3.4) due to the decrease in biodiversity. The bird species declined from 139 to 47 species in the period of last 1980's (1986-1991). The Guandu Nature Park was therefore established on the north side of Guandu Nature Reserve in 1996 and has been operated by Wild Bird Society of Taipei (WBST) since 2001. This conservation area is about 57 hectares, the constructions are divided into four parts: the first part "main area" (5 hectares) includes the areas of tourist information, bird watching houses, exhibition centre, and other infrastructure. The second part "care reserve area" occupies the biggest portion of Nature Park and is not open for tourists to reduce the impacts of human activities. The third part "outdoor observational area" has two spots for bird watching. The fourth part "sustainable management area" is a buffer zone between natural environment and human activities. This is also a special breeding area for local farmers, where they can cultivate plants for the habitats of birds. The Guandu Nature Park plays a role as habitable base of bird species for breeding and rest. It completes the ecological services with the Guandu Nature Conservation.

G. **Recreation areas**: there are some playgrounds and parks near the Keelung River. The most famous places are such as Yuanshan playground, Taipei Fine Arts Museum, Martyrs Shrine.

H. **Others**: some military areas and non-grouped areas are divided into this part.

To combine the previous physical and biological information about the Keelung River, Table 3.12 shows an overview of the characteristics along the Keelung River.

Table 3.12: Characteristics along the Keelung River (Chen, 2003)

Characteristics \ Sections		Non-tidal reach			Tidal reach (Estuary)
		Upper stream	Middle stream	Lower stream	
Shape of river	slope	steep	flat	flat	flat
	Width of channel	Narrow	Little wide	wide	wide
	depth	shallow	deep	deepest	deep
Water body	Temperature	cool	warm	mild	mild
	Turbidity	low	high	high	High to middle
	Oxygen index	high	Middle	low	Low to middle
	Water quality	good	middle	Bad to middle	Bad to middle
	Water quantity	Small	middle	great	great
	Flowing speed	rapid	fast	slow	Slow to stagnant
	Tidal influence	no	no	no	yes
River bed	Deposit	Gravel, rock	arenite	silty clay	Sand and soil
	Granular organic matter	big	middle	small	Small
	Quantity of organic matter	Less	more	middle	middle
riparian	Ratio of vegetation cover	high	Middle	Low	Low
	Development	low	Middle to high	High	High
				Study area	

Table 3.12: Continuance

Characteristics \ Sections			Upper stream	Middle stream	Lower stream	Tidal reach (Estuary)
Biological group in river	Structure	Fauna	Chimarra sp. A*, Plecoptera (stoneflies), Foraminiferida*	Class *Ephydroidea*, Class *Nematoda, Stylochus orientalis Bock*, Class *Hirudinidae, Chloeia capillata*; freshwater fishes	Class *Polychaeta*, subclass *Oligochaeta*, Family *Unionidae*, Family *Corbiculidae*, Class *Gastropoda*; zooplankton	Class *Polychaeta*, subclass *Oligochaeta*, Family *Unionidae*, Family *Corbiculidae*, Class *Gastropoda*; zooplankton
		flora	Family *Cladophoraceae*, Phylum *Bacillariophyta*, Order *Oscillatoriales*, Order *Prasiolales*	**Affixed aquatic vegetation:** *Potamogeton crispus L., Potamogeton malaianus Miq, Myriophyllum spicatum L.* **Phytoplankton:** Genus *Pediastum, Tetraedron sp.*	**Affixed aquatic vegetation:** *Potamogeton crispus L., Potamogeton malaianus Miq, Myriophyllum spicatum L.* **Phytoplankton:** Genus *Pediastum, Tetraedron sp*	**Affixed aquatic vegetation:** *Potamogeton crispus L., Potamogeton malaianus Miq, Myriophyllum spicatum L.* **Phytoplankton:** Genus *Pediastum, Tetraedron sp*
	un cti	Productive ability	low	high	middle	high
		P/R (primary productivity / total respiration)	<1 (diversity)	>1	<1 (diversity)	<1 (diversity)
					Study area	

4. Methodologies of Biotope Classification and its Evaluation Criteria

For measuring the habitat functions of urban rivers, it is essential to specify the reference status of habitats first. A biotope classification for the urban river areas can be a recommendable instrument as database in this case. Therefore, developing methodologies for biotope classification for the urban river areas and its corresponding evaluation criteria are the key issues in this study. The evaluation indicators usually reflect the requirements of the database on physical and environmental variables, which are related to the condition of species and communities. Accordingly, the research design is firstly introduced in Section 4.1. The process of biotope classification in the scope of urban rivers is presented in Section 4.2. The most important part regarding the assessment of habitat functions is displayed in Section 4.3. Moreover, bird species are chosen as estimative objects for comparing the habitat quality to illustrate the habitat functions of urban rivers.

4.1 Research Design

The evaluation framework in this study was developed based on the previous assessment systems (e.g. SIAM) in Taiwan and European Directives. It seems useful and important to establish a biotope typology for the study areas (urban rivers) as an updatable database. Figure 4.1 shows an overview of the research framework of this study, in which the key work in this case is marked in the dotted-line frame in the middle – the results of biotope classification provide a basis for evaluation and further with the results of evaluation contribute to environmental policies and legislations. Boon (1992) suggested that there are three basic requirements for the core work while developing scientific studies for river conservation – “description” (current status of landscape and ecosystem in urban river areas), “classification” (biotope types) and “assessment” (to identify the conservation values of urban rivers).

For evaluating the habitat functions of urban rivers, the first central research process focuses on establishing a biotope classification for urban river areas, which is useful and important to determine the current condition and changes of habitats. It is especially meaningful for complex ecosystems like urban rivers. The physical, biological and chemical data should be collected based on the research targets by document review and biotope mapping. In which, the physical characteristics are taken as a basis for biotope classification, because the physical properties of the river drive the entire ecosystem. It is also the central premise of stream remediation: the ecosystem can be largely managed through manipulation of stream resources. Accordingly, the classification must include some aspects: 1) the determination of the hydrodynamic and morphodynamic conditions that are essential to support the ecosystem, 2) analysis of the seasonal and annual variation in the habitat availability and suitability due to river dynamics, 3) vegetation and 4) habitats on species scale and ecosystem scale (Duel et al., 2003).

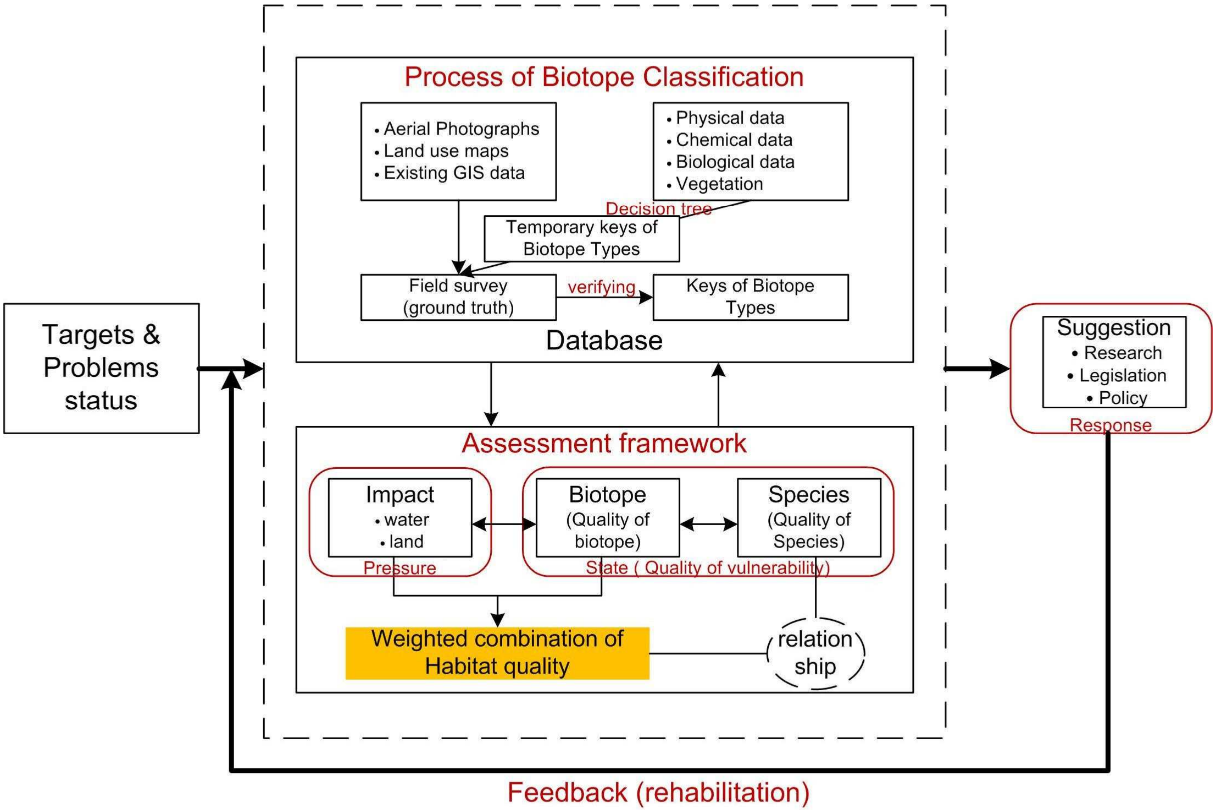


Figure 4.1: Research framework of evaluation on habitat function of urban rivers

The second core work for developing evaluation indictors is based on the biotope classification to evaluate the ecological services of urban rivers with environmental pressure and status. The habitat evaluation framework has become an accepted approach for ecological impact assessment of river management strategies and ecological rehabilitation projects in Europe and throughout the whole world (Duel et al., 1996, 1999; Semmekrot et al., 1996; Kerle et al., 2002; Duel et al., 2003). Accordingly, the criteria are developed by PSR framework based on the theories of landscape ecology and integrated urban river basin management. The longitudinal and latitudinal connections of river basin and riparian environment should be concerned due to the complex and dynamic urban environment. In other words, the evaluation of the study areas, in principle, may discuss the biotope condition itself, the relationship with biological condition (bird species-habitats interactions), and also review the interactions with upper stream and neighbourhoods. Herewith the criteria can be grouped into three categories: 1) impact factors I: water body, 2) impact factors II: flood plains and 3) biotope factors. The observed river functioning is associated particularly with reference to the organic matter (Dunn, 2000). Therefore, the results of the evaluation are showing the habitat quality, which are further compared with the species factor (vulnerability of bird species) to represent the habitat functions for bird species (Detail in Chapter 4.3.4).

Furthermore, the bird species were taken as estimative objects of habitat functions in the study areas, because bird species are conspicuous (e.g. colourful, large, bodies, etc.) and easily observed and recorded, they can be easily distinguished from one another. The result is an idea of taxonomic group to be monitored. Meanwhile, the urban bird species are high heterotrophic organisms which are especially often used as umbrella species in conservation planning. The quantity of wild bird species is usually regarded as an indicator in urban ecology. Bernotat et al. (2002a) specified that the traces of bird species can display the values in almost all habitat types, as well as indicate the worth in many different aspects (e.g. space-environment-relationship, abiotic environmental parameter, structural element, habitat dynamic, etc) (Reich in Haaren v. (Ed.), 2004).

The whole concept of developing biotope classification and its evaluation framework will contribute to rehabilitation in the study areas, and also apply to other projects of urban river management. The methodologies are shown in the next paragraphs.

4.2 Developing a Biotope Classification for Urban River Areas

4.2.1 Principles of Biotope Classification for Urban River Areas

The biotope classification is usually developed dependent on the study targets. A biotope classification for urban areas is usually carried out with existing data and displayed on the digital maps with mapping of ground truth, which is defined with essential ecological relevance on the basis of field survey, data analyses and field trials (Connor et al., 2004; Olenin and Ducrotoy, 2006). The concept of biotope classification for urban river areas in this case was carried out according to Sukopp’s methodology for biotope classification for urban areas (Sukopp, 1998); the progress can be mainly divided into three phases with ten steps to “prepare the requirement of data” (preparation), to “present the biotope condition” (survey), and to “evaluate the current status” (assessment) (Kim, 2007).

Moreover, for developing an updatable database, Connor et al. (2004) argued that some requirements should be concerned with the process of biotope classification: 1) it should be scientifically sound, adopting a logical structure in which the types are clearly defined. The ecologically similar types should be placed near to each other and at an appropriate level (within a hierarchical classification). 2) the description should be common and easily understandable. 3) the classification should be comprehensive, accounting for all the river habitats within the geographic scope. 4) the presentation should be practical in format. That can have applicability for various users (e.g. planner, field surveyors) on different scales of physical and biological features (whole river ecosystem or individual riparian areas). 5) available data at different levels of detail. The detail of biotope types can be used for conservation and field survey at national and international levels. This information should be even usable by non-specialists with a variety of intended applications. 6) the classification should be flexible to enable modification results from the addition of new information, but stable enough to support ongoing uses (Connor et al., 2004). With these requirements an updatable database can show the context of changes over time, the newly defined types should be clearly documented to refer back to previous versions of classification. Accordingly, the flowchart of biotope classification in this case is illustrated in Figure 4.2.

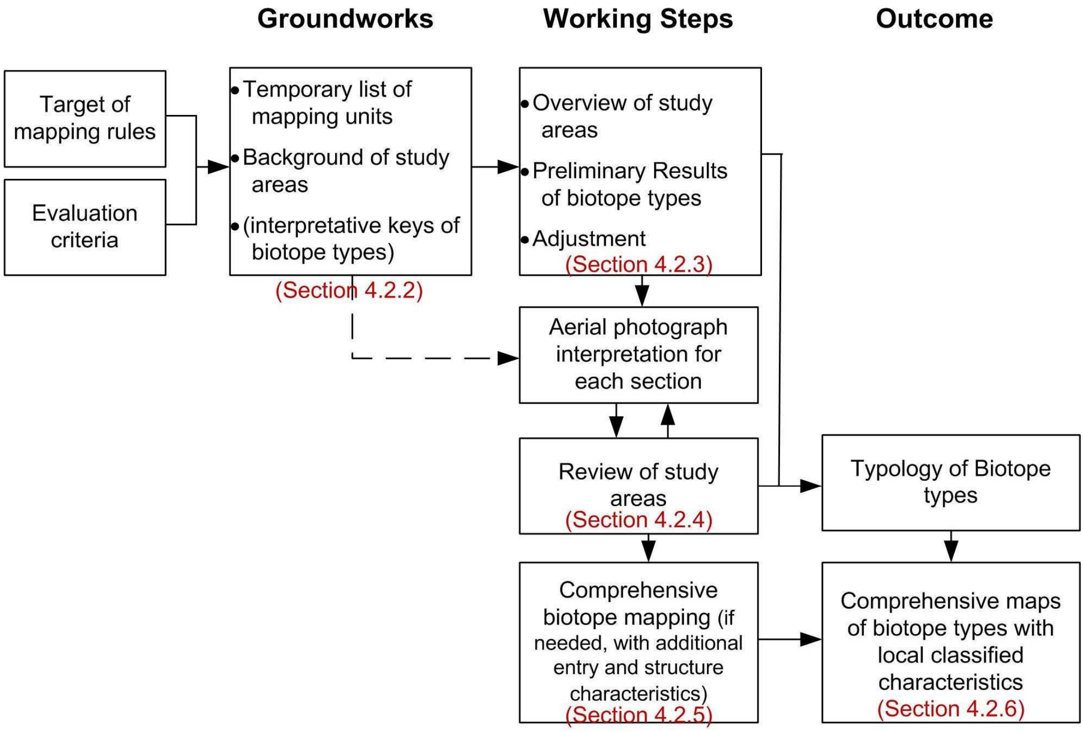


Figure 4.2: Illustration of working steps for comprehensive biotope classification (revised from Knickrehm and Rommel, 1994)

To summarize, the concept of biotope classification in this case includes: 1) define the investigative data according to the mapping targets, herewith a list of available data should be inventoried, 2) select the test areas and determine biotopes described in the catalogues: the preliminary identification of biotope types in the field of urban rivers must be defined according to the existing data and legislation, 3) make base maps for field work which combines the aerial photographs with existing available information (e.g. physical, chemical and biological data), 4) record land use, vegetation and other physical information in the study cases. While taking photos and marking special elements on the base map, the high-biodiversity areas and valuable biotope for bird species should be especially concerned, 5) summarize the data and display the result on digital maps. The phases of description and classification process of biotope types are shown in the subsequent sections. The biotope classification for the Keelung River was carried out according to these proposed steps and requirements.

4.2.2 Available Data for Habitat Classification (Materials and Instruments)

As shown above, the methodology and data collection for biotope classification is held according to the study targets and evaluation criteria. The process of “preparation/description” is used to collect and classify the existing data and maps as basis for field survey of ground truth and a temporary list of biotope types. The preparation with near simultaneous sampling of numerous examples of different biotope types can provide valuable information about river conditions (Amoros et al., 1987; Copp, 1991). The information must include physical habitats in/along the stream (e.g. rock, sand or mud). The physical characteristics of environment are the substratum and particular local conditions to show the various structural components as habitats (Olenin and Ducrotoy, 2006). A review of classification schemes and literature describing biotope types of river ecosystems in comparable visions was undertaken as background (Connor et al., 2004). The information contributes to understanding and describing the nature and dynamics of biotope conditions before taking field work (Lake and Machant, 1990; Dunn, 2000). One of the applications for ecological services relies on mapping geographical units with their physical and dominant biological features for river management. The database about the abiotic and biotic environmental elements (e.g. soil, structure of vegetation and current land use) is essential for respective environmental planning (Kim, 2007).

Table 4.1 shows that two kinds of data should be collected in this phase: 1) base maps which display on the aerial photographs with existing available information (e.g. vegetation structure, land use and other landscape characteristics in the study areas). 2) relevant legislation, policies and studies: this kind of parameters pay attention to the potential protective habitats for field survey and provide information about data which may be relevant for later evaluation. In brief, the phase of preparation which considers geophysical and biological relevant variables shows the consistent relationship between the biotic and abiotic elements as fundamental structure. The types can be determined at various scales, enable to serve as a basis for ecologically sound of ecosystems in a hierarchical typology for environmental management and nature conservation (Hong et al., 2004; Connor et al., 2004; Olenin and Ducrotoy, 2006). Furthermore, this database can be revised and adapted for different planning and expert projects, as well as updated regularly with the current inventory data (Kim, 2007).

Table 4.1: Available data for biotope classification for the urban river areas

Data Set	Description	Reference and purposes
Regional map	Scale of 1:25,000 – 1:60.000	For verification of position, landmark
Exiting spatial digital data with land use	•North Taiwan •Taipei Planning •Ecological Taipei	For georeference and analysis
Aerial photographs with preliminary mapping (if applicable)	Scale of 1:2,500 – 5,000	Working maps with existing data for verification of biotope and land use
Vegetation	List of vegetation covers and structure	For biotope mapping and classification
Landscape characteristics	Water body, man-made modification, obstruction, discharge, existing enhancement, etc.	historical status of landscape for verification of biotope types and land use
Data of Bird species	List of bird species along the lower Keelung River, especially emphasize the red-list	For confirming the habitat of the bird species
Physical information	Soil, rainfall, weather, Hydrology, etc	For analysis
Chemical information	Water quality, etc.	For analysis
Laws, policies	Local, regional and central legislations, special policies of river management	For showing specific biotope types by biotope mapping and data needed for later evaluation

4.2.3 Preliminary Identification of Biotope Types in the Field of Urban Rivers on the Basis of Existing Geo-Data

The methodology used in biotope classification usually takes CIR (Colour Infrared)-aerial photographs as background information for a rough identification of spatial units for the field survey. This method can classify the main groups of biotope types. Further information about vegetation types and structures must be collected by field work. This project is a pilot biotope classification in the field of urban river areas in Taiwan, there were no CIR aerial photographs as basis for this study. Therefore, the preliminary identification of biotope types and accordingly a rough classification of main biotope groups for the urban river areas were determined with descriptive information (e.g. soil, topography, climate, land use and vegetation types) from existing data. The main groups of biotope types were identified and denominated by a decision tree based on the concepts of biotope classification in Lower Saxony in Germany. Other information which may be relevant for assessment or identification functions, such as climate (rainfall, typhoon), hydrology (water quality and quantity) and endangered species (Detail in Table 4.2), should be recorded as well as mapped during field work (Haaren v. et al., 2004). The results are displayed on GIS layers (i.e. the spatial pattern of environmental variables and vegetation characteristics) as base maps.

Table 4.2: Possible parameters from existing data for preliminary classification for surveying biotope types (altered from Knickrehm and Rommel, 1995; McHarg and Steiner, 1998; Yang, 2001; Haaren v. et al., 2004)

Parameter	Potentially relevant for the identification of biotope functions
Vegetation and flora - endangered species - endangered communities - biodiversity	Protection requirements, potential ability as habitats for flora and fauna, abiotic habitat factors, variance of landscape, culture historical specifics
Selected animals - endangered species - target species	Require of protection, potential ability as habitats
Structure - vegetation structure - micro relief - age	Potential ability as habitats of wildlife, damage, erosion, continuousness of habitats
Spatial structure - areas - connection - complexity	Potential fragment of habitats, biotope interconnection, possibility of rehabilitation and expansion, damage, causes of endangerment
Land use - type of use - intensity	Influence on flora and fauna, influence on abiotic habitat condition, potential development, causes of endangerment
Abiotic habitat factors - humidity - micro climate - rainfall - hydrology	Potential qualification as habitats for flora and fauna, requirement of protective vegetation biotope, potential development

"Decision tree" is a tool used to support the decision-maker with a graph or a model of decisions to infer the possible consequences. The results from decision tree are logic and easy to understand with grouped elements into root node, split and terminal node (leaf) (McConnachie, 2002; Figure 4.3). With this concept, the data can be successively subdivided into smaller groups after continuing tests and at each leaf node refers to the class label assigned to each observation. Perhaps the most important feature of decision tree classifiers is their ability to break down a complex decision-making process into a collection of simpler decisions, thus providing a solution which is often easier to interpret (Safavian and Landgrebe, 1991; McConnachie, 2002). The main groups determined by a decision tree were displayed on the aerial photographs as base maps for field survey.

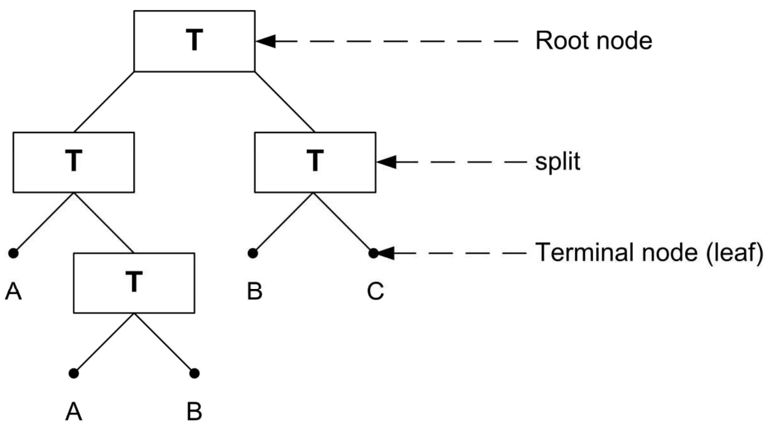


Figure 4.3: A decision tree classifier (McConnachie, 2002)

The main groups of biotope types in this case were divided into five splits associated with site-specific data (e.g. land use), vegetation covers with topographic and substrate features and structure of landscape which was available at the time of survey. The biotopes may be subdivided by further characteristics, for example vegetation type by age, class of major tree, vertical stratification (tree, sub-tree, shrub and herb layers) of forest and human use (Hong et al., 2004). However, due to the research limits, this study only lists the vegetation in rough ideas. In the areas of non-vegetation type, the classification depends on the structural attributes of ground surface (i.e. road, playground).

As shown in Figure 4.4, the river habitats are divided into “inland water” and “land” at first step by geographic characteristics; they are namely water bodies and riparian areas (flood plains). At the second split, the land was separated into two parts according to vegetation covers. Then, these two parts were separated respectively with different characteristics. The “vegetation cover” included tall vegetation (forest) and short vegetation; the “ground” was shown as “unvegetated ground” and “artificial area”. The fourth step further grouped the short vegetation into “wet short vegetation” (wetland) and “dry short vegetation”. The last split displayed the dry short vegetation as “shrubbery” and “green land”. Whereupon, there are in total seven main types of biotopes in urban river areas: 1) forest, 2) shrubbery, 3) inland water, 4) wetland, 5) exposed ground, 6) green land and 7) artificial area. The sub-groups and eventual keys of biotope types were carried out with consideration of parameters as shown in Table 4.2 by field work (Detail see Chapter V).

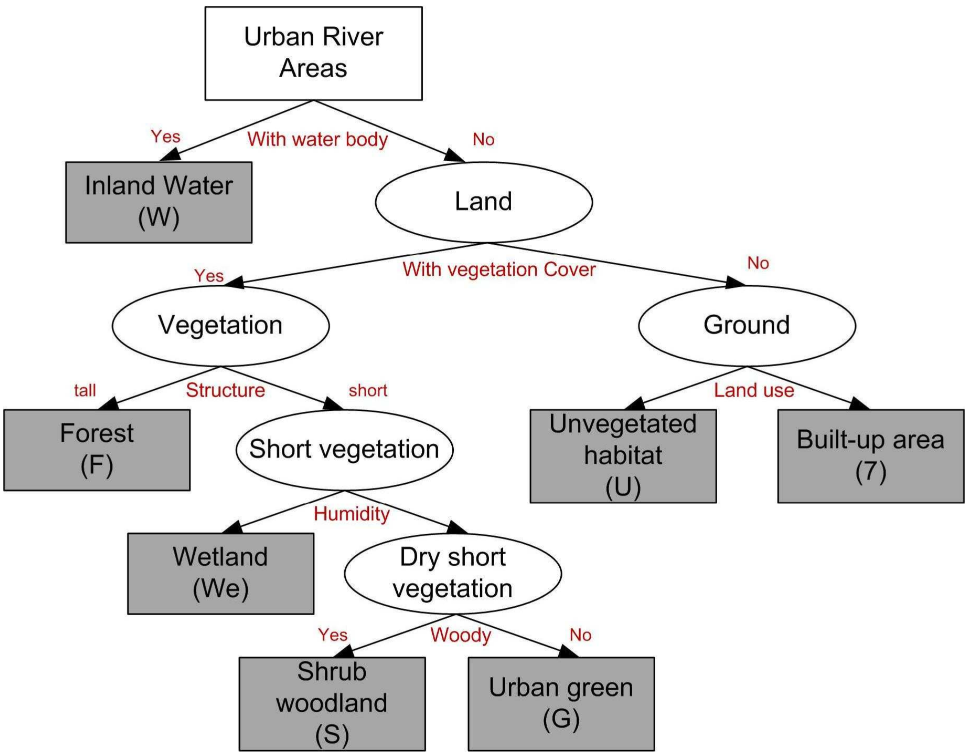


Figure 4.4: Two-class hierarchical tree used in determining the biotope classification in the field of urban rivers

4.2.4 Checking the Topographical Data and Preparing the Base Maps for Field Work

The historical situation can serve as a reference to imply the valuable data of the river ecosystems on base maps. The background of physical, vegetation and ecological states in the field of lower Keelung River. The land use on river flood plains and the neighbourhoods were displayed and digitized with geographic photographs as base maps in order to provide a basis for determining the high-biodiversity areas by field survey in the next step. Some of the base maps were carried out according to the existing integrated geodata by Taipei City government, which display the current status of land use, master urban planning and soil types. The biological database for ecological research targets (e.g. vegetation cover, bird species) were collected both by document review and field work.

Due to the lack of official aerial photographs from the Taiwanese governments or institutes (reasons of national defense), the base maps of this study were obtained from Google Earth (GE) and then georeferenced with geographic coordinate system “Taiwan 1997”. The serial numbers of maps are given equal to the layout of Aerial Survey Office, Forestry Bureau, Taiwan, thus the products of maps in this study can be combined or compared with the other existing aerial photographs and maps. Accordingly, the eleven base maps are listed in Table 4.3. The finished maps for overview shows at a scale of 1:60,000 and the maps for field survey are identified at 1:2,500 scale. The results of preliminary biotope classification are shown at a scale of 1:15,000 (see Chapter V).

Table 4.3: Serial base maps of field survey in the Keelung River

Serial numbers*	**Name***	**Coordinate points**	
9623-II-059	Guandu	121°27'00" E, 25°07'30" N	121°28'30" E, 25°07'30" N
		121°27'00" E, 25°06'00" N	121°28'30" E, 25°06'00" N
9623-II-060	Linung	121°28'30" E, 25°07'30" N	121°30'00" E, 25°07'30" N
		121°28'30" E, 25°06'00" N	121°30'00" E, 25°06'00" N
9723-III-061	Shilin	121°30'00" E, 25°06'00" N	121°31'30" E, 25°06'00" N
		121°30'00" E, 25°04'30" N	121°31'30" E, 25°04'30" N
9723-III-062	Dazhi	121°31'30" E, 25°06'00" N	121°33'00" E, 25°06'00" N
		121°31'30" E, 25°04'30" N	121°33'00" E, 25°04'30" N
9723-III-063	Gangqian	121°33'00" E, 25°06'00" N	121°34'30" E, 25°06'00" N
		121°33'00" E, 25°04'30" N	121°34'30" E, 25°04'30" N
9623-II-070	Sanchung Exit	121°28'30" E, 25°06'00" N	121°30'00" E, 25°06'00" N
		121°28'30" E, 25°04'30" N	121°30'00" E, 25°04'30" N
9723-III-071	Shuanglian	121°30'00" E, 25°04'30" N	121°31'30" E, 25°04'30" N
		121°30'00" E, 25°03'00" N	121°31'30" E, 25°03'00" N
9723-III-072	Shongshan Airport	121°31'30" E, 25°04'30" N	121°33'00" E, 25°04'30" N
		121°31'30" E, 25°03'00" N	121°33'00" E, 25°03'00" N
9723-III-073	Shongshan	121°33'00" E, 25°04'30" N	121°34'30" E, 25°04'30" N
		121°33'00" E, 25°03'00" N	121°34'30" E, 25°03'00" N
9723-III-074	Nehu Exit	121°34'30" E, 25°04'30" N	121°36'00" E, 25°04'30" N
		121°34'30" E, 25°03'00" N	121°36'00" E, 25°03'00" N
9723-III-075	Nangang	121°36'00" E, 25°04'30" N	121°37'30" E, 25°04'30" N
		121°36'00" E, 25°03'00" N	121°37'30" E, 25°03'00" N

*the serial numbers and name of base maps are given according to the official maps by government.

Moreover, some potential biological protective areas should be marked on the base maps that should be considered to specific local species or endangered species and their surrounding areas in the field work. Mapping identified areas with at least some of the following characteristics: “species-rich area and the occurrence of at least some rare species”, “areas with high structural diversity” and “areas of importance with opportunities for urban residents to have contract with nature” (Jarvis and Young, 2005). This information helps to emphasize the vulnerability and assets for objective evaluation and respondent actions (e.g. important biotopes with biological richness and worth protection).

4.2.5 Verification and Differentiation by Field Survey

“Survey” provides a standardised system for classifying and mapping biotopes along the urban river that included areas of water body and the flood plains (Jarvis and Young, 2005). It shows the spatial and qualitative differentiation of characterisation. The aim of this part is to provide a record of vegetation and other ground truth over large a scale of 1:2500. According to the targets of this study, the field survey paid attention to: 1) vegetation cover and structure, 2) the valuable biotopes for bird species, 3) structure of landscape / geodiversity, 4) types and intensity of land use. Hence, the river habitat survey provides a description of the nature and features of rivers (Simpson et al., 1999; Dunn, 2000). Other relevant data should be marked on the maps, for instance, the relevant conditions of natural environments (e.g. the ecological value, naturalness and landscape value) are evaluated, also graded and embodied on the maps (Hong et al., 2005). The mapping of biotope types from descriptive information and ground truth provides an understanding of habitat condition, species endanger, rarity of geomorphological features and their interactions, which serves as an updatable database for biotope mapping in urban river areas.

One aim of this study is to determine the geo-ecological factors relating to spatial patterns relevant for plant communities, which was verified by the environmental variables and vegetation characteristics. The correspondence analyses of habitat functions were carried out using the result of biotope classification. The ordination component value of the first axis shows significant regression to some environmental variables. This spatial distribution of potential habitats and vegetation characteristics were predicted and the impact of human trails on the neighbouring vegetation was also examined for restoration planning (Hong et al., 2004). Hence, the vegetation survey is developed for wildlife habitat evaluation of urban rivers to apply to the mega-city ecosystems. The ground truth provides a standardized system for classifying and mapping the biotope types in the study areas. Generally speaking, the records by survey should include the vegetation types, geomorphology (e.g. channel shape, topographic elevation), sand, substrate features, landscape and the biological validation (species list) as possible at the same time (Dunn, 2000; Newson and Newson, 2000; Jarvis and Young, 2005). Then the ground truth information can be included into the natural source database (MaHard and Steiner, 1998) in the next step.

The field survey of biotope mapping for the lower Keelung River was held during the winter 2006/2007 (December 2006 to February 2007). The main work was proofing the ground truth and collecting the relevant information as database. The process of mapping is divided into three steps to record and verify the ground truth of “landscape characteristics”, “intensity and type of human activities”, “special characteristics of site and vegetation types” and “land use on flood plains and in neighbourhoods”.

The first round of mapping was sifted quickly through the land use, main landscape characters and the obvious problems and assets along the lower Keelung River. All the data were noted as in Table 4.4 as reference for further field work. The main outputs of the second-round mapping were getting identification of vegetation types and record of landscape structure. The intensity of human impacts and the land use in the neighbourhoods were also marked down in this phase, because many investigations in cities have shown that the land use types constitute homogeneous habitats for flora, vegetation and wildlife (Gilbert 1989; Müller, 1998). However, it is difficult to collect and identify the intensity of human impacts. To consider the influences on habitats, the data were collected from regular activities on riverbanks (e.g. biking, parking, sport) and irregular big events (e.g. festivals).

After going through survey and verification repeatedly, the data were arranged in Table 4.5 for the last round of mapping. The key work of this step was checking of some special sites which play an important role to show the species-habitats-interactions. For instance, some specific local species on the red-list should be remarked and shown with the mapping results.

Table 4.4: Sample of code / classification table for downstream Keelung River

Date	Habitat conditions									Photo		Note
	Section	Map No.	District	riverside	River order	Bank type	Bikeway type	Main land use	Code of Biotope	Photo No.	Location	
04.12.'06	Confluence-20km	9623-II-059	Betou	right	5	Revetment, lower claybank	Asphalt	wetland	4, 3.2.1, 2.1.2, 6.2			Saw great quantity of *Bubulcus ibis.*
04.12.'06	20km-18km	9623-II-059, 9623-II-060	Betou	right	4-5	Revetment, lower claybank	asphalt	Wetland	4, 3.2.2, 2.1.2, 6.2			Saw great quantity of *Bubulcus ibis.*

Table 4.5: Example of Field survey table in the lower Keelung River

Biotope Mapping of Urban Rivers: Keelung River						Code: 4	
District	Betou	City	Taipei	Map No.	9623-II-059	Scale	1:2500
Researcher		Lin, Yu-Fang		Invest. Date		04.12.2006	
Location		Confluence, right side		Size (ha)		55	
Biotope		Wetland		Biotope in the surrounding		lower claybank, Asphalt bikeway, near nature water, etc.	
Impact		Recreation, pollution, flood		Land use in the neighbourhood		Guandu Nature Park, Agriculture	
Biotope Description: biotope structure, plant communities, importance for nature conservation		The mangrove swamp is the important treasure of Keelung River. It occurs normally at around latitude 25 grad in the North and South. A mangrove swamp or mangal is a salt or brackish water environment dominated by the mangrove species of tree, such as Sonneratia. Mangrove is characterized by brackish water conditions with fluctuating salinity, periodically wet and dry, alternating aerobic and anaerobic soil environments as well as finely particulate, unstable substrata (Anderson, 1994; Tam & Wong, 2000a and b) A distinctive character of a mangrove community is its relatively low plant diversity (Tomlinson, 1994), most of them are viviparous plants. It may feature grasses, rushes, reeds, sedges and other herbaceous plants (possibly with low-growing woody plants) in a context of shallow water. The dominant plants are mangrove swamp, reed, Oriental Cat-tail, etc. §					
Recommendations for Bird species and Habitat functions							
Dominant and characteristic plants							
Observed bird species							

(Frame No. 9623-II-059)
Source: base photograph from GE with georeference "Taiwan 1997"

Location: Aquatic Bird Marshlands, Guandu, on the right side of Keelung River (L1040749)

4.2.6 Summarising the Data and Display in the Results with Legislative Basis of Biotope Classification and Nature Conservation in Taiwan

Unlike the treatment of forests or the habitat in rural areas, the urban river is an open, complex and dynamic ecosystem. This background for biotope classification with legislative basis is important for nature conservation (e.g. biodiversity) in further projects of urban planning and river management. Neither legislation nor policies are specifically directed to protect urban rivers for ecosystem conservation in Taiwan so far. However, the government attempted to protect the representative habitats of the Keelung River (Guandu Wetland) over the past years, also paid attention to protecting the ecological values of rivers. Though these legislations and policies only apply to the area within some special areas, the definition and description can be used to determine the biotope classification for purpose of evaluating the urban river ecosystem. Moreover, some values of rivers may be protected through rare and threatened species legislation if amelioration of threatening processes or critical habitats protection lies within the scope of the legislation (Dunn, 2000). Accordingly, a legislative basis for biotope mapping and nature conservation in urban river areas must be added into the background in this case.

First, referring to the recent EU regulations and policies for the protection and conservation of habitats for endangered species in the field of rivers (e.g. the Water Framework Directive, the Habitat Directive and the Bird Directive and Natura 2000; Duel et al., 2003), some regulations and policies of river management in Taiwan have been reviewed and arranged as background of biotope classification. For instance, the *Regulation Governing River Management*, which was announced in 2002 and amended in 2007, was set as a basic law on water management in Taiwan. Though it defines the basic rights and duties of river design and management in general, it is still too rough to protect and govern the development and management of rivers. The basic ideas from the river-management laws are based on the concepts which may offer a mirror for a comprehensive river management: 1) in order to reduce the flood disaster, the administration usually demarcates the boundaries of river management plans or embankments. The regular flood areas are limited for land use types. 2) all activities and constructions are prohibited in the way of water flowing. 3) the land use on flood plains cannot be changed, unless it bothers the water flowing. 4) the vegetation and constructions next to the river channel can be redesigned, moved or demolished when they interfere with the water flowing. This case can also be applied to the historical sights and scenic spots or valuable buildings. 5) to prevent the water pollution, the waste water over the discharging standards, is prohibited to discharge directly into rivers. However, some important standards still need clear definitions. The distance from the source of pollution to river is one of them. 6) being without any overall review of river management, the laws cannot be adapted and response to the change of environment. 7) there is a lack of articles on protecting the fauna and flora along and within the rivers. 8) the basic design of laws on river management is based on the humanistic thoughts and tries to solve problems by (ecological) engineering.

Therefore, the legislative basis for biotope classification and nature conservation encompasses *Water Act*, *Enforcement Rule for Water Act*, *Water Pollution Control*

Act, *Regulation Governing River Management*, *Special Act Governing the Management of Keelung River Basin*, *Regulation Governing the Land Use of Flooded Area of Keelung River*, *Soil and Water Conservation Law*, *Regulations Governing Water Recreation Activities*, *Earth and Rock Excavation Act*, *Special Act for Flood Management*, *Wildlife Conservation Act and Environmental Impact Assessment Working Standards* (Detail in Annex D).

Accordingly, the main groups of biotopes were individually listed in order as follows (Results in Chapter V). The river environment has been grouped into eight main types and twenty-five sub-groups (main units, DE: Haupteinheit) by classifying, including “cultural landscapes”.

A. Layout of descriptions for type

The layout describes each unit in the classification, from broad habitats to sub-biotopes, are laid out as follows. Some groups with sub-groups (main units) and in more detail with functions/characteristics (subunits) are listed with codes and titles in this part. Each code reflects the level of the described type within the classification hierarchy. The designation gives the image of key biological and physical features of the type, with emphasis on the features which help to distinguish it from related types of the same level in the hierarchy. It is very important to refer to the habitat characteristics and full description.

B. Habitat characteristics and description

The typical habitat characteristics of the type must show the particular condition of the type (e.g. salinity, wave exposure, tidal currents, substratum, zone, height or depth band and, where appropriate, other factors). The range given for each factor tends to be broader for higher types and more tightly defined for lower types. It should be taken ensured that another type has not been described to cover the example being considered. General speaking, the general nature of habitat characteristics and its micro/habitat features should be presented.

C. Situation and temporal variation

To describe the general situation in the urban river areas that is in relation to other types. Besides, the temporal variation relating to the changes in the distribution of biotopes within the ecosystem, which may only appear for short time or can be removed over time, outlines the natural temporal dynamics of the biotope types (e.g. seasonal changes in physical environment). This part is important to emphasize the difference between other types.

D. Similar types (if applicable)

Before doing the field survey of the ground truth, it should pay attention to the similar types. The main similarities and principal distinguishing features are described for each similar biotope.

E. Characterising species

A list of those species which contribute most to the overall similarity between core records assigned to the type, which work with associated information on their frequency of occurrence, their individual contribution to the similarity within the core data set of records, and the typical abundance at which they occur (Connor et al., 2004).

4.3 Evaluation Framework for Habitat Functions of Urban Rivers

4.3.1 Current States of Evaluation Framework in the Urban River Areas in Taiwan

The reliability of urban river ecosystem is often unknown and changed constantly, which is influenced by a wide range of natural factors (e.g. local climate and geology) and human activities (Schneiderbruber et al., 2004). The uncertain inputs and temporary impacts cause the degradation of biodiversity and ecological services in cities. The uncertainty analysis with biotope conditions is therefore presented as a method to evaluate the applicability of habitat functions for nature conservation and spatial planning (Duel et al., 2003). The evaluation framework on the habitat functions of urban rivers based on the understanding of urban ecosystem and biodiversity must relate riparian habitats to hydrography. As shown in research design, a considerable number of studies on the Keelung River boomed over the past few years. However, it still lacks evaluation criteria for habitat functions. Developing the evaluation criteria for habitat functions in the built environment is essential, because the impacts on river values may be an element of environmental impact for development affecting the river and entire urban ecosystem, and then the results may contribute into the master urban planning and nature conservation (Dunn, 2000).

The targets of evaluation for habitat functions basically focus on the protection, conservation and development of the natural environment as habitats for numerous species of vegetation and wildlife as well as for the human beings (Arbeitsgruppe "Methodik der Biotopkartierung im Besiedelten Bereich", 1993; Kim, 2007). According to the theories of urban ecology and river management, the evaluation criteria based on biotope classification for the urban river areas can be grouped into two categories in this study: 1) **impact factors** (both on water body and flood plains): to show the impacts from natural environment and human activities, which reflect the pressure from upper stream to lower reach, from the neighbourhoods to riversides on water body and riparian areas; 2) **biotope factors** (habitat value): to display the physical condition, vegetation structure and landscape diversity to verify the quality of habitat (i.e. the state of vulnerability of biotope types). Besides, the impacts and the interactions between target species (bird species) and environment should be included in assessing the ecological services of habitats, which is defined as "**species factors**". This part is going to indicate the condition of target species to prove the possible ability as habitats with the relationship between biotopes and bird species. The relationship with biotopes and bird species represents the quality of habitat functions in each study section. The findings from the evaluation show the satisfactory or required actions for rehabilitation. A regular investigation represents as a monitoring tool to show the environmental changes and the context of impacts. Before turning to the design of evaluative indicators, the principles according to the current state and problems in study areas should be defined by PSR framework.

4.3.2 Design of Ecological Assessment for Habitat Functions

4.3.2.1 Basic Principles of Indicator Design – PSR Analysis (Pressure – State – Response Framework) applied to the lower Keelung River

The negative feedbacks on urban ecosystems often circuit in urban sprawl, with reduction of ecological footprint (EF) and of lower environmental carrying capacity. These problems could be regarded as great impacts on the entire urban ecosystem, due to the rapid urbanization and the lack of comprehensive plans in the past. Such kind of problems also reflected on river management. The environmental influences on the habitat scale display the relationship between species and their certain environment, which is a combination of environmental factors (niche; e.g. micro-climate, hydrodynamic condition, etc.) that the species be able to live within (Connor et al., 2004). Besides, the spatial distribution of certain important habitats and vegetation characteristics provide fundamental information to discuss the human-environment interactions. The interactions with selected species are important signals to show the habitat functions. Generally speaking, the investigation on habitat functions of urban rivers is fulfilled through a structural-functional analysis based on biotopes and comparable spatial units (Reise, 1985; Kuznetsov, 1980; Burkovsky and Stoliarov, 2002; Olenin and Ducrotoy, 2006).

Jarvis and Young (2005) mentioned that the criteria to assess the importance of habitats should include three big parts: 1) degree of naturalness and risk of the biotopes (or individual components of the biotopes), 2) reproducibility of habitats, it can be measured by intensity of land use, age of the site, size, location in the city, degree of impact or pollution, 3) the structural and species variety. Moreover, Connor et al., (2004) argued that the understanding of the distribution, extent and status or quality of habitats is required to facilitate the protection of threatened and rare species and their habitats. With this in mind, bird species which well-known as a conspicuous, easily observed and high-heterotrophic organisms, should be selected as target species to review the habitat functions in urban river areas. Tanner and Clark, Jr. (1999) also indicated that the utilization of restored sites by bird species for resting, foraging and breeding, the survival of native plantings (marsh and riparian) and recruitment of plant species should be observed from the pilot projects.

For evaluating the ecological values of urban rivers, to consider the context of the river ecosystem seems important for the design of evaluation framework. The parameters should be also a focus for future research of developing river restoration (Brookes and Shields, 1996; Petts and Calow, 1996; Newson and Newson, 2000), rehabilitation and restoration (Newson and Newson, 2000). The PSR analysis helps to display the environmental context, which shows the design of evaluation criteria with human-environment interactions on the habitat quality.

PSR Analysis (Pressure – State – Response Framework) in the lower Keelung River

The PSR framework shows the linkage among the pressures exerted on the environment by human activities (pressure box), the changes in the environmental quality (state box), and the responses to these changes in society to release the problems, current environmental contents or preservation of the natural resources. It is also a guideline for further spatial planning and landscape. In this case, the PSR analysis has reviewed the human activities occurring pressures on river environment (e.g. urbanization, overloading or wrong development, expanding water transportation, and the intensity and frequency of recreation in riverside parks) along the Keelung River. The pressures on changed environmental quality represent in “state box”, which are also the useful information to propose legislation, policies or studies. The features in this procedure can be used to describe the river ecosystems and interpret changes in relation to human impacts, environmental variability and biological processes. Meanwhile, the assessment of relationship between biodiversity and that of biotope types should be the aim of river management about intervening in the channel form or its flow regime, to optimize the parameters of the pattern of biotopes.

However, for preventing flood, the Taiwanese government used to build up the levee systems as the only and temporary solution, which resulted in that flooding disaster, and occurs even after heavy rainfall. The flood control works not only separate the view of landscape, but also destroy the natural habitats along the urban river. Wang (1999) argued that the main causes of decreasing urban river biodiversity in Taiwan are water pollution, lack of ecological in-stream flows[1], simplex

[1] ‘Instream flows are essential determinants of channel morphology, riparian and aquatic flora and fauna, water quality estuarine inflow and stream load transport. The ecological and environmental

habitats and river flows, disconnection and fragment of habitats, alien species and impacts from human activities and development. The rivers in mega-city Taipei especially show the worst case. All rivers flowing through Taipei City are modified for the purposes of flooding prevention and recreation (Change, 2004). The habitats on flood plains are fragmented by man-made infrastructure, which threaten the diversity of species and their living spaces. The main problems, which have been studied and discussed for the Keelung River, can be grouped in four dimensions (Lin, et al., 2001; Yang, 2001; Chang, 2004).

1. Channelization, urbanization and hydrologic effect: the redirection of water flow and other flood control works may decrease or fragment the potential habitats, and also increase the ratio of impermeable stratum that gradually raises surface runoff. Besides, the relationships between watershed dynamics and urban development have been frequently addressed. Most of the documents have emphasized the effects of urbanization on stream flows and networks (Huang et al., 2007; Kibler, 1982). In addition, the lunar phase causes the tidal effect on the urban river, which increases the difficulties to deal with flooding problems in the tidal sections.

2. Water pollution: there is about 80% of water pollution from family sewage in Taipei. In the upper and middle streams, agriculture irrigation is also a cause of pollution. Moreover, the lower Keelung River is usually taken as a non-paid sewage treatment store. Many illegal buildings and unauthorized factories are spreading in the surrounding areas; then the industrial waste water drains directly into the river. Non-point source pollution strikes against the habitats along the river and the urban ecosystems. The self-regulation of urban rivers therefore malfunctions by heavily polluted water quality.

3. Low variety and disconnection of habitat: channelization and straightened engineering changed the structure and characteristics of habitats. The man-made vegetation cover or single alien plant species decrease the habitat diversity. Meanwhile, the land use in neighbourhoods next to the Keelung River are disordered or overloaded, which also impacts on the biodiversity on riverbanks. The transportation construction (e.g. bridges) brings much more impacts of human activities, which may disconnect the natural habitats and cause more pollution.

4. Separated view and landscape: the view and scenery along the lower Keelung River are separated by embankments, speedways, highways and other infrastructure next to or across through the river. Therefore, the citizens have poor access to enjoying the waterscape in Taipei City.

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instream flow requirements (EEIFR) should be estimated to make the exploitation and utilization of water resources in a highly efficient and sustainable way and maintain the river ecosystem good health (Song *et al.*, 2007).'

According to the main problems, the societal responses in this research are expressed in three ways as the forms of legislation, policies and studies. The biotope classification for the lower Keelung River and its further evaluation serve as database for decision-making of spatial planning and nature conservation. At the same time, the government should legislate for protecting the endangered species and habitat; formulate relative complete sets for maintaining the environmental regulations, and also protecting the natural resources and biodiversity. Therefore, the indicators for assessing habitat functions should be either able to monitor the individual or combined application to the issues of environmental status, trends, quality and threats. Moreover, an integrated river management must base on the balance of ecosystem and sustainable development with establishing targets as “environmental protection”, “water and soil preservation”, “ecosystem conservation” and “Landscape maintenance”. In relation to these targets, the evaluation indicators were turned from the environmental status and planning context by the PSR analysis (Figure 4.5).

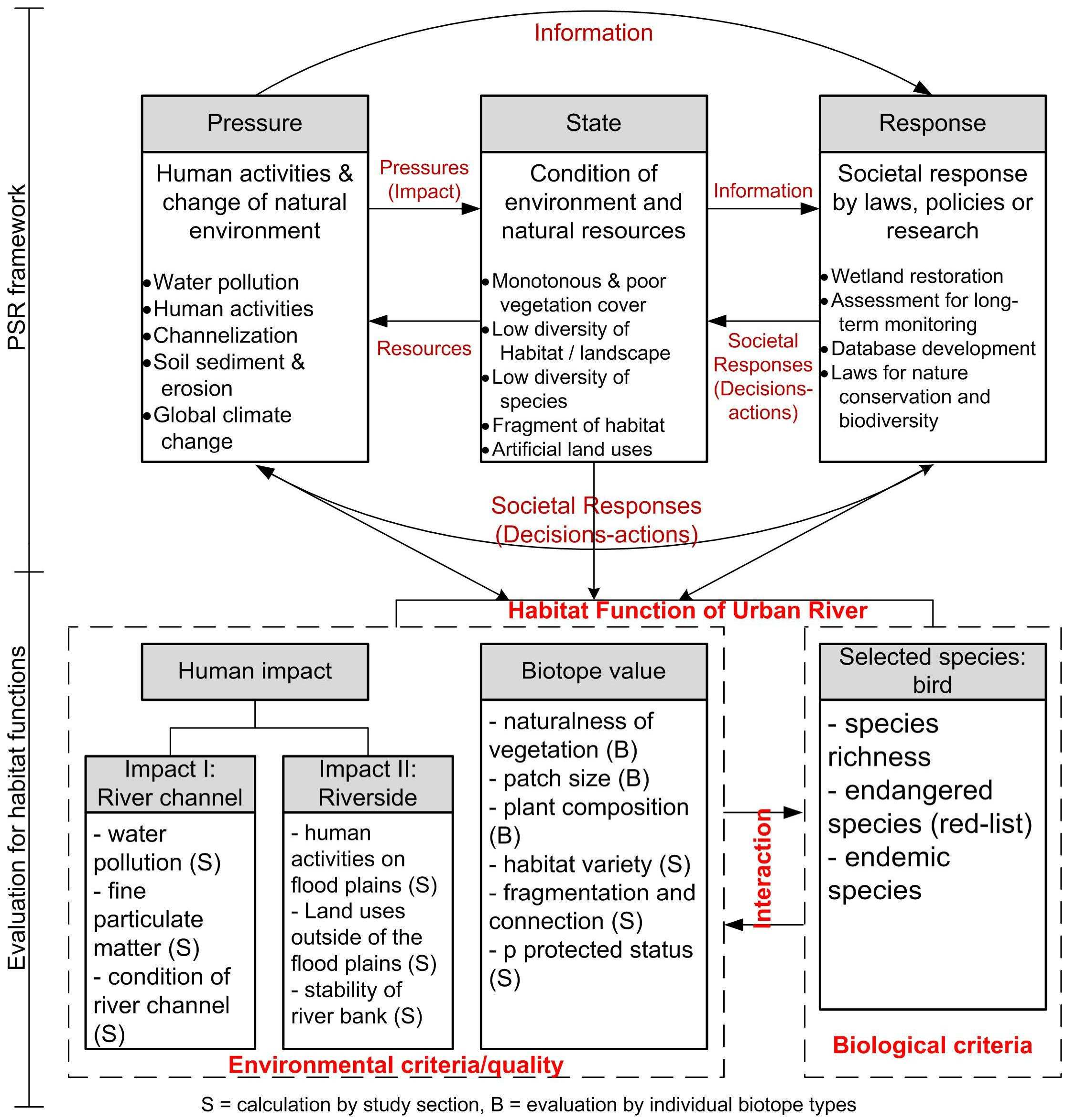


Figure 4.5: PSR Analysis of the lower Keelung River (designed by author)

The impact factors are associated with the consideration of "pressure", which can reflect on water body and flood plains. The biotope factor is designed for estimating the "state" of habitats, in which the criterion of "protected status" also refers to the previous response to former pressure and state. A long-term development with this evaluation framework may represent the context of environmental changes and their causes and responses. In addition, the influences on river ecosystem should consider about four categories: longitudinal dimension, latitudinal connection, vertical connection and temporal dimension. The longitudinal and latitudinal connections usually refer to river continuum concept and the relationship between water body and riparian areas. The vertical connection shows the exchanges between groundwater and water surface. The temporal dimension is defined as the casual or regular impact that the casual impacts can be at indefinite or historical scale, and the regular impacts might be monthly or annual. These impacts should be concerned to evaluate the impacts on urban river areas.

For checking the completeness of indicator design, as well as flexibly applying to the further studies, the design of indicators should also consider about five fundamental parameters: 1) unity: each indicator should be familiar and adapted to the urban river as well as easily handled, 2) representative: they are reprehensive and remarkable to show the condition and trend biotopes, 3) being quantifiable: it is easier to reflect the current situation and useful for both of quantification and qualitative studies, 4) long-term simulation: the indicators should be adjusted to reflect the changes over time, and 5) easily collected: referred to the official statistics, which can be widely used by further or relative projects. With this concept above while measuring the habitat functions, the condition of river habitats can be standardized and regularly updated. Then, it will be applied in long-term river management and nature conservation. In order to determine these parameters more precisely, the following criteria were shown on impacts, environment (biotope itself) and species condition in Table 4.6 and listed in more detail in the next section. The overall display of environmental criteria shows the comprehensive performance of habitat quality (HQ) in urban river areas, which may further compare with the species factor (bird species) to show the habitat functions of urban river.

Moreover, to consider the available data, one basic design of evaluation framework should be emphasized that some indicators are calculated with each individual biotope (e.g. naturalness of vegetation with condition "B" as listed in Table 4.7) and then displayed the results with sum of each test sections. Nevertheless, the other indicators can be only shown in section (e.g. water pollution with condition "S"). In order to compare the further analysis with selected species, all the evaluation results will be rearranged and displayed in sections to represent the habitat functions in the lower Keelung River (results described in more detail in Chapter VI).

Table 4.6: Criteria of assessment model on habitat functions of urban rivers

Human impact I	Human impact II	Biotope value	Selected species
Water Pollution: (D1-1*)	Human activities on flood plains (D2-1)	Naturalness of vegetation cover (B-1)	Species richness (S-1)
Fine particulate matter (D1-2)	Land use outside of the flood plains (D2-2)	Patch size (B-2)	Endangered species (red-list) (S-2)
Condition of river channel (D1-3)	Stability of river bank (D2-3)	Plant composition (B-3)	Endemic species in (S-3)
		Habitat variety (B-4)	
		Fragmentation and connection (B-5)	
		Protected status (B-6)	
	Habitat Quality ◄	**interaction**	**► Species condition**

* indicator code

Table 4.7: Attribution of indicators for habitat functions in the lower Keelung River

Evaluation factors		Criteria items	Condition*
Human impacts factors	Water	D1-1: Water pollution (PSI index)	S
		D1-2: Fine particulate matter	S
		D1-3: Condition of river channel	S
	Land	D2-1: Human activities on flood plains	S
		D2-2: Land use outside of the flood plains	S
		D2-3: Stability of river bank	S
Biotope value		B-1: Naturalness of vegetation	B
		B-2: Patch Size	B
		B-3: Plant composition	B
		B-4: Habitat variety	S
		B-5: Fragmentation and connection	S
		B-6: Protected status	S

* "B" means the condition of each biotope; "S" means the measure shown in every section of study areas. The seven testing sections are shown in Chapter VI.

4.3.2.2 Hierarchical Scales of Habitat Quality based on the Concept of Hemeroby Value

The degrees of assessment should be structured in a hierarchy to show the results of assessment (e.g. condition of biotope types and their complexes). A hierarchy scale for habitat quality was designed according to the concept of hemeroby value, which is originally designed for an integrated measure for the anthropogenic influence on landscapes or habitats and the organisms which inhabit it (Fu et al., 2006), because the hemeroby values can be also applied to show the intensity of impacts of human intervention on ecosystems by grades (Sukopp, 1969; Kim, 2001). To compare with some studies (Kunick, 1974, Klotz, 1984 and Kowarik, 1988), Kim (2001) indicated that the hemeroby-system not only displays the land use, biotope characteristics and the transformation of landscape pattern, but also determines the pleasure from human activities on individual organism groups (above all the vegetation types). Showing the habitat condition and its vulnerability on scales is an important tool to compare with different spots in large study areas. It also serves responsible emphases and the human influence on ecosystems with the indicators of naturalness and biodiversity. Before discussing the criteria in more detail, the hemeroby value for showing and summing up the scale of impacts/effects should be introduced as follows.

The earlier ideas of hemeroby value were developed from more informal concepts by Jalas (1955), who proposed a four-point scale based largely on the degree of impact to the soil. The definition by Jalas (1955) was subsequently extended to a 10-point scale, which has been used to categorize both plants and places in central Europe (Kowarik 1990, 1999; Sukopp 1990; Grabherr et al. 1995, 1996; Hill et al., 2002). On the basis of research targets and integrity of database, the parameters of hemeroby can be grouped into 3 to 10 different scales; the 10-point scale is a measure of human impact varying from 9 (ahemerobic or completely natural) to 1 (polyhemerobic, for instance consisting of pioneer vegetation of railways, rubbish dumps and salted motorways) (Hill et al., 2002). Kowarik (1988) further defined the hemerobie as "a measure for human impacts on ecosystems, in which the assessment of hemerobic degree is carried out by the extent of those anthropogenic influences which affect the system's development towards the final conditions".

In brief, the original idea of hemerobic index was for assessing the naturalness of habitats. Nowadays the concept of hemeroby value is generally applicable for assessing the environmental quality. The term "hemeroby value" is exclusively used in scientific literature and thus less likely to be confused than the term "naturalness" (Grabherr et al., 1999). Table 4.8 shows the parameters of hemeroby value in four different concepts. The parameters were measured on the sampling areas and subsequently converted into an ordinal scale from 0/1 (artificial) to 9 (natural).

Table 4.8: Different scales of hemeroby values (altered from Grabherr et al., 1999)

Hemeroby values	**Hemeroby classes***	**Near-natural classes**	**scale of naturalness**	**Blume & Sukopp, 1976***
9	ahemerob	natural	natural	ahemerob
8	γ-oligohemerob	near-natural	semi-natural	ahemerob
7	β-oligohemerob	near-natural	semi-natural	oligohemerob
6	α-oligohemerob	moderately altered	moderately altered	oligohemerob
5	β-mesohemerob	moderately altered	moderately altered	oligohemerob
4	α-mesohemerob	strong altered	altered	mesohemerob
3	β-euhemerob	strong altered	altered	mesohemerob
2	α-euhemerob	artificial	artificial	α-, β-euhemerob
1	polyhemerob	artificial	artificial	polyhemerob
0				metahemerob

*the original hemeroby scales are shown as **ahemerob**=natural: unaffected; oligohemerob=near-natural: light unaffected; mesohemerob=semi-natural: moderately affected like cultural landscape; **euhemerob**=altered: strong affected like agriculture; **polyhemerob**: very strong affected as partial cropped areas; **metahemerob**=artificial areas

For showing the evaluation results of habitat quality and the relationship of bird species and their habitats, the evaluative scales in this case were developed as simple and objective as possible to sufficiently assess in site directly based on the ideas of hemeroby values adapted to the available data. It is in set of 5 scales (between 0-4) as "bad (e.g. artificial)" (0), "poor (e.g. altered)" (1), "fair (e.g.

moderately altered)" (2), "good (e.g. semi-natural)" (3) and "excellent (e.g. natural)" (4). As displayed in Table 4.9, the scales of values applied to each indicator, for instance, the criterion of naturalness of vegetation shows natural by "4" and indicates artificial at "0". The colour code may be the reference to show evaluation results on maps. Then, the sum of all indicators (12 criteria in 3 aspects) are calculated in the end to perform the ranking of habitat quality on nine scales (from 9 to 1 means excellent to bad; detail in Chapter 4.3.3.4)

Table 4.9: Colour code of Scales of values in the assessment framework of urban rivers

Scales of values	**4**	**3**	**2**	**1**	**0**
Level of condition	Excellent (e.g. Natural)	Good (e.g. Semi-natural)	Fair (e.g. Moderately altered)	Poor (e.g. Altered)	Bad (e.g. Artificial)
Colour code					

4.3.3 Evaluation Criteria for Habitat Functions in Urban River Areas

4.3.3.1 Human Impacts I: Water Body

The degrading water quality causes the completely lost of sensitive organisms from the stream. The main impacts on water quality are strongly made by "land use" (e.g. farming, urban areas, construction and industry), "stock assesses to stream" (e.g. increasing turbidity and nutrient load) and "point sources of pollution" (such as drains, sewage effluent and industrial wastewater). The impacts on water bodies seem to be a term to evaluate the condition of habitat condition. Therefore, the impact indicators on water body fall into three categories with "water pollution", "fine particulate matter" and "condition of river channels".

A. Water Pollution (Indicator Code: D1-1)

The environmental disturbance is an effective indicator of the extent and magnitude of pollution impacts in estuarine environments like urban rivers (Engle, Summers and Gaston, 1994; Weisberg et al., 1997; Borja, Franco and Pérez, 2000; Caeiro et al., 2005). Water pollution control is usually an important issue in urban river areas for ecological rehabilitation or flood risk in an integrated project of river management. The Environmental Protection Administration of Taiwanese Central Government has started collecting the data of water quality every month since 1987. This system is the so-called "River Pollution Index (RPI)", calculating the water quality with Biochemical Oxygen Demand (B.O.D.), Dissolved Oxygen (D.O.), Suspended Solids (SS) and Ammonia nitrogen (NH_3-H) into four scales of non-polluted (1 point), light-polluted (3 points), medium-polluted (6 points) and heavy-polluted (10 points). The average of the points with these four indexes would be regrouped into the condition of water quality (Table 4.10).

Table 4.10: Degree of River Pollution Index in Taiwan

	Non-polluted	Light-polluted	Medium-polluted	Heavy-polluted
DO	> 6.5	4.6-6.5	2.0-4.5	<2.0
BOD_5	<3.0	3.0-4.9	5.0-15	>15
SS	<20	20-49	50-100	>100
NH_3-N	<0.5	0.5-0.99	1.0-3.0	>3.0
Point*	1	3	6	10
Ave. of Point*	**< 2.0**	**2.0-3.0**	**3.1-6.0**	**> 6.0**

* The point in this system is taken to indicate the condition of each index, point = 4 means heavy polluted. Then, to get the final RPI by calculating the average of the four indexes – when the RPI is 1, the average of points is less than 2. (Source: Environmental Protection Administration, Taiwan, 1997)

Based on the concept of RPI, the scales of value for water pollution can be shown in four scales in Table 4.11: non-polluted (SV=3), light-polluted (SV=2), medium-polluted (SV=1) and heavy-polluted (SV=0). Since the completely non-polluted river would be too ideal to existent in reality, the highest scale of values with 4 would not be listed in this criterion.

Table 4.11: Scales of values for water pollution in urban river areas

Scales of values	Degree	Definition	Point*
4	--	failed	-
3	Non-polluted	RPI (River Pollution Index) < 2.0	1
2	Light-polluted	RPI (River Pollution Index): 2.0-3.0	3
1	Medium-polluted	RPI (River Pollution Index): 3.1-6.0	6
0	Heavy-polluted	RPI (River Pollution Index) > 6.0	10

* The points are the reference of RPI as shown in Table 4.10

B. Fine Particulate Matter (PM) (Indicator Code: D1-2)

The term “fine particulate matter” stands for the fine matters in air discharged by the industry or transportation that would flow into the water after raining. The fine particulate matter is one indicator of Pollutant standards Index *(*PSI) in Taiwan, since acid rain is a typical pollution problem by fine particulate matter in development cities and the pollutants may dissolve into the water. Besides, the fine particulate matter also makes impact on the process of photosynthesis; it is therefore an important index to show the air pollution and water quality. In another viewpoint, the more fine particulate matter would indirectly reduce the quantities of aquatic species (e.g. fishes and waterfowl). Based on the data from Technical Laboratory of Department of Environmental Protection in Taipei City, the transformed indexes into Scales of values are listed in Table 4.12. The non-polluted condition (SV=4) seems too ideal and unreachable to be contained in the scales of values.

Table 4.12: Scales of values of fine particulate matter in water body

Scales of values	Degree	Definition
4	--	failed (Ideal condition)
3	micro-PM	<65 (μg/m^3)
2	Medium-PM	66-95 (μg/m^3)
1	Heavy-PM	95-124 (μg/m^3)
0	extreme heavy-PM	>125 (μg/m^3)

* Technical Laboratory of Department of Environmental Protection in Taipei City

C. Condition of River Channel (Indicator Code: D1-3)

The state of channel is a criterion to show the impact on river channel, which may pay attention to the stability of riversides, washout, soil erosion and alluvial. The stable river channels have fewer changes both in regular and irregular ways to serve relatively stable habitat for wildlife. The changes in river regulation and natural flooding should be the key impacts in assessing the impacts on river channel. Meanwhile, when two sections have the same strength of changes, the section with alluviums may have better habitat quality than the section with dynamic process of erosion or sedimentation, since the unstable river channel does not regularly serve functions for refuge and breed; but the stable section, especially with alluviums, play a role as stepping stone for rest or forage for wildlife. Therefore, the scales for evaluating condition of river channel can be listed in Table 4.13. The relatively stable river channel with alluvium may supply better environment for wildlife and can be indicated at 4.

Table 4.13: Evaluation state of river channel (altered from SERAS by Liang, 2001)

Scales of values	Degree	Definition
4	Minimally disturbed	Generally stable, unaltered or only slight altered river channel with mostly natural conditions. No erosion of river base, water flows steady. The influenced channel is in ratio of less 5%.
3	Moderately disturbed with alluviums	Some alluviums and sedimentation. The river channel is altered with ratio of 5-30%.
2	Moderately disturbed with erosion	Steep river channel, small water flowing, has erosion recently but can be restored easily. The influenced channel is in ratio of 30-50%.
1	Heavily disturbed with alluviums	Although the flat river channel seems obviously destruction and has high dynamic process of erosion and flooding, but with a few apparent alluvia. The influenced channel is in ratio of 50-70%.
0	Heavily disturbed with erosion	The river channel is altered by river regulation. It is eroded often by rapid storm water; the exploited river bank has high risk of erosion by flooding. The influenced channel is in ratio of more than 70%.

4.3.3.2 Human Impacts Factors II: Land

The riparian areas usually play a role as buffer zone to conjunct the water bodies and the neighbourhoods of river corridors. The control and limitation of human impact is important to manage habitat quality and biological conservation in the wildlife ecosystem. However, sometimes management by humans is necessary to maintain habitat quality of special areas (Hong et al. 1995; Hong 2001). This criterion checked the impacts on land condition in neighbourhoods and on riverbanks. The impacts on the buffer zone may decrease the nutrient, functions of habitats (rest, refuge, etc), degrade the bank stability and increase soil erosion. The performance in this case was assessed by “human activities on the flood plains”, “land use in the surrounding outside of the flood plain” and “stability of river bank” to show the impacts from human activities on ground surface.

A. Human Activities on Flood Plains (Indicator Code: D2-1)

If the land use paved or covered with man-made constructions, the habitat value is lower because of lack of vegetation, minimal habitat structure and fragment (Efroymson et al., 2008); especially the impact may be stronger by human activities. The impacts from human uses on flood plains can be discussed in two aspects – intensity and frequency of activities. The regular, slight impacts might not destroy the steady state of habitat content, but the resilience of habitat functions might be decreased because of accidents and strong impacts. The information about intensity of human activities on flood plains can be collected by questionnaire and local observation, because of the limit of time and coworkers, this study is only done with local observation. The results can be clarified and described in two parts: weekdays and weekend to show the intensity on flood plains. This criterion analyzes the intensity of human impacts based on the accessibility and the intensity of activities. Since the intensity is difficult to prove with quantification data, the existing schedule of activities and observation by field work are the evidences to show the intensity of human activities on flood plain (Table 4.14).

Table 4.14: Evaluation of intensity of impact from human activities on riverbanks

Scales of values	Degree	Definition
4	None impact	No human activities IMP (percentage of impervious area) < 20%
3	Light impact	Has human activities once in a while and people do not get to this place often. IMP is 20-40%.
2	Middle impact	Has human activities often, people can easily reach this place. IMP is 40-60%.
1	Usual impact	Has human activities usual and has strong impact once in a while, people can easily reach this place. IMP is 60-80%.
0	Heavy impact	Has strong human activities in usual. IMP is 80-100%.

B. Land use in the Surrounding Outside of the Flood Plains (Indicator Code: D2-2)

The causes of the decline in the number of the species are the changes in land use due to urban development (e.g. urban growth, development of residential areas for industrial use, urban renewal and roads, etc.). In the case of plants found in residential neighbourhoods, more intensive uses and changes in the methods of management, including the increased application of herbicides (cf. Kunick, 1979). The neighbourhood land use can bring about the impact on river biotopes; therefore, the land use in surrounding areas must be evaluated. The zoning of Taipei City is divided into thirteen main types: “residential area”, “commercial area”, “industrial area”, “administrative area”, “culture and education area”, “entertainment area”, “airport area”, “public facilities area”, “scenic area”, “agricultural area”, “reserved area”, “waterside area”, “special area and land for other uses” (Department of Budget

Accounting and Statistics, Taipei City Government[2]). Different zoning types have different intensity and offers different possibility as habitats for wildlife. This criterion is firstly classified with the degree of naturalness by percentage of vegetation cover. It reflects the location of biotope in the city as well (related to building type and land use, etc.).

And then, the naturalness of land use in neighbourhoods plays the role as weight to convert into the scales of values. It calculates the intensity of land use with the areas to assess the impacts for each section. The formula is: $\mathbf{UL=SW_i*P_i}$ (W_i=weight of different land use, P_i=areas of each land use). The scales of values of land use in neighbourhood areas are defined in Table 4.15. The values of UL in the last column show the naturalness in neighbourhoods after calculating with the weight of different land use. The higher scales of values refer to lower UL value.

Table 4.15: Scales of values for land use in surrounding areas of urban rivers with weights of impact of land use (Taipei City Government; Lin, 2001)

Scales of values	Degree	Definition	Weight*	UL**
4	Natural	Relative natural land use, e.g. agricultural area, reserved area	0	0-0.1
3	Semi natural	Some high-developed agricultural areas, riparian area, scenic area and some culture and education areas which build up by natural materials	0.25	0.1-0.25
2	Moderately altered	1st and 2nd residential area, 1st commercial area, 1st industrial area, culture and education areas, administrative area which build up by natural materials	0.5	0.25-0.5
1	Altered	3rd and 4th residential area, 2nd and 3rd commercial area, 2nd industrial area, administrative area, entertainment area	0.75	0.5-0.75
0	Artificial	Highly developed area, e.g. 4th commercial area, 3rd industrial area, airport area, public facilities area, special area and land for other use	1	0.75-1

* Weight is taken to show the special of different land use by multiplying the areas of each land use.
** UL is the abbreviation of urban land-use types to show the impacts of land-use types in the surrounding urban areas in this case.

C. Stability of River Bank (Indicator Code: D2-3)

The impacts on habitats may be observed on mechanical intervention in soil (e.g. soil compaction, break, drainage, waste dumping, etc), directly mechanical intervention on vegetation structure (e.g. regularly and irregularly altered by planting or removal of plants) and material intervention (e.g. chemical soil quality) (Kim, 2001). It displays the stability of river bank on both sides, which shows the state of vegetation cover and as well as soil erosion (Table 4.16). Normally speaking, the

[2] Department of Budget Accounting and Statistics, Taipei City Government, available from: http://www.dbas.taipei.gov.tw/.

stable riversides are covered with vegetation which can slow down the rapid flow and reduce the river washout and consequently mitigate the soil erosion.

Table 4.16: Scales of values of stability of riverbank (altered from SERAS by Liang, 2001; Chang, 2004)

Scales of values	Degree	Definition
4	Minimally disturbed	- Generally stable riverbanks with mostly natural condition. No striking damage of vegetation and river bank, no exploited roots of plants. - The areas of destroyed riverbanks are less then 5%.
3	Lightly disturbed	- No continuous damage of vegetation and river bank, a few exploited roots of plants - The areas of destroyed riverbanks are about 5-20%.
2	Moderately disturbed	- A few replacement of natural vegetation on riparian sides, a few apparent damage, some exploited roots of plants - The areas of destroyed riverbanks are about 20-40%
1	Heavily disturbed	- Unstable river bank, many exploited roots of plants or poor vegetated, some apparent erosion recently - The areas of destroyed riverbanks are between 40-60%.
0	Extremely disturbed	- Rapid heavy erosion, no vegetation, no stable river banks. - Greater than 60% of riverbanks are destroyed.

4.3.3.3 Biotope Condition (Quality of Biotope Types)

The biotope condition and structure of riparian areas, i.e. the vegetation condition, are the main factors to show the quality as being habitats for wildlife based on its physical conditions. Efroymson et al. (2008) mentioned that the absence of the vegetation communities might be a measure of fragmentation of wildlife habitats, i.e. loss of the original habitats area, reduction in habitat patch sizes, and increasing isolation of habitat patches. It is a major step towards the synthesis of ecological and geographical approaches, which was firstly formulated as the “biogeocenosis” concept by Sukachev in 1942 (Novikov, 1980; Olenin and Ducrotoy, 2006). The condition may compare with the biological information to show the natural phenomenon, location on a relatively limited area, functionally correlating living organisms and their environment, with a specific type of interactions of its components and a certain type of matter and energy exchange between themselves and with other natural phenomena (Reimers, 1990; Olenin and Ducrotoy, 2006). From these ideas, an evaluation for biotope condition can be analysed with the landscape composition and landscape configuration, for example by patch size and quantities, patch form and distribution, corridors connection and density, landscape diversity, fractal dimension. Accordingly, there are six indicators to assess the biotope condition as habitat for wildlife: “naturalness”, “patch size”, “plant composition”, “habitat diversity”, “fragmentation and connection”, and “protected areas”.

A. Naturalness of Vegetation (Indicator Code: B-1)

Naturalness is considered to be of high ecological value in itself. It causes some debate since the modification of river basin for human demands and urban development. Naturalness is also an indicator to reflect the condition or health of river areas (Dunn, 2000). Any land use change within a river basin will have an effect on the naturalness and increasing impermeable surfaces that prevent water from percolating into the ground (Schneiderbruber et al., 2004).

The naturalness of vegetation is so-called spontaneous occurrence of the areas, which shows the capacity of natural vegetation types. The weight for assessing the naturalness of different biotope types is given firstly according to the vegetation condition and structure (shown in Table 6.9). Then the scales of values are multiplied by the areas of biotopes to show the state of naturalness in each test section as SVS_{B1}. ($\mathbf{SVS_{B1}=W'_i*P'_i}$; W'_i=weight of different biotopes, P'_i=areas of each biotope types, and SVS is the Scales of values of naturalness in test sections). Finally, the scales of values for naturalness of vegetation are displayed with the biotope types and the percentage of vegetation cover; which can be displayed on five scales: “natural”, “semi natural”, “moderately altered”, “altered” and “artificial” (Table 4.17).

Table 4.17: Naturalness of biotopes (revised from Kowarik, 1988 Grabherr et al., 1997; Dierßen, 1990; Kim, 2001)

Scales of values	Degree of naturalness	Definition
4	Natural	- No human impact, essentially natural. The types of biotope include old forest, wetland and marsh area - Site with purely natural species & considerable rare, endangered species
3	Semi natural	- Near natural biotope, less artificial structure. The types of biotope are covered economic forest, farmed, neglected grassland and meadow - Site with mostly indigenous species, several rare species
2	Moderately altered	- Moderate modification, some man-made construction of timber. The biotopes are highly utilised grassland, growing along roadsides, in disturbed or abandoned farmland, traditional field - Site with settled & indigenous species; rarely rare or endangered species
1	Altered	- Major modification, much man-made construction of concrete and steel. The types of biotope are involved field, garden, man-made environment with vegetation - Site with mostly indigenous species
0	Artificial	- High modification, no natural biotope. - Site with solely exotic generalist species

B. Patch Size (Indicator Code: B-2)

Habitat size is an important element of habitat quality, because the large areas may serve the greater probability of diverse community. Farina (2000) also mentioned that habitat quality is decided by size effect, which means, when the large habitat blocks are broken into small ones, the area change of ecosystem may directly affect biodiversity. To compare two similar areas, a larger habitat patch is generally more valuable as habitat than a smaller one (Efroymson et al., 2008). According to Forman's studies (1995), a single large habitat has high ecological value to many specialists. In general, the larger area shows greater possibility of the species diversity and also performs self-regulation to impact; however, several small habitats also have an important role as stepping stones for wildlife. These stepping stones connect large habitats and small habitats for the dispersal of animals. This indicator assesses the size of main biotopes for wildlife, which are wetland, woodlands, wetlands, shrubbery and inland water. According to some studies on urban landscape in Taiwan (e.g. Koh et al., 2008), the patch size as habitats in cities can be divided into three groups: big habitat (> 5 ha), medium habitat (1-4.99 ha) and small habitat (0.1-0.99 ha), the scales of values (SV_{B2}) of each biotope are listed in Table 4.18 added the larger patches and very small patches. Moreover, the results of SV in each test section may further be multiplied by the areas as SVS_{B2} (**$SVS_{B2}=SV_{B2}$*P"$_{il}$**, SV_{B2} is Scales of values of each patch of biotopes, P_i means areas of biotope).

Table 4.18: Scales of values on size of the Biotopes (revised from Kim, 2001)

Scales of values	Degree	Definition
4	Very large	Area>50 ha, this characters is the main matrix or patch in that section.
3	Big	Area=5-50 ha, which is the main patch in that section.
2	Medium	Area=1-4.99 ha, there are many useful stepping stones in the surrounding area
1	Small	Area=0.1-0.99 ha, there are some stepping stones in the surrounding area
0	Very small	Area<0.1 ha, too small to serve the habitat function and even not good enough as stepping stone.

C. Plant composition (Indicator Code: B-3)

Habitat diversity is an important criterion to demonstrate the habitat complexity, since high habitat diversity procures high community diversity / species diversity. For instance, Roth (1970s) discovered that higher landscape diversity affects on the distribution of bird species (Farina, 1998; Yang, 2001). Forman also considered that the landscape diversity influences movement of species (Forman, 1995; Yang, 2001). Therefore, many indicators have been designed to assess habitat diversity. Franklin et al. (1981) and Noss (1990) proposed monitoring habitat diversity with three components: composition, function and structure (McCleary and Mowat, 2002). However, function is often difficult to be measured (Franklin and Spies, 1991; McCleary and Mowat, 2002), habitat structure and habitat composition seem to be likely to show the habitat diversity. Accordingly, "plant composition" (indicator code: B-3) and "habitat variety" (indicator code: B-4) are designed in this study to display the vertical and horizontal diversities of habitat.

A friendly environment for wildlife may have multiple vegetation cover to serve functions of breeding, refuge and feeding. Therefore, the riparian vegetation plays a significant role in relation to soil erosion, channel stability, wildlife and fish habitat and water quality (Kuusemets and Mander, 1999; Vought et al., 1995; Gregory et al., 1991; Apan et al., 2002). The habitat structure, i.e. plant composition at sites, is representing variety of vegetation cover with the composition of vegetation types on different biotope types. More kinds of plant types may serve functions as habitats for different wildlife. Accordingly, the scales of values of each biotope (SV_{B3}) can be listed in Table 4.19. Then the scales of values are multiplied by the areas of biotopes to show the state of plant composition in each test section as SVS_{B3}. (**SVS_{B3}= SV_{B3}*P'_i**; SV_{B3} is scales of values of each biotope, P'_i=areas of each biotope types, and SVS_{B3} is the Scales of values of plant composition in test sections)

Table 4.19: Scales of values for variety of vegetation cover (revised from WHIP, 2003)

Scales of values	Degree	Definition
4	Highly various	Predominantly native species of trees or shrubs
3	Various	Predominantly mixed species of trees or shrubs
2	Medium	Predominantly native herbaceous plants
1	Low various	Predominantly introduced plants
0	Monotonous	Invasive plants or bare ground (not vegetated)

D. Habitat Variety (Indicator Code: B-4)

"Habitat variety" is defined as "a number of different types of wildlife habitat within a given area". The measures of variety account for both abundance and evenness of habitat types in this criterion. Firstly, to categorize the biotopes in urban river areas into three groups: "semi-natural environment", "intermediate environment" and "anthropogenic environment". The habitat variety only respects the number of biotope types represented as habitats for wildlife, i.e. "semi-natural environment" and "intermediate environment". Then, summing up the biotope types in the seven sections of study areas and estimating the habitat variety on five scales: high variety, variety, medium, low variety and monotony (Table 4.20). SVS_{B4} (habitat variety) = numbers of habitats for wildlife in sections/numbers of all biotope types in study areas (in proportion).

Moreover, **Evenness index** (the change of landscape structure) can be calculated as reference to see the equal distribution of biotopes. Evenness is the proportion of the total area covered by each biotope type. Maximum evenness occurs when every type occupies an equal area of the landscape. In principle, habitat composition is monotony as Evenness index which is close to 0 (Forman, 1995; Xiao, 1992; Farina, 1998; Yang, 2001). E=H'/H'max (H'max=-nx1/nx$\log_e$(1/n), H'max is the maximal numerical value).

Table 4.20: Scales of values for evaluating habitat variety (altered from Jian and Fong, 2002)

Scales of values	Degree	Definition
4	Highly various	SVS_{B4}=E is more than 90%
3	Various	SVS_{B4}=E is between 75%-90%
2	Medium	SVS_{B4}=E is between 50%-75%
1	Low various	SVS_{B4}=E is between 25%-50%
0	Monotonous	SVS_{B4}=E is less than 25%

E. Fragmentation and Connection (Indicator Code: B-5)

Habitat fragmentation influences native species and large animals that prefer large habitat size (Diffendorfer et al. 1995; Forman 1995; Mano et al. 2001). Forman (1995) emphasized that the habitat fragmentation might threaten some species and increase the risk of species extinction. The separation of patches would raise direct risk to endangered species even cause the extinction of the interior species. An ecological corridor is supposed to be a natural stepping stone and corridor to increase the habitat connectivity between each fragmented landscapes. Connectivity gives an important role to multi-habitat species that use several habitats (Barrett and Peles 1999; Seo 2000). Therefore, this indicator is designed to evaluate the condition of fragmentation and to test the connection isolated habitats as stepping stones.

This criterion evaluates the isolation and connection of the main habitats of wildlife (grassland, wetland, shrubbery and freshwater) based on the ideas of "island biogeography" [3] by "γ index for network connectivity" (denotes "mean nearest distance") and "α index for network circuitry" (means "proximity"). The indexes of γ and α show the linkage of habitats with the idea of habitat connection, and the mean D_{ij} and Px display the distance of main habitats for ability of moving in between.

In graph theory, nodes are generally non-linear elements that can be considered to be a place or an event, while links and routes are defined as linear elements that facilitate the accessibility and the flow of energy, matter or species (Zhang and Wang, 2006). The networks structure analysis shows the interactions among individual notes, which play a role as stepping stones. The **γ index for network connectivity [$\gamma = L/L_{max} = L/3(V-2)$** (L=number of linkages, Lmax=maximum possible number of linkages, V=number of nodes)], which shows the ratio of the number of links in a network to the maximum number of links possible (Zhang and Wang, 2006). In addition, **α index for network circuitry [$\alpha = (L-V+1)/(2V-5)$** (L=number of linkages, V=number of nodes)] to measure the possibility and complexity of connection.

[3] "Island Biogeography" was firstly brought up by Robert MacArthur and E. O. Wilson (1963, 1967). It explains the factors that affect the species richness of particular community in island and then be applied to assess the isolated habitats. The main targets of this theory are: the equilibrium theory of island biogeography, empirical evidence, biogeography of habitat islandsand Conservation applications.

The **mean nearest distance** shows the average of nearest distance between each Habitat (**D_{ij}= 1-d_{ij}/Σd_{ij}**, d_{ij}=the nearest distance). A **proximity index (PX)** inspired by island biogeography theory is described which quantifies the spatial context of a habitat patch in relation to its neighbours. The index distinguishes sparse distributions of small habitat patches from clusters of large patches. (Gustafson and Parker, 1994) **PX=Σ(S_i/z_i)** where S_i is area of patch, z_i is the distance of nearest-neighbour patch. Table 4.21 is listed the scales of evaluation in these four indexes from best connection (1 point) to isolation (10 points). The average of these four indexes can be further recounted in fiver scales: the average of points less than 2 points belongs to best connection (point 1) and the average of points more than 10 is isolated habitats.

Table 4.21: Degree of isolation of main habitats for bird species (altered from Jian and Fong, 2002; Chou, 2004)

Refer to	Index	Best connection	Better connection	Less connection	Bad connection	isolation
Linkage	γ index	75-100%	40-75%	25-40%	10-25%	0-10%
	α index	75-100%	40-75%	25-40%	10-25%	0-10%
Distance	Mean nearest distance	>0.75	0.5-0.74	0.25-0.49	0.01-0.24	0
	Proximity	0	<100	100-1000	1000-10000	>10000
Point*		1	3	5	7	10
Ave. of Point*		< 1.0	1.1-3.0	3.1-5.0	5.1-7.0	≥ 7.0

* The point in this system is taken to indicate the condition of each index, point = 10 means isolated condition of habitat. Then, to obtain the final values by calculating the average of the four indexes – when the final point is 1, the average of points is less than 1.

With the reference to Table 4.21, the results of evaluation can further contrast with the definition described in Table 4.22 and display in scales of values.

Table 4.22: Connection of main habitats for bird species

Scales of values	Degree	Definition
4	Best connection	Ave. of point <1.0
3	Better connection	Ave. of point is between 1.1-3.0
2	Less connection	Ave. of point is between 3.1-5.0
1	Bad connection	Ave. of point is between 5.1-.7.0
0	Isolation	Ave. of point ≥7.0

F. Protected Status (Indicator Code: B-6)

Dunn (2000) mentioned the value of any uncommon habitat, which may contribute to the global biodiversity or geo-diversity context. From this viewpoint, to survey the protected status in study areas indicate the specific habitats that should be highly protected due to the rarity or individual elements of it. The results of this indicator represent the planning context at sites and provide useful information for further decision-making of environmental policies. Moreover, to associate with the consideration of species-oriented protection and multifunction habitat networks, the protected status of habitats in study areas should be discussed, because the integrated nature conservation goals with land use practices may affect biodiversity at site and the surrounding areas (Haaren v. and Reich, 2006).

Though there is no general legislation for protecting specific habitats in Taiwan as national legislation on nature conservation in Europe (e.g. Fauna-Flora-Habitat (German: FFH-Gebiete), biotope network (German: Biotopverbund), Natura 2000, etc.), a national plan has been developed since 1980's to specify the "**environmentally sensitive area**" as background of environmental development and nature conservation. The term of "environmentally sensitive area" is defined as "a place with special value or potential natural disaster, where can be destroyed by wrong or overloading development and should be protected or enhanced" (CEPD, 1985). These special landscape, wildlife or historic areas are designated by central government (Council for Economic Planning and Development, CEPD) in four categories and formulated in detail by local governments with the specific local conditions. Accordingly, the local and regional planning should follow policies for limited development by "land-use suitability analysis".

The plan of "environmental sensitive area" was made for protecting ecosystem and conserving natural resources based on Taiwan's special landscape structure and biodiversity. The four categories designated by CEPD are "**ecological sensitive area**" (e.g. nature conservation, national parks, wildlife reserve), "**landscape sensitive area**" (e.g. special natural landscape, historic spot), "**sensitive area of production resources**" (e.g. groundwater resources, good farmland) and "**sensitive area of natural disaster**" (e.g. flooding areas, fault zone, landslide area) (CEPD, 1985; Chang, 2001). To associate with habitat functions, areas of "ecological conservation areas", "national wildlife reserve", "important habitats" and "coastal conservation areas" should be considered in this criterion. The protected status is evaluated with special habitats for wildlife in proportion (Table 4.23).

Table 4.23: Scales of values for evaluating protected status

Scales of values	Degree	Definition*
4	Highly protected	The biotope is special natural habitats, e.g. spawning area in water bodies, moorland, flood plain forest, wetland, etc. More than 50% of study areas are protected
3	Protected	Some important biotopes are protected for wildlife. 31-50% of study areas are protected
2	Medium	The biotope type shows as a characteristic of the landscape. 11-30% of study areas are protected
1	Low protected	The biotopes have not been protected for wildlife. Less than 10% of study areas are protected
0	Not protected	No single biotope type has been protected in study areas

* the proportion on scales of values should be flexibly redefined at different scales.

4.3.3.4 Integrated Analysis of Habitat Quality (Sum of Environmental Criteria)

Except the first two indicators of impact factor I (D1-1 and D1-2), all the criteria have highest scale at 4. Therefore, the sum of the habitat criteria is 48 (points). To combine the three different aspects of criteria (impact factors I, impact factors II and biotope condition), the comprehensive performance of **habitat quality** (HQ) can be grouped into seven scales, from excellent (HQ=7) to bad (HQ=1) condition (Table 4.24). For instance, a section of study areas has the total HQ with 42, which is classified on scale 7 of habitat quality. The excellent condition of habitats represents the less impact and better biotope value. This outcome cannot only contribute to analyse the quality of biotopes, further to emphasize the relationship between bird species and their habitats, but also to be a basis for decision-making of legislation, policies of nature conservation and habitat rehabilitation (Lin, 2009).

Table 4.24: Entire evaluation of habitat functions (Refer to Machado, 2004; Kurz, 1998)

Degree of habitat quality	Habitat quality	Definition	Colour code
7	Excellent	Optimal status from viewpoint of nature-conservation, the original condition is great with rich biodiversity. The important biotope types are protected by legislation and policies. The minimal man-made infrastructure is temporary and removable, which would not be used for any other functions but habitats of wildlife. **Total habitat values*: 42-48**	
6	Good	The biotope plays an important role as refuge site and as well as an important part of natural landscape. But there are extensive anthropic activities of low physical impact; facilities if present, dispersed, not connected; wild exotic species well established but not dominant; natural structures modelled but not distorted (re-location of physical or biotic elements). Moderate extractions, if present. Little alteration of water dynamics **Total habitat values: 35-41**	
5	Good-moderate	The biotope has been extensively used but still serves basic habitat functions for refuge and breeding. Anthropic infrastructure scarce or concentrated; possible dominance of wild exotic species; native elements considerably reduced. Occasional addition of energy and / or wild exotic species; native elements considerably reduced. Occasional addition of energy and / or extraction of renewable resources or of non/relevant materials. General dynamic still controlled by natural processes. It may include abandoned cultural systems undergoing natural recovery. **Total habitat values: 28-34**	
4	Moderate	The biotope has been extensively used but can be improved by reducing the sources of impacts. Processes conditioned by extensive human activities; biological production not too forced. Native species altered, occasionally managed. Little or no presence of constructions. Little or no management of water cycle (passive). **Total habitat values: 21-27**	

Table 4.24: Continuance

Degree of habitat quality	Habitat quality	Definition	Colour code
3	Moderate -poor	The biotope has been extensively developed and cannot serve good ecological services as habitat. Important infrastructures and / or conditioning of the physical environment; forced biological production; moderate addition of matter (usually with pollution associated). Natural elements intermixed, in patches or corridors. Active management of water. **Total habitat values: 14-20**	
2	Poor	The Biotope is developed strongly, the habitat functions can only serve for some species as refuge and breeding. The land use is mixed with buildings and infrastructures. Natural biodiversity severely reduced; its elements rather isolated (intense fragmentation). Water dynamic manipulated. Geomorphology usually altered; soils eventually removed. **Total habitat values: 7-13**	
1	Bad	The biotope is complete a man-made environment, where has poor biodiversity, not well for habitat function. **Total habitat values: 0-6**	
* The maximum sum of the total habitat value is 48, since the optimum state is 4 in 12 different indicators.			

4.3.4 Selected Species for Assessing Habitat Functions

Connor et al. (2004) argued that the importance of biocoenosis concept in urban river ecosystem emphasize the interrelationships among species in the geographical areas. Dunn (2000) also mentioned that the interactions between physical factors and biological characteristics are adapted and responded to the consideration of further planning, the observed river functions, particularly with reference to the different types of species. Therefore, the ideas of discussing the relationship between selected species and their habitats may not only reflect the current habitat functions, but also present the consideration for environmental planning, policies and further studies.

Many species are valuable as biological indicators as target species, identifying particular environmental conditions, favourable or otherwise. The appropriate monitoring allows the identification of environmental improvement or deterioration, for example tracing improvements in air quality using lichens as biological indicators. In this study, bird species were taken as the study objects, since urban bird species are high heterotrophic animals to play a role as umbrella species in conservation planning and urban ecology. They are conspicuous (e.g. colourful, large, etc.) and as well as easily observed and distinguished. Bernotat et al. (2002a) specified that the traces of bird species can display the values in almost all habitat types (Bernotat et al., 2002a), as well as indicate the worth in many different aspects (e.g. species-environment-relationship, abiotic environmental parameter, structural element, habitat dynamic, etc) (Haaren v., 2004). Moreover, the biological evaluation aims to describe the environment-species-relationship, i.e. the changes in species composition/population within their habitats. In addition, the results may help the decision-makers propose the policies and planning of rehabilitation. Based on the PSR-framework analysis, the selection of target species should pay attention on some points: 1) representative, 2) responsive to change, 3) realistic to collect, 4) policy relevant, and 5) tractable (Gregory et al., 2005).

To combine with the previous environmental criteria, the evaluation with species condition is discussed from aspects of "species richness", "endangered species (red-list)" and "Endemic species in special interests". There are two different aspects to review the habitat functions with each indicator. The target species-habitat-relationship is discussed in two aspects: general interrelationship between environment and bird population and the evaluation of target species for suggestion of rehabilitation.

A. Species Richness (Indicator Code: S-1)

Species richness is evaluated with all bird species and resident birds appeared in study areas to show the habitat quality with quantity of bird species. Firstly, the biological condition is assessed with general discussion of all bird species, and then the amount of resident birds should be especially discussed for considering the local environment. Some representative resident birds are important to show the environmental changes with discussion of their breeding habitats. For long-term monitoring, this indicator can provide information about climate change. General speaking, better habitat condition usually serves better habitat functions for wildlife; species richness denotes the correlation between bird species and their habitats. The scales of value on species richness are shown in Table 4.25.

Table 4.25: Scales of values on Richness of bird species (altered from Lu and Chen, 2006)

Scales of values	Degree	Definition*
4	Excellent	Biotopes with great quantity of bird species, which included more than 200 different species that mostly contained resident birds, and the habitat is conserved well for these species
3	Good	Biotopes with great quantity of bird species, which included 101-200 different species that mostly contained resident birds, and the habitat can be maintained for these species
2	Fair	Biotopes with some bird species, which included 51-100 different species that mostly contained resident birds, but would be disappeared if the habitat is changed
1	Poor	Biotopes with a few quantity of bird species, which included less than 50 different species that mostly contained resident birds; or biotope with bird species included 51-100 that mostly contained introduced/migrant birds, which would be disappeared if the habitat is changed
0	Non-species	Man-made environment, no species

* When the proportion of sedentary birds is less than 50% of total species in the section, the scales of value of this section should decrease to the next scale.

B. Endangered Species (Red-List) (Indicator Code: S-2)

The studies of biodiversity usually pay attention to rare and threatened species, which is part of ecological value to have the backing of legislative protection in most countries (Dunn, 2000). Hartley and Kunin (2003) indicated the measures of endangered species, rates of decline and population fragmentation to categorize species according to their risk of extinction. The endangered bird species should be taken as an important indicator for evaluating habitat functions, because the presence of endangered species denotes a special ecological value at site. Hartley and Kunin (2003) concluded that the IUCN (the World Conservation Union) criteria for categorizing extinction risk consider all measures, which is so-called "Red-List[4]", can be taken as the basis to review the condition of endangered species at global and regional scales. In their study, they defined to set an area-of-occupancy threshold, which can nearly always be met if area of occupancy is calculated from a sufficiently fine-scale (high-resolution) grid. The IUCN Red-List criteria are important to assess the quality of habitats and support a database for the nature conservation. According to the IUCN Red List Categories, the endangered species can be divided into **Extinct** (EX), **Extinct in the Wild** (EW), **Critically Endangered** (CR), **Endangered** (EN), **Vulnerable** (VU) and **Least Concern** (LC) as listed in Table 4.26. This is the world's most comprehensive inventory of the global conservation status of plant and animal species nowadays.

Besides, considering the climate change and environmental impact at different scales, the assessment of species endangered species should be discussed in three phases. Therefore, in this case, the criterion of endangered bird species would be measured and analyzed with the differences among the reports from IUCN (global) in 2007, BirdLife International (regional) in 2004 and local Taiwanese system in 2005 and 2008[5].

Table 4.26: Definition of IUCN Red List (IUCN, 2004)

Degree	Definition	Risk of extinction
Extinct (EX)	There is no reasonable doubt that the last individual has died.	Extinction
Extinct in the Wild (EW)	It is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.	
Critically Endangered (CR)	It is considered to be facing an extremely high risk of extinction in the wild.	Threatened
Endangered (EN)	It is considered to be facing a very high risk of extinction in the wild.	
Near Threatened (NT)	It does not qualify for critically endangered or vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future	Lower risk

[4] The IUCN has studied the threatened species as "IUCN Red-List", which was firstly created in 1963 and published with categories and criteria in 1994 (IUCN, 1994).

[5] These four different indicators of measuring Red-List were the newest printed version during study period.

Table 4.26: Continuance

Degree	Definition	Risk of extinction
Least Concern (LC)	It has been evaluated against the criteria and does not qualify for critically endangered, endangered, vulnerable or near threatened	

According to the latest red list of IUCN (ver. 4.1, 2001 released in 2007) and BirdLife International (published in 2004), the states of red list in the lower Keelung River would be grouped into 5 scales: **Critically Endangered** (CR), **Endangered** (EN), **Vulnerable** (VU), **Near Threatened** (NT) and **Least Concern** (LC). The categories CR, EN and VU stand for the species considered as being threatened and facing the risk of extinction in the wild; NT means the species which is close to be qualified as the threatened in the near future, and LC represent the lower-risk but need concern of protections. In addition, Taiwanese Council of Agriculture has its own standard degree of protected species in three groups: I “Endangered Species”, II “Rare and valuable Species”, and III “Other conservation-deserving wildlife”. To make the standard in tune with the definition of the three different scales, the criteria of endangered species in this study are adapted as “**Endangered**”, “**Vulnerable**”, and “**Least Concern**” (Table 4.27).

Table 4.27: Different scales of Red List (IUCN, 2004; BirdLife International, 2007; Chinese Wild Bird Federation, 2005, 2008)

Source	IUCN	BirdLife International	TW	This study
Scales	**Global**	**Regional**	**Local**	**Combinative**
Indicators of red-list	- Extinct (EX) - Extinct in the Wild (EW) - Critically Endangered (CR) - Endangered (EN) - Vulnerable (VU) - Least Concern (LC)	- Critically Endangered (CR) - Endangered (EN) - Vulnerable (VU) - Near Threatened (NT) - Least Concern (LC)	- Endangered Species (I) - Rare and valuable Species (II) - Other conservation-deserving wildlife (III)	- Endangered (EN) - Vulnerable (VU) - Least Concern (LC)

To further define, the indicator of endangered species was established based on the concepts of IUCN Red-List, since the criteria by IUCN can even be applied to the flexibility in the scale of mapping. Besides, the local partner of BirdLife International, Chinese Wild Bird Federation, shows another observing list which is used for regional-scale conservation. While contrasting the three scales, an interesting difference has been found that some species were listed at higher ranking at global scale, but estimated as lower risk at local scale. On the other hand, some bird species which have great quantity in other areas seem to be paid with least attention while doing local observation. To combine the scales by IUCN, BirdLife International and Taiwanese government, Table 4.28 shows the analysis of endangered species with scales of values.

Table 4.28: Analysis the endangered species (Red-List) of bird species

Scales of values	Degree	Definition
4	Excellent	Biotope with great quantity of bird species, especially serve the special ecological services as habitat for many threatened species in red-list at different scales
3	Good	Biotope with many bird species, it is an important habitat for threatened bird species in red-list at regional and local scale
2	Fair	Biotope with a few bird species, which has lower risk in red-list at regional scale but endangered or vulnerable at local scale
1	Poor	Biotope where is affected strong from human activities, but still a habitat for endangered species in red-list at local scale
0	Worse	Biotope where is affected strong from human activities and can not serve any ecological functions for bird species

C. Endemic Species (Indicator Code: S-3)

Extinction of endemic species is an important issue of island biogeography, because endemic species are often found on islands due to the geographical isolation that populations interbreed and evolve to fill the role within the certain ecosystems. “Endemic species” are plant and animal species that naturally occur or be found in one specific location, limited area or certain region (e.g. specific island, habitat type) (National Geographic, 2001). Endemic species are native or confined to a certain ecological state of being unique, some endemic species can even only in that part of the world and nowhere else (Vreugdenhil et al., 2003). From these viewpoints, endemic species are characteristic of or prevalent in a particular geography, which are important due to the contribution to regional biodiversity and significance to nature conservation. Endemic bird species, for instance, may be vulnerable to extinction caused by habitat destruction (Pimm et al., 1998; Biber, 2002). Meanwhile, endemic bird species on islands are threatened or replaced by introduced species. Therefore, a great number of studies on the endemic bird species on islands have been discussed about the causes and process of vulnerability to endangerment or extinction (e.g. Biber, 2002, Collar, 2004).

Habitats, where some endemic bird species are dominant, especially represent the relationship between the special resident birds and their habitats (well-known as Emdemic Bird Areas (EBAs) by BirdLife International to show the most important places for habitat-based conservation of bird species) (BirdLife International, 2003). The ranking results can contribute to the discussion of the relationship between endemic bird species and their habitats, and also to achieving specified conservation goals. Through a long-term monitoring, the apparent changes of specific endemic species should be taken as signals of maintaining and improving the habitat functions. In Table 4.29 is listed the degree and definition of scales of values.

Table 4.29: Scales of values on special endemic species of resident birds in single habitats

Scales of values	Degree	Definition
4	Excellent	Habitat with great quantity of endemic bird species: having more than 75% of endemic bird species of Taipei City
3	Good	Habitat with many endemic bird species: having 51-75% of endemic bird species of Taipei City
2	Medium	Habitat with some endemic bird species: having 25-50% of endemic bird species of Taipei City
1	Poor	Habitat with few endemic bird species: having less than 25% endemic bird species of Taipei City
0	Non-species	No endemic bird species

5. Biotope Classification for the Urban River Areas

Based on the field work (an entire area of ca. 774.43 hectare) the urban river environment was classified into biotope types. All the biotope types belong to eight main groups that can be further identified into sub-groups with functions or characteristics (sub-groups can be divided into main units and subunits in hierarchy). Table 5.1 represents the classes of biotope types in the study areas: the letters of the alphabet denote the main groups of biotope types (e.g. F means forest), the first numbers indicate the ordinal sub-groups. Some biotope types with information about functions or characteristics can be associated with the last two serial numbers showing the subunits of biotope types. More details of each biotope types are shown in the next paragraphs.

Table 5.1: Classification of Biotopes along the downstream Keelung River

Code*	Biotope	Total areas (ha)	Number of biotopes
F000	Forest		
F100	....Subtropical broad-leaved forest**	10	1
S000	Shrub woodland		
S100	....Broad-leaved shrub woodland	7.86	42+
W000	Inland water bodies		
	--Flowing Waters		
W100	….Stream		
W110	……..Moderately altered stream	1.48	2
W120	……..Channelized stream	2.38	2
W200	….River		
W210	……..Moderately altered river	65.59	1
W220	……..Channelized river with dredging	133.41	5
W230	……..Channelized and straightened river	94.02	4
W300	….Side channel	1.7	3
W400	….Canal	4.11	40
	--Standing Waters		
W500	….Pond		
W510	……..Moderately altered pond	1.06	14
W520	……..Artificial pond	0.97	2
W600	….Backwater	0.05	1
We000	Wetland		
We100	….Estuarine wetland §		
We110	……..Estuarine wetland with natural flooding regime	37.51	6
We120	……..Estuarine wetland with artificial flooding regime**	57	1
We200	....Riparian wetland		
We210	……..Riparian marshland	14	3
We220	……..Riparian reed land	0.57	1
U000	Unvegetated habitat		
U100	....Stones	7.7	37
U200	....Gravel bar	36.94	48
U300	....Sand bar	0.13	2
U400	....Soil	6.72	33
G000	Urban green		
G100	....Tall forb grassland	58.49	70
G200	....Artificial greensward / turf	164.3	286
G300	....Garden	2.72	23
A000	Buildings, Transportation and Industrial areas		
A100	....Fixed surface		
A110	……..Water-bound surface	8.06	11

Table 5.1: Continuance

Code*	Biotope	Total areas (ha)	Number of biotopes
A120	……..Pavement	2.01	6
A130	……..Concrete / asphalt	7.61	8
A200	….Embankment		
A210	……..Dike	14.12	4
A220	……..Wall	3.07	4
A230	……..Claybank	0.05	1
A240	……..Dam	-	1
A250	……..Revetment	2.37	11
A300	....Bikeway		
A310	……..Terrazzo bikeway	8.34	33
A320	……..Paved bikeway	3.22	3
A330	……..Asphalt bikeway	22.05	25
A340	……..Timbered bikeway	1.58	1
A400	....Sport- / play- / recovery area		
A410	……..Sport area	30	74
A420	……..Playground	0.13	7
A500	….Buildings		
A510	……..Agricultural building	0.01	2
A520	……..Temple	0.04	3
A530	……..Other buildings	0.14	9
A600	....Transportation area		
A610	……..Parking area	17.85	66
A620	……..Square	8.84	83
A630	……..Riverine dock / port	1.13	5
A640	……..Evacuation gate	dot	
A650	……..Bridge	0.24	13
A700	....Supply and waste management (discharge)		
A710	……..Pumping station	0.23	7
A720	……..Other technical building	dot	-
X000	....Others		
X100	....Discard dirt	0.41	3

§ means that this biotope type is taken with regulations of river management or urban planning.

* The code of biotope types is assigned by ordinal number. The first letter is the abbreviation of each main group of biotope types. The first number shows the ordinal sub-groups, the last two numbers denote the serial numbers of biotope types with functions or characteristics.

** “Subtropical broad-leaved forest” and “Estuarine wetland with artificial flooding regime” are actually located outside of the flood plains, because they are usually associated and evaluated with the lower Keelung River in many studies, they are also listed in this classification.

5.1 Biotope Types in the lower Keelung River

5.1.1 Forest (General Type Code: F000)

Forest is an important habitat for wildlife. It especially plays a key role in the urban ecosystems. There is only one type of forest in the lower Keelung River, which is called “broad-leaved forest”. Due to urbanization, the most forests in Taiwanese cities are developed forest, which are maintained as mixed-forest with *Moraceae* and *Lauraceae*.

5.1.1.1 Subtropical Broad-Leaved Forest (Type Code: F100)

A. Habitat characteristics and description

The broad-leaved forests mainly distribute over the flats or hillside at the altitude under 500 metres in Taiwan, since Taiwan is located in the warm, humid subtropical climate areas. The deciduous trees are part of angiosperm, which have broad and flat leaves displaying in various trunks. The urban forest is an important primary producer and plays an important role as habitat for wildlife. The forest also contributes to groundwater and soil protection.

B. Characterising species

The main vegetation types are *Machilus thunbergii, Ficus microcarpa L., Trema orientalis* (L.) Blume, *Ficus septica Burm.F., Moraceae* and *Lauraceae*, which are common trees of broad-leaved forest in Taiwan.

C. Situation and temporal variation in the study areas

There are only some fragmentary forests in the neighbourhoods of floodplains along the lower Keelung River. In this case, only one site, close to the right side of Nangang Riverside Park (Figure 5.1), is covered with the broad-leaved forest. It has an area of around 10 hectares. The dominant trees are evergreen trees (e.g. *Machilus thunbergii*, *Moraceae* and *Lauraceae*) with heights of around 20 metres. The structure of forest is simple and short, because the natural impact from northeast monsoon. Generally, the areas of forest along the lower Keelung River gradually shrank due to urban development. The vegetation structure is tending to be monotonic by both natural changes and human activities over time.

a. (Frame No. 9723-III-075)

b. Location: on right side of Keelung River, near Nanhu Bridge(Photo No.: L1040486)

Figure 5.1: Illustration of broad-leaved forest with aerial photograph and picture

5.1.2 Shrub Woodland (General Type Code: S000)

A shrub or bush is a horticultural rather than strictly botanical category of woody plant, distinguished from a tree by its multiple stems and lower height, usually less than six metres tall. An area of cultivated shrubs is known as shrub woodland. Shrubs in common garden practice are generally broad-leaved plants.

5.1.2.1 Broad-Leaved Shrub Woodland (Type Code: S100)

A. Habitat characteristics and description

The shrubs in the lower Keelung River are generally broad-leaved plants. Though they are an important feature of permanent landscape planting, being used for formal decorative groups, hedges, screens, and background plantings, to which they contribute pattern, color, fragrance, or utility. They also play a role as resting area for bird species in some semi-natural shrub woodland areas.

B. Characterising species

The main species of riparian shrub woodland in the lower Keelung River are *Broussonetia kazinoki*, *Lantana camara* L., *Pittosporum pentandrum* (Blanco) Merr., *Hibiscus tiliaceus* L., *Cycas revoluta* and *Musa basjoo*.

C. Situation and temporal variation in the study areas

There are only some areas covered with naturally maintained shrubs due to channel redirection, river control works and construction in riparian parks (Figure 5.2). The shrubs also grow up on the gravel bar, and the vegetation is characterized by *Ficus septica Burm. f*. along the Keelung River. The broad-leaved shrubs cover an area of 7.86 hectares along the lower Keelung River. The natural maintained shrubs spread on both sides of the Keelung River from the confluence of the Shuangxi and the Keelung River down to the confluence of the Keelung River and the Danshui River. Besides, the seasonal rapid rainfall (e.g. typhoon) is usually flooding the man-made shrubs in the riparian parks.

a. (Frame No. 9723-III-074)

b. Location: on left side of Keelung River, in Chengmei Riverside Park (Photo No.: L1040541)

Figure 5.2: Illustration of broad-leaved shrub woodland with aerial photograph and picture

5.1.3 Inland Water Bodies (General Type Code: W000)

The inland water bodies can be divided into two sub-groups of “flowing waters” and “standing waters”. As the other urban rivers, the lower Keelung River is highly altered for human demands and urban development, only some areas are maintained in moderately altered condition. The most types of flowing waters are under control by legislations or river management. In general, there are four types of flowing waters titled “stream (W100)”, “river (W200)”, “side channel (W300)” and “Canal (W400)”. The standing waters include “pond (W500)” and “discontinued water bodies (W600)”.

5.1.3.1 Stream (Type Code: W100)

A. Habitat characteristics and description

“Stream” is defined as smaller flowing water in this study, which is often a tributary of a river. There are five main tributaries running into the downstream Keelung River. Streams provide food and shelter as habitat functions. In this case the width of stream channels are 10-100 metres, so the bottom of the stream channel can be conjectured with pebbles, rubbles and boulders by Surface-Visual-Method [1]. Vegetation cover was only seen along the riverside of moderately altered stream.

B. Characterising species

The main vegetation types along the moderately altered stream (type code: W110) in the lower Keelung River include *Brachiaria mutica* (Forsk.) Stapf, *Pennisetum purpureum* Schumach, *Ludwigia hyssopifolia* (G. Don) Exell, *Phagmites communis*, *Potamogeton malaianus Miq*. and *Hydrilla verticillata*.

C. Situation and temporal variation in the study areas

There are two types of streams in the lower Keelung River. The moderately altered streams, for example Shuangxi and old Shuangxi, are maintained with less man-made constructions and less human disturbance. The other type is the channelized stream (type code: W120), which was channelized for irrigation or preventing floods. The Taipei City government delivered many projects to rebuild the tributaries of the Keelung River; Guizikengxi is one of the cases (Figure 5.3). The moderately altered stream within the study areas has an entire area of 1.48 hectares and the channelized stream covers an area of 2.38 hectares.

[1] Wang (2000) argued that there are five types of flow regime (riffle, glide, pool, run and riparian slow flow). The cover of river bottoms of each flow regime can be conjectured by Surface-Visual-Method with the flow velocity (more or less 30 cm/s) and the water depth (more or less 30 cm). In brief, the river bottoms of each flow regime cover: 1) riffle: boulder and cobble, 2) glide: smooth surface, gravel and pebble, 3) pool: cobble, rock and large boulder, 4) run: boulder, rubble and pebble, 5) riparian slow flow: fine sediment and gravel.

a. (Frame No. 9623-II-060)

b. Location: on the right side of Keelung River, near the mouth of old Shunagxi (Photo No.: L1040767)

c. (Frame No. 9623-II-060)

d. Location: Guizikengxi brook, flows from right side of Keelung River. (Photo No.: L1040719)

Figure 5.3: Illustration of moderately altered stream (a. and b.) and channelized stream (c. and d.) with aerial photograph and picture

5.1.3.2 River (Type Code: W200)

A. Habitat characteristics and description

The large running water is defined as a “river” in this study. The bottom of river beds are covered with cobble, rubble, pebbles and boulders, some sections on the riversides are covered with fine sediment and gravels due to sedimentation.

B. Characterising species

The main vegetation types in the lower Keelung River include *Brachiaria mutica* (Forsk.) Stapf, *Pennisetum purpureum* Schumach, *Ludwigia hyssopifolia* (G. Don) Exell, *Phragmites australis* (Cav.), *Miscanthus sinensis*, *Typha orientalis* Presl, *Potamogeton malaianus Miq*. and *Hydrilla verticillata*.

C. Situation and temporal variation in the study areas

The river channel of the lower Keelung River is between 100-300 metres wide. The downstream Keelung River has been regulated for boat navigation as well as for flood control and water retention. The dredged and embanked river channel has resulted in the loss of natural characteristics (e.g. flood meanders) for ecological services. However, the freshwater is still one of the favorite habitats of bird species. Besides, there are still some aggradational areas with marsh, reed and shrub in the lower Keelung River, which serve for foraging and resting for water fowl (Detail in type of wetland: We200).

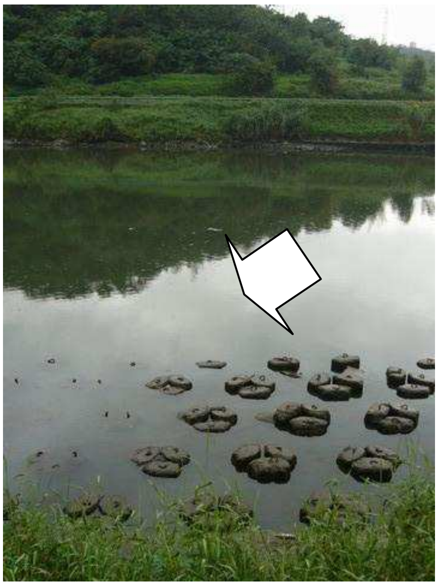
Generally speaking, the lower Keelung River is mainly a man-made environment due to redirection of the channel and river dredging. Only some sections are maintained in condition of “moderately altered river (W210)” with vegetation cover (Figure 5.4), which covers an area of 65.59 hectares and ca. 300 metres wide. The channelized river channel can be divided into “with dredging (W220; 133.41 ha)” and “straightened river (W230; 94.02 ha)” For preventing floods, the lower Keelung River has ever been straightened in two segments, which are Jientai (between Dazhi Bridge and Highway Bridge) and Jiouzhuang (between Minquan Bridge and Chengmei Bridge).

b. Location: near Zhoumei Express Way (L1040780)

a. (Frame No.: 9623-II-070)

Figure 5.4: Illustration of moderately altered river (a. and b.) with aerial photograph and picture

c. (Frame No. 9723-III-075)



d. Location: near Nanhu Bridge (L1040481)

e. (Frame No. 9723-III-074)

f. Location: Jiouzhuang segment, near Minquan Bridge (No. L1040561)

Figure 5.4: Continuance: “channelized river with dredging” (c. and d.) and “channelized and straightened river” (e. and f.) with aerial photograph and picture

5.1.3.3 Side Channel (Type Code: W300)

A. Habitat characteristics and description

A side channel that typically flows year – round, which has a well – an established riparian zone and contains large woody debris, and is often protected from the full effect of peak flows by logjams or berms at the inlet end (Mason, B., R. Knight, 2002).

B. Characterising species

The main vegetation types of the side channel are *Potamogeton malaianus Miq*. and *Hydrilla verticillata*.

C. Situation and temporal variation in the study areas

The width of side channels in the lower Keelung River is between 10-50 metres. The bottom of river channel covers two different types – the side channel at

Yuanshan (narrowest river channel in the lower Keelung River) covers with boulders, cobbles and pebbles with less of aquatic plants. The other territories of side channel near the confluence of the Keelung River and the Danshui River mainly cover with fine sediment, sand and graves (Figure 5.5). The tidal influence changes the river levels and the shape of form frequently. The entire area of side channels is around 1.7 hectares.

Location: at Aquatic Bird Marshlands, right side of Keelung River, (L1040750)

(Frame No. 9623-II-059)

Figure 5.5: Illustration of side channel with aerial photograph and picture

5.1.3.4 Canal (Type Code: W400)

A. Habitat characteristics and description

A canal is usually defined as a small to moderate depression created to channel water. A canal can be used for drainage, to drain water from low lying areas, alongside roadways or fields, or to channel water from a more distant source for plant irrigation. Sometimes the long narrow ditch is defined as trench, which is included into canal in this study. The canals by Keelung River are such constructed watercourses that carry storm flows, provide adequate drainage and irrigation for agricultural.

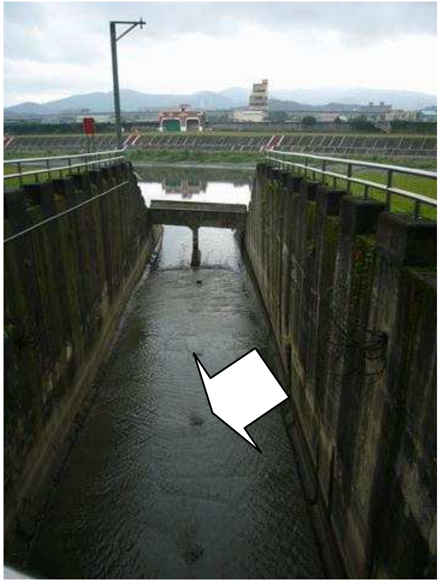
B. Characterising species

The main vegetation types of canal are *Kyllinga brevifolia Rottb., Hyfrilla verticillata*.

C. Situation and temporal variation in the study areas

There are 41 canals by the lower Keelung River with the functions of drainage or irrigation, which cover an area of 4.65 hectares in the investigation areas. The canals are channelized by concrete construction with less vegetation covers (Figure 5.6). Overflowing usually occurs after heavily raining in the typhoon season.

(Frame No. 9723-III-074)



Location: on left side of the Keelung River, by Chenggong pumping station (L1040506)

Figure 5.6: Illustration of side canal with aerial photograph and picture

5.1.3.5 Pond (Type Code: W500)

A. Habitat characteristics and description

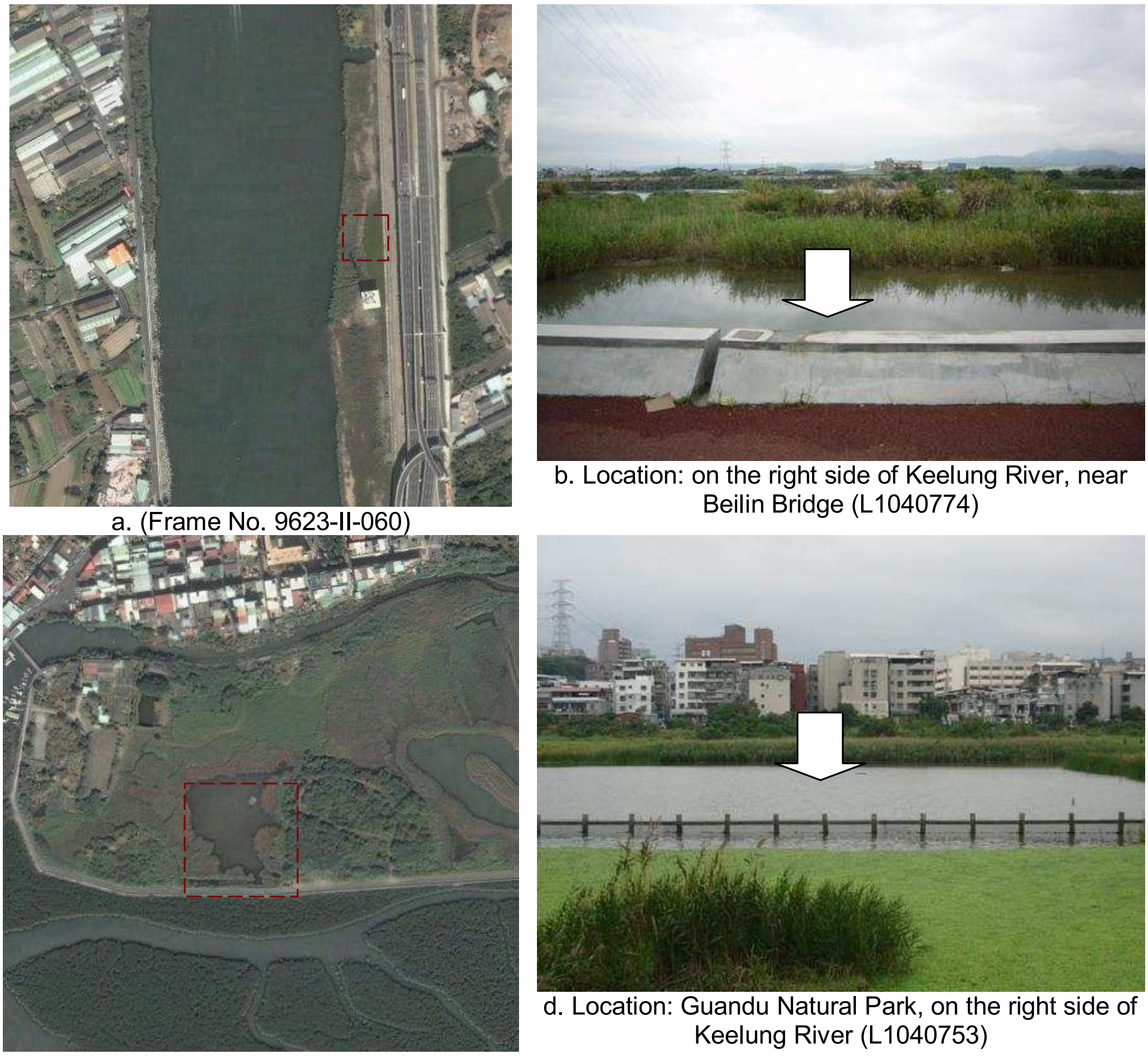
A pond is a body of standing water, either natural or man-made, usually has less extent than a lake. A pond is usually an independent ecosystem due to the closed body of water. A healthy pond covers with stones and sediment on bottom and has diversity of vegetation structure. The emergent plants and flowing plants serve habitats for fish and water fowl. Generally speaking, the water temperature, dissolved oxygen (DO) and CO_2 are changed heavily by weather daily. Therefore, a naturally maintained pond plays an important role as stepping stone in the urban river environment.

B. Characterising species

The main vegetation types of pond are *Eichhornia crassipes, Potamogeton malaianus Miq., Eclipta prostrate L.,* and other aqua-plants.

C. Situation and temporal variation in the study areas

Two types of ponds are grouped in this study, the moderately altered pond (W510) and artificially confined pond (W520). The moderately altered ponds exist in by nature or imitated following natural way (Figure 5.7 a. and b.). They have been functioning either for agriculture or storage before. The man-made ponds in this study were built with concrete construction for artificial or imitation; functioning or occurring in a normal way or designed as landscape or architectural features. Some artificial ponds are so-called fountains. Totally, the moderately altered ponds have an area of 0.62 hectares and the artificially confined ponds cover an area of 1.4 hectares in the lower Keelung River.



a. (Frame No. 9623-II-060)

b. Location: on the right side of Keelung River, near Beilin Bridge (L1040774)

c. (Frame No. 9623-II-059)

d. Location: Guandu Natural Park, on the right side of Keelung River (L1040753)

Figure 5.7: Illustration of moderately altered pond (a. and b.) and artificial pond (c. and d.) with aerial photograph and picture

5.1.3.6 Backwater (Type Code: W600)

A. Habitat characteristics and description

Backwater is defined as the body of water, which may be disconnected with the river channel permanently or temporarily, the water levels are changed due to tide, rainfall and other physical environment. Backwater is a changeable ecosystems as part of streams or as independent ponds.

B. Characterising species

The main vegetation types of backwater are *Phagmites communis (L.)Trin., Pennisetum purpureum Schumach., Bidens pilosa L. var. minor* and *Ludwigia octovalvis (Jakq.) Raven*.

C. Situation and temporal variation in the study areas

There is only one obviously backwater in the lower Keelung River. It is located close to the confluence of Shuangxi and the Keelung River (Figure 5.8).

(Frame No. 9723-III-061)

Location: Heshuang No. 21 Riverside Park, on the right side of Keelung River (L1040794)

Figure 5.8: Illustration of discontinued water body with aerial photograph and picture

5.1.4 Wetland (General Type Code: We000)

Wetland is an environment "at the interface between truly terrestrial ecosystems and truly aquatic systems making them different from each yet highly dependent on both" (Mitsch & Gosselink, 1986). It is an important ecotone, where is an also typically highly productive habitat, often hosting considerable biodiversity and endemism. The common contributions of wetland are: 1) vital to healthy stream ecosystems, 2) provide habitat essential to fish and wildlife, 3) reduce the impacts of floods, 4) act as filters for sediment and chemicals. It may feature grasses, rushes, reeds, sedges, and other herbaceous plants (possibly with low-growing woody plants) in a context of shallow water.

5.1.4.1 Estuarine Wetland (Type Code: We100)

A. Habitat characteristics and description

Estuarine wetlands are a type of wetland found near coastal areas in the downstream. The water in the wetlands is a mixture of tidal water coming in from the sea and freshwater runoff from the land. The soils can range from clayey to sandy. Therefore, the salt or brackish water may be featured with grasses, rushes, reeds, sedges, and other herbaceous plants (possibly with low-growing woody plants) in a context of shallow water. The dominant plants are mangrove swamp, reed, Oriental Cat-tail. The estuarine wetlands are important habitats for bird species, amphibious animals and fishes.

B. Characterising species

There are totally about 38 types of vegetation in the biotope of wetland (Detail in Annex A). The main vegetation species include *Phragmites australis* (Cav.), *Kandelia obovata*, *Paspalum distichum* L., *Cyperus malaccensis*, *Typha orientalis* Presl, *Miscanthus sinensis* in this biotope.

C. Situation and temporal variation in the study areas

There are two types of estuarine wetland in the lower Keelung River by different maintenance of river regime. The estuarine wetland with natural flooding regime (We110; Figure 5.9), which is so-called the Guandu Wetland, is a mangrove wetland by natural treasure, which normally occurs at around latitude 25 grad in the North and the South. It is a salt or brackish water environment dominated by the mangrove species of tree, such as Sonneratia. Mangrove is characterized by brackish water conditions with fluctuating salinity, periodically wet and dry, alternating aerobic and anaerobic soil environments as well as finely particulate, unstable substrata (Anderson, 1994; Tam & Wong, 2000a and b) A distinctive character of a mangrove community is its relatively low plant diversity (Tomlinson, 1994), most of them are viviparous plants. Since the mangrove swamp has been getting preeminent in the last decades (cover over 70%), the vegetation structure of wetland has been turned into mono-species, which is helpless for maintaining biodiversity, even the wetland serves near-natural environment as habitats.

The estuarine wetland with artificial flooding regime (We120) denotes the specially developed Guandu Nature Park, which is intended to absorb flash floods, clean sewage, enhance wildlife or for some other human reason. The featuring surface-flow design is usually in the form of a marsh. There are many migrant birds flying to Aquatic Bird Marshlands for getting along the winter (e.g. snipe, wild goose and wagtail, etc.). In the past decades, around 193 species of bird species have been ever spending the winter at Guandu. For providing better environment for the aquatic bird, and also enhancing the habitat function, the Taipei City government made the constructed wetland – Guandu Nature Park – in 1984. The area is around 60 hectares. This nature park is one important habitat for migrant birds from north China, Siberia, Japan, and Korea. As the wetland with natural flooding regime has been flooding with regular tidal or temporal typhoon disaster with submerged muddy flat, the bird species must move and rest in the Guandu Nature Park.

(Frame No. 9623-II-059)

Location: Aquatic Bird Marshlands, Guandu, on the right side of Keelung River (Photo No.: L1040749)

Figure 5.9: Illustration of estuary wetland with aerial photograph and picture

5.1.4.2 Riparian Wetland (Type Code: We200)

A. Habitat characteristics and description

A riparian wetland is an aggradational area created when a stream lays down thick layers of sediment. When the gradient of stream becomes very slight and its velocity decreases, forcing it to drop sediment brought from higher regions nearer its source. Consequently the lower portion of the river valley becomes filled with gravel bar. In times of flood, the rush of water in the high regions tears off and carries down a greater quantity of sediment resulting in plantation (creation of a flat terrain) as well as aggradation.

B. Characterising species

The main vegetation species include *Phragmites australis* (Cav.), *Paspalum distichum* L., *Cyperus malaccensis*, *Typha orientalis* Presl and *Miscanthus sinensis* in this biotope.

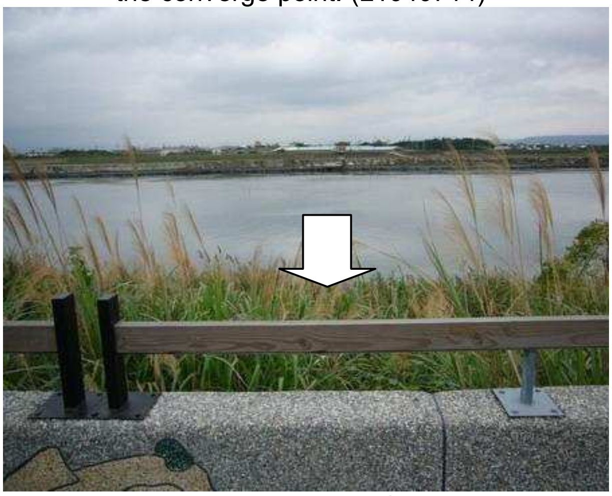
C. Situation and temporal variation in the study areas

There are two types of riparian wetland in this case, which are “riparian marshland” (We210; Figure 5.10 a. and b.) and “riparian reedland” (We220, Figure 5.10 c. and d.). The range and location of aggradational areas are dynamic due to flooding and river flow. This temporal variation is apparent in the raining season and dry season. This area is usually species-poor and often dominated by one species growing in stagnant or slowly flowing water.

a. (Frame No. 9623-II-060)

b. Location: at right side of Keelung River, near the converge point. (L1040714)

c. (Frame No. 9623-II-060)



d. Location: on the right side of Keelung River, near Shuangxi brook(L1040710)

Figure 5.10: Illustration of riparian marshland (a. and b.) and riparian reedland (c. and d.) with aerial photograph and picture

5.1.5 Unvegetated Habitat (General Type Code: U000)

This biotope type is generally speaking about the ground without vegetation cover. They are usually occurred by natural geological effects, for instance flooding, river flowing and accumulation.

5.1.5.1 Stones (Type Code: U100)

A. Habitat characteristics and description

Stones are common unvetated type in river environment and have usually no vegetation cover. However, stones still supply the shelters for fish species and aquatic insects.

B. Characterising species

Euphorbia hirta L. has been observed in the holes of stones.

C. Situation and temporal variation in the study areas

The stones spread at the riverbanks along the lower Keelung River (Figure 5.11), which have been recorded with an area of 7.7 hectares. The spaces between the stones can be important habitats for fishes. However, less fish species have been found in the lower Keelung River due to poor water quality.

(Frame No. 9723-III-074)

Location: at the right side of Nanhu riverside park (L1040502)

Figure 5.11: Illustration of stones with aerial photograph and picture

5.1.5.2 Gravel Bar (Type Code: U200)

A. Habitat characteristics and description

The clay or slit or gravel carried by rushing streams and deposited where the stream slows down. As the hills erode due to weathering and water flow the sediment from the hills is transported to the lower plain. Gravel bar provides function as “stepping stones” for rest of migration and stopover. They usually spread next to the riparian aggradational area along rivers, which increases the habitat functions for waterfowl.

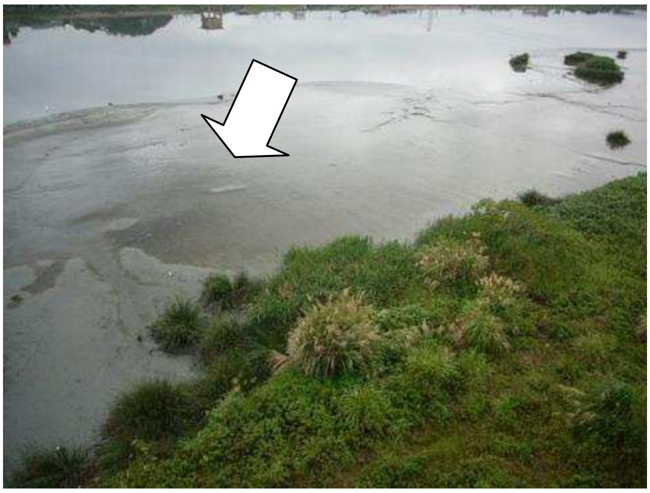
B. Characterising species

None.

C. Situation and temporal variation in the study areas

The lower Keelung River is a typical tidal reach, the gravel bar results from flat topography and slow river flow (Figure 5.12). Grave bar covers around an area of 36.94 hectares in the lower Keelung River during the investigative period.

(Frame No. 9723-III-061)



Location: Near Zhoumei express way, on the right side of Keelung River (Photo No.: L1040784)

Figure 5.12: Illustration of gravel bar with aerial photograph and picture

5.1.5.3 Sand Bar (Type Code: U300)

A. Habitat characteristics and description

Sand deposits in river beds, particularly significant in large river systems. This submerged bank of sand near a shore or in a river; can be exposed at low tide. There are unvegetated and vegetated sand bars. The definition of sand bar in this case is only referred to the unvegetated type. Sand bar, as gravel bar, plays a role as “stepping stones” for rest of migration and stopover.

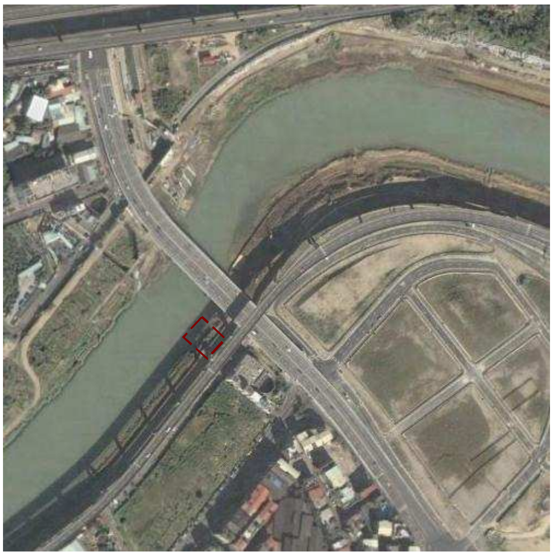
It should be distinguished among gravel bar, sand bar and riparian wetland. Generally they are all aggradational areas in urban river environment, but gravel bar and sand bar in this typology are referred to the shoals in the urban river without vegetation cover. The location of gravel bar and riparian aggradational area are at the riversides, but riparian wetland is covered with plants.

B. Characterising species

None.

C. Situation and temporal variation in the study areas

There were only 2 sand bars being investigated during the investigated period and covered an area of 0.13 hectares (Figure 5.13).



(Frame No. 9723-III-075)

Location: near Nanhu Bridge, on the left side of Keelung River (L1040525)

Figure 5.13: Illustration of sand bar with aerial photograph and picture

5.1.5.4 Soil (Type Code: U400)

A. Habitat characteristics and description

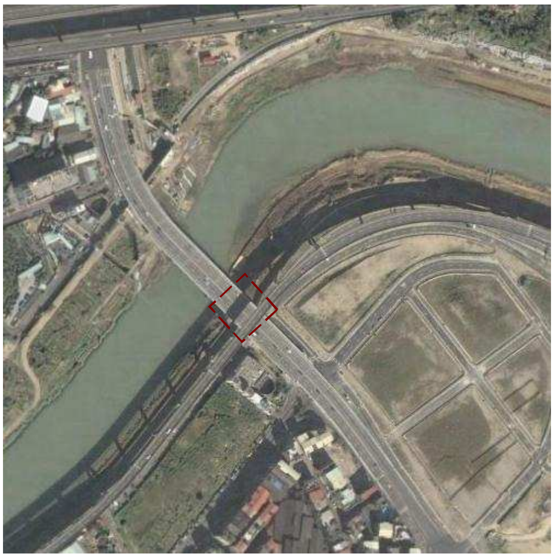
Soil is the area without vegetation cover where recent disturbance, either human activity or natural change has exposed the soil substrate. The unstable composition does not provide safe environment for wildlife for feeding and refuge. It procures behavioral changes of potential species, including movement and migration.

B. Characterising species

None.

C. Situation and temporal variation in the study areas

Exposed ground in the area of urban river is altered with river flow and urban development. Every time it storms, water drains from soil, carrying some of the soil into the waterways. The cover of soil not provide areas for escape, shelter and forage for wildlife, the washing surface even increases problem of water quality in streams. Soil covers an area of 7.7 hectares in the lower Keelung River (Figure 5.14).



Location: near the Nahu Bridge, on the left side of Keelung River (Photo No.: L1040528)

(Frame No. 9723-III-075)

Figure 5.14: Illustration of soil on riverbanks with aerial photograph and picture

5.1.6 Urban green (General Type Code: G000)

Green land is referred to the herb vegetation covers and other man-made green areas (e.g. garden) in urban areas. According to the fertileness and naturalness of the vegetation types, the sub-groups can be divided into three types: "Tall forb grassland" (G100), "artificial greensward/turf" (G200) and "garden" (G300).

5.1.6.1 Tall Forb Grassland (Type Code: G100)

A. Habitat characteristics and description

"Tall forb grassland" is an area of grassland by river, subject to controlled seasonal flooding which increases the productivity of the grassland. It usually spreads at the riversides with fertile flora, which is one of the favorite habitats for bird species.

B. Characterising species

The characteristing species include *Commelina auriculata* Blume, *Amaranthus spinosus* L., *Ipomoea cairica* (L.) Sweet, *Eleusine indica* (L.) Gaertn., *Commelina communis* L., *Polygonum longisetum* De Bruyn, *Cyperus*, *Cyperus pilosus* Vahl, *Alternanthera philoxeroides* (Mart) Griseb., *Ludwigia octovalvis* (Jacq.) Raven, *Polygonum sagittatum* L. **(riversides)**. *Bidens pilosa* L, *Wedelia chinensis* (Osbeck) Merr., *Pennisetum purpureum* Schumach, *Miscanthus floridulus* (Labill.) Warb. ex K. Schum. & Lauterb, *Phragmites australis* (Cav.), *Rumex acetosa* L. **(on riverbanks)**

C. Situation and temporal variation in the study areas

Tall forb grassland on the riverbanks of the lower Keelung River have been mainly fragmented by man-made constructions and usually changed by flooding (Figure 5.15). Therefore, the tall forb grassland in the lower Keelung River especially has functions of water conservation, reducing soil flushing and surface runoff in the raining season (May to September). It serves a stable riparian environment for shelter, rest and breeding of bird species.

(Frame No. 9723-III-062)

Location: near Zhongshan Bridge, on the right side of Keelung River (Photo No.: L1040550)

Figure 5.15: Illustration of rich tall grassland with aerial photograph and picture

5.1.6.2 Artificial Greensward / Turf (Type Code: G200)

A. Habitat characteristics and description

Artificial greensward is defined as artificial urban green with cover of grassland, this man-made surface layer contains a mat of grass and grass roots, which does not serve multi-environment for breeding, resting and foraging for bird species.

B. Characterising species

There are plants such as *Eclipta prostrata* (L.) L., *Soliva anthemifolia* (Juss.) R. Br. ex Less., *Kyllinga brevifolia* Rottb.

C. Situation and temporal variation in the study areas

For maintaining the groundwater and reducing soil erosion by rain, the artificial greenswards were spread on riverbanks along Keelung River. This kind of biotopes is common in the downstream Keelung River due to river regulation and floodplain development (Figure 5.16). The most areas of riverbanks are swallowed up in floods after the torrential rain. The vegetation covers, especially the artificial greensward and gardens must been rehabilitation with new plants.

Location: near Maishuai 1st Bridge, on the left side of Keelung River (L1040513)

(Frame No. 9723-III-073)

Figure 5.16: Illustration of artificial greensward with aerial photograph and picture

5.1.6.3 Garden (Type Code: G300)

A. Habitat characteristics and description

Garden is an area where herbs, fruits, flowers or vegetables are cultivated, which is often with enjoyment of plants and other forms of nature. Both natural and man-made elements can be incorporated in a garden. From this viewpoint, some bird species like to have habitats in areas of farm, orchard and garden in cities. It is especially worthful in urban river areas due to the multi-structure of environment.

B. Characterising species

The species of plant are characteristic by Phoenix rupicola T. Anders., Washingtonia filifera (Lindl. ex Andre) Wendl. *Roystonea regia (H.B.K.) O.F. Cook*, *Ficus elastica Roxb.*, *Hibiscus rosa-sinensis Linn*. and *Luffa cylindrical (L.) Roem*.

C. Situation and temporal variation in the study areas

There is no big producing garden in the downstream Keelung River. Some areas are maintained with enjoyment of plants in the surroundings of the buildings (e.g. next to the temples, ports). It covers an area of 2.72 hectares in the lower Keelung River. Figure 5.17 shows one case near Sanjiaodu on right of the lower Keelung River.

(Frame No. 9723-III-061)

Location: Sanchjaodo, on the right side of Keelung River (Photo No.: L1040826)

Figure 5.17: Illustration of garden with aerial photograph and picture

5.1.7 Buildings, Transportation, and Industrial areas (General Type Code: A000)

All the man-made areas and infrastructure are listed in this group, which have been altered for human activities and services. According to the functions, the sub-groups can be sorted into seven types: "fixed surface" (A100) for stable riversides, "embankment" (A200) for preventing flooding and protecting riverbanks, "bikeway" (A300) and "sport- / play- / recovery area" (A400) for recreation, "buildings" (A500), "transportation area" (A600) and "supply and waste management" (discharge) (A700).

5.1.7.1 Fixed Surface (Type Code: A100)

A. Habitat characteristics and description

Fixed surface is defined as fixed ground or water-bound pavements. Fixed surface covers mainly with concrete, stone and asphalt, which is not a favorite habitat for wildlife due to the heavily altered pavement. However, with the development of "ecological engineering methods", some areas are covered with tile paving surface and bricks, which help decrease the percentage of impervious surfaces and surface runoff. Generally speaking, fixed surface does not serve the basic functions as habitats for wildlife, but some sections with brick pavement, tile paving surface with plants in cracks or crevices.

Normally, the man-made areas are not popular habitats for wildlife. However, the development with Ecological Engineering Methods changes the characteristics and elements of some man-made areas (e.g. dike, sport areas, etc.) to apply the wildlife for rest.

B. Characterising species

Euphorbia hirta L., *Oxalis cornieulata L.*

C. Situation and temporal variation in the study areas

For reducing soil erosion and protecting the riverbanks, the both sides of the lower Keelung River have been altered with fixed surface (Figure 5.18), which has an entire area of 17.68 hectares. Water-bound surface (A110), pavement (A120) and concrete/asphalt (A130) represent different pavements of fixed surfaces. The concrete construction fragments the natural biotope types and adds the percentage of impervious covers, which can not really help decrease soil erosion, but increases the probability of surface runoff after torrential rainfall.

a. (Frame No. 9723-III-075)

b. Location: along Nanhu Riverside Park, on the left side of Keelung River (L1040499)

c. (Frame No. 9723-III-074)

d. Location: Near the Chengmei Bridge (L1040554)

Figure 5.18: Illustration of fixed surface with concrete (a. and b.) and stone pavement (c. and d.) with aerial photograph and picture

5.1.7.2 Embankment (Type Code: A300)

A. Habitat characteristics and description

Embankment is well-known as holding back water and preventing flooding. Embankment can be levee or dike, an artificial bank raised above the immediately-surrounding land to redirect or prevent flooding by a river. To distinguish the structure and location between embankment and fixed surface, which embankment is built at riversides (e.g. revetment) and between floodplains and other developed areas (e.g. wall, dike, etc). Much more attention has been attracted to urban ecology on wall plants in the last years. With this consideration the embankment may contribute to serve ecosystem services in urban river areas.

B. Characterising species

Ficus pumila, Axonopus affinis, Zoysia sinica, Paspalum notatum and *Cynodon dactylon* (Linn.) Pers.

C. Situation and temporal variation in the study areas

The most sections of the lower Keelung River have been altered as riparian parks for the functions of recreation and parking areas. For preventing floods and enhancing the riversides, the floodplains are fragmented by man-made construction (e.g. embankment). This man-made construction can be further divided into different groups by construction (Figure 5.19): “dike” (A310) with stone-filled or earth-filled even with functions of roads or walkways along it, “wall” (A320) with concrete construction along the riversides, “claybank” (A330) with materials of earth, rocks and soil for preventing flooding, “dam” (A340) for controlling and regulating river regime, “revetment” (A350) for strengthening the stability of riverbanks.

To summarize, embankment covers an area of 19.61 hectares. The height of dike is 3-4 metres; it lies on both sides of the Keelung River from city boundary to Chengmei Bridge. The ferroconcrete walls are built to prevent flooding with height of 8-11 metres; which are common on both sides of the lower Keelung River from Chengmei Bridge to Chengde Bride. The earth-filled or rock-filled claybanks have height of 3-4 metres. Claybanks are wider with functions of roads or walkways, which lie in both sides of the Keelung River from Chengde Bridge the confluence of the Keelung River and the Danshui River. Dam is a barrier constructed across a waterway to control the flow, raise the level of water or obstructs, direct or slow down the flow, which generally serve the primary purpose of retaining water. One dam is located at Yuanshan in the lower Keelung River.

a. (Frame No. 9723-III-073)

b. Location: under Maishuai 2nd Bridge, on the left side of the Keelung River (L1040576)

c. (Frame No. 9623-II-060)

d. Location: near Shuangxi, on the right side of the Keelung River (L1040775)

Figure 5.19: Illustration of wall (a. and b.) and claybank (c. and d.) with aerial photograph and picture

5.1.7.3 Bikeway (Type Code: A200)

A. Habitat characteristics and description

Bikeways are designed for recreation in the study areas with the reuse projects of riparian parks.

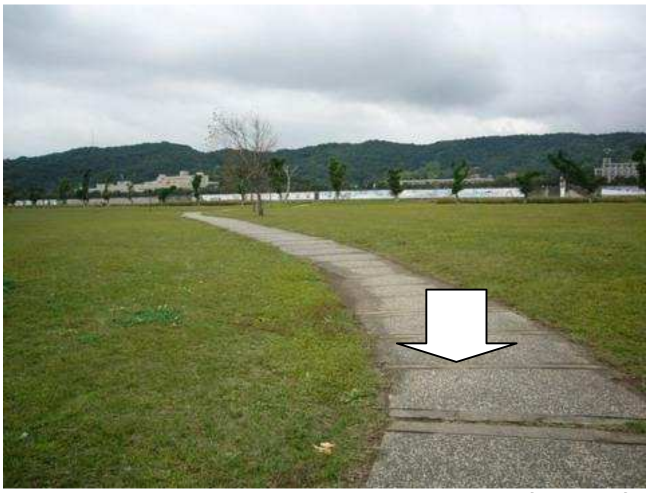
B. Characterising species

Some plants have been seen by bikeways: *Bidens pilosa L. var. Minor, Rμmex acetasa L.*

C. Situation and temporal variation in the study areas

For providing more recreation area for the citizen, the Taipei City Government organized bikeway system along the rivers. The most complete one is built along the Keelung River, which is also combined with the project “River Cruise”. Except the period of preventing and controlling flooding, people can bike by rivers easily. The length of bikeways along the left side of the Keelung River is 18.1 km and 17.6 km long along the right side, which covers an area of 32.03 hectare. With different pavements the bikeways can be grouped into "terrazzo bikeway" (A310), "paved bikeway" (A320), "asphalt bikeway" (A330) and "timbered bikeway" (A340) (Figure 5.20). The terrazzo paving surface covers by moderately impervious man-made surfaces, which causes more surface water flow. The paved bikeways and asphalt bikeways have more covers of impervious surface, which affect rapidly run-off of surface water. The timbered bikeways have better drainage than other pavements

a. (Frame No. 9723-III-072)



b. Location: Dajia Riverside Park, on the left side of the Keelung River (L1040644)

c. (Frame No. 9723-III-075)

d. Location: Nanhu Riverside Park, on the left side of the Keelung River (L1040497)

Figure 5.20: Illustration of terrazzo bikeway (a. and b.), asphalt bikeway (c. and d.) with aerial photograph and picture

e. (Frame No. 9623-II-059)

f. Location: next to the Aquatic bird marshlands, on the right side of the Keelung River (L1040738)

Figure 5.20: Continuance: timbered bikeway (e. and f.) with aerial photograph and picture

5.1.7.4 Sport- / play- / recovery area (Type Code: A400)

A. Habitat characteristics and description

This type is referred to outdoor areas being equipped for recreation and exercise (e.g. basketball courts, softball stadiums, tennis courts, etc), where covers mainly impermeable surface. Some areas of courts and playgrounds cover with artificial grasslands, where provide a minimum function of rest for bird species.

B. Characterising species

In the recreation areas and within the parking areas can see the single tree of *Ficus microcarpa L., Lauraceae* and *Macaranga tanarius*.

C. Situation and temporal variation in the study areas

There are 11 recreation parks on both sides of Keelung River. Some of them are built with lot of man-made constructions (e.g. Dajia Riverside Park), the other only cover with greenswards and bikeways (e.g. Nanhu Riverside Park). Totally, “sport area” (A410) plus “playground” (A420) has an area of 30.13 hectares in the lower Keelung River (Figure 5.21). Regular human activities and floods by typhoons change the structure and composition very often.

(Frame No. 9723-III-072)

Location: Dajia Riverside Park, on the left side of the Keelung River (L1040665)

(Frame No. 9723-III-073)

Location: Yingfeng Riverside Park, on the left side of the Keelung River (L1040630)

Figure 5.21: Illustration of fixed tennis court (a. and b.) and riverside park (c. and d.) with aerial photograph and picture

5.1.7.5 Buildings (Type Code: A500)

A. Habitat characteristics and description

Building is any man-made structure used or intended for supporting or sheltering any use or continuous occupancy. This type is uncommon in urban river areas, but some buildings are located in the study case.

B. Characterising species

None.

C. Situation and temporal variation in the study areas

There are three different sub-types of buildings in the lower Keelung River (Figure 5.22): “agricultural building” (A510) is built for agricultural demand (e.g. farm tool place), “Temple” (A520) reflects and relate to folk belief of residents (e.g. Tu-Di-Gong (meaning: the earth god for wealth and merit), some buildings can not be included into the above categories (e.g. bower, pylon, etc) belonging to the others. The buildings are located at 14 different places with an entire area of 0.19 hectares.

a. (Frame No. 9723-III-061)

b. Location: Shanjiaodu, on the right side of the Keelung River (L1040823)

c. (Frame No. 9723-III-073)

d. Location: near Minquan Bridge, on the left side of the Keelung River (L1040597)

Figure 5.22: Illustration of agricultural building (a. and b.) and temple (c. and d.) with aerial photograph and picture

5.1.7.6 Transportation area (Type Code: A600)

A. Habitat characteristics and description

Transportation area means the entire infrastructure includes the transport networks (roads, pipelines, etc.) that are used, as well as the nodes or terminals (e.g. port, square).

B. Characterising species

Ficus microcarpa L., Lauraceae and *Macaranga tanarius*.

C. Situation and temporal variation in the study areas

According to the functions of transportation, there are five different sub-types in the lower Keelung River (Figure 5.23): “parking area” (A610), “square” (A620), “Riverine dock/port” (A630), “evacuation gate” (A640) and “bridge” (A650). The ports along the Keelung River are facilities for receiving ships and sightseers to and from them. Evacuation gate is the movement of persons from a dangerous place due to the threat or occurrence of a disastrous event. Here are the evacuations of a district because of a flood from a city due to a storm. A Bridge is a structure built to span road, river, body of water, or any other physical obstacle. All the transportation areas cover around 28.06 hectares in the lower Keelung River.

a. (Frame No. 9723-III-072)

b. Location: Yingfeng Riverside Park, on the left side of Keelung River (Photo No.: L1040632)

c. (Frame No. 9723-III-072)

d. Location: Dajia Riverside Park, on the left side of the Keelung River (L1040641)

Figure 5.23: Illustration of parking area (a. and b.) square (c. and d.) along the lower Keelung River with aerial photograph/picture

e. (Frame No. 9723-III-073)

f. Location: Tayou Evacuating Gate, on the left side of the Keelung River (L1040602)

Figure 5.23: Continuance: illustration of evacuation gate (e. and f.) along the lower Keelung River with aerial photograph/picture

5.1.7.7 Supply and waste management (Type Code: A700)

A. Habitat characteristics and description

This type relates to the construction for water supply and waste management, such as sewage works and pumping station.

B. Characterising species

None.

C. Situation and temporal variation in the study areas

Pumping stations (A710) are facilities including pumps and equipment for pumping fluids from one place to another (Figure 5.24). They are used for a variety of infrastructure systems that many people take for granted, such as the supply of water to canals, the drainage of low-lying land, and the removal of sewage to processing sites. Other supply and control construction (A720) included all other equipments of supply and waste management, which can not be grouped in the previous construction. Altogether, this type covers an area of 0.23 hectares.

(Frame No. 9723-III-074)

Location: Chenggung Pumping Station, on the left side of the Keelung River (L1040508)

Figure 5.24: Illustration of pumping station along the lower Keelung River with aerial photograph/picture

5.1.8 Others (General Type Code: X000)

All habitats, which not be easily sorted into other categories, are grouped into "others".

5.1.8.1 Discard Dirt (Type Code: X100)

A. Habitat characteristics and description

During or after constructing bring the cubic metre of earth, stone and concrete, for example dredging, channeling, and mining. The slope and vegetation cover are changed after filling, and the run-off would be also different; in case the drainage system lose efficacy, the ground-flow might bring flood heavily.

B. Characterising species

None.

C. Situation and temporal variation in the study areas

The lower Keelung River has been regulated for preventing flooding and serving other human demands, the discard dirt and soil occur due to the civil engineering works and cover an area of 0.41 hectares (Figure 5.25).

(Frame No. 9723-III-061)

Location: under the Zhongshan Bridge (L1040838)

Figure 5.25: Illustration of discard dirt with aerial photograph and picture

5.1.9 Overall Review of Biotope Types in the Lower Keelung River

A biotope classification for urban river areas with eight main biotope groups and twenty-five sub-groups was carried out and verified by field survey. The results are shown as in Figure 5.26, which are essential to provide a context and reference for assessment both with existing data and new developed ecological information. The observed features and current conditions can be compared with former environmental status. The use of functional groups (sub-groups) helps to distinguish dynamics with ecological, hydraulic, hydrological, morphological information and assess ecosystem functions further. Each type of biotope can be developed to relevant changes in flood duration and land use to the biotope change (van der Molen et al., 2003). Then the predicated biotope maps can be used to analyse the availability and quality of habitats with knowledge rules (Duel et al., 1996). In whole lower stream Keelung River, the main biotope type on the riverbanks is “urban green (G)”, which can be further classified as “tall forb grassland”, “artificial greensward/turf”, and “garden” according to the richness of vegetation types. Generally, the lower Keelung River covers mainly with man-made land-uses, the natural biotope types are mostly fragmented by man-made constructions.

Moreover, since this classification is relevant to the habitat requirements of bird species, the results of assessing habitat functions in the urban river areas can supply a reference for natural conservation and priorities of rehabilitation, as well as for various ecosystem functions and biodiversity of mobile species.

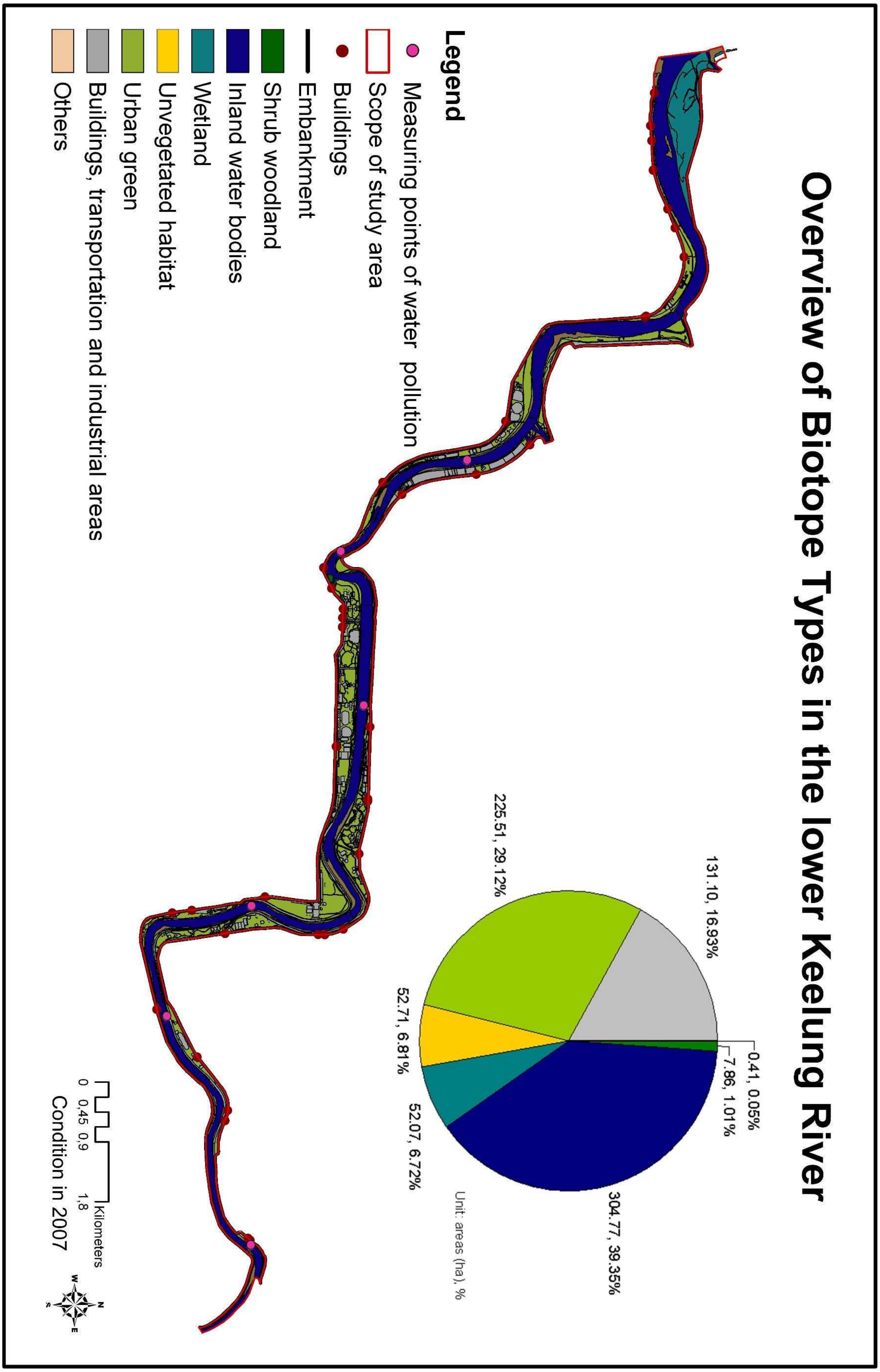


Figure 5.26: Biotope types of the lower Keelung River

5.2 Habitat Condition in the Lower Keelung River

5.2.1 Definition of Testing Areas

For surveying the habitat quality and proposing priorities of rehabilitation, the comparison with habitat condition in different river sections should be listed as reference. According to the existing data of water quality, the test areas are further divided into seven sections (Table 5.2), at which the evaluation was taken with the mean of two measuring points of water quality (See Table 6.1). The scope of each testing area is regulated to coordinate the structure of river. These seven sections are the basis to measure and display the habitat quality along the lower Keelung River.

Table 5.2: Reference of basic maps for investigation areas along the lower Keelung River

Section	Coordinate points*		Length (m)	Areas (ha)
I	121°35'52", 25°04'02"	121°37'25", 25°04'02"	3131.98	35.62
	121°35'52", 25°03'15"	121°37'25", 25°03'15"		
II	121°34'02", 25°03'41"	121°35'52", 25°03'41"	3919.88	93.54
	121°34'02", 25°03'01"	121°35'52", 25°03'01"		
III	121°33'25", 25°04'44"	121°34'25", 25°04'44"	3193.72	139.19
	121°33'25", 25°03'41"	121°34'25", 25°03'41"		
IV	121°32'05", 25°04'44"	121°33'25", 25°04'44"	2262.29	101.03
	121°32'05", 25°04'17"	121°33'25", 25°04'17"		
V	121°30'45", 25°04'52"	121°32'05", 25°04'52"	2660.09	70.59
	121°30'45", 25°04'16"	121°32'05", 25°04'16"		
VI	121°29'08", 25°07'00"	121°31'10", 25°07'00"	5797.9	213.77
	121°29'08", 25°04'52"	121°31'10", 25°04'52"		
VII	121°27'40", 25°07'07"	121°29'08", 25°07'07"	2400.9	120.65
	121°27'40", 25°06'31"	121°29'08", 25°06'31"		

* The coordinate points are the correspondent points at the four corners of each section. (According to the coordinate system by Aerial Survey Office, Forestry Bureau, Administration Executive Yuan, Taiwan)

Figure 5.27 shows roughly the divisions between each test section with the basic land use and location on both sides of river channel. The results of biotope classification in each testing area will be shown in the following paragraphs in more detail.

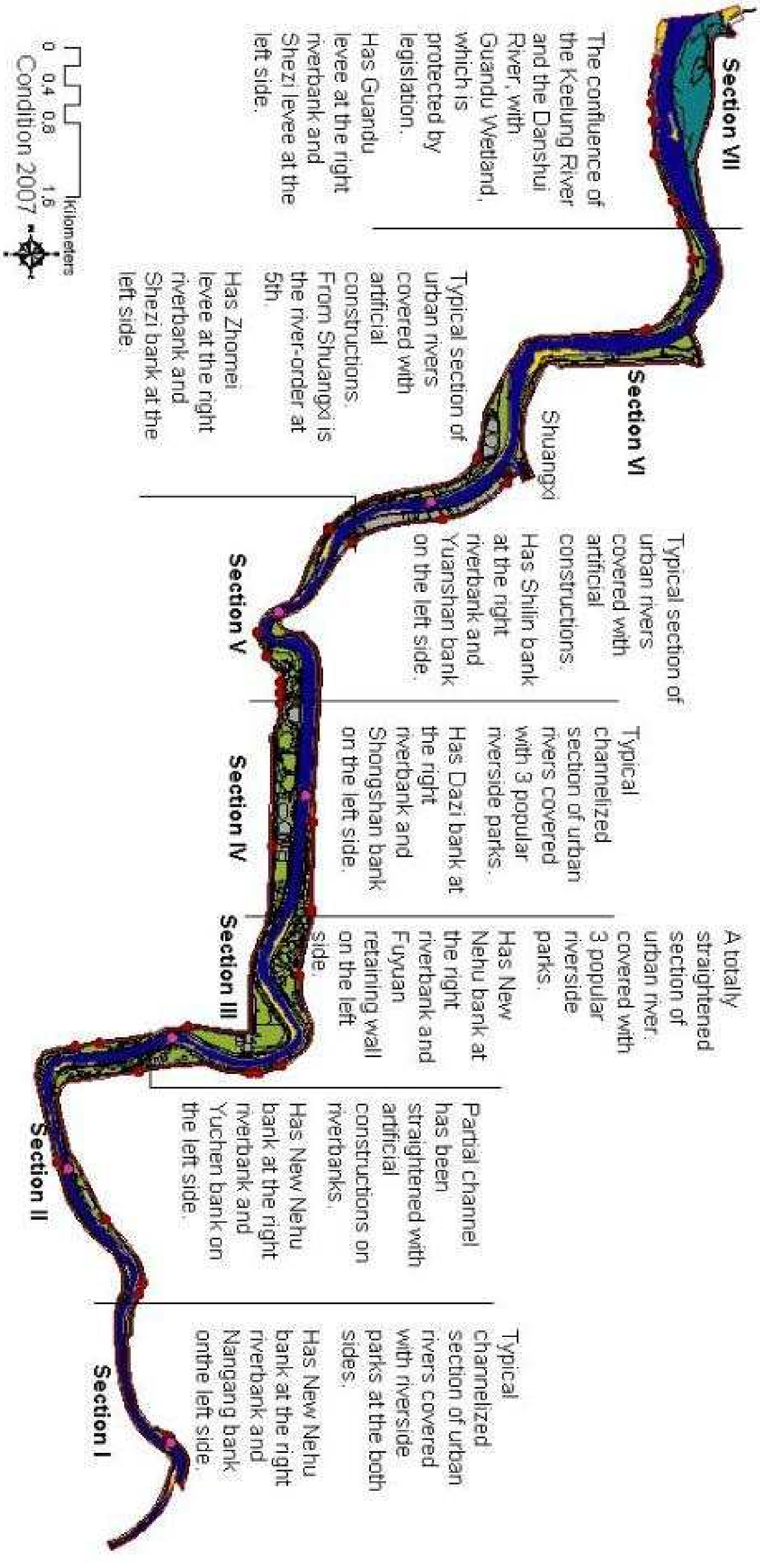


Figure 5.27: Overview of test areas in lower Keelung River

5.2.2 Test and Verified Results of Biotope Condition in the Lower Keelung River

5.2.2.1 Section I in the Lower Keelung River

The range of Section I includes the both sides of river plains and from the boundary of county to the Chengmei Riverside Park (Figure 5.28). Section I has an area of 35.62 hectares and length of 3.13 kilometres, which mainly covers inland water (60%) consisted of “channelized river with dredging”, “channelized river” and some canals (Table 5.3). The river channel in this section has been altered for preventing flooding with revetments and walls. The flood plains are generally the narrowest in the whole lower Keelung River, where are designed as Nanhu Riverside Parks. The both sides of floodplains cover mainly “urban green” (17.93%), which includes “artificial greensward / turf” (53.43%) and “tall forb grassland” (46.57%). However, the covers of grasslands have been fragmented by man-made infrastructure (e.g. bikeways, playgrounds, revetments and soil ground). Generally speaking, this section covers mainly altered biotopes, even the section of inland water has been altered, and the structure of landscape is monotonous. A big quantity of barren soil stock (discard dirt) was even found near the border between Taipei City and Taipei County.

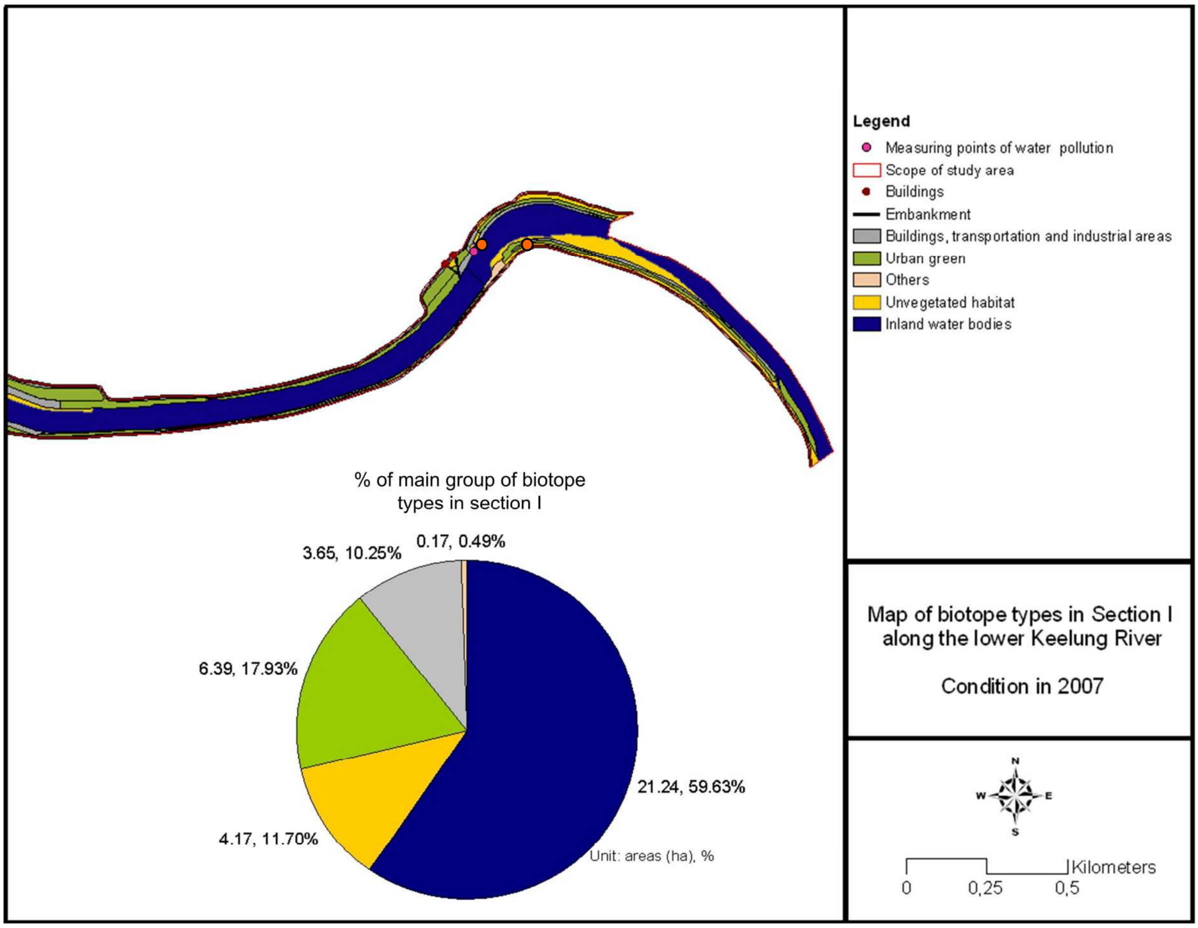


Figure 5.28: Map of biotope types in Section I along the lower Keelung River

Table 5.3: Biotope types in Section I of the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
W220	Channelized river with dredging	9.703150	45.69	59.63
W230	Channelized and straightened river	11.451658	53.92	
W400	Canal	0.084080	0.39	
U200	Gravel bar	1.994313	47.85	11.70
U400	Soil	2.173616	52.15	
G100	Tall forb grassland	2.974399	46.57	17.93
G200	Artificial greensward / turf	3.412237	53.43	
A110	Water-bound surface	0.777429	21.29	10.25
A120	Pavement	1.047955	28.69	
A250	Revetment	0.113033	3.09	
A320	Paved bikeway	0.247571	6.78	
A330	Asphalt bikeway	1.359727	37.23	
A610	Parking area	0.106733	2.92	
X100	Discard dirt	0.173450	100	0.49

* The single shrubs in this section are too less to be counted into the areas of cover.

The structure of vegetation cover in each biotope types shows similar condition in a monotonous way as structure of landscape. The narrow flood plains on both sides have been altered as riverside parks and covered mostly with bikeways along. Moreover, the riverbanks in this section are lined by revetments, only *Euphorbia hirta L.* shows in between the heat of stones on riverbanks. Though, the corridors of grassland between the bikeways and river channel display slightly different on the both side (Figure 5.29). On the left side with Left Nanhu Riverside Park is covered mainly *Paspalum notatum*, *Bidens pilosa L. var. minor, Ipomoea cairica (L.) Sweet* and *Humulus scandens (Louri) Merr.* come out in between as dominant plants. Some herb plants (e.g. *Emilia sonchifolia (L.) DC., Rumex acetasa L., Oxalis corniculata L.* and *Portulaca oleracea L.*) can be found at the foundation of preventing wall.


a. left side(Photo No.: L1040485)


b. right side (Photo No.: L1040491)

Figure 5.29: View on both sides of river plaints in Section I of the lower Keelung River (Located at orange points in Figure 5.28)

On the right side of Section I shows comparative multi-structure of plants to the left side. *Miscanthus floridulus* and *Paspalum notatum* are dominant plants in this area, some single shrubs (e.g. *Musa basjoo, Trema orentalis (L.) Blume*) grew up on the river plains. More than 15 herb plants are found in the biotope of “tall (forb) grassland” (e.g. *Bidens pilosa L. var. minor, Brachiaria mutica (Forsk.) Stapf,* *Eleusine indica*, etc.). Moreover, an urban forest covers an area of 10 hectare next to the Nanhu Yoan Riverside Park, it helps to increase the multi-structure of vegetation communities and improve therefore the habitat quality for wildlife.

5.2.2.2 Section II in the Lower Keelung River

Section II is a highly developed river corridor after channel straightening. The matrix, for instance Section I, is also man-made river channel (40.56% as shown in Figure 5.30 and Table 5.4). The both sides of river channel are designed as Chengmei Riverside Parks. Although the main patch on riverbanks is grassland (34.91%), the main areas of grassland cover artificial greensward (83.26%, ca. 29.07% of all areas of biotope types in Section II). The main biotope types are composed of artificial greenland and man-made constructions on both sides of extremely altered riverbanks, which show poor or monotonous vegetation covers. Only some reeds and sedge grassland appear at the watersides.

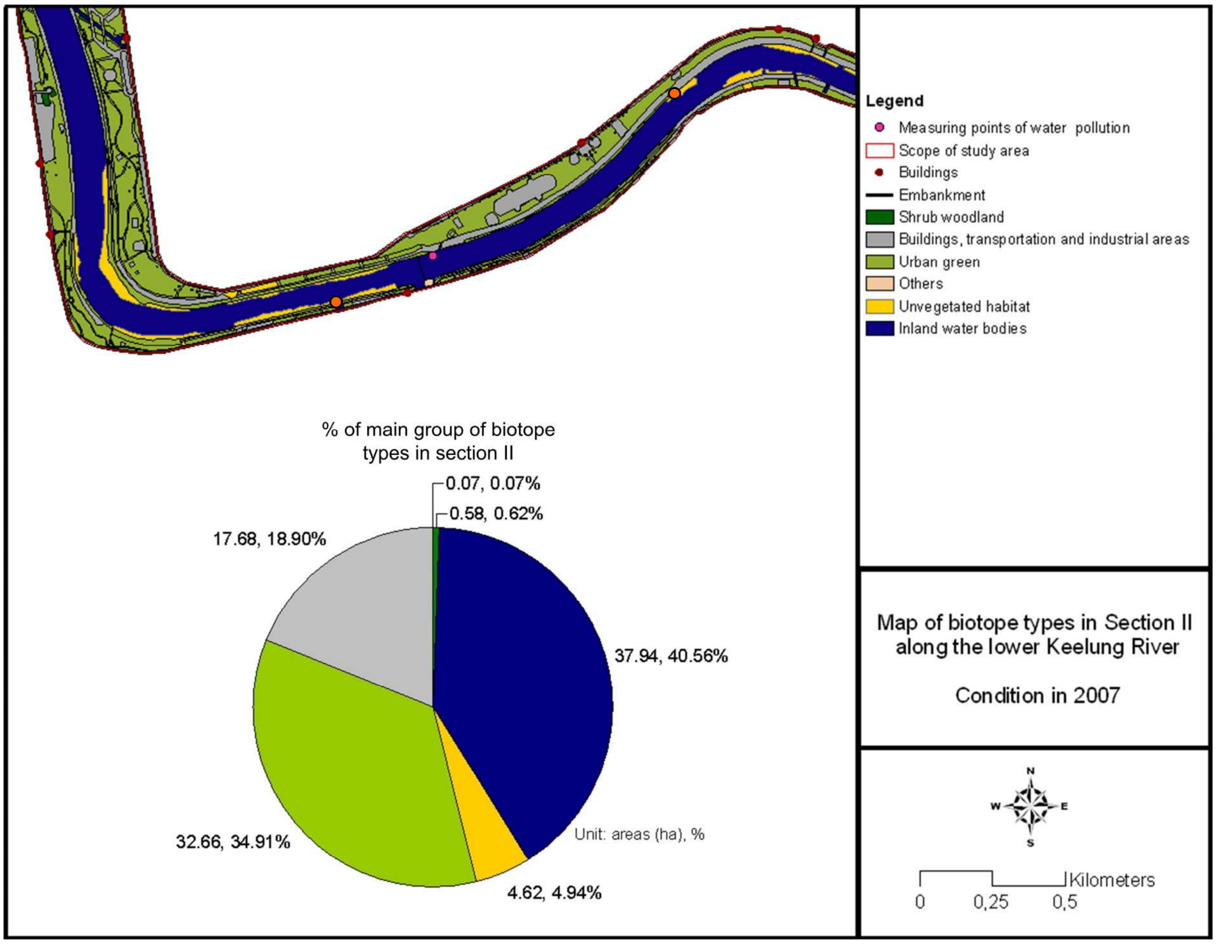


Figure 5.30: Map of biotope types in Section II along the lower Keelung River

Generally speaking, Section II displays mainly man-made environment both in river channel and on flood plains. On the left side, the structure of vegetation between the Chengmei Zuoan Riverside Park and Maishai 1st Bridge covers mainly artificial greensward (*Cynodon dactylon* and *Zoysia sinica var. nipponica*), bikeway, sport areas and parking areas, some single shrubs such as *Platycladus orientalis, Lantana camara L.*, *Musa basjoo*, *Hibiscus tilaceus L.* and *Cycas revolufa* are planted on the flood plains. The concrete riverbank is only covered less plants such as *Bidens pilosa L. var. minor, Humulus scandens (Louri) Merr.*, *Kyllinga brevifolia Robbt*. and *Alternanthera philoxeroides* near the Rainbow Bridge (Figure 5.31 a.). On the contrary, near the Maishai 1st Bridge that covered with dominant plant of *Brachiaria mutica (Forsk.) Sta,f,* has multi-structure of vegetation. More than 10 types of plants (e.g. *Trifolium repens Linn*., Bidens pilosa L. var. minor, Rumex acetasa L.) have been found at this corner. From the Maishai 1st Bridge down to the Minquan Bridge displays broader flood plans as riverside parks, however, the vegetation covers show a doll condition with mainly artificial greensward (Cynodon dactylon).

Table 5.4: Biotopes types in Section II of the lower Keelung River

Code	**Biotope types**	**Area (ha)**	**% of type**	**% of section**
S100	Shrub woodland	0.57737	100	0.62
W220	Channelized river with dredging	22.309985	58.81	
W230	Channelized and straightened river	15.064478	39.71	40.56
W400	Canal	0.562864	1.48	
U100	Stones	0.179719	3.89	
U200	Gravel bar	3.992672	86.45	4.94
U400	Soil	0.446165	9.66	
G100	Tall forb grassland	5.148978	15.77	
G200	Artificial greensward / turf	27.189051	83.26	34.91
G300	Garden	0.317643	0.97	
A110	Water-bound surface	2.857433	16.16	
A120	Pavement	0.965681	5.46	
A130	Concrete / asphalt	1.253379	7.09	
A250	Revetment	0.731119	4.13	
A310	Terrazzo bikeway	0.056047	0.32	
A320	Paved bikeway	1.608180	9.09	
A330	Asphalt bikeway	3.877183	21.93	
A410	Sport area	2.775986	15.70	18.90
A420	Playground	0.133711	0.76	
A520	Temple	0.016998	0.10	
A530	Other buildings	0.073971	0.42	
A610	Parking area	2.816535	15.93	
A620	Square	0.466891	2.64	
A650	Bridge	0.009438	0.05	
A710	Pumping station	0.041203	0.23	
X100	Discard dirt	0.068044	100	0.07

On the right side of Section II shows better vegetation covers than the left side. The riverbank is lined by revetment as the left side. However, the aggradational area with rich tall grassland due to the river flow increases the ratio of vegetation cover and the community. *Brachiaria mutica (Forsk.) Stapf, Miscanthus floridulus, Ipomoea cairca (L.) Sweet* and *Hibiscus tilaseus L.* are the dominant plants at riverbanks. The flood plain is mainly covered artificial greensward with *Zoysia sinica var. nipponica* and *Cynodon dactylon*. Some single shrubs are planted on riverside parks and the backyard of a temple (Hexin Tempel) (e.g. *Trema orentalis (L.) Blume, Cinnamomum Camphora (L.) Presl*). The reclaimed land from straightening engineering on the right side between the Maishai 1st Bridge and Minquan Bridge is designed as riverside parks and sport areas with doll vegetation cover. However, the aggradational area with rich tall grassland along this section serves better quality of ecological functions.

a. left side, at Rainbow Bridge
(Photo No.: L1040559)

b. right side at Chengmei Riverside Park
(Photo No.: L1040536)

Figure 5.31: View on both sides of river plaints in Section II of the lower Keelung River
(Located at orange points in Figure 5.30)

5.2.2.3 Section III in the Lower Keelung River

The main part on the right side of the flood plains in Section III has been built up by land reclamation after straightening river for preventing flooding. The channelization works carried out more areas of riverside parks on both sides of river channel. In Figure 5.32 and Table 5.5 shown, the matrix is urban green (42.25%) primarily covered with artificial greensward (83.34%). In general, Section III is one section where is principally covered with man-made constructions (e.g. riparian parks, parking areas, etc). In additions, the super highway is built across the river channel and an airport is located next to the river on the left side of the channel. The busy traffic causes impacts on the habitat quality.

To review the structure of vegetation cover on flood plains, the both sides are covered with artificial greensward (*Trifolium repens Linn., Paspalum notatum (Flugge, Zoysia sinica var. nipponica* and *Cynodon dactylon*) for recreation, sport field and in between the pavements. On both sides of riverbanks show a long distance of aggradational areas where have rich and tall plants, for indstance *Miscanthus floridulus*, *Brachiaria mutica (Forsk.) Stapf*. Another case with multi-structure of vegetation cover shows at Meiti Riverside Park with a moderately altered pond (Figure 5.15 b.), which covers an area of 0.4347 hectares. Around this pond *Cyperus malaccensis*, *Typha angusifolia L.*, *Carex brunnea Thunb*. and *Miscanthus floridulus* were planted to increase the imitated environment of wetland for wildlife.

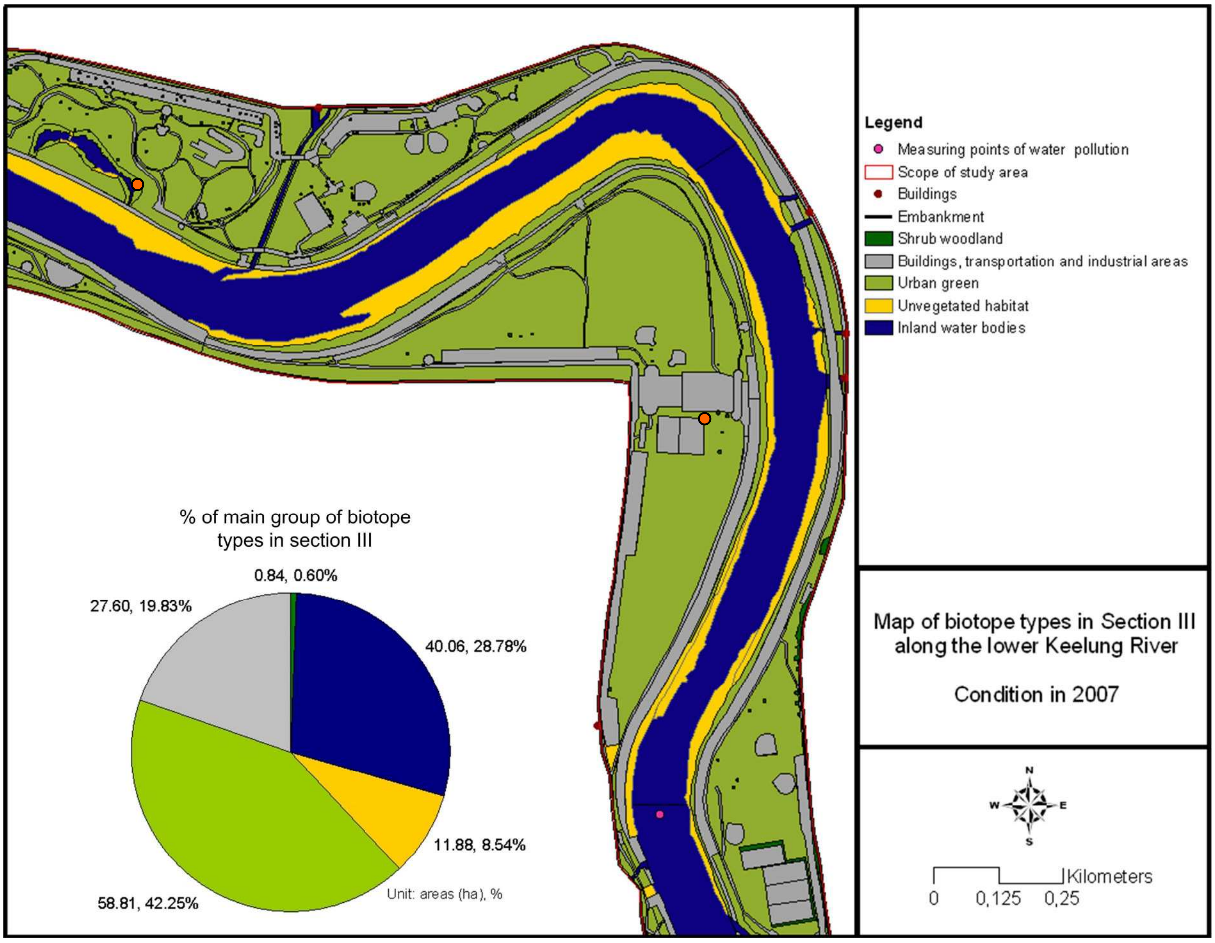


Figure 5.32: Map of biotope types in Section III along the lower Keelung River

Table 5.5: Biotopes types in Section III of the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
S100	Shrub woodland	0.839855	100	0.60
W220	Channelized river with dredging	3.031982	7.57	
W230	Channelized and straightened river	36.031391	89.94	28.78
W400	Canal	0.561434	1.40	
W510	Moderately altered pond	0.434771	1.09	
U100	Stones	1.896339	15.96	
U200	Gravel bar	9.901565	83.32	8.54
U400	Soil	0.086182	0.72	
G100	Tall forb grassland	9.698097	16.49	
G200	Artificial greensward / turf	49.005759	83.34	42.25
G300	Garden	0.102376	0.17	
A110	Water-bound surface	4.426726	16.04	
A130	Concrete / asphalt	4.656775	16.87	
A250	Revetment	0.391441	1.42	
A310	Terrazzo bikeway	5.933822	21.50	
A330	Asphalt bikeway	1.245182	4.51	
A410	Sport area	3.279308	11.88	19.83
A520	Temple	0.018789	0.07	
A610	Parking area	4.809081	17.43	
A620	Square	2.789310	10.11	
A650	Bridge	0.045425	0.16	

a. left side, at Guanshan Riverside Park
(Photo No.: L1040609)

b. right side at Meiti Riverside Park
(Photo No.: Z500-4-9)

Figure 5.33: View on both sides of river plaints in Section III of the lower Keelung River
(Located at orange points in Figure 5.32)

5.2.2.4 Section IV in the Lower Keelung River

The flood plains in "Section IV" are also highly developed as riverside parks. Two most famous riverside parks are located individually on both sides of river in this section (Dajia Riverside Park on left side and partial Meiti Riverside Park on right side). The man-made infrastructure therefore covers more areas (ca. 25.63%) than the other land-uses in this section, for example for recreation, parking area and passages (See Figure 5.34 and Table 5.6). The biotope types in this section are infertile, dull and unnatural.

Table 5.6: Biotopes types in Section IV of the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
S100	Shrub woodland	0.805552	100	0.80
W220	Channelized river with dredging	12.883146	43.52	29.30
W230	Channelized and straightened river	15.088036	50.98	
W400	Canal	0.764944	2.58	
W520	Artificial pond	0.863752	2.92	
U100	Stones	1.361424	39.30	3.43
U200	Gravel bar	0.189369	5.47	
U400	Soil	1.913431	55.23	
G100	Tall forb grassland	5.147505	12.47	40.84
G200	Artificial greensward / turf	35.433220	85.87	
G300	Garden	0.684592	1.66	
A130	Concrete / asphalt	1.702139	6.57	25.63
A250	Revetment	0.854220	3.30	
A310	Terrazzo bikeway	2.000290	7.73	
A410	Sport area	6.469714	24.99	
A610	Parking area	5.867686	22.66	
A620	Square	4.001318	15.45	
A630	Riverine dock / port	0.790498	3.05	
A650	Bridge	0.037802	0.15	
A710	Pumping station	0.019476	0.08	

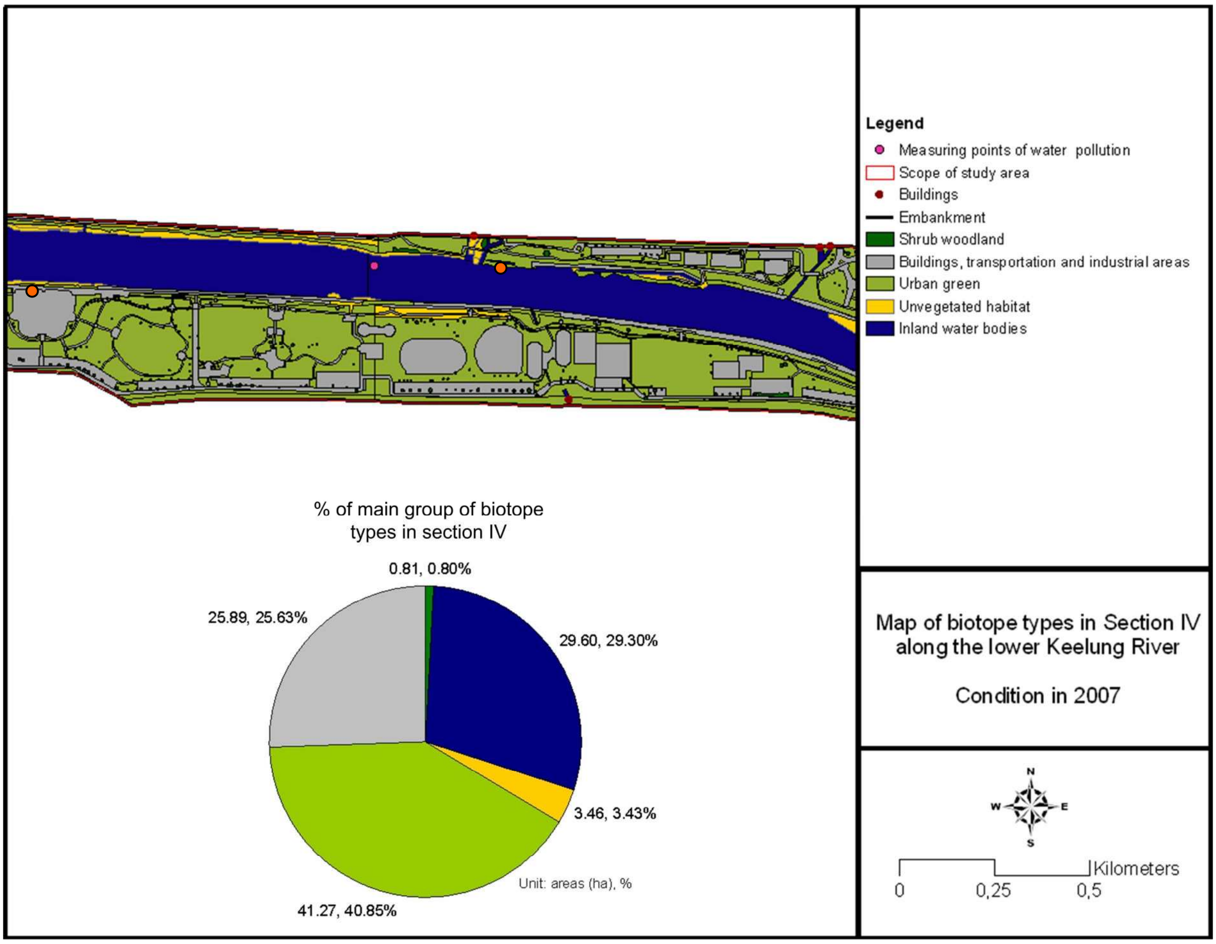


Figure 5.34: Map of biotope types in Section IV along the lower Keelung River

The main area-covers are man-made land use in Section IV, such as artificial greensward (ca. 35.07%) and man-made infrastructures (25.63%), in which, the vegetation covers are mainly artificial greensward (e.g. *Paspalum notatum (Flugge), Zoysia sinica var. nipponica* and *Cynodon dactylon*) except a short part of right-side riverbanks. Large areas of floodplains have been even drained and surrounded by dikes, where the natural vegetation cover is removed and the landscape structures are simplified. The man-made areas (e.g. parking areas and concrete bikeway) lie between the natural biotopes. Such a phenomenon is especially obvious on the left side of the lower Keelung River.

The riverbank on the opposite of Dajia Riverside Park spreads a long corridor of grassland with *Paspalum distichum L.*, *Cyperus malaccensis*, *Trema orentalis* (L.) *Blume*, *Salix warburgii*, and other types of grass. Many single shrubs are planted on the riverside parks as ornamental plants (*Pittosporem pentandrum, Musa basjoo, Hibiscus tilaceus L., Platycladus orientalis* and *Bombax ceiba*). Generally speaking, it shows mainly the man-made environment with cultural landscape in Section IV (Figure 5.35).

a. left side, at Dajia Riverside Park
(Photo No.: L1040649)

b. right side at Meiti Riverside Park
(Photo No.: Z500-4-20)

Figure 5.35: View on both sides of river plaints in Section IV of the lower Keelung River (Located at orange points in Figure 5.34)

5.2.2.5 Section V in the Lower Keelung River

The narrowest part of Keelung River channel is at Yuanshan, a study area in Section V (red circle in Figure 5.36). Many studies pointed out that the obstruction of water flow plus the tidal influence cause floods after heavy raining and the overflowing water would destroy the infrastructure in the neighbourhoods in this section. The majority biotopes in this section are channelized river stream (43.37%, Table 5.7) and man-made environment (e.g. riverside parks, parking areas, total ca. 40%, in which, the land use for parking areas and transportation cover around 60%). The highly developed riverside parks (partial Dajia Riverside Park, Yuanshan Riveside Park and Sanjiaodu) in Section V have larger areas with impervious surface than the other sections. The biotopes of grassland are mainly artificial greenswards (83.74%, *Zoysia sinica var. nipponica* and *Cynodon dactylon*), which are usually infertile and revegetated after flooding.

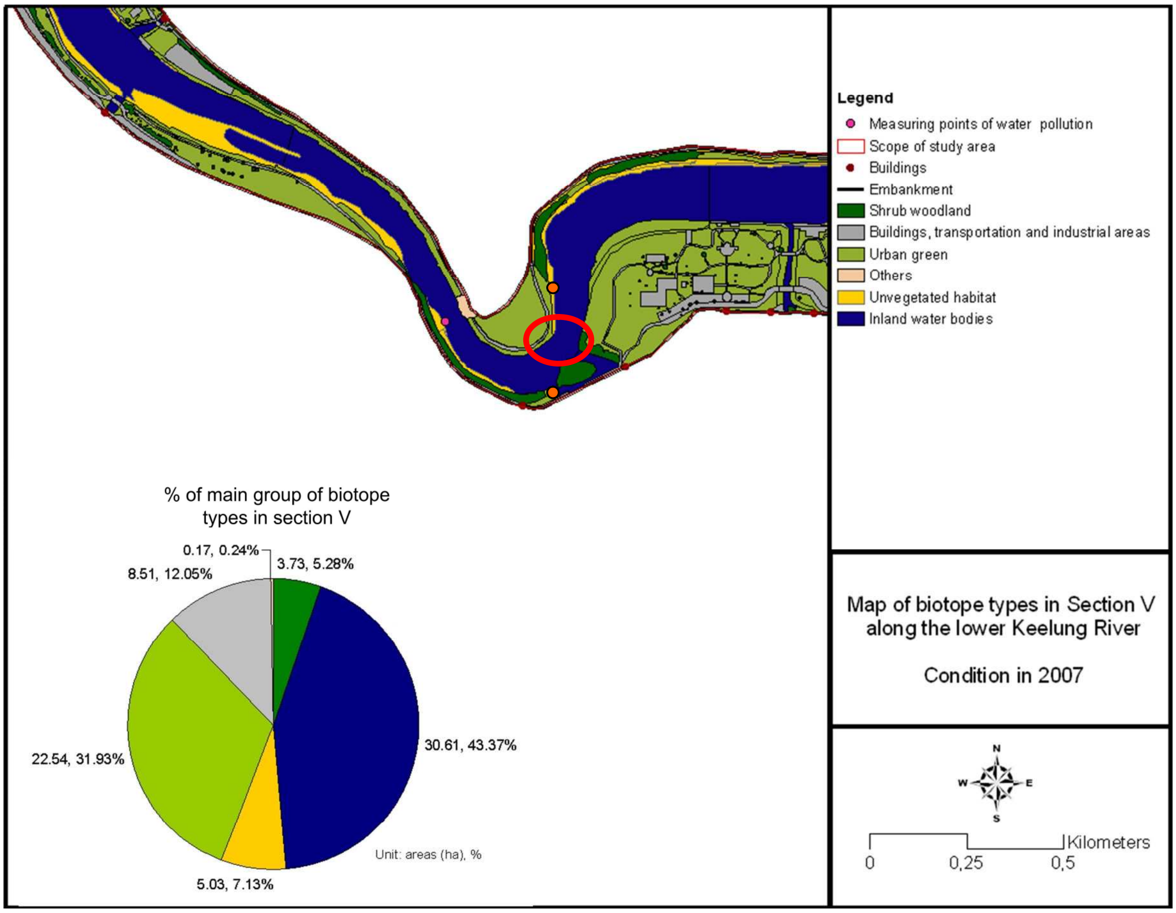


Figure 5.36: Map of biotope types in Section V along the lower Keelung River

Table 5.7: Biotopes types in Section V of the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
S100	Shrub woodland	3.729115	100	5.28
W220	Channelized river with dredging	12.968164	42.36	
W230	Channelized and straightened river	16.379444	53.50	
W300	Side Channel	0.540224	1.76	43.37
W400	Cannel	0.620207	2.03	
W520	Artificial pond	0.105776	0.35	
U100	Stones	1.049431	20.86	
U200	Gravel bar	2.910995	57.87	7.13
U400	Soil	1.070150	21.27	
G100	Tall forb grassland	2.278085	10.11	
G200	Artificial greensward / turf	18.872322	83.74	31.93
G300	Garden	1.385239	6.15	
A210	Dike	1.080190	12.70	
A250	Revetment	0.170165	2.00	
A310	Terrazzo bikeway	0.348577	4.10	
A320	Paved bikeway	.0568187	6.68	
A330	Asphalt bikeway	3.268192	38.43	
A410	Sport area	0.793743	9.33	
A510	Agricultural buildings	0.009136	0.11	12.05
A520	Temple	0.002980	0.04	
A610	Parking area	1.555540	18.29	
A620	Square	0.384609	4.52	
A630	Riverine dock / port	0.197020	2.32	
A650	Bridge	0.127636	1.50	
X100	Discard dirt	0.171672	100	0.24

However, there are two corridors of green areas with tall herb plants (e.g. *Brachiaria mutica (Forsk.) Stapf*, *Miscanthus floridulus*, *Bidens pilosa L. var. minor*) and shrubs (e.g. *Hibiscus tilaceus L.*, *Trema orentalis (L.) Blume*, *Broussonetia kazinoki*) in Section V – one is on the right side close to the Yuanshan Riverside Park and the area under Zhongshan Bridge on the left side.

a. left side, at Dajia Riverside Park (Photo No.: L1040679)

b. right side close to Yuanshan Riverside Park (Photo No.: L1040848)

Figure 5.37: View on both sides of river plaints in Section V of the lower Keelung River (Located at orange points in Figure 5.36)

5.2.2.6 Section VI in the Lower Keelung River

The riverbanks in Section VI can be divided into two parts by different natural condition of biotope types; the north part (from Shuangxi to Linung on right side and Shezi on left side, Figure 5.38) is close to Guandu and maintains more natural than the south part does. Both sides of the river in south part are highly developed as riverside parks after straightening works, where cover more man-made areas on the both side of Keelung River. Generally speaking, in the south part, the sport areas (basketball court, baseball field, etc.) are the main constructions (Table 5.8). However, it covers much more natural biotopes for example wet grassland in the north part, where the slowly river flow cause many areas of gravel bars and sand bars along the river channel.

The north part (at Zhomei, Linung and Shezi) has more natural and better quality of habitats for wildlife, where cover mainly tall grassland with multi-structure of vegetation (e.g. *Brachiaria mutica (Forsk.) Stapf*, *Pennisetum Purpureum Schumach*, *Miscanthus floridulus*, Eleusine *indica, Euphoribia hirta L.*, *Carex brunnea Thunb.*, *Phagmites communis (L.) Trin*. etc.) on riverbanks. The main patch is urban green (cover areas of 28.18%) in the whole section, which covers biotope of tall forb grassland about 49.82%; and most natural fields are in the north part. On both sides of the south part are Bailin Riverside Parks, where has been developed as sport areas for baseball, softball, football and basketball and covered the artificial greensward (*Zoysia sinica var. nipponica* and *Cynodon dactylon*; Figure 5.39 d.).

Next to the sport fields, some short herb plants (e.g. *Bidens pilosa L. var. minor*, *Emilia sonchifolia (L.) DC*, *Ageratum conyzoides L.*, etc.) and single trees (e.g. *Ficus septica Burm. F.*, *Hibiscus tilaceus L.*, *Cycas revolufa*, etc.) have been surveyed.

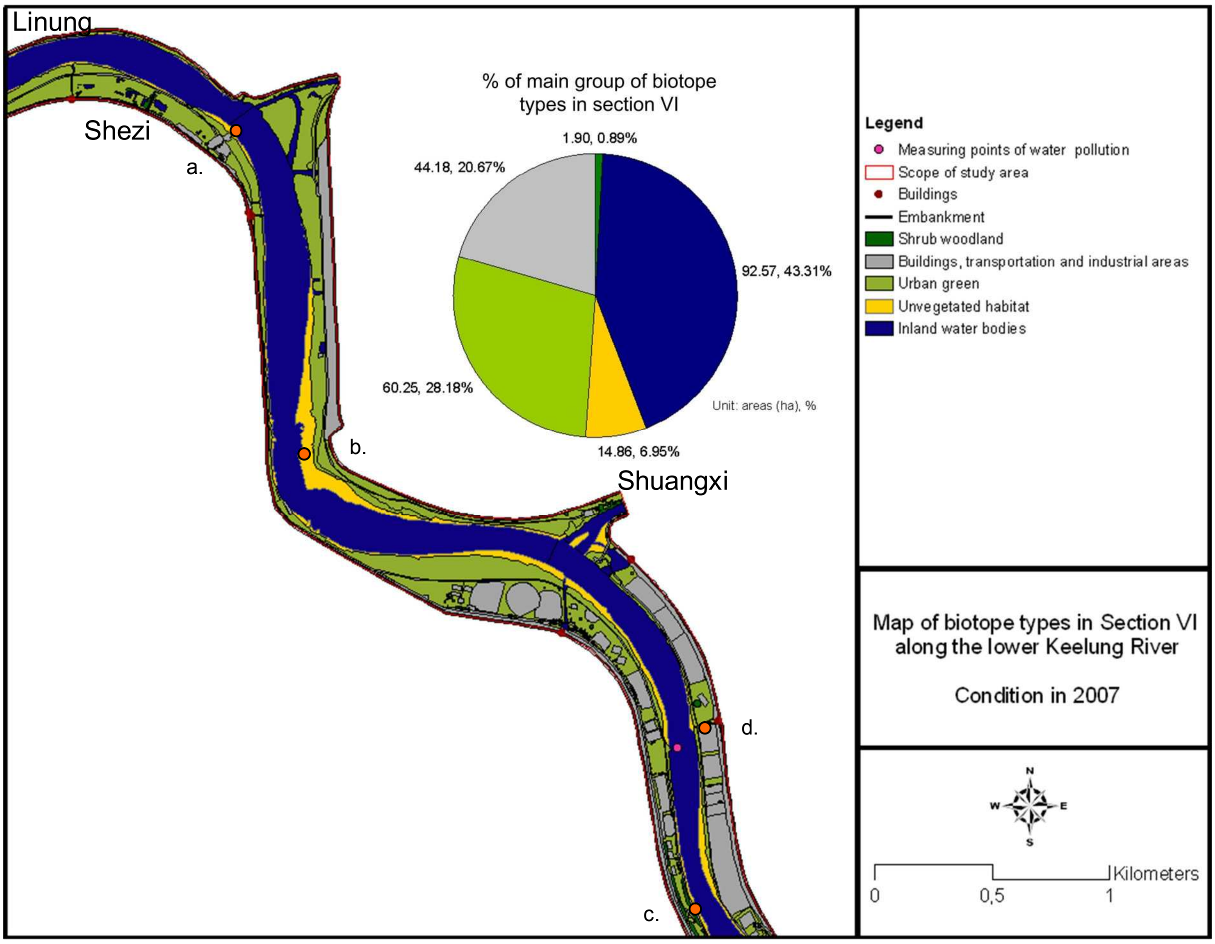


Figure 5.38: Map of biotope types in Section VI along the lower Keelung River

Table 5.8: Biotopes types in Section VI in the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
S100	Shrub woodland	1.904861	100	0.89
W110	Moderately altered stream	0.566789	0.61	43.31
W120	Channelized stream	2.366000	2.56	
W210	Moderately altered river	14.274641	15.42	
W220	Channelized river with dredging	72.517279	78.33	
W300	Side channel	0.715068	0.77	
W400	Canal	1.458820	1.58	
W510	Moderately altered pond	0.621035	0.67	
W600	Backwater	0.054885	0.06	
U100	Stones	1.473243	9.93	6.95
U200	Gravel bar	13.103529	88.18	
U300	Sand bar	0.205226	1.38	
U400	Soil	0.077514	0.52	
G100	Tall forb grassland	30.015161	49.82	28.18
G200	Artificial greensward / turf	29.999611	49.79	
G300	Garden	0.231649	0.38	
A210	Dike	13.044379	29.52	20.67
A220	Wall	1.946538	4.41	
A250	Revetment	0.108255	0.25	

Table 5.8: Continuance

Code	Biotope types	Area (ha)	% of type	% of section
A320	Paved bikeway	0.796798	1.80	
A330	Asphalt bikeway	7.229972	16.36	
A340	Timbered bikeway	0.400475	0.91	
A410	Sport area	16.687642	37.77	
A520	Temple	0.000083	0	
A530	Other buildings	0.061561	0.14	
A610	Parking area	2.549627	5.77	
A620	Square	1.168745	2.65	
A620	Bridge	0.018565	0.04	
A710	Pumping station	0.169424	0.38	

Moreover, although the most sections of the riverbanks are lined by embankment, the aggradational areas with reed, grass and shrub woodland show the more natural environment than the previous sections in the lower Keelung River.

a. left side in the north part, at Sheizi (Photo No.: L1040725)

b. right side in the north part, close to Zhomei Highway (Photo No.: L1040777)

c. left side in the south part, at BailinYoan Riverside Park (Photo No.: Bailin-35)

d. right side in the south part at Bailin Zuoan Riverside Park (Photo No.: L1040810)

Figure 5.39: View on both sides of river plaints in Section VI of the lower Keelung River (Located at orange points in Figure 5.38)

5.2.2.7 Section VII in the Lower Keelung River

Section VII mainly covers the Guandu wetland, the partial areas of Shezi and Linung (Figure 5.40). The speed of river flow becomes slow due to the flat topography and wider channel; hence it shows the geographic characteristics as many intertidal zones. Moreover, the biggest treasure in the Section VII and the whole ecosystem of Keelung River is Guandu Wetland, which is a typical estuary wetland at the confluence of the Keelung River and the Danshui River, which is located at north-west of Taipei City. This area is a hot spot of migratory birds, great quantities of migratory birds stop by here over the winter (e.g. *Anas Formosa, Platalea minor*, etc. detail in Chapter VI); hence it is also an important bird area (IBA) of BirdLife International (IBA Code: TW003). Table 5.9 shows that the Guandu Nature Preserve is the main biotope, plus mug flats and sand bars. The matrix is inland water in this section (43.71%), and the wetland covers an area of about 52.07ha (43.16%) as main patch. The left side is Shezi, where was used to be taken as the extension area of Guandu Conservation and covered with *Kandelia candel* and agricultural area, but it has been reshape as riparian park in the last years.

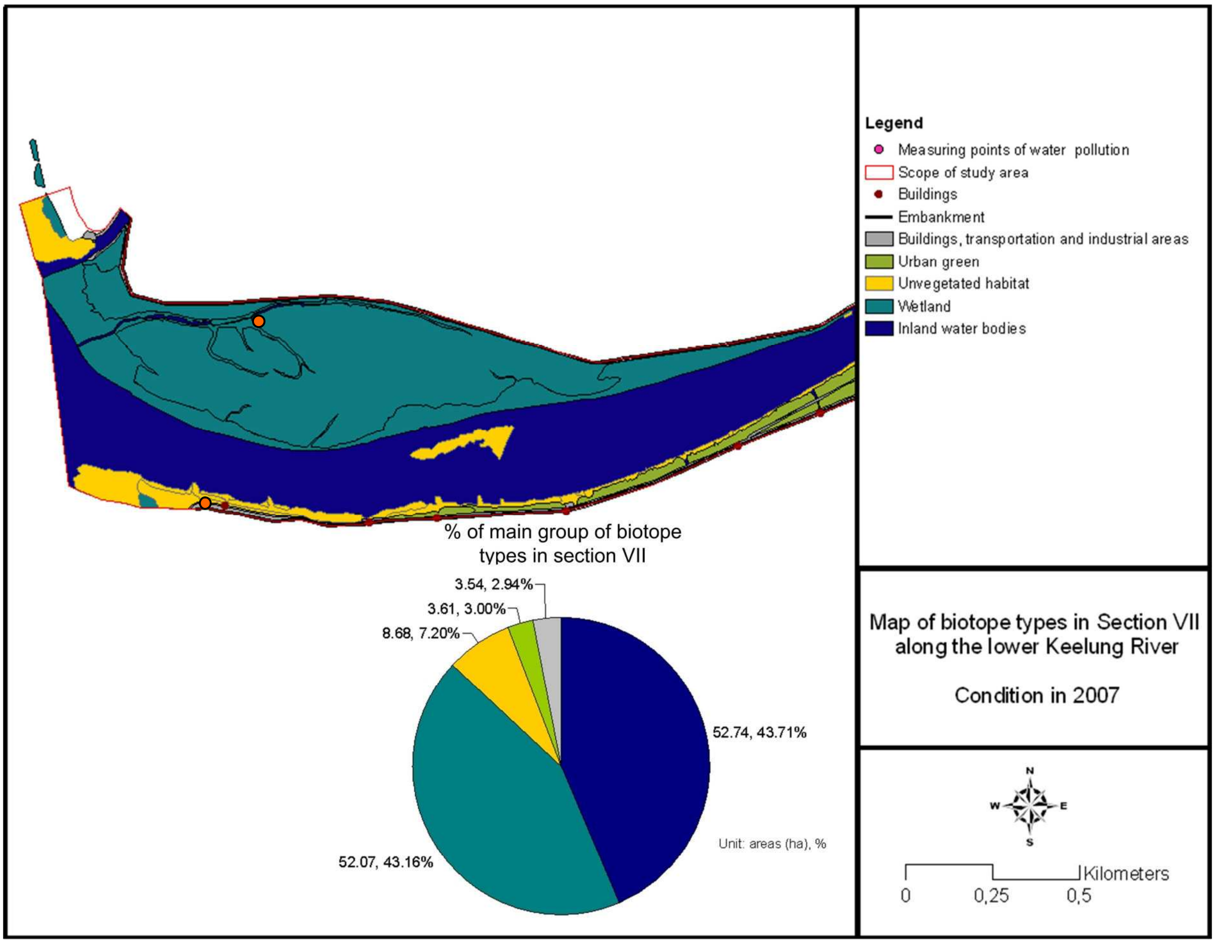


Figure 5.40: Map of biotope types in Section VII along the lower Keelung River

From Linung down to the confluence on the right side of the Keelung River is lined by muddy ground, on the aggradational area covers mainly mangrove swamp with the dominant plant of *Kandelia candel* (ca. 17.34 ha, Figure 5.41 b.). Besides, the shrubs with *Pittosporem pentandrum, Broussonetia kazinoki, Hibiscus tilaceus L., Trema orentalis (L.) Blume* and *Melia axedaracb* contribute to increase the multi-structure of vegetation covers. The shrinking marshlands at Guandu Wetland have more than 15 types of herb plants with the dominant plants of *Cyperus malaccensis, Typha angusifolia L.* and *Phagmites communis (L.) Trin.* On the left side is covered mainly the riverside park on flood plain (Figure 5.41 a.). At the riverbank shows rich grassland (*Bidens pilosa L. var. minor, Brachiaria mutica (Forsk.) Stapf,* etc.), shrubs (*Hibiscus tilaceus L.*, *Trema orentalis (L.) Blume*, etc.) and a small area of mangrove swamp.

Table 5.9: Biotopes types in Section VII of the lower Keelung River

Code	Biotope types	Area (ha)	% of type	% of section
W110	Moderately altered stream	0.910778	1.73	43.71
W120	Channelized stream	0.018027	0.03	
W210	Moderately altered river	51.315293	97.30	
W300	Side channel	0.442161	0.84	
W400	Canal	0.054922	0.10	
We110	Estuary wetland with natural flooding regime	37.505842	72.03	43.16
We210	Riparian marshland	14.0000.98	26.89	
We220	Riparian reedland	0.565709	1.08	
U100	Stones	1.743922	20.08	7.20
U200	Gravel bar	4.818580	55.49	
U300	Sand bar	1.134994	13.07	
U400	Soil	0.985583	11.35	
G100	Tall forb grassland	3.230047	89.36	3.00
G200	Artificial greensward / turf	0.384452	10.64	
A220	Wall	1.125740	31.78	2.94
A330	Asphalt bikeway	0.924908	26.11	
A340	Timbered bikeway	1.177381	33.23	
A610	Parking area	0.143671	4.06	
A620	Square	0.025034	0.71	
A630	Riverine dock / port	0.146103	4.12	

c. left side at Shezi
(Photo No.: Z500-11-3)

d. right side at Guandu Wetland
(Photo No.: L1040750)

Figure 5.41: View on both sides of river plaints in Section VI of the lower Keelung River
(Located at orange points in Figure 5.22)

In Table 5.10 is listed the details of vegetation along the lower Keelung River with their names and distribution as reference.

Table 5.10: Common plants on flood plains along the lower Keelung River

Code	Scientific Name	Common Name	Chinese Name	Status of distribution*						
				S1	S2	S3	S4	S5	S6	S7
Woody plants										
T-001	*Ficus septica Burm. F.*	Fig trees	綠榕		○	⊙	○	⊙	⊙	
T-002	*Cinnamomum camphora (L.) Sieb.*	Camphor tree	樟樹		○	○	○	○	○	
T-003	*Bombax ceiba*	Cotton tree	木棉			○	○			
T-004	*Platycladus orientalis*	Chinese Arborvitae	柏樹		○	⊙	⊙	⊙	⊙	
T-005	*Salix warburgii*	Water Willow	水柳			○	○	○	○	○
S-001	*pittosporem Pentandrum*	Taiwanese cheesewood	七里香（海桐）			○	○			○
S-002	*Lantana camara L.*	Lantanas	馬纓丹		⊙					
S-003	*Broussonetia kazinoki*	Japanese Paper Mulberry	小構樹		○	⊙	○	○	⊙	⊙
S-004	Macaranga tanarius (L.)	Macaranga	血桐		○	○		○	⊙	⊙
S-005	*Musa basjoo*	Japanese Banana	芭蕉	○	○	○	○	○	○	
S-006	*Hibiscus tilaceus L.*	*Cuban Bast*	黃槿		○	○	○		⊙	○
S-007	*Hibiscus rosa-sinensis L.*	Chinese hibiscus	紅槿			○	○		⊙	○
S-008	*Cycas revolufa*	Sago palm	蘇鐵		○				○	
S-009	*Trema oirentalis (L.) Blume*	Pigeon wood	山黃麻	○	○	○	○		⊙	⊙
S-010	*Kandelia candel*	Pisang pisang	水筆仔						○	●
S-011	*Melia axedaracb*		苦楝		○				⊙	○
Herb plants										
H-001	*Brachiaria mutica (Forsk.) Stapf*	Para grass	巴拉草		○	○				●
H-002	*Commelina auriculata Blume*	Dayflowers	耳葉鴨跖草			○				
H-003	*Ludwigia hyssopifolia*	Water-primrose	細葉水丁香	○	○	○	○	○	○	○
H-004	*Ipomoea cairica(L.) Sweet*	Mile-a-minute Vine	番仔藤	○	⊙	⊙	○	○	●	⊙
H-005	*Eclipta prostrata L.*	False Daisy	鱧腸		○	○				○
H-006	*Polygonum plebeium R.Br.*	Knotweed	節花蕗蓼-蓼屬(溼地植物)		○	○				○
H-007	*Polygonum longisetum De Bruyn.*	Posumbu knotweed	睫穗蓼				○			

Table 5.10: Continuance

Code	Scientific Name	Common Name	Chinese Name	Status of distribution*						
				S1	S2	S3	S4	S5	S6	S7
H-008	*Kyllinga brevifolia Rottb.*	Shortleaf spikesedge	短葉水蜈蚣	○	○	○		○	○	
H-009	*Alternanthera philoxeroides*	Alligator weed	空心蓮子草		○	○			○	○
H-010	*Ludwigia octovalvis (Jakq.) Raven*	Yellow willow herb	黃花水丁香						○	
H-011	*Pennisetum purpureum Schumach.*	Napier grass	象草	○	○	○	○	○	◉	◉
H-012	*Ludwigia octovalvis (Jakq.) Raven*	Yellow willow herb	牛筋草	○	○	○	○	○	◉	◉
H-013	*Erigeron bonariensis L.*	Asthmaweed	野塘蒿	○	○	○		○	○	
H-014	*Cosmos bipinnatus Cav.*	Garden cosmos	大波斯菊		○	○	◉	○	○	○
H-015	*Bidens pilosa L. var. minor*	Spanisch Needle	咸豐草、鬼針草	○	○	○	○	○	◉	○
H-016	*Wedelia chinensis (osbeck) Merr.*	Chinese Wedelia	蟛蜞菊		○	○	○	○	○	○
H-017	*Amaranthus spinosus L.*	Spiny amaranth	刺莧		○	○	○	○	○	
H-018	*Miscanthus floridulus*	Perennial grass	五節芒	○	◉	◉	○	○	●	◉
H-019	*Phagmites communis (L.)Trin.*	Common reed	蘆葦			○			●	◉
H-020	*Carex brunnea Thunb.*	Greater brown sedge	莎草		○	○			◉	
H-021	*Paspalum distichum L.*	Knotgrass	雙穗雀稗			○	○		◉	
H-022	*Cyperus malaccensis*	Papyrus sedges	茳芏鹹草			○	○		◉	◉
H-023	*Typha angusifolia L.*	Narrow Leaf Cattail	香蒲（水蠟燭）			○			◉	◉
H-024	*Ficus pumila*	creeping fig	薜荔	○	◉	◉	○	◉	◉	
H-025	*Lycianthes biflora（Lour）Bitter.*		雙花龍葵、耳鉤草	○	○					○
H-026	*Emilia sonchifolia (L.) DC. var. javanica (Burm. f.) Mattfeld*	Lilac tasselflower	紫被草	○	○	○	○		◉	
H-027	*Soliva anthemifolia R. Br.*	Button Onehunga-weed	假吐金菊		○				○	
H-028	*Euphorbia hirta L.*	Gatas-gatas	大飛揚草	○	○	○	○		◉	
H-029	*Ageratum conyzoides L.*	Goat weed	藿香薊	○	○	○				
H-030	*Rμmex acetasa L.*	Garden Sorrel	酸模(羊蹄)	○	○	○		○	◉	

Table 5.10: Continuance-2

Code	Scientific Name	Common Name	Chinese Name	Status of distribution*						
				S1	S2	S3	S4	S5	S6	S7
H-031	*Humulus scandens (Louri) Merr.*	Hop	葎草	⦿	○	○	○		⦿	⦿
H-032	*Portulaca oleracea L.*	Little Hogweed	馬齒莧	○		○	○			
H-033	*Trifolium repens L.*	White Clover	白花三葉草(花苜蓿)		⦿	●	⦿			
H-034	*Oxalis corniculata L.*	Creeping Woodsorrel	酢醬草	○	○	○	○	○	○	
H-035	*Paspalum notatum*	Bahia Grass	巴西亞雀稗（百喜草）	⦿		⦿	⦿	⦿	⦿	
H-036	*Axonopus affinis*	Carpet Grass	地毯草		⦿	⦿				
H-037	*Zoysia sinica*	Zoysia grasses	結縷草		⦿	⦿	⦿	⦿	⦿	
H-038	*Cynodon dactylon (Linn.) Pers.*	Dog’s tooth grass	百慕達草(狗牙根)		⦿	⦿	⦿	⦿	⦿	

* The status of distribution shows sketchily the distribution and condition in the seven test sections with 3 degree. ● means large areas of cover. ⦿ shows the medium cover. ○ represents the less or rare quantity of distribution.

6. Analysis of the Habitat Functions in the Lower Keelung River

Based on the results of biotope classification by field survey (Chapter V), this chapter is going to show the analysis of habitat functions in the lower Keelung River with consideration of species-environment-relationship for bird species. The evaluation took account of three factors (i.e. the impact factors on river channel and riversides, and the biotope condition) to discuss the impact pressure on water and flood plains and the actual biotope condition that conjoint assessment displaying the habitat quality and habitat structure itself (Section 6.1). Then, the states of bird species along the lower Keelung River are listed in Section 6.2, which helps to evaluate the habitat functions for bird species in the seven test sections and to show the interaction between bird species and their habitats in Section 6.3. The results from this chapter may contribute to decision-making of planning and priority of habitat remediation for government and further studies (Lin, 2009). It attempts to propose the ranking and emphasis on improvement in reality in the conclusion (Chapter VII).

6.1 Human Impacts and Habitat Functions in the Lower Keelung River

6.1.1 Human impacts on the River Channel in the Lower Keelung River

Human impacts on river channel are evaluated with regard to the water quality and the stability of river channel, which included: “water pollution”, “fine particulate matter” and “condition of river channel”. The first two indicators represent the water quality according to the monitoring and report from the National Environmental Protection Administration and the Taipei City Government.

A. Water Pollution (Indicator Code: D1-1)

The data of water pollution is carried out with River Pollution Index (RPI) by Taiwan’s National Environmental Protection Administration. The RPI has been taken as an official standard while measuring and monitoring the water quality of rivers in Taiwan. It is a comprehensive index by testing the water quality with ”DO (dissolved oxygen)”, “BOD (biochemical oxygen demand)”, “SS (suspended solids)” and “NH_3 (ammonia nitrogen)”. As what is shown in Table 6.1, there are seven investigation and measuring points of water quality in the lower Keelung River[1], the seven test sections area accordingly divided in the study areas. The information regarding the water quality provides an important basis while measuring the habitat functions of urban rivers and the healthy of river ecosystem.

[1] There are six investigative points in Taipei City, which are at Nanhu Bridge, Chengmei Bridge, Minquan Bridge, Dazhi Bridge, Zhongshan Bridge and Bailin Bridge, and one at the confluence of the Keelung River and the Danshui River – Guandu.

Table 6.1: Test points of water pollution in the lower Keelung River (Environmental Water Quality Information[2], Taiwan)

Controlling and measuring station	No.	Coordinate points	Distance to estuary* (km)	Study reaches
Nanhu Bridge	1269	121°36'43', 25°03'47'	29.26 (22.31)	I
Chengmei Bridge	1270	121°34'58', 25°03'15'	25.54 (18.59)	II
Minquan Bridge	1010	121°34'09', 25°03'53'	23.48 (16.53)	III
Dazhi Bridge	1011	121°32'41', 25°04'35'	20.19 (13.24)	IV
Zhongshan Bridge	1280	121°31'32', 25°04'23'	16.29 (9.34)	V
Bailin Bridge	1012	121°30'50', 25°05'18'	13.91 (6.96)	VI
Guandu Bridge	1003	121°27'27', 25°07'28'	6.95	VII

* The distances in the parentheses are the lengths from test points to the confluence of Keelung River and Danshui River.

Figure 6.1 represents the RPI in the lower Keelung River during the period of field work (between December 2006 and February 2007). The water condition surveyed at most of the test points was medium-polluted, except the measuring points at Nanhu Bridge (light-polluted) and Guandu Bridge (medium-polluted to heavy-polluted). The data showed that water quality is getting worse along with the flow direction. In other words, the polluted materials amass and degrade the water quality with water flowing.

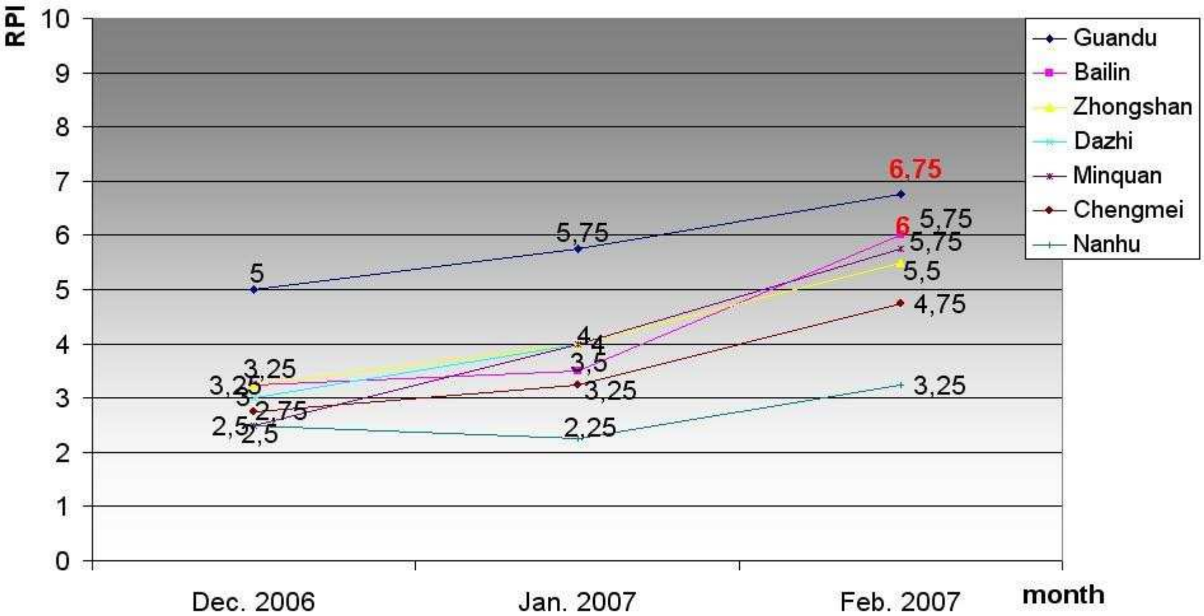


Figure 6.1: River Pollution Index during the period of field work in the lower Keelung River

To have a further review of the water quality in the last decade (1998-2007), the change of trend can be analyzed as "RPI2" in the third column of Table 6.2 as reference for long-term monitoring (detail in Annex E). In general, the water quality in the lower Keelung River was better in the fall and winter and turned worse in spring and summer. The worst condition happened in summer time due to the heavy rainfall and heat. The test sections I, II, and III were regularly middle-polluted, these three

[2] Environmental Protection Administration Executive Yuan, Taiwan, available from: http://wqshow.epa.gov.tw/

sections also appeared the variance in seasons, the water condition was even under controlled at light-polluted and below in recent year. The water qualities in test sections IV, V, and VI were heavy-polluted over the past ten years, but were obviously improved in recent three years. The difference between summer and fall/winter was noticeable; in some heavy-polluted sections (e.g. Section IV) the RPI was even getting better to light-polluted once in a while. The water quality in Section VII was floating at medium-polluted and not improved in evidence to compare with the other sections. Accordingly the evaluation of water quality in the seven test sections is listed in Table 6.2 and illustrated in Figure 6.2.

Table 6.2: Scales of values for water pollution in the lower Keelung River

	RPI 1*	RPI 2*	Degree	Scales of value
Section I	2.5-3.25	2-8	Light-polluted	2
Section II	2.75-4.75	2-8	Medium-polluted	1
Section III	2.5-5.75	1.5-8	Medium-polluted	1
Section IV	3-5.75	2-9	Medium-polluted	1
Section V	3.25-5.5	2.25-9	Medium-polluted	1
Section VI	3.25-6	2-9	Medium-polluted	1
Section VII	5-6.75	2.75-8.25	Medium-polluted	1

* RPI 1 is the water quality during the period of field survey. RPI 2 is the long-term water quality from 1998 to 2007. SVS=3, when RPI (River Pollution Index) <2.0; SVS=2, when RPI between 2.0 and 3.0; SVS=1, when RPI between 3.1 and 6.0; SVS=0, when RPI>6.0.

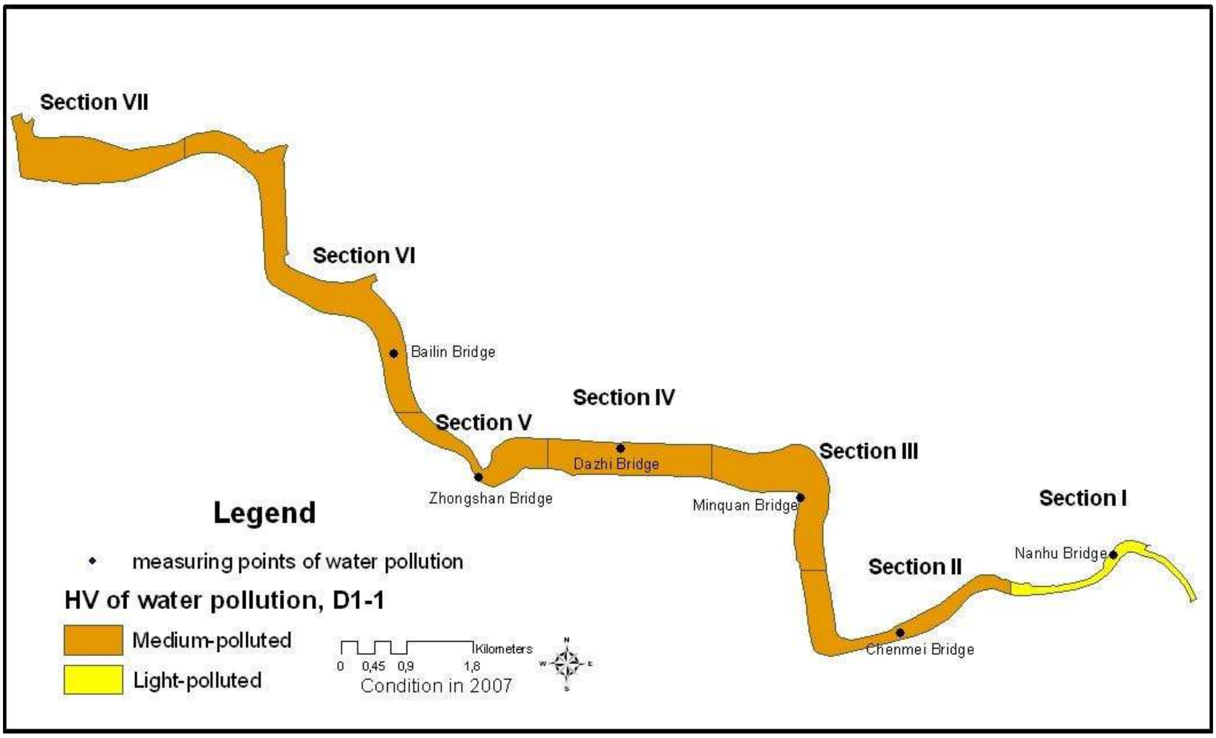


Figure 6.2: Scales of value for water pollution in the lower Keelung River

B. Fine Particulate Matter (Indicator Code: D1-2)

The second criterion of aqua-impact is fine particulate matter which is showing the impact on rivers with regards to the air quality, the fine particulate matter in the air. The rainfall in Taipei City, especially during the plum rain season (usually in May) and typhoon season (i.e. raining season), brings rapid flow into rivers. Hence, the fine particulate matter is an important index to check the impact on rivers in mega-cities.

There are five test stations of "Fine Particulate Matter" along the lower Keelung River (at "Chengde", "Zhongshanbei", "Dazhi", "Nehu", and "Nangang". Among what mentioned before, "Nehu" is close to Section II and III and "Chengde" is located near Section VI and VII). In general, the conditions of fine particulate matter were good during the period of field survey; the only exception was collected at Station Nehu (medium-PM) that may be related to the land use of industrial area in the neighbourhoods. Going further to review the data from 2004 to 2007, they can be concluded that the particulate matter was under control in Taipei City. Table 6.3 and Figure 6.3 show the evaluation results of fine particulate matter in the lower Keelung River.

Table 6.3: Scales of values for Fine particulate matter in the lower Keelung River

	PM 1*	PM 2*	Degree**	Scales of value
Section I	32.13-51.49	32.13-78.88	Micro-PM	3
Section II	60.83-79.30	36.30-91.65	Medium-PM	2
Section III	60.83-79.30	21.47-82.92	Medium-PM	2
Section IV	33.32-50.83	33.32-66.94	Micro-PM	3
Section V	36.66-54.15	32.50-71.48	Micro-PM	3
Section VI	41.50-64.44	36.30-91.65	Micro-PM	3
Section VII	41.50-64.44	36.30-91.65	Micro-PM	3

* PM1 refers to the state during the period of field survey; PM2 is a result of long-term observation.
** Micro-PM means the few fine particulate matter in the air, which has better quality to reducing the impact into water body. Medium-PM displays the moderate condition of fine particulate matter.

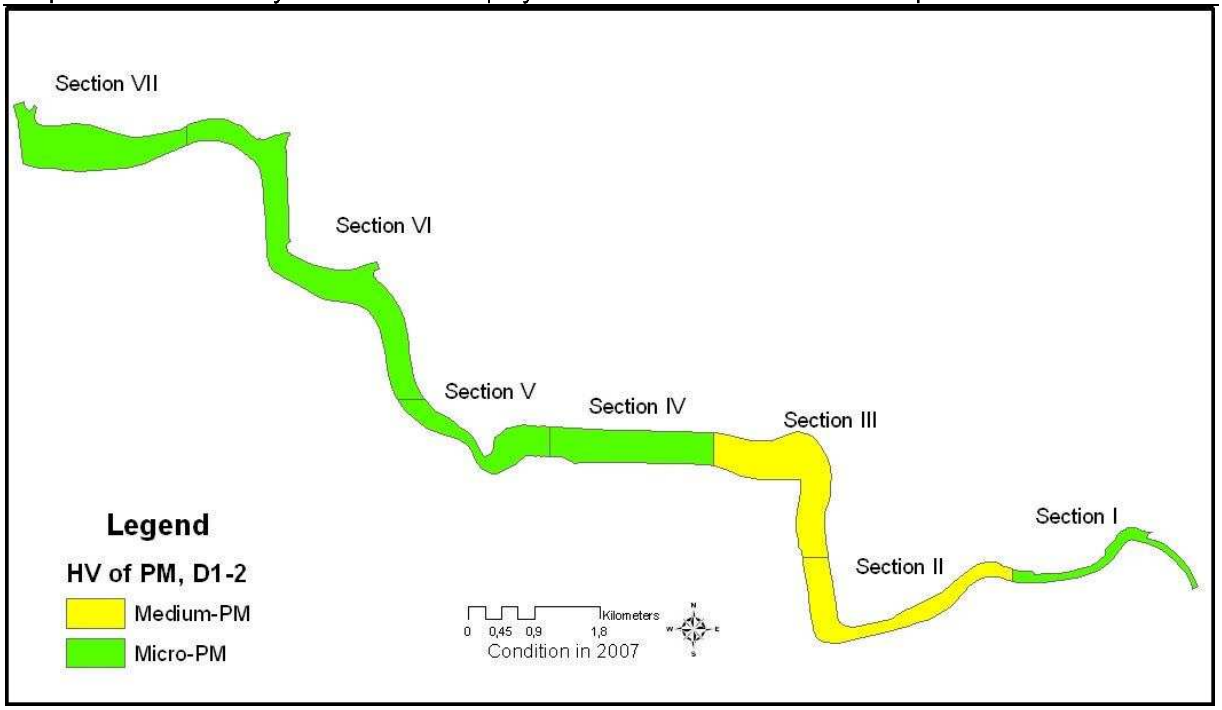


Figure 6.3: Scales of value for fine particulate matter in the lower Keelung River (legend)

C. Condition of River Channel (Indicator Code: D1-3)

This criterion focuses on the stability of the river channels, since flooding in impulse may increase soil erosion in the waterway that reflects both the sources of impacts from the neighbourhoods (latitudinal) and the upper streams (longitudinal). For instance, the slight-strength change of river channel with alluviums may contribute a friendly environment for bird species, but the strong-strength change in river channel with erosion may rush out the soil and present unstable channel as habitats. Generally speaking, the river channel of the lower Keelung River has been altered for preventing flooding by dredging or straightening. The riverbanks are mostly lined by embankments. The heavy-strength changes showed mainly from the county boundary to Sanjiaodu (Section I to V). Table 6.4 and Figure 6.4 briefly show the observational results from field work.

Table 6.4: Scales of values of state of channel in the lower Keelung River

	Situation	Degree	Scales of value
Section I	There are revetments on the watersides. The river channel is totally altered by channelization and embankment. Besides, the acute soil erosion occurs often at the county boundary.	Heavily disturbed with erosion	0
Section II	It is also a channeled reach. Even there are revetments on the watersides. There are alluvia by river flow at some spots at riverbanks.	Heavily disturbed with alluviums	1
Section III	It is a completely altered channel and straightened in two sections. The revetments do not work well to protect the water channel. The soil erosion is remarkable on the river bed. However, the alluviums at riversides serve as habitats for wildlife	Heavily disturbed with alluviums	1
Section IV	It is typically channeled river bed with revetments. The whole section has been altered but still has to be prevented from soil erosion.	Heavily disturbed with erosion	0
Section V	The river channel can be destroyed after heavy rainfall. The soil erosion is remarkable on the river bed. However, at Yuanshan have a few alluvia as habitats for water fowl.	Heavily disturbed with alluviums	1
Section VI	The direction of river channel has been altered about 30 years ago. With the regular maintaining the river channel is getting stable at the both side. The .great numbers of alluvia serve as stopping stones or habitats for water fowl.	Moderately disturbed with alluviums	3
Section VII	Similar to Section VI that the water flows slowly and stable in the wider channel, the sand and soil stop up in this section; which joins the tidal influence twice a day. Alluvia are observable on the channel.	Minimally disturbed	4

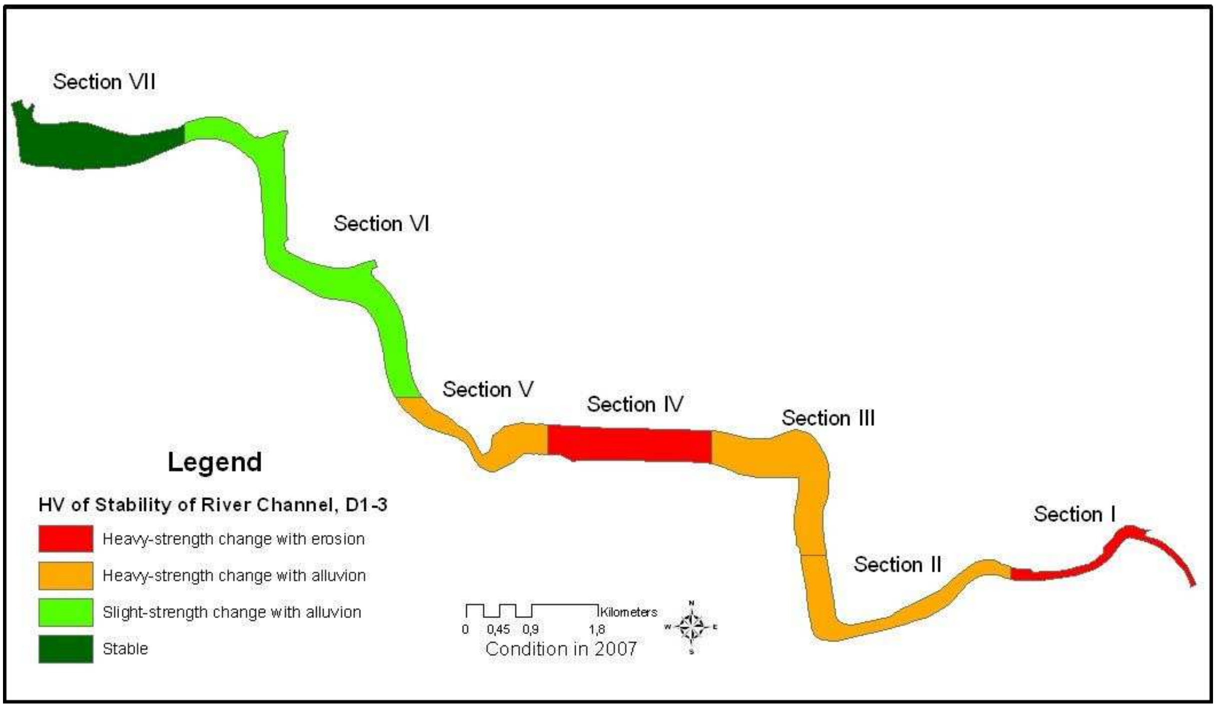


Figure 6.4: Scales of value for state of channel in the lower Keelung River

6.1.2 Human Impacts on the Flood plains

The impacts on flood plains should be an important factor to review the ecological services for wildlife in urban river ecosystems. In this case, three indicators are included to evaluate the human impacts on riverbanks: “human activities on the flood plains”, “land use in the surrounding outside of the flood plains” and “stability of riverbanks”.

A. Human Activities on the Flood plains (Indicator Code: D2-1)

The main human activities on flood plains were on weekend and at nightfall, which were regularly seen in Section IV, Section V, and Section VI, because there are many sport areas (e.g. basketball courts, baseball fields, tennis courts, and other sport areas) in the riparian parks. Moreover, the Dajia Riverside Park (Section IV) and Bailin Riverside parks (Section VI) are popular places for events and festivals, the big off-and-on events sometimes affect and destroy the quality of habitats more serious than the small regular activities (detailed results in Table 6.5 and Figure 6.5).

Table 6.5: Scales of values of Intensity of human activities on flood plain in the lower Keelung River

	Situation	Degree	Scales of value
Section I	Except a few passing traffic, the human activity is not obvious in this area.	Light impact	3
Section II	There are regular human activities in Rainbow riparian park. Besides, the parking areas were often full during the period of field work.	Usual impact	1
Section III	There are three riparian parks in this section. They are not only famous places for citizens, some sport teams gather and do training in these three riparian parks.	Heavy impact	0

Table 6.5: Continuance

	Situation	Degree	Scales of value
Section IV	There are many infrastructure public entertainments in Dajia riparian park. The citizens exercise and bike usual there in weekdays and at weekend.	Heavy impact	0
Section V	This section covers over three different riparian parks, in which, the Sanjiaodu was a dock in early days. There are regular citizens' gatherings. The Dajia riparian park is also a popular recreational place in Taipei City	Usual impact	1
Section VI	There are riparian parks on both sides of the south part in this section. The sport areas are often full of people at nightfall and on weekend. There is no regular human impact in the north section.	Middle impact	2
Section VII	Normally has no impact from human activities, but the tourists visit Guandu Nature Preserve often at weekend.	Light impact	3

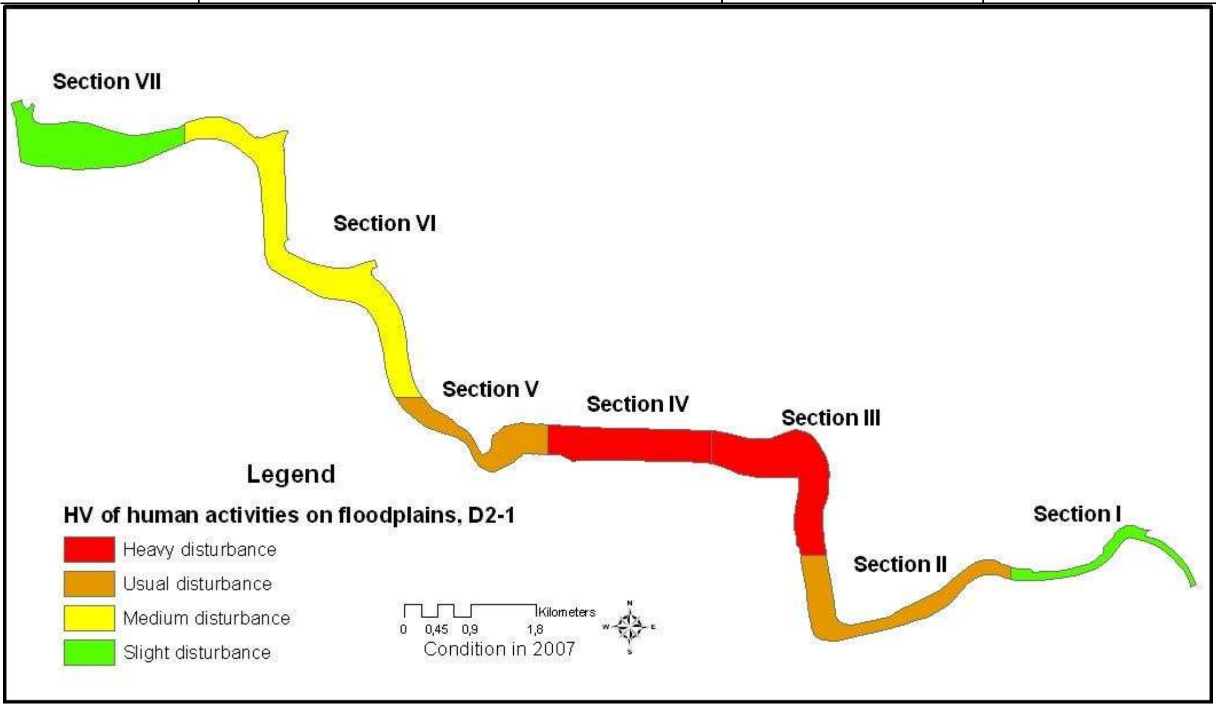


Figure 6.5: Scales of value of Intensity of human activities on riverbanks in the lower Keelung River

B. Land use in the Surrounding Outside of the Flood Plains (Indicator Code: D2-2)

The land use in the neighbourhoods highly influences the habitat functions, especially when there is no buffer zone between the riparian areas and built-up areas. The dynamic human activities are strong in highly developed urban areas (e.g. commercial area, industrial area, and other developed areas). These areas usually cover full of man-made constructions and thus cannot be unable to provide habitat functions. On the other hand, the land use of urban green (such as parks, agricultural, etc.) next to the riparian areas could be regarded as the expansion of rest/breeding places for wildlife.

The effective demarcation was defined as one block away from the embankments, and then examined the intensity of land use in neighbourhoods along the Keelung River. Table 6.6 first displays the existing zoning districts by Taipei City Government and the weights of different land use. The weights of each zoning district reflect the strength of human activities in different land use (See Table 4.15). The weight should be then calculated with the areas of land use to show the strength of impacts.

Table 6.6: Redefinition of land use (Version 2) in Taipei City (altered from digital data from Taipei City Government) and the weight of land use

	Coding of Zoning	Weight
Residential area	1	0.5-0.75
Commercial area	2	0.75-1
Industrial area	13	0.5-1
Administrative are	7	0.75
Cultural and education area	5	0.25-0.5
Entertainment area	32	0.75
Airport area	6	1
Public facilities area	3	1
Scenic area	4	0.25
Agricultural area	11	0-0.25
Reserved area	8	0
Waterside area	9	0.25
Special area and land for other use	20	1

Basically speaking, the neighbourhoods of the lower Keelung River except Section VII are highly developed areas. In Section VII, the Guandu Nature Park is located on the right side of the Keelung River, where is a restored wetland to maintain the biodiversity of Guandu wetland. The Keelung River flows through the centre of the Taipei City between Section II and Section VI that the highly developed man-made environment may impact on the habitats of wildlife. In the case of Section IV, V and VI, the neighbourhoods of the three sections are even close/next to the Songshan Airport and industrial areas that extremely influence on the quality of natural environment. The greenlands/parks in the surroundings of Section V (ca. 13.46%) and Section VI (ca. 19.58%) help to decrease the impacts on the man-made areas. The land-use types next to Section I are mainly industrial areas (ca. 42.45%), this section is covered by build-up environment of 25.43% in total, and consequently regarded as progressing in degree “altered”. The evaluation results show in Table 6.7 can also layout in Figure 6.6.

Table 6.7: Scales of values for land use in neighbourhoods in the lower Keelung River

	Naturalness of land use*	Degree	Scales of value
Section I	0.6567	Altered	1
Section II	0.7827	Artificial	0
Section III	0.9556	Artificial	0
Section IV	0.8913	Artificial	0
Section V	0.5243	Altered	1
Section VI	0.6377	Altered	1
Section VII	0.2015	Semi-natural	3

* The values in the second column mean naturalness of each land use in the neighborhoods, which are calculated with areas and weight of land use. The results refer to the value “UL” in Table 4.15.

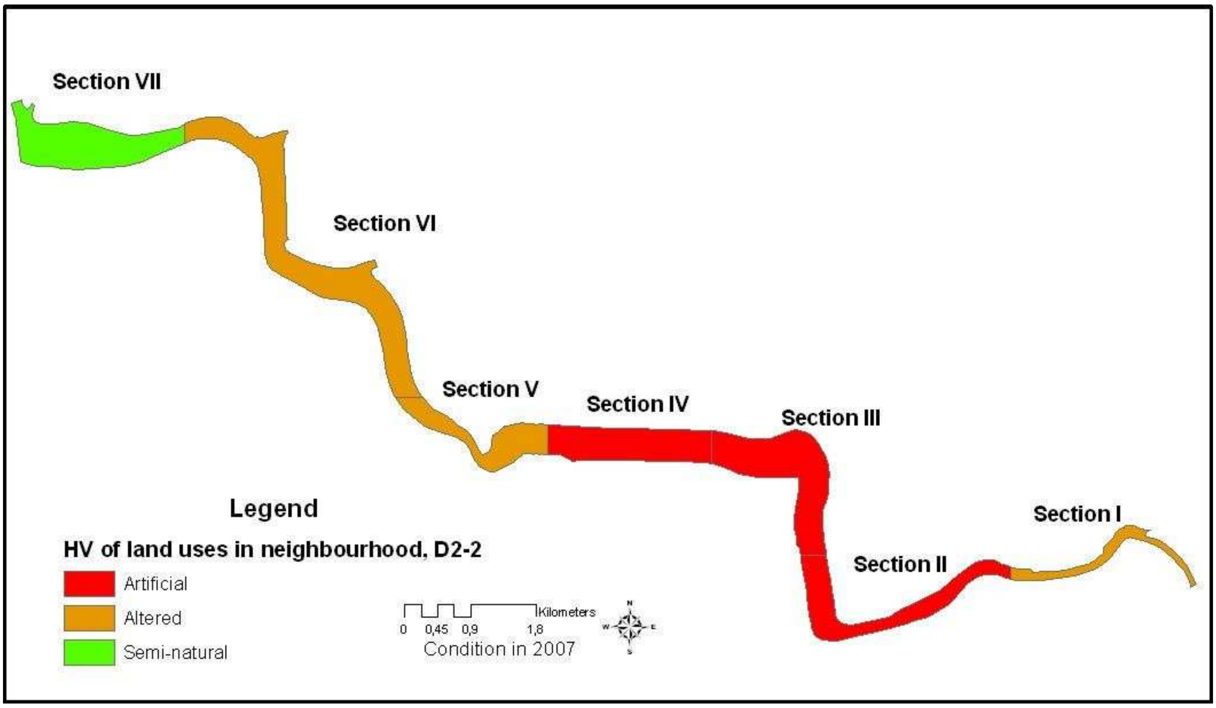


Figure 6.6: Scales of value for Land use in the neighbourhoods in the lower Keelung River

C. Stability of River Bank (Indicator Code: D2-3)

This indicator represents the condition of riverbanks under regular impacts (e.g. human activities) which also showed if the habitats would change after heavy spot disturbances (e.g. flooding). Basically, the soil types in downstream Keelung River are yellow soil (Section I, II, and III), incipient yellow soil (Section II, III, V, and VI), red soil (Section VI), and alluvial soil (Section III, VI, and VII)[3]. The evaluation was formed with the results of field work, which are concluded in Table 6.8 and illustrated in Figure 6.7.

Table 6.8: Scales of values for stability of river banks in the lower Keelung River

	Situation	Degree	Scales of value
Section I	There are revetments on the watersides; the vegetation covers are also rich and stable to protect the riverbanks.	Moderately disturbed	2
Section II	Even though there are revetments on the most section of watersides, there are many exploited roots of plans on the riverbanks. The vegetation covers are often destroyed by floods caused from typhoons. However, Chengmei Bridge nearby has richer vegetation cover and stable riverbanks than the other parts in this section.	Heavily disturbed	1

[3] According to the latest studies, the new types of soil taxonomy include: Histosols, Spodosols, Andisols, Oxisols, Vertisoils, Aridisols, Ultisols, Mollisols, Alfisols, Inceptisols, and Entisols. To contrast with these four types, which can be sorted as: Incipient yellow soils (Inceptisols, Alfisols, Ultisols), Yellow soils (Inceptisols, Ultisols), Red soils (Alfisols, Ultisols, Oxisols), Alluvial soils (Entisols, Inceptisols, Alfisols). (Source: available from: http://www.ac.ntu.edu.tw/soilsc/soilsc/taiwan.htm)

Table 6.8: Continuance

	Situation	Degree	Scales of value
Section III	Similar like Section II, some areas of riverbanks are destroyed for building infrastructure.	Heavily disturbed	1
Section IV	Similar like Section II, and even has more exploited roots of plans in this section, which is worse at the right side.	Heavily disturbed	1
Section V	Similar to Section II and Section III. It is especially worse under the Zhongshan Bridge.	Heavily disturbed	1
Section VI	The stability of riverbanks is different in the north section and south section, which can be divided from the influx of Shuangxi. The north part has rich vegetation cover and relative stable riverbanks; but there are Bailin Riverside Parks at the both side in the south section, where has more exploited roots of plants.	Moderately disturbed	2
Section VII	At the right side is Guandu Wetland, Mangrove covers most part of areas. It protects the riverbanks from impact of flood and erosion. The main land use at the left side was chiefly farmlands, even it has been redesigned into recreative area; there is no obvious soil erosion on both sides of Keelung River.	Lightly disturbed	3

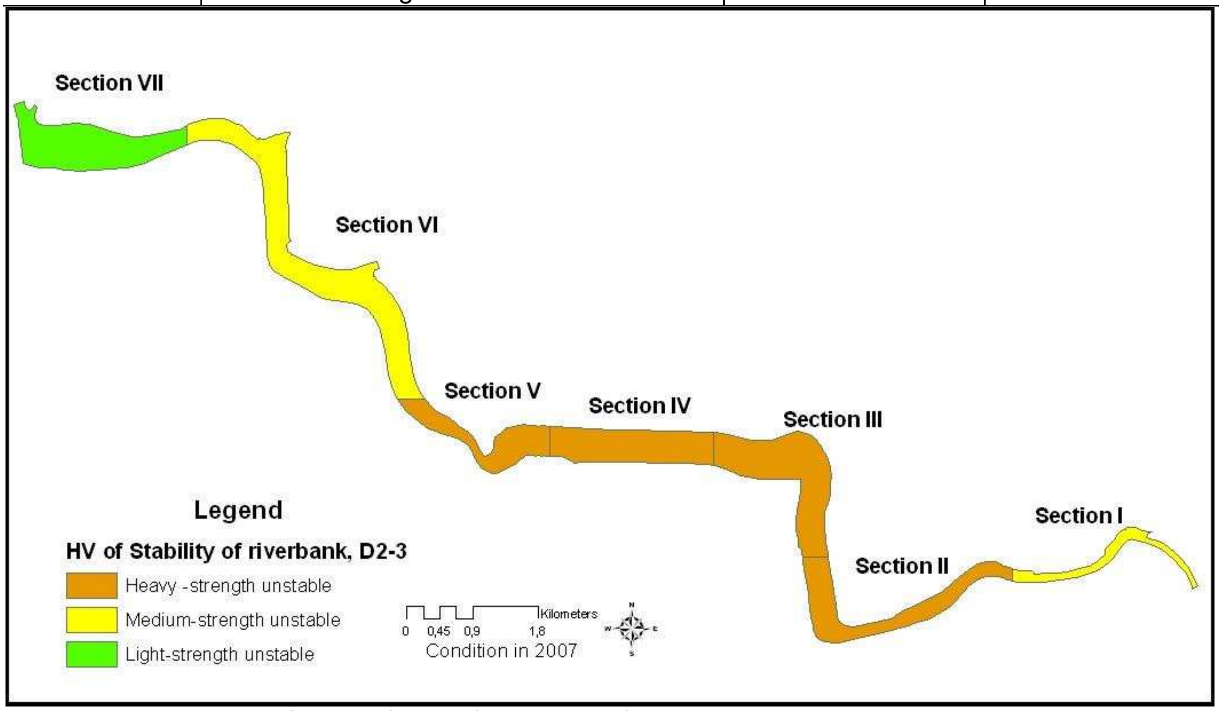


Figure 6.7: Scales of value for stability of river bank in the lower Keelung River

6.1.3 Biotope Quality in the Lower Keelung River

Many sections of the lower Keelung River have been straightened; the incision caused by the straightening work has declined in the diversity of habitats both in river bed and on riverbanks. Such redesigned works removed the habitats of instream and riverine areas; and sediment deposition smothered the river bed. It expresses the biotope condition and then presents the habitat qualities in the test sections with combined values of the other evaluation criteria. The indicators include six parts: “naturalness of vegetation covers”, “patch size”, “plant composition”, “habitat variety”, “fragmentation and connection” and “protected status”.

A. Naturalness of Vegetation Covers (Indicator Code: B-1)

This criterion represents whether the biotopes offer the basic habitat functions for wildlife with the naturalness of vegetation cover. The degree of naturalness provides fundamental information to denote the habitat quality. The naturalness of biotopes was measured according to the weight of vegetation covers (Table 6.9) and illustrated the condition of naturalness of each biotope types in Figure 6.8. The weight of naturalness was multiplied respectively with the areas of biotopes to demonstrate the naturalness of biotope type in the seven test sections. Generally speaking, the entire lower Keelung River has been altered from a heterogeneous, meandering river into a homogeneous, straight channel with uniform flow condition and lower habitat diversity. Most areas on the riverbanks are covered with the artificial except partial Section VI and Section VII. The comprehensive results in the seven test sections show in Table 6.10 and Figure 6.9.

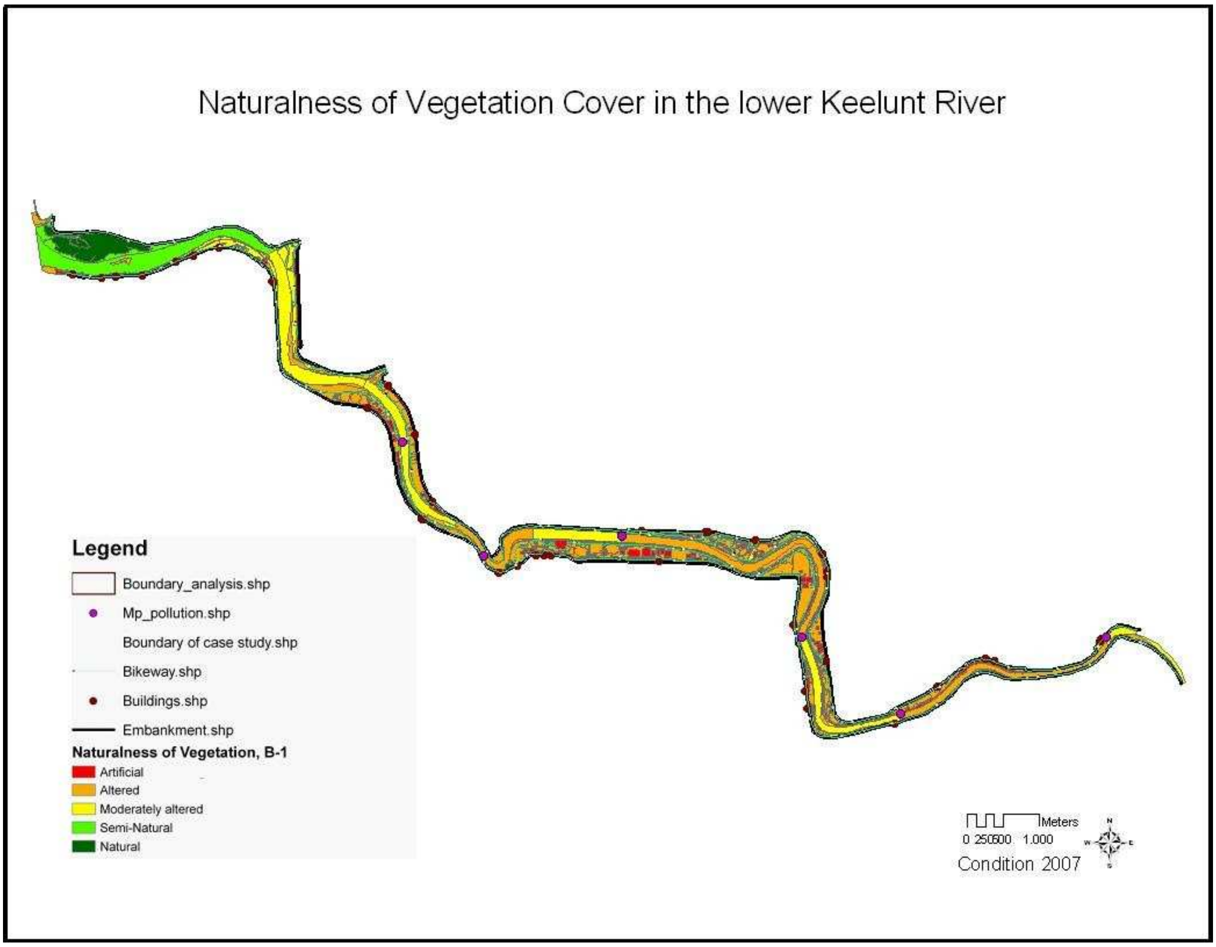


Figure 6.8: Illustrations of naturalness of vegetation covers in the lower Keelung River

Table 6.9: Weight of naturalness of each biotope types in the lower Keelung River

Code*	Biotope	Naturalness
F000	Forest	
F100	....Subtropical broad-leaved forest	3
S000	Shrub woodland	
S100	....Broad-leaved shrub woodland	2 (3)
W000	Inland water bodies	
	--Flowing Waters	
W100		
W110	……..Moderately altered stream	2
W120	……..Channelized stream	1
W200	….River	
W210	……..Moderately altered river	2
W220	……..Channelized river with dredging	1
W230	……..Channelized and straightened river	1
W300	….Side channel	1 (3)
W400	….Canal	1
	--Standing Waters	
W500	….Pond	
W510	……..Moderately altered pond	2
W520	……..Artificial pond	1
W600	….Backwater	2
We000	Wetland	
We100	….Estuarine wetland	
We110	……..Estuarine wetland with natural flooding regime	4
We120	……..Estuarine wetland with artificial flooding regime	3
We200	....Riparian wetland	
We210	……..Riparian marshland	3
We220	……..Riparian reed land	3
U000	Unvegetated habitat	
U100	....Stones	0
U200	....Gravel bar	0
U300	....Sand bar	1
U400	....Soil	1
G000	Green land / gardening	
G100	....Tall forb grassland	2
G200	....Artificial greensward / turf	1
G300	....Garden	2
A000	Buildings, Transportation and Industrial areas	
A100	....Fixed surface	
A110	……..Water-bound surface	0 (1)
A120	……..Pavement	0
A130	……..Concrete / asphalt	0
A200	….Embankment	
A210	……..Dike	0
A220	……..Wall	0
A230	……..Claybank	0 (1)
A240	……..Dam	0
A250	……..Revetment	0
A300	....Bikeway	
A310	……..Terrazzo bikeway	0
A320	……..Paved bikeway	0
A330	……..Asphalt bikeway	0
A340	……..Timbered bikeway	0
A400	....Sport- / play- / recovery area	
A410	……..Sport area	0 (1)
A420	……..Playground	0
A500	….Buildings	
A510	……..Agricultural building	0
A520	……..Temple	0

Table 6.9: Continuance

Code*	Biotope	Naturalness
A530	……..Other buildings	0
A600	....Transportation area	
A610	……..Parking area	0
A620	……..Square	0
A630	……..Riverine dock / port	0
A640	……..Evacuation gate	0
A650	……..Bridge	0
A700	....Supply and waste management (discharge)	
A710	……..Pumping station	0
A720	……..Other technical building	0
X000	....Others	
X100	……..Discard dirt	0

* The code of biotope types is assigned by the **ordinal** of biotope types. The letters of alphabet are the abbreviation of each main group of biotope types. The first number shows the ordinal sub-groups, the last two numbers denote the serial numbers of biotope types with functions or characteristics.
*Value: The column value means the values of naturalness index to various land use/biotopes, which is one of the criteria of evaluation.

Table 6.10: Scales of value for naturalness in the lower Keelung River

	SVS_{B1}*	Degree	Scales of value
Section I	0.92	Altered	1
Section II	0.89	Altered	1
Section III	0.87	Altered	1
Section IV	0.79	Altered	1
Section V	0.99	Altered	1
Section VI	1.09	Altered	1
Section VII	2.59	Semi-natural	3

* detail in Annex F

To describe the condition of naturalness in more detail, the main covers of biotope in Section I and Section II are man-made infrastructure, such as bikeways, playgrounds, embankments and other infrastructure. The riverbanks in these two sections are narrower than which in the other areas. Therefore, the Scales of values in these two sections are also shown by “altered”. Section III and Section IV are broadly covered with man-made constructions (e.g. squares, parking areas, sport areas, etc.) on riparian parks (55.04% in Section III and 60.70% in Section IV), hence they display the worst naturalness in these seven sections. In the case of Section V and Section VI, it showed that these two sections are valued as altered to semi-altered overall. The man-made constructions of riparian parks decrease the naturalness in these two sections (27.21% in Section V, and 37.09%in Section VI). The best condition of naturalness showed in Section VII, which is included the main biotopes of inland-water and wetland (Guandu wetland), the heterotrophic multi-environment provides more natural habitats for resting, breeding, and foraging. It covers approximately 86% of natural or semi-natural habitats in Section VII.

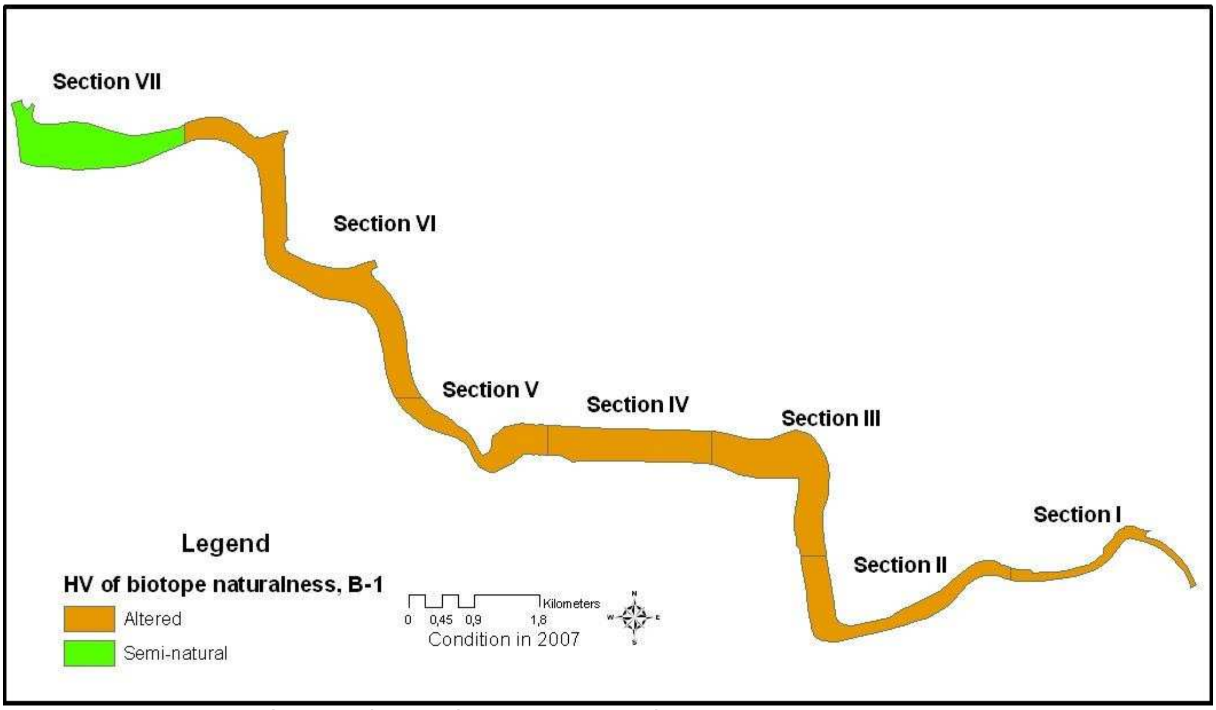


Figure 6.9: Scales of value for naturalness of biotopes in the lower Keelung River

B. Patch Size (Indicator Code: B-2)

Patch size affects the cluster structure of organism. The bigger biotopes are generally suited to play the functions of refuge, resting, breeding and foraging for wildlife. These criteria was measured with the size of main habitats of bird species (fresh water, green lands, shrubs, etc.) and displayed in five scales (from complete to little at 4-0, see Table 4.18 and Figure 6.10). The entire performance was calculated in the seven test sections in Table 6.11 and Figure 6.11.

Table 6.11: Scales of value for patch size in the lower Keelung River

	SVS_{B2}*	Degree	Scales of value
Section I	2.27	Medium	2
Section II	1.76	Medium	2
Section III	1.86	Medium	2
Section IV	1.48	Small	1
Section V	1.90	Medium	2
Section VI	2.06	Medium	2
Section VII	3.09	Big	3

* detail in Annex G

To survey the patch sizes in more details, the bikeways and passages apparently cut off the connection of habitats in the seven test areas, the patch sizes of biotopes are consequently decreasing. The “area effects” show on the diminishingly biodiversity of wildlife. However, some small habitats still act as stepping stones for wildlife and offset the risk of fragment. For instance, Section VII is mainly covered with *Kandelia candel(L.)Druce* , which serves as habitats for many water fowl. The sizes of fresh water, rich wet grasslands are also bigger than those in the other sections. Being contrary to Section VII, the habitats in Section IV are disconnected due to the man-made constructions on the riparian parks. The quality of biotopes in

Section IV is not good enough to act as normal habitats. The patch size was assessed by medium in the other sections of the lower Keelung River that the most biotopes cover at least areas for the role as habitats.

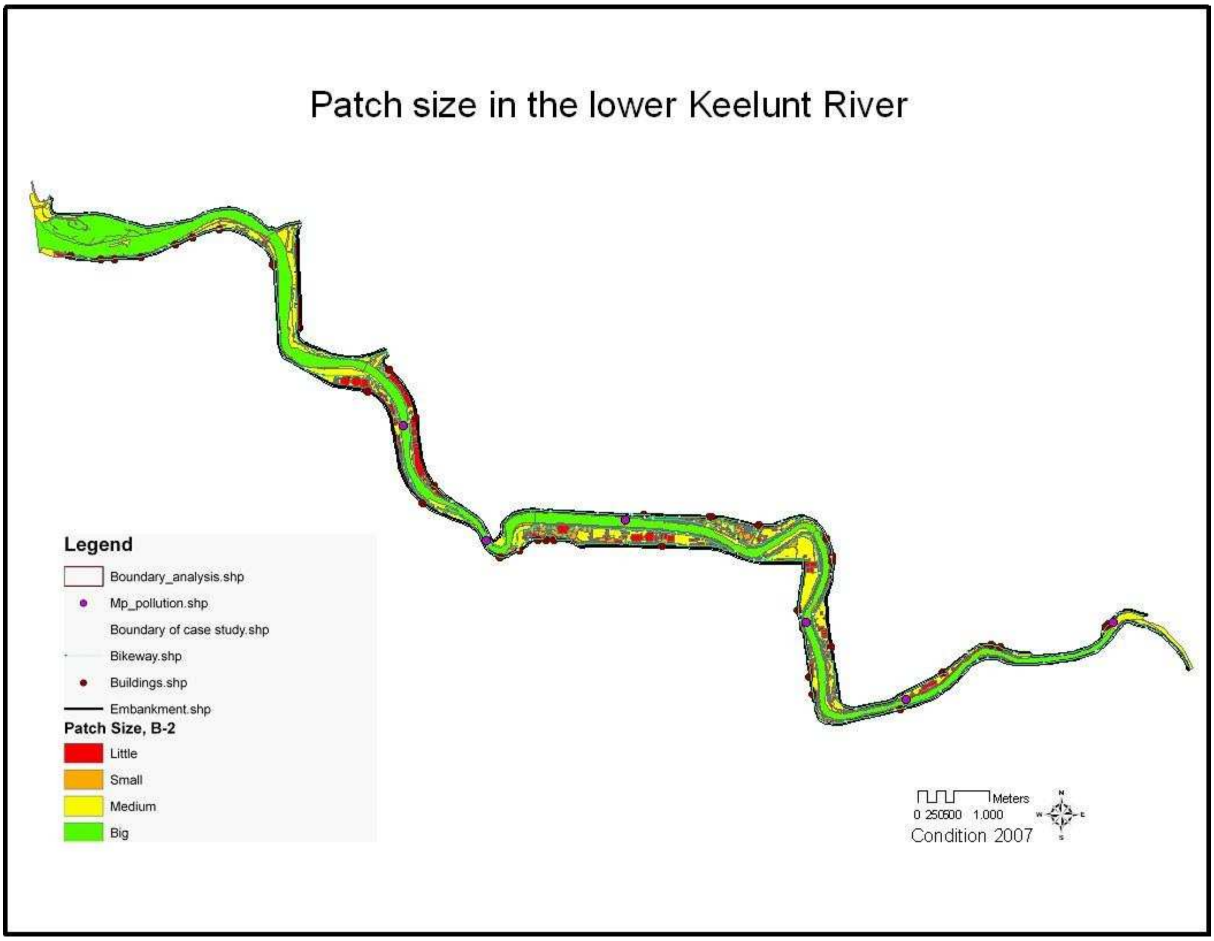


Figure 6.10: Illustrations of patch size in the lower Keelung River

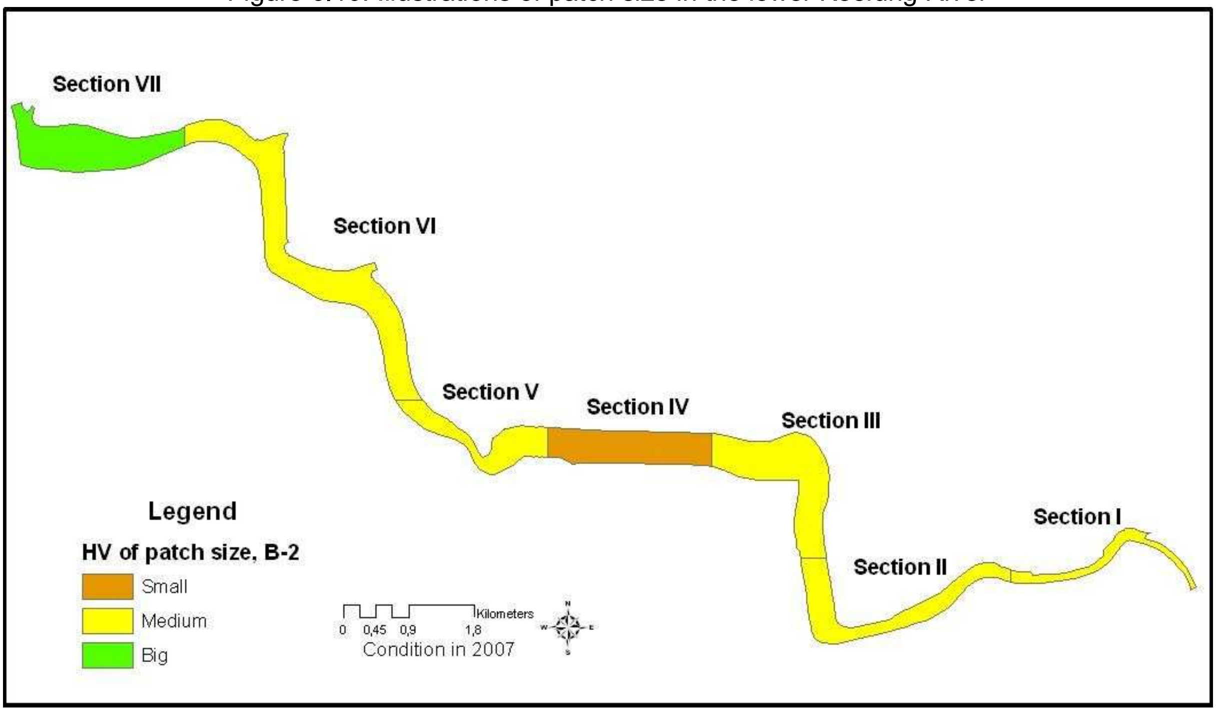


Figure 6.11: Scales of value for patch size in the lower Keelung River

C. Plant Composition (Indicator Code: B-3)

Plant composition is one criterion of habitat diversity to estimate the vertical structure of habitats. The multi-structure of vegetation provides better habitat quality for wildlife. In this perspective, this indicator denotes firstly the plant composition on each biotope type (scales as in Table 4.19). As shown in Figure 6.12, the plant composition is mainly at medium scale (Predominantly native herbaceous plants; ca. 47% of total areas) in the entire lower Keelung River. Then, to multiply the habitat value of each biotope types by their areas, the condition of the test sections showed in Table 6.11 and Figure 6.12. The poorest conditions appear in Section III and Section IV which are mostly covered with introduced plants or not vegetated ground. The best section with medium plant composition displays in Section VII.

Table 6.12: Scales of value for plant composition in the lower Keelung River

	SVS_{B3}*	Degree	Scales of value
Section I	1.45	Low various	1
Section II	1.22	Low various	1
Section III	1.05	Low various	1
Section IV	1.04	Low various	1
Section V	1.36	Low various	1
Section VI	1.30	Low various	1
Section VII	2.42	Medium	2

* detail in Annex H

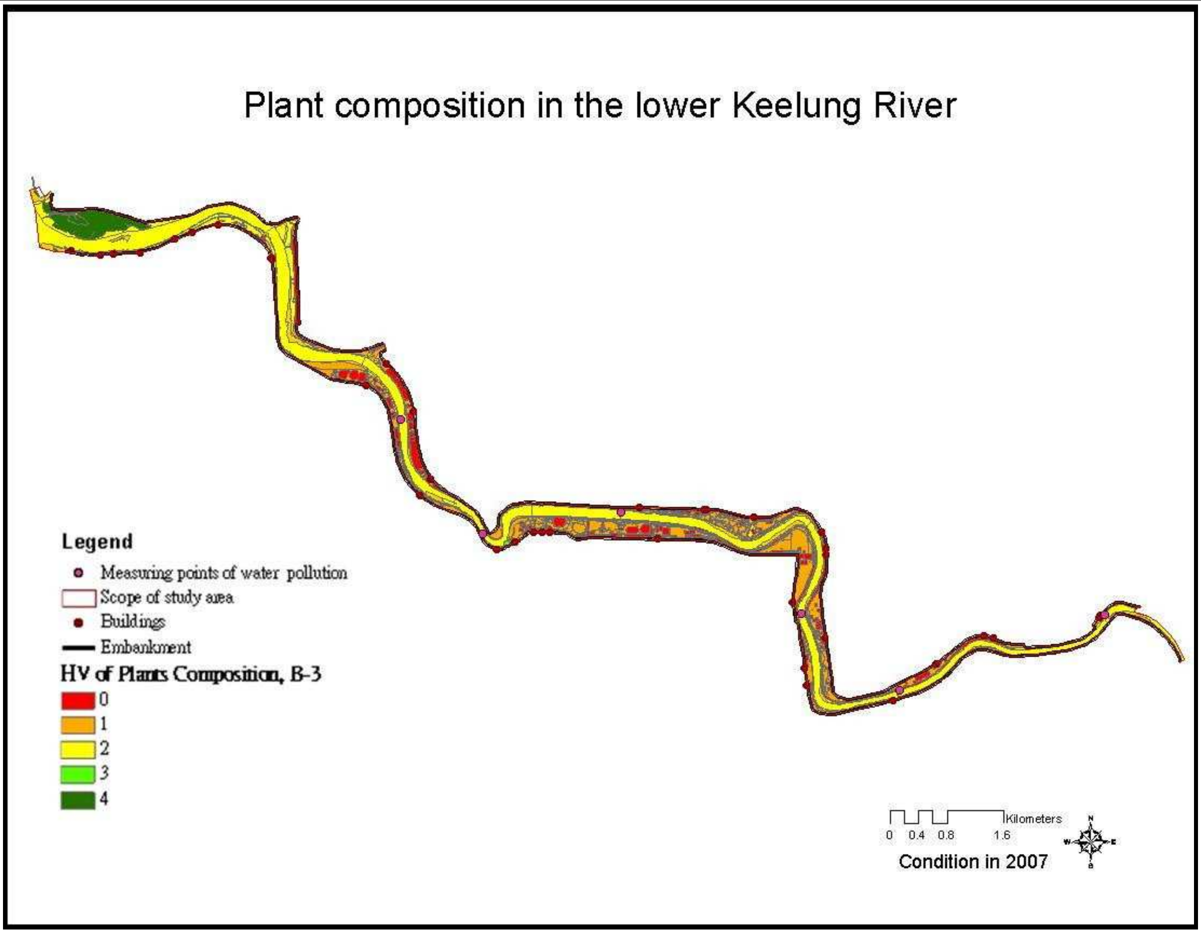


Figure 6.12: Illustrations of plant composition in the lower Keelung River

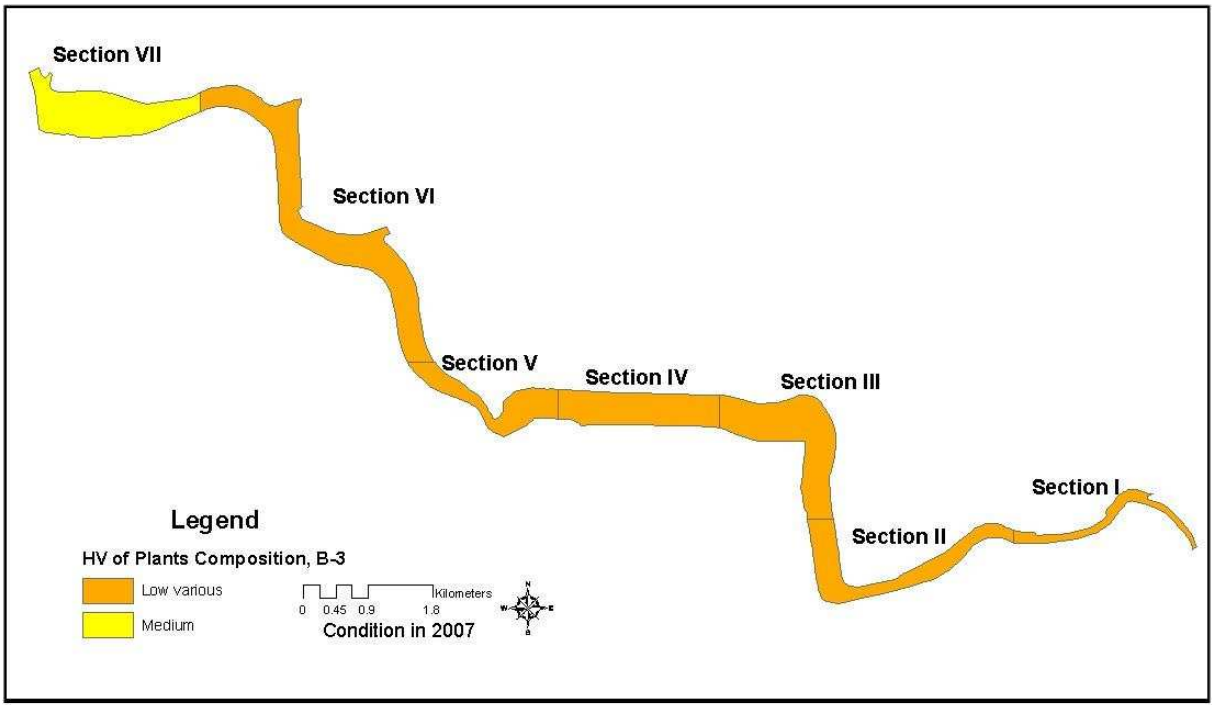


Figure 6.13: Scales of value for plant composition in the lower Keelung River

D. Habitat Variety (Indicator Code: B-4)

The reduction of biotope types may affect the relationship between the habitat components and narrow the biodiversity. This indicator measures the habitat composition in the study areas to estimate horizontal habitat diversity. In other words, the relationship between vegetation structure and wildlife habitat (i.e. geodiversity and biodiversity) may reflect the species richness. The number of biotope types is then counted and grouped in the study sections. There are totally 47 biotope types in the lower Keelung River as shown in Table 5.1, which can be further divided into "semi-natural environment", "intermediate environment" and "anthropogenic environment" (Table 6.13). The distribution of biotope types in test sections displays in Figure 6.14. Only the semi-nature environment (e.g. freshwater, grasslands, wetland, and shrubs, etc.) and intermediate environment were taken to estimate the habitat variety in this study that 22 biotope types are counted as habitats in this indicator. Accordingly, the scales of values are grouped as: "highly various" with more than 19 biotope types, "various" with 17-19 biotope types, "medium" with 11-16 biotope types, "low various" with 6-10 biotope types and "monotonous" with less than 10 biotope types.

Table 6.13: biotope types in the lower Keelung River redefined by habitat condition with the number of biotopes and areas (ha)

Semi-natural environment			Intermediate environment			Anthropogenic environment		
Biotope	No	Area (ha)	Biotope	No	Area (ha)	Biotope	No	Area (ha)
Subtropical broad-leaved forest	1	10	Channelized stream	2	2.38	Water-bound surface	11	8.06
Broad-leaved shrub woodland	42+	7.86	Channelized river with dredging	5	133.41	Pavement	6	2.01
Moderately altered stream	2	1.48	Channelized and straightened river	4	94.02	Concrete / asphalt	8	7.61
Moderately altered river	1	65.59	Canal	40	4.11	Dike	4	14.12
Side channel	3	1.7	Artificial pond	2	0.97	Wall	4	3.07
Moderately altered pond	14	1.06	Stones	37	7.7	Claybank	1	0.05
Estuarine wetland with natural flooding regime	6	37.51	Gravel bar	48	36.94	Dam	1	-
Estuarine wetland with artificial flooding regime	1	57	Sand bar	2	0.13	Revetment	11	2.37
Riparian marshland	3	14	Soil	33	6.72	Terrazzo bikeway	33	8.34
Riparian reed land	1	0.57	Artificial greensward / turf	286	164.3	Paved bikeway	3	3.22
Tall forb grassland	70	58.49	Garden	23	2.72	Asphalt bikeway	25	22.05
						Timbered bikeway	1	1.58
						Sport area	74	30
						Playground	7	0.13
						Agricultural building	2	0.01
						Temple	3	0.04
						Other buildings	9	0.14
						Parking area	66	17.85
						Square	83	8.84
						Riverine dock / port	5	1.13
						Evacuation gate		dot
						Bridge	13	0.24
						Pumping station	7	0.23
						Other technical building		dot
						Discard dirt	3	0.41

Figure 6.14: Proportion of main group of biotope types in the lower Keelung River

Table 6.14 shows the number of habitat types represented in the seven sections and sums up the areas (ha). Generally speaking, the lower Keelung River has low various habitats. The better cases only showed at medium in Section VI and Section VII (Figure 6.15).

Table 6.14: Analysis of habitat variety—main habitats for wildlife

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
No	5	7	8	8	9	12	10
ha	27.63	71.17	99.71	71.67	56.88	154.73	108.43
SVS_{B4}	0	1	1	1	1	2	2
Degree	Monotonous	Low various	Low various	Low various	Low various	Medium	Medium

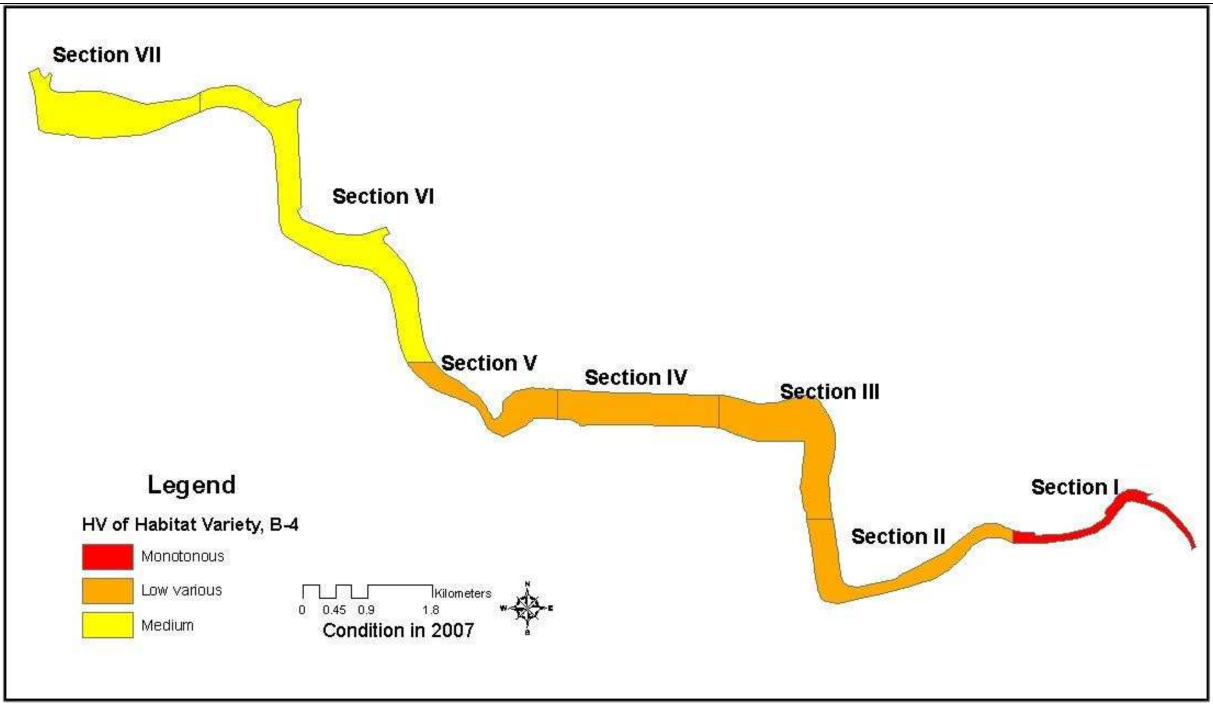


Figure 6.15: Scales of value for habitat variety in the lower Keelung

E. Fragmentation and Connection (Indicator Code: B-5)

Habitat fragmentation is a serious and important issue in the urban environment. The connection and distance of habitats are usually discussed with this issue. Better connection of habitats could improve the defect of small patches, play as stepping stones to link to other habitats, which has function as corridors. Some cluster stepping stones work as strategic linkages of entire system. However, small biotopes are unable to be habitats for wildlife in big quantity. This indicator only measures the certain habitats for wildlife with an area larger than 0.5 hectares (e.g. grasslands, shrubbery and freshwater) to estimate the isolation/connection of habitats according to the formulas in Table 4.21. Then it displays the results of calculation in Table 6.15.

The γ index and α index are used to measure the linkage of the same kind of habitats. The Mean Dij, and proximity index (Px) present the distances to the nearest same type of habitats.

Table 6.15: Calculation of connection/isolation along the lower Keelung River

	Linkage				Distance			
	γ index		α index		Mean Dij		Px	
	index	point	index	point	index	point	index	point
Section I	22%	7	0	10	0.650	3	48.30	3
Section II	19%	7	0	10	0.722	3	27872.24	10
Section III	30%	3	2%	10	0.670	3	113984.60	10
Section IV	16%	3	0	5	0.732	3	76761.25	10
Section V	49%	3	39%	5	0.619	3	14372.20	10
Section VI	19%	5	0	10	0.690	3	89244.59	10
Section VII	39%	3	28%	5	0.528	3	25489.68	10

The evaluation results in Table 6.16 represent that the state of linkage in study areas could be divided in two groups: bad connection and isolation. Section IV, Section V and section VI showed better connection among the main habitats for wildlife and the results of the other four sections indicate from bad connection to isolation. However, the evaluation of distances shows different results, all test spots except section I presented bad proximity of habitats. The main reason being occurred the difference between linkage and distance might be the interruption of man-made infrastructure, such as bikeways and riparian parks. Besides, the connections of the flood plains on both sides of the Keelung River are also bad, which result in that the measure of linkage shows less connection in general (se Table 6.16 and Figure 6.16).

Table 6.16: Evaluation of fragmentation and connection of habitats in the lower Keelung River

	Ave. of Points	Degree	Scales of value
Section I	5.75	Bad connection	1
Section II	7.5	Isolation	0
Section III	6.5	Bad connection	1
Section IV	5.25	Bad connection	1
Section V	5.25	Bad connection	1
Section VI	7	Isolation	0
Section VII	5.25	Bad connection	1

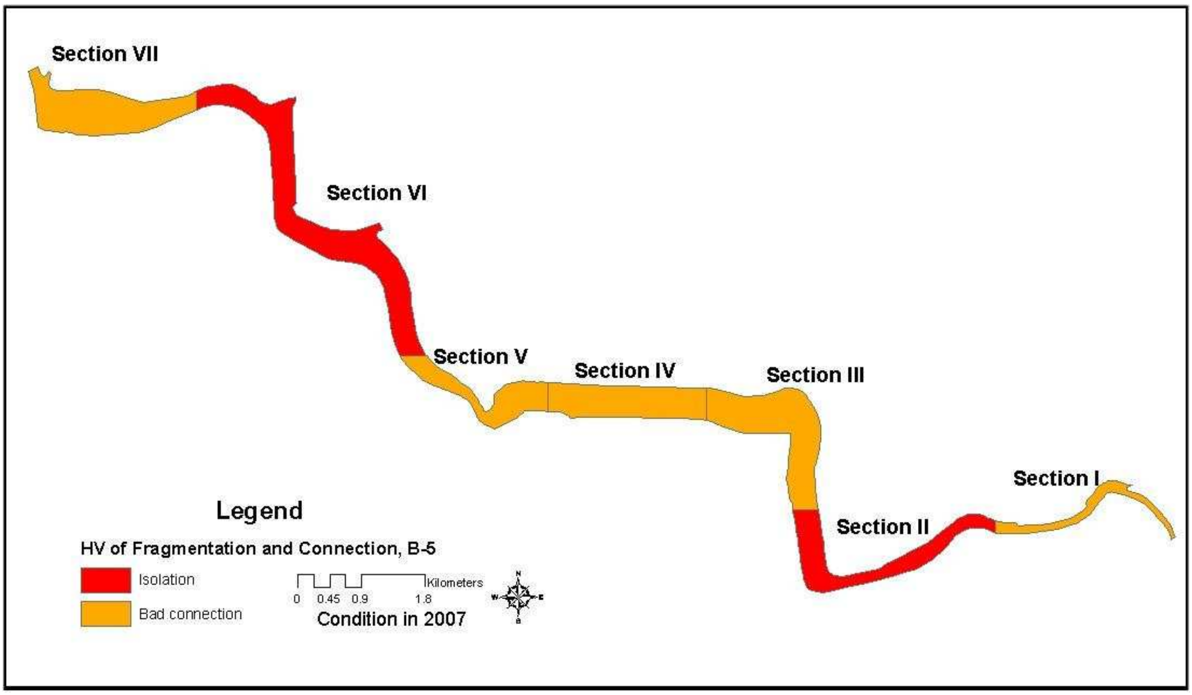


Figure 6.16: Scales of value for habitat fragmentation and connection in the lower Keelung River

F. Protected Status (Indicator Code: B-6)

Protected status is taken to review the present planning context. It reflects vulnerability of habitats and a possible intensity of development in study areas. As introduced in Chapter 4.3.3.3, areas of “ecological conservation areas”, “national wildlife reserve”, “important habitats” and “coastal conservation areas” should be considered in this criterion. Figure 6.17 illustrates the overview of protected status in the lower Keelung River (Illustration as in Table 6.17). It shoots an image that habitats are mainly protected for nature conservation, coastal protection and wildlife preserves in Section VII, this protected area even expended to part of Section VI. Besides, there were still some small areas being taken as ecological sensitive areas in Section I, Section II and Section III. Figure 6.18 further illustrates the results of protected status in the seven test sections of the lower Keelung River.

Table 6.17: Protected status in the lower Keelung River with areas (ha) and proportion

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
Protected area (ha)	12.92	5.54	7.09	0	0	29.47	113.09
%	36.28	5.93	5.1	0	0	13.78	93.73
SVS_{B6}	3	1	1	0	0	2	4
Degree	Protected	Low protected	Low protected	Not protected	Not protected	Medium	Highly protected

Source: Environnemental Protection Administration (EPA), Taiwan, avalable from: http://edb.epa.gov.tw/localenvdb/index.asp

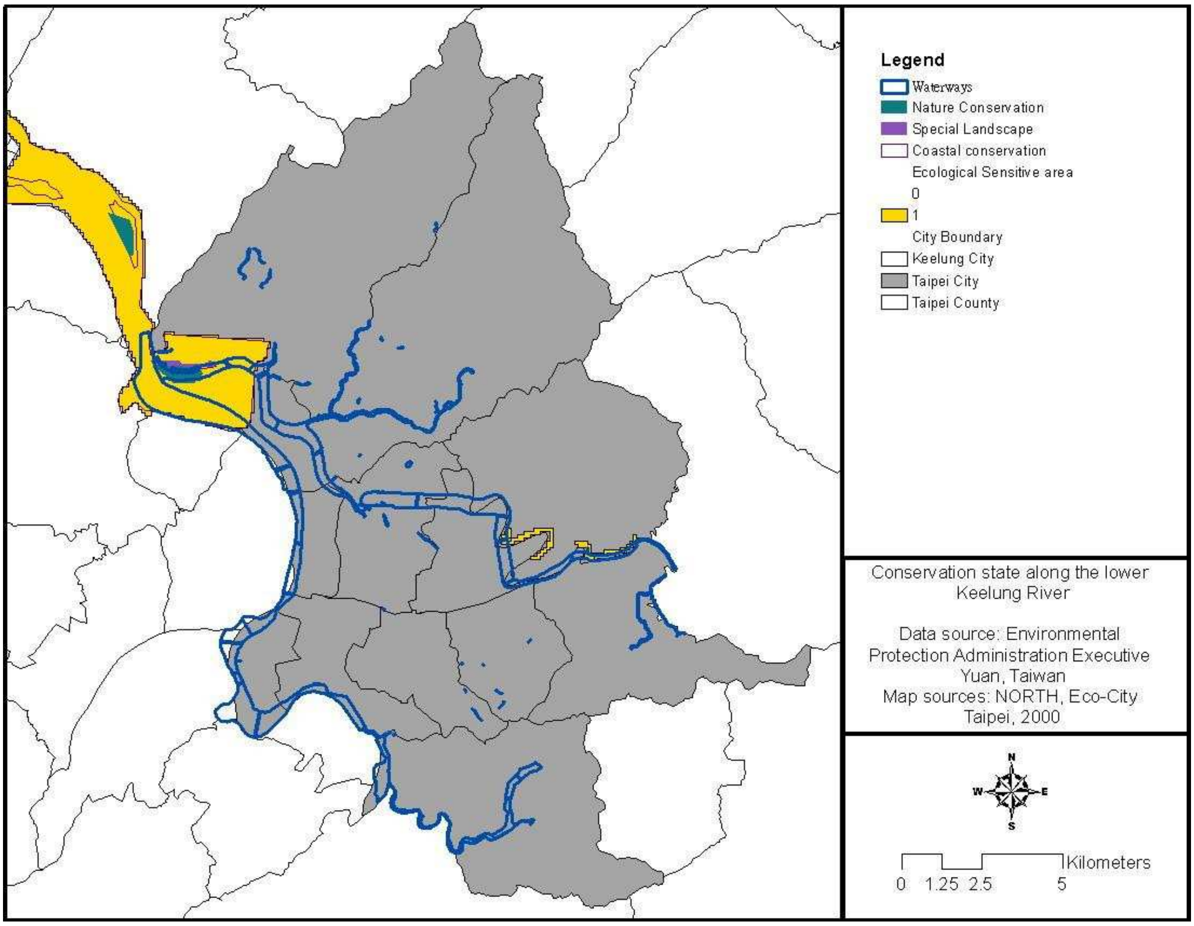


Figure 6.17: Protected status of habitats in the lower Keelung River

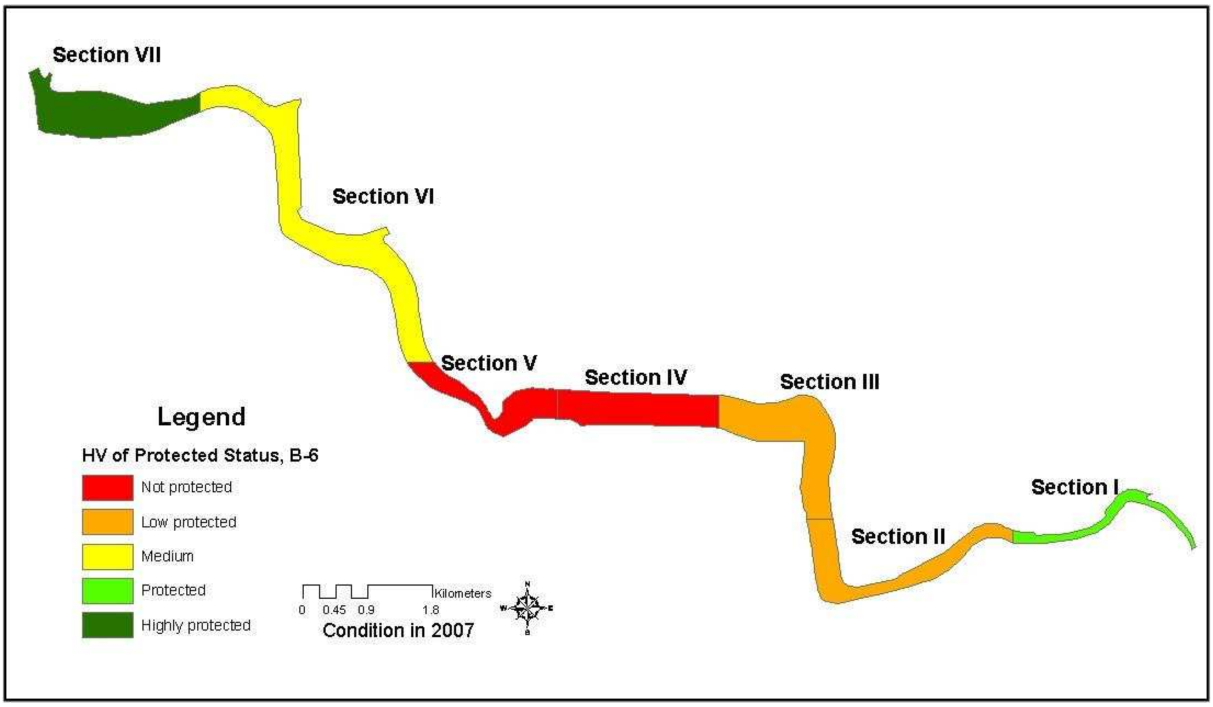


Figure 6.18: Scales of value for protected status of habitats in the lower Keelung River

6.1.4 Overview of Evaluation on Habitat Quality in the Lower Keelung River

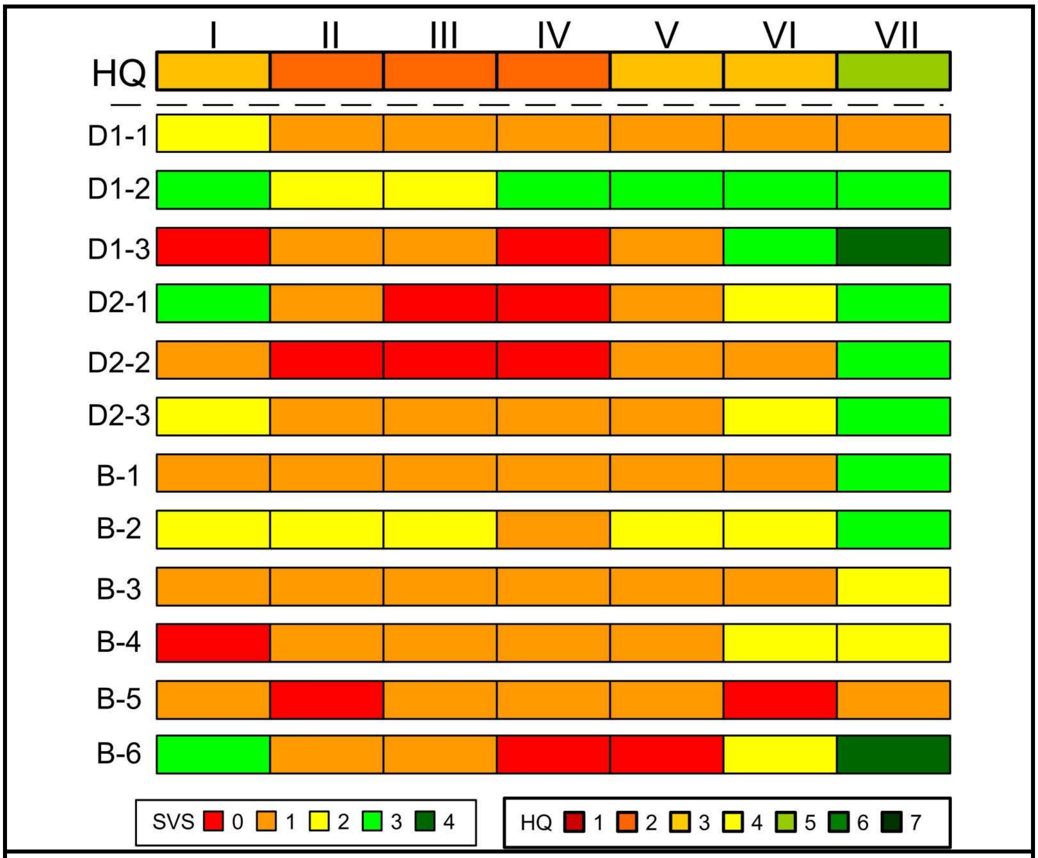
Most large areas of flood plains in the lower Keelung River have been altered by urban development. Since the removal of natural vegetation covers may simplify the landscape structure and reduce geodiversity, which tends to increase surface-water flow and sedimentation of watercourses, as well as decrease in biodiversity. The scales of values in sections (SVS) of all criteria were summed up in Table 6.18. Section VII had 32 points (good-moderate) in total which was the best condition in the whole study areas. The other sections fell into two different groups by moderate-poor or poor. The sections with moderate-poor condition had habitat quality at 3 of 9 scales (HQ=3), which summed up the scales of value between 14 and 20 points. Section IV showed the worst ranking in the seven test sections, which had poor habitat quality (HQ at 2) and summed up the scales of value of 10 points. Figure 6.19 gives an overview of the habitat quality in the lower Keelung River with all evaluation criteria.

In brief, the entire analysis of habitat quality in the lower Keelung River was generally at a fair state, such an outcome meant that the lower Keelung River might not serve better ecological functions with extensive development of remediation. Figure 6.20 further shows the habitat quality with some key points in each in test section. The evaluation results show the problems as many urban rivers that the characteristics of riverine and habitats on flood plains were mainly destroyed or fragmented due to river regulations and the utilisation of flood plains for recreation and urbanisation in the past decades. The quality and functions of remaining habitats have been deteriorated. The further evaluation of each study area with bird species will be listed in the next paragraphs to specify some problems and current condition as references for rehabilitation of the river ecosystems and restoring the ecological values.

Table 6.18: Entire Scales of values in the lower Keelung River

Code*	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
D1-1	2	1	1	1	1	1	1
D1-2	3	2	2	3	3	3	3
D1-3	0	1	1	0	1	3	4
SVS_{D1sum}	**5**	**4**	**4**	**4**	**5**	**7**	**8**
D2-1	3	1	0	0	1	2	3
D2-2	1	0	0	0	1	1	3
D2-3	2	1	1	1	1	2	3
SVS_{D2sum}	**6**	**2**	**1**	**1**	**3**	**5**	**9**
B-1	1	1	1	1	1	1	3
B-2	2	2	2	1	2	2	3
B-3	1	1	1	1	1	1	2
B-4	0	1	1	1	1	2	2
B-5	1	0	1	1	1	0	1
B-6	3	1	1	0	0	2	4
SVS_{Bsum}	**8**	**6**	**7**	**5**	**6**	**8**	**15**
SVS_{sum}	**19**	**12**	**12**	**10**	**14**	**20**	**32**
HQ*	**3**	**2**	**2**	**2**	**3**	**3**	**5**

*SVS_{sum} represents the sum of the points of habitat quality with impact factors and biotope condition. HQ means the scale of entire evaluation of habitat quality. HQ 2= Poor habitat quality, HQ 3= Moderate-poor habitat quality, HQ 5= Good-moderate habitat quality.



* Explanation: SVS means the scales of value in test sections. HQ denotes the habitat quality.

Figure 6.19: Overview of Habitat Quality in the lower Keelung River

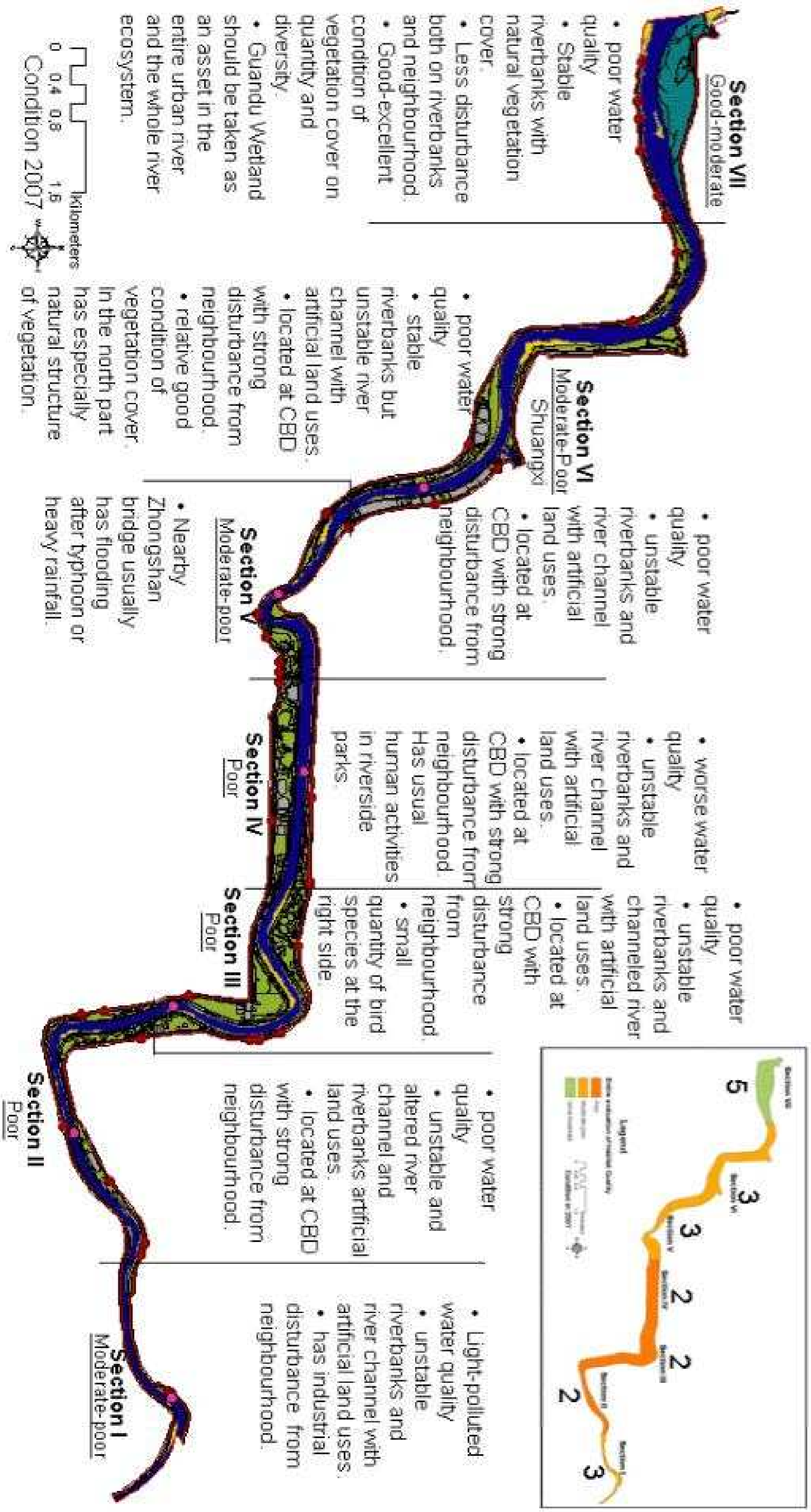


Figure 6.20: Results of evaluation on habitat quality in the lower Keelung River

6.2 Condition and Evaluation on Bird Species in the Lower Keelung River

In order to verify and improve the habitat functions, bird species were taken as the study objects in this study. The analysis of bird species in the lower Keelung River was carried out according to the exploration and databank of Digital Museum of Zoology by National Taiwan University (NTU) [4]. This databank displays the information about bird species with characteristics, movement, main habitats, special properties and their distribution on grid maps. A list of bird species in the study areas was carried out based on the information in this databank. About 293 bird species in the lower Keelung River (grouped into 17 different orders and 52 families) have been recorded (Annex B). Among these bird species, waterfowl possess about 60% of the total bird species, which are mainly migrant birds (ca. 70%). The behavior of movement could be grouped into three groups: migrant (36.86%), transit or vagrant (32.08%), and resident (27.3%). There are also 3.75% of introduce species, some exotic birds, gradually endanger the native species. Most of bird species were particularly observed at Guandu Wetland, Shezi, Linung, Meiti Riverside Park, Guanshan Riverside Park and Rainbow Riverside Park (points in Figure 6.21).

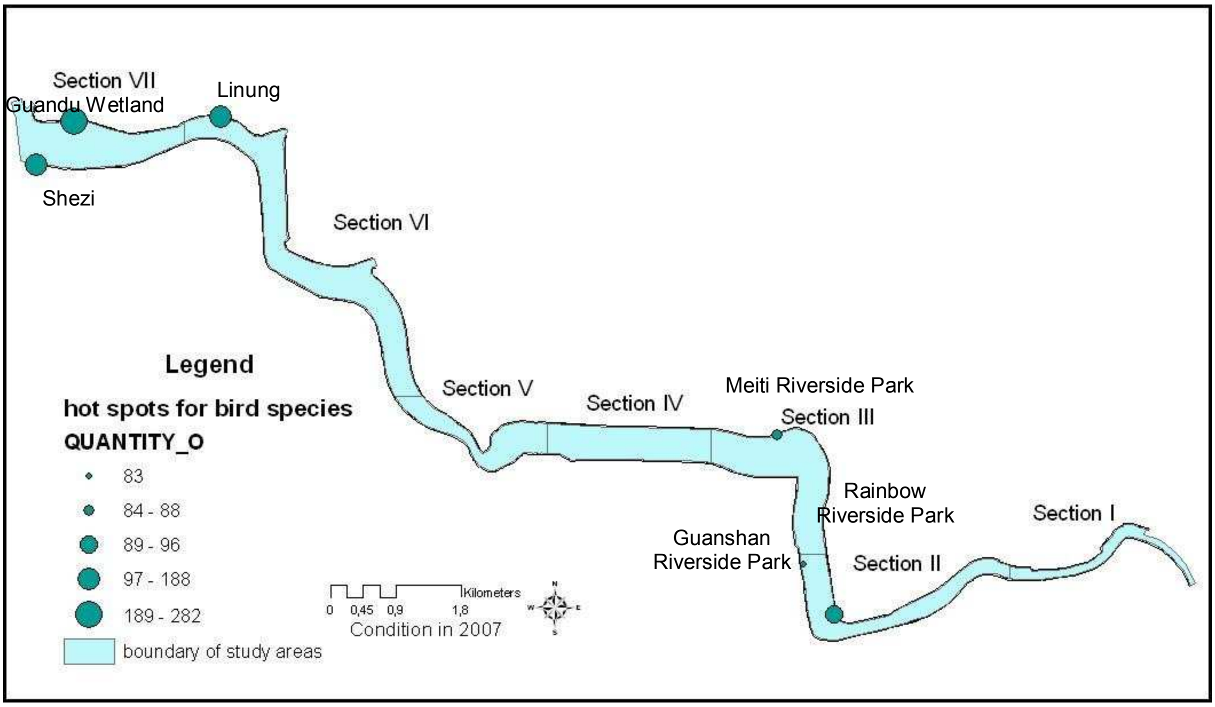


Figure 6.21: Main areas of habitats for bird species in the lower Keelung River

Moreover, the original designed analysis of this study should be taken to show the species condition with the population of individual bird species by field survey and the data from “Wild Bird Society of Taipei (WBST)”. However, because of the limit of coworkers and research budget, there were only data of bird species in partial Section III, Section VI and Section VII. The entire analysis of species indicator is thus

[4] Digital museum of Zoology, National Taiwan University, available from: http://archive.zo.ntu.edu.tw/bird/r_bird_search.asp.

done according to the historical record plus further explanation of the situation in Section I and Section II with the investigative result during Dec. 2006 and Feb. 2007. The assessment of bird species is firstly shown by "species richness", "endangered species" and "endemic species" in the next paragraphs, the results of evaluation on bird species may contribute to show the environment-species-relationship with target species in Chapter 6.3.

A. Species Richness (Indicator Code: S-1)

Table 6.19 represents the richness of all bird species in the seven sections. All the families in record of the lower Keelung River also have ever been observed in Section VII which the species were listed about 96.25% of all. Section VI had ranking of species richness at the second place (64.42%) and showed much richer species than the other five sections. In Section II, Section III, and Section IV, there are about 90 bird species in about 32 different families that have been recorded, and most of them are winter migrant and transit making short break and clustering in small groups. There are also some resident species, such as Chinese Bulbul (*Pycnonotus sinensis*) and Cattle Egret (*Bubulcus ibis*), also often appear in these areas for short break and foraging. Up to now, either none or no big quantity of bird species have ever been found and recorded in Section I and Section V.

Table 6.19: Species richness in the lower Keelung River (Digital museum of Zoology, 2007)

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
Species	0	96	83	88	15	188	282
Family	0	35	32	32	11	39	52
Order	0	13	11	11	6	13	17

Moreover, to review the species richness with sedentary birds, the results are shown as in Table 6.20. Though Section VII and Section VI have the best condition of species richness with total species in the entire study areas, they do not present high species richness on sedentary birds (respective 26.6%). Reciprocally, Section V has few bird species but all of them are resident birds. The half proportion of bird species in Section II is residents. Section III and Section IV have around one-third sedentary birds of all.

Table 6.20: Species richness of sedentary birds in the lower Keelung River (Digital museum of Zoology, 2007)

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
Species	0	48	37	35	15	50	75
% of sum in section	-	50	44.58	39.77	100	26.6	26.6

To combine the species richness both with all species and sedentary birds, the states of bird richness in the lower Keelung River are presented in Table 6.21 and Figure 6.22.

Table 6.21: Scales of values for richness of bird species in the lower Keelung River

	State	Degree	Scales of value
Section I	Non species	Non-species	0
Section II	Fair richness of all bird species and bird species	fair	2
Section III	Fair species richness of all but are mostly not residents	poor	1
Section IV	Similar situation as in Section III	poor	1
Section V	Less bird species, but all of them are sedentary birds	poor	1
Section VI	Good richness of all bird species, but only one-third are sedentary birds	fair	2
Section VII	Excellent richness of all bird species, but only 26.6% are residents	good	3

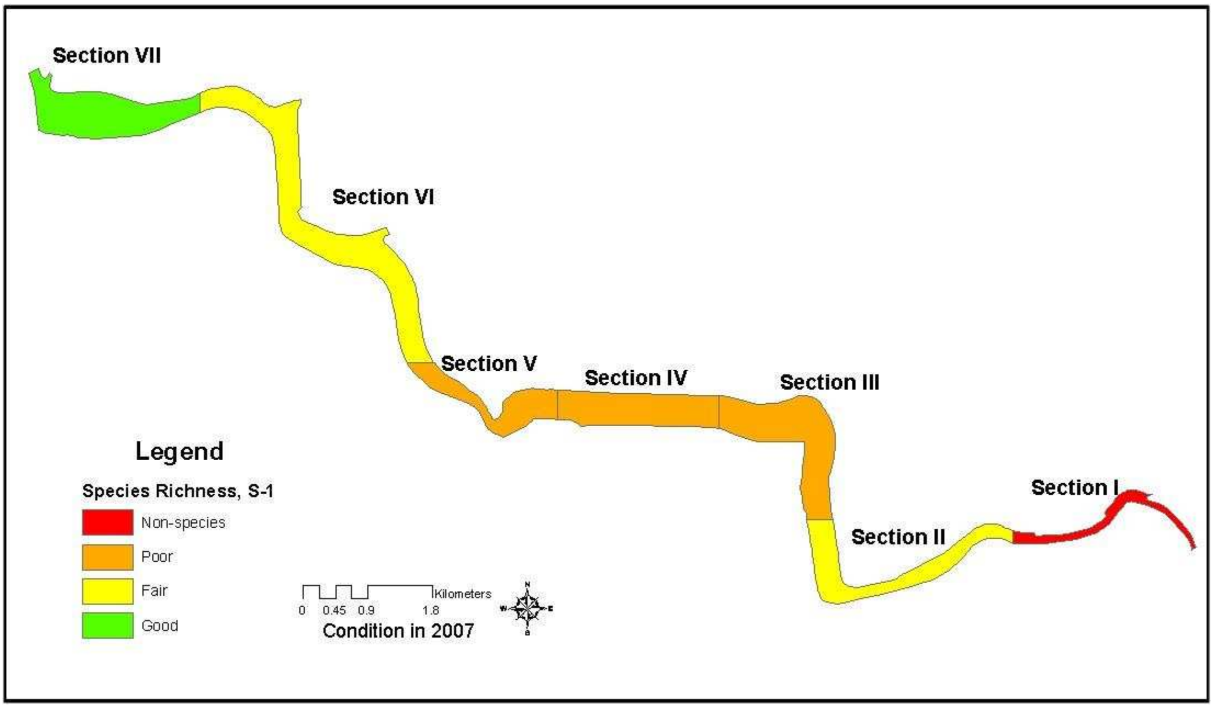


Figure 6.22: Evaluation result of bird species richness in the lower Keelung River

B. Endangered Species (Red-List) (Indicator Code: S-2)

There are about 87.03% of species in the lower Keelung River being listed in the IUCN Red List. From the perspective of regional scale, there were 228 bird species in the red list. *Eurynorhynchus pygmeus* is even set as critically endangered species. In August 2008, the Taiwan's Council of Agriculture renewed the roll of protected wildlife, comparing the new roll with the old one in 2005, some bird species are reclassified and put in different protected states (e.g. *Pica pica* was in third protected scale in 2005, but now is removed from the list in 2008. *Urocissa caerulea* was in second protected scale in 2005, and is shifted to third scale nowadays). Overall, the species in local lists are much less than those in global or regional scales, because the uncommon migrant species are not estimated in local areas where the sedentary birds and regular migrants are caught more attention. Table 6.22 shows the main endangered bird species at different scales (global, regional and local) with five different threatened statuses (CR, EN, VU, NT and LC). However, the most species with status of least concern at global and regional scales are too much to be listed in this table (detail in Annex B; only 56 species are included in this table).

Table 6.22: Red List at different scales in the lower Keelung River (IUCN, 2007; BirdLife International, 2004; Taiwan, 2005, 2008)

Scale** / Species*	**Global**	**Regional**	**Local**		Main habitats	movement	Endemic species
	(IUCN)	(BirdLife International)	Taiwan ('05)	Taiwan ('08)			
Accipiter gularis	LC	LC	-	VU	woodland	transit	no
Accipiter nisus	LC	LC	-	VU	woodland	vagrant	no
Accipiter soloensis	LC	LC	VU	VU	woodland	transit	no
Accipiter trivirgatus	LC	LC	VU	VU	woodland	resident	yes
Accipiter virgatus	LC	LC	VU	VU	woodland	resident	yes
Acridotheres cristatellu	-	-	-	VU	farmland, grassland	resident	yes
Aix galericulata	LC	LC	VU	VU	freshwater	resident	no
Anas falcata	NT	NT	-	-	waterbody	winter migrant	no
Anas formosa	VU	-	VU	VU	wetland	winter migrant	no
Anous stolidus	LC	LC	VU	VU	waterbody	resident, migrant	no
Anser cygnoides	EN	VU	-	-	waterbody, wetland	transit	no
Anser erythropus	VU	VU	-	-	waterbody, wetland	vagrant	no
Aquila clanga	VU	VU	-	-	woodland	vagrant	no
Asio flammeus	LC	LC	VU	VU	woodland, grassland	winter migrant	no
Asio otus	LC	LC	VU	VU	woodland, grassland	winter migrant	no
Aythya baeri	VU	EN	-	-	waterbody, wetland	vagrant	no
Bombycilla japonica	NT	NT	-	-	woodland	vagrant	no
Butastur indicus	LC	LC	VU	VU	woodland	transit	no
Buteo buteo	LC	LC	-	VU	woodland	vagrant	no
Ciconia boyciana	EN	EN	EN	EN	wetland	vagrant	no
Circus cyaneus	LC	LC	-	VU	woodland	transit	no
Circus melanoleucos	LC	LC	-	VU	woodland	transit	no
Circus spilonotus	LC	LC	-	VU	woodland	transit	no
Egretta eulophotes	VU	VU	VU	VU	wetland	transit	no
Emberiza aureola	NT	VU	-	-	grassland	transit (rare)	no
Emberiza sulphurata	VU	VU	-	VU	grassland	winter migrant	no
Eurynorhynchus pygmeus	EN	CR	-	LC	waterbody	transit (rare)	no
Falco peregrinus	LC	LC	EN	EN	grassland	transit	no
Falco tinnunculus	LC	LC	-	VU	grassland	winter migrant	no
Garrulax canorus	LC	-	VU	VU	woodland	resident	yes
Glareola maldivarum	LC	LC	VU	LC	wetland	summer migrant	no
Gorsachius goisagi	EN	EN		LC	wetland, grassland	transit	no

Table 6.22: Continuance

Scale** / Species*	**Global** (IUCN)	**Regional** (BirdLife International)	**Local** Taiwan ('05)	Taiwan ('08)	Main habitats	movement	Endemic species
Hydrophasianus chirurgis	LC	-	VU	VU	wetland	resident	no
Larus saundersi	VU	VU	-	VU	waterbody	winter migrant	no
Limnodromus semipalmtus	NT	NT	-	LC	wetland	vagrant	no
Limosa limosa	NT	NT	-	-	wetland	transit (rare)	no
Milvus migrans	EN	-	VU	VU	woodland	resident	no
Numenius arquata	LC	NT	-	LC	wetland	winter migrant	no
Oriolus chinensis	LC	LC	VU	EN	woodland	resident, transit	no
Otus bakkamoena	LC	LC	VU	VU	woodland	resident	no
Otus spilocephalus	LC	LC	VU	VU	woodland	resident	yes
Pandion haliaetus	LC	LC	VU	VU	waterside	resident	no
Phasianus colchicus	LC	LC	VU	VU	grassland	resident	yes
Platalea leucorodia	LC	LC	VU	VU	wetland	vagrant	no
Platalea minor	EN	EN	EN	EN	wetland	winter migrant	no
Rostratula benghalensis	LC	LC	VU	VU	wetland	summer migrant	no
Spilornis cheela	LC	LC	VU	VU	woodland	resident	yes
Sterna albifrons	LC	LC	VU	VU	waterbody	resident, migrant	no
Sterna anaetheta	LC	-	VU	VU	waterbody	summer migrant	no
Sterna bergii	LC	LC	-	VU	waterbody	summer migrant	no
Sterna dougallii	-	LC	-	VU	waterbody	resident, migrant	no
Sterna sumatrana	LC	LC	VU	VU	waterbody	resident, migrant	no
Threskiornis melanocephalus	NT	-	VU	VU	wetland	transit	no
Tringa guttifer	EN	EN	-	EN	wetland	transit (rare)	no
Tryngites subruficollis	NT	-	-	-	wetland	vagrant	no
Urocissa caerulea	LC	LC	VU	LC	woodland	resident	yes

* The species names in bold indicate higher endangered at global or regional scales but low at local scale. The underlined species name present higher endangered at local scales but low at regional or global scales.
** CR (Critically Endangered), EN (Endangered), VU (Vulnerable), NT (Near Threatened), LC (Least Concern).
*** Available from: IUCN: http://2007.iucnredlist.org/;
BirdLife International: http://www.birdlife.org/datazone/search/species_search.html;
Taiwan's Council of Agriculture: http://conservation.forest.gov.tw/mp.asp
**** Detail in Annex B, Column 3 to 5

According to the database of NTU, Table 6.23 gives an overview to check the endangered species in the test sections and sum up the threatened bird species in different categories. Most bird species appeared in the lower Keelung River were listed at lower risk (least concern) in the red-list of IUCN or BirdLife International.

Moreover, most of the threatened bird species cluster in Section VI and Section VII. It deserves to mention some endangered species (e.g. *Glareola maldivarum, Gorsachius goisagi, Spilornis cheela*, etc.) at local scale which exist mainly in Section VI and Section VII, and also appear in small quantity in Section II, Section III and Section IV.

Table 6.23: Red lists in the lower Keelung River (IUCN, 2007; BirdLife International, 2004; Taiwan, 2005, 2008)

		Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
IUCN	CR		0	0	0	0	0	0
	EN		1	1	1	0	5	6
	VU	0	0	0	1	0	4	7
	NT		0	0	0	0	4	7
	LC		84	72	76	13	158	226
BirdLife International	CR		0	0	0	0	0	1
	EN		1	1	1	0	4	4
	VU	0	0	0	0	0	4	6
	NT		0	0	0	0	4	5
	LC		79	72	77	11	148	205
TW '05	I		0	0	0	0	3	3
	II	0	12	8	8	1	13	24
	III		2	2	1	0	1	3
TW '08	I		0	0	0	0	4	5
	II	0	12	9	10	1	17	34
	III		5	4	4	0	4	7

Generally speaking, the evaluation results of endangered species could be concluded by the condition of red-list at three different scales (global, regional, and local) as shown in Table 6.24 and Figure 6.23.

Table 6.24: Scales of values for rarity of bird species in the lower Keelung River

	State	Degree	Scales of Value
Section I	Non-species	Worse	0
Section II	Most bird species are grouped by least concern at the global and regional scales. However, some of these bird species are assessed as threatened species in Taiwan.	Fair	2
Section III	Similar state as Section II	Fair	2
Section IV	Similar condition as Section II and Section III	Fair	2
Section V	There are some bird species listed by least concern at the global and regional scales; in which Serpent Eagle (*Spilornis cheela*) is estimated at near threatened and endemic to local system.	Poor	1
Section VI	Most bird species are listed by least concern at global and regional scales, but there has less bird species than in the Section VII	Good	3
Section VII	Most bird species are listed by least concern at global and regional scales. Many species are estimated as endangered species or vulnerable species at local scale	Good	3

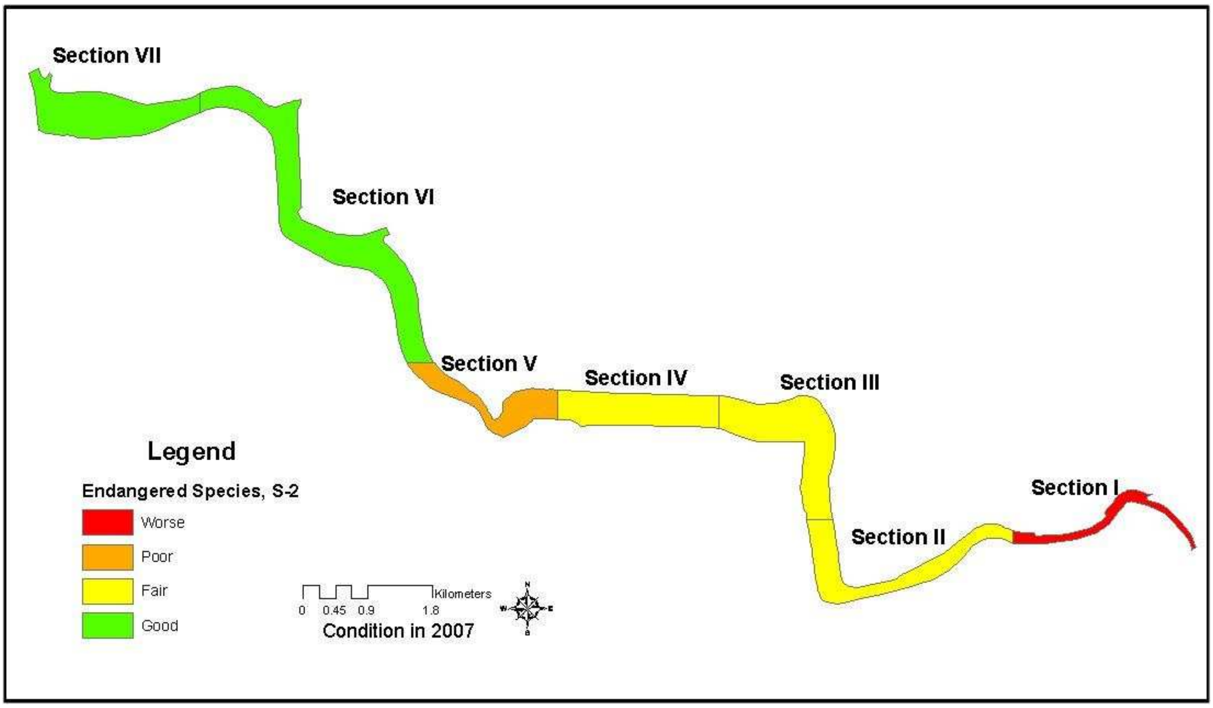


Figure 6.23: Endangered bird species in the lower Keelung River

C. Endemic Species in the lower Keelung River (Indicator Code: S-3)

There are 85 endemic bird species in total and living in Taiwan[5] (15 endemic bird species and 70 subspecies), in which, 36 endemic bird species of them have been recorded in Taipei City[6] (Detail in Annex B). *Urocissa caerulea* (Formosan Magpie), *Myophonus insularis* (Formosan Whistling Thrush), *Heterophasia auricularis* (White-eared Sibia) and *Bradypterus alishanensis* (Brown Bush Warbler) are endemic species; the other 32 species are subspecies. All the endemic bird species are residents in Taiwan except Orange-breasted Green Pigeon *(Treron bicincta*). They can be grouped in 17 families and 7 orders. To review their statement, the main habitats of these endemic bird species are woodland / shrubbery (69.44 % of areas in the study case), grasslands (27.78 %) and wetland (10 %).The number of their cluster means the local condition of habitats, as well as the states of food-chain.

Some of the endemic bird species are threatened by the other same genus of introduced species. For instance, numbers of Crested Myna (*Acridotheres cristatelly*) began declining due to the introduction of Great Mynah (*Acridotheres grandis*) in the past five years; hence the numbers of specific species, especially the target species, show the change on food chain and might impact the habitat structure to the long-term monitoring. In Table 6.25, it represents the categories of endemic bird species in the seven sections. Generally speaking, in Section II and Section VII that more specific native bird species were observed, there are also some endemic species in

[5] Taiwan Biodiversity Network (2010), available at: http://www.tbn.org.tw/
[6] Source from Endemic Species Research Institute, COA, available at: http://www.tbn.org.tw/

the other sections except Section I. To measure the ratio of the endemic species all endemic bird species in Taiwan, it especially represents the importance of habitats for endemic bird species at regional scale. Accordingly, the scales of value for endemic bird species further present in Table 6.26 and Figure 6.24.

Table 6.25: Specific species in lower Keelung River (in record)

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
Order	0	6	5	3	4	5	6
Family	0	15	12	9	7	12	15
Species	0	24	15	13	10	17	32
%City*	(0)	(66.67)	(41.67)	(36.11)	(27.78)	(47.22)	(88.89)
%ALL**	(0)	(28.24)	(17.65)	(15.29)	(11.76)	(20)	(37.65)

* %City: proportion of endemic bird species in section to endemic bird species in Taipei City.
** %ALL: proportion of endemic bird species in section to all endemic bird species in Taiwan.

Table 6.26: Scales of values for endemic species in special interests of bird species in the lower Keelung River

	State	Degree	Scales of Value
Section I	Non-species	Non-species	0
Section II	There are about 66.67% of endemic species at local scale (Taipei)	Good	3
Section III	There are about 41.67% of endemic species at local scale (Taipei)	Medium	2
Section IV	There are 13 bird species in this area. The ratio of district natives to endemic bird species at local scale is 36.11%.	Medium	2
Section V	There are only 10 bird species native to this area (ca. 27.78% at local scale)	Medium	2
Section VI	Almost the half endemic bird species in Taipei rest in this section.	Medium	2
Section VII	About 88.89 % of endemic species appear in Section VII (local scale)	Excellent	4

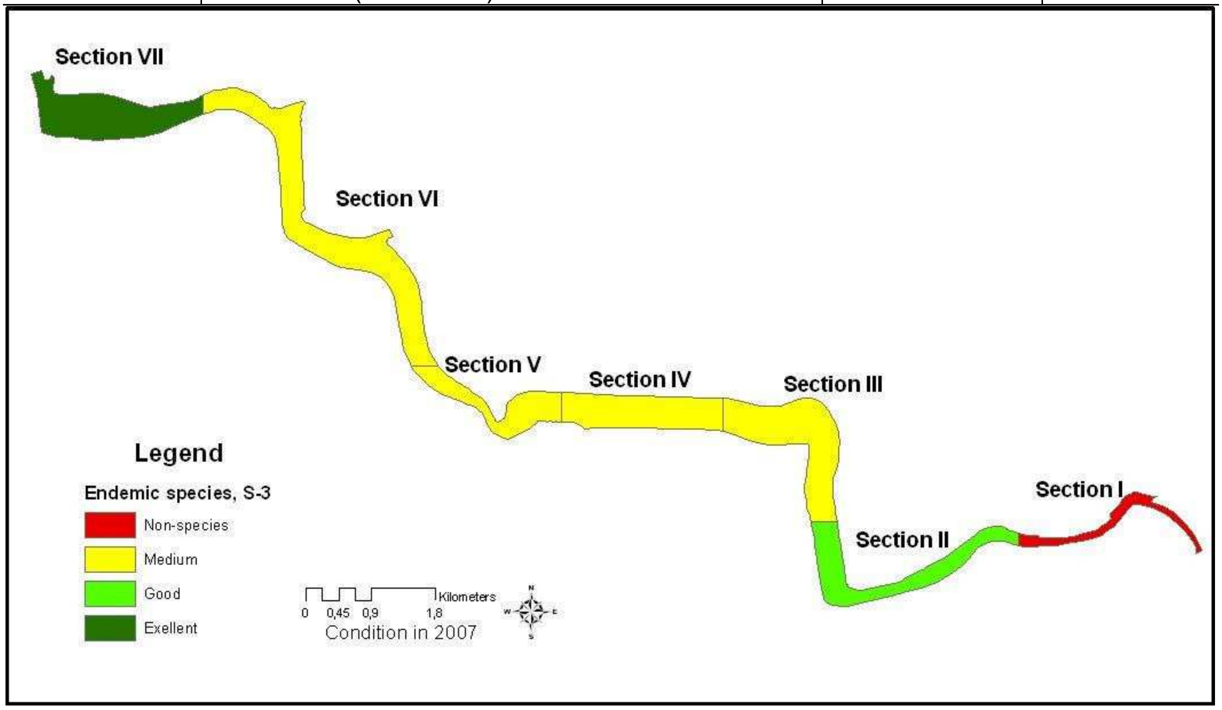


Figure 6.24: Endemic bird species in the lower Keelung River

6.3 Analysis of the Species-Biotope-Relationship with Bird Species in the Lower Keelung River

6.3.1 General Comparison between Evaluation of Habitat and Evaluation of Bird Species

Bird species are high mobile animals. To discuss the habitat functions for bird species in the complex river ecosystem which should consider the diverse environment with special characteristics in water and amphi-areas for bird species. Generally speaking, the downstream Keelung River has been altered for preventing floods and urban development. Some sections of river channel have been changed in the direction or water flow; the riverbanks are mainly lined by embankments. The heavy-strength changes occurred mainly from the county boundary to Sanjiaodu (Section I to V). Channelization and simple man-made land covers display in most sections of the lower Keelung River. However, the alluviums spread at some places in Section II, III and V that play a role as stepping-stones or small habitats for water fowl. With the influence from tide, water flow and flat slop, the river channel had more areas of alluviums at the riverbanks in Section VI and Section VII which the river channels were also getting stable at the both side. Even the silty state is usually the problems after rapid heavy rainfall, the great numbers of alluvium serve the benefits as habitats for bird species. Moreover, the impacts on riversides are also important to review the habitat functions for bird species, since these impacts may result in changes of habitat structure and habitat quality.

Figure 6.25 displays an overview of the evaluation results with habitat quality (HQ), criteria of impacts, biotopes and bird species. In general, Section VII showed the best habitat quality and species condition in the seven sections. However, two interesting cases should be especially mentioned – Section I was listed at third place of habitat quality in the lower Keelung River, but represented the worst condition of bird species, since no bird species have been recorded in this section. Section II has poor habitat quality but presents good species condition, especially at indicator of endemic species. These results provide the cogitation of further study and planning.

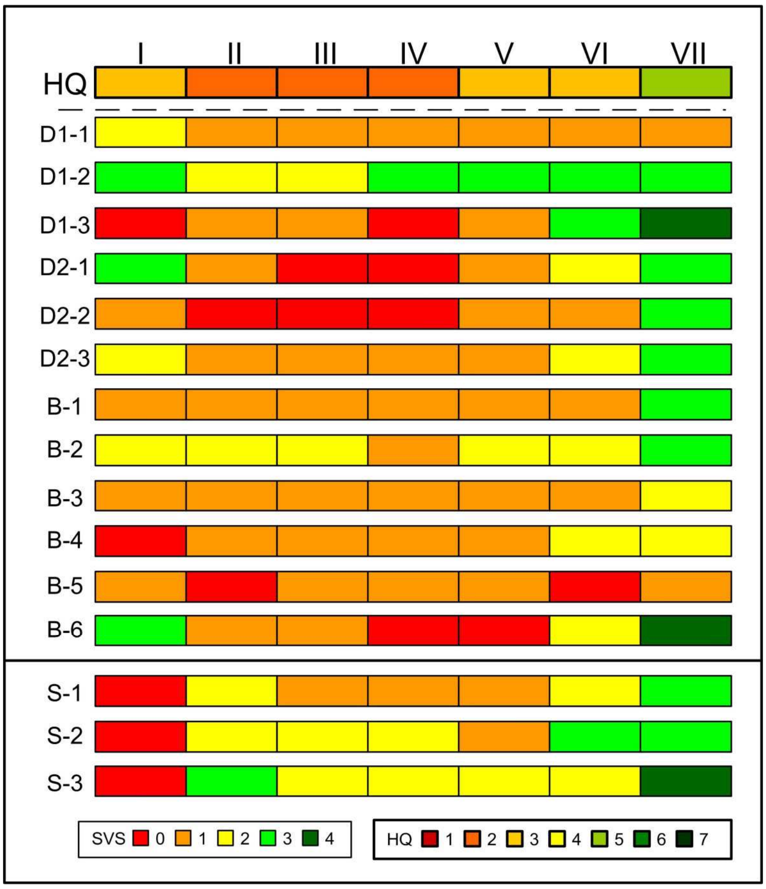


Figure 6.25: Overview of Habitat Quality and species condition in the lower Keelung River

Furthermore, the correlation between habitats and species is an important measure to show the relationship between two or more indicators. The results provide the emphases of decision-making for urban river management and habitat remediation as reference. As shown in Table 6.27 that each species criterion has high or very high correlation with stability of river channel. The endangered species are also easily influenced by land use in surrounding areas and the stability of riverbanks. Water quality showed negative correlation with all species criteria, which is an important point to be discussed.

Table 6.27: Correlation analysis between species condition and impacts on water / flood plains

Species / Impact	**Species richness**		**Endangered species**				**Endemic species**
	Resident	ALL	IUCN	BirdLife	TW '05	TW '08	
Water quality	-0.6695	-0.4812	-0.2931	-0.2935	-0.4884	-0.4322	-0.6863
Fine particulate matter	-0.1496	*0.1244*	0.3682	0.3520	*0.0210*	*0.1346*	-0.2443
River channel	**0.8047**	**0.9089**	**0.9446**	**0.9561**	**0.8802**	**0.9008**	**0.7512**
Activities on riverbanks	*0.0887*	0.3442	0.5624	0.5652	0.3264	0.3963	*0.0698*
Land use outside of flood plains	0.4279	0.6404	**0.8094**	**0.7831**	0.6092	0.6992	0.4263
Flood plains	0.4453	0.6934	**0.8486**	**0.8367**	0.6582	**0.7334**	0.3653

* $\rho_{x,y}$ is between -1 and 1 to show the negative and positive correlation of two indicators. When $\rho_{x,y}$ <0.3 denotes low correlation, 0.3< $\rho_{x,y}$ <0.7 means middle correlation, 0.3< $\rho_{x,y}$ <0.7 represents high correlation and $\rho_{x,y}$ >0.8 shows very high correlation.

Moreover, the correlation between habitats condition and species is another key tone to review the species-habitat-relationship (Table 6.28). Endangered species act high correlations with all habitat criteria except “habitat fragmentation and connection”. The protected status of habitats also plays an important role for serving habitat functions for bird species. More details about species-biotope-relationship in the lower Keelung River are shown in the next paragraphs.

Table 6.28: Correlation analysis between species condition and habitat quality

Species / Habitat	**Species richness**		**Endangered species**				**Endemic species**
	Resident	ALL	IUCN	BirdLife	TW ‘05	TW ‘08	
Naturalness	0.6901	**0.8074**	**0.8604**	**0.8223**	**0.8083**	**0.8664**	0.6968
Patch Size	0.4325	0.6288	**0.7694**	**0.7476**	0.6.196	0.6941	0.4318
Plant composition	0.5080	0.6664	**0.7826**	**0.7451**	0.6705	**0.7421**	0.5422
Habitat variety	0.6293	0.6943	**0.7077**	**0.7396**	0.6141	0.6231	0.5177
Fragmentation & connection	*0.2059*	*0.0564*	-0.0931	-0.0259	*0.1128*	-0.0076	*0.1987*
Protected status	**0.7122**	**0.8554**	**0.9142**	**0.8838**	**0.8492**	**0.9042**	0.6830

* $\rho_{x,y}$ is between -1 and 1 to show the negative and positive correlation of two indicators. When $\rho_{x,y}$ <0.3 denotes low correlation, 0.3< $\rho_{x,y}$ <0.7 means middle correlation, 0.3< $\rho_{x,y}$ <0.7 represents high correlation and $\rho_{x,y}$ >0.8 shows very high correlation.

6.3.2 Species-Biotope-Relationship in the Lower Keelung River

6.3.2.1 Habitat Function for Birds in Section I of the lower Keelung River

Section I is a special case in the seven test sections along the lower Keelung River, since it showed the third best condition of habitat quality (SVS_{sum}=19 at moderate-poor scale, Figure 6.26) but has no bird species in records. To survey the evaluation with each factor of indicators, this section showed moderate status of impact and biotope conditions in average. The evaluation of these factors is better than that in the other reaches located in the central part of Taipei City (Section II to Section V). However, there was no record of bird species (SVS_S=0). The assumption that the none-treated waste water from the neighbourhoods (industrial areas and residential areas) makes the water quality worse in this section. Besides, habitat diversity displaying on plant composition (SV_{B3}=1) and habitat variety (SV_{B4}=0) is poor to serve functions as habitats. Even though the biotope condition of “patch size” and “protected status” are summarized at fair or good scale (SV_{B2}=2 and SV_{B6}=3), the habitat naturalness and fragmentation represent at poor condition (SV_{B1}=SV_{B5}=1). Moreover, next to the Keelung River at the right side in this section covers an urban forest with an area of about 10 ha, an inference can be made therefrom, the bird species have habitats in the forest.

Generally speaking the riparian parks on both sides of the Keelung River in Section I mainly cover man-made infrastructure, the impact from human activities showed on water quality and doll vegetation structure, which reduce the habitat quality. Some good qualitative habitats are fragmented by man-made constructions. The unnatural land covers serve unfriendly environment for bird species to forage rest or breed in this area.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	2	0 4
		D 1-2	3	0 4
		D 1-3	0	0 4
	Impact: Riverside	D 2-1	3	0 4
		D 2-2	1	0 4
		D 2-3	2	0 4
State of habitats	Biotope condition	B-1	1	0 4
		B-2	2	0 4
		B-3	1	0 4
		B-4	0	0 4
		B-5	1	0 4
		B-6	3	0 4
Sum of SV (SVS)			19	Section I: Moderate-poor (3)

Figure 6.26: Evaluation results of habitat quality in Section I along the lower Keelung River

6.3.2.2 Habitat Function for Birds in Section II of the lower Keelung River

Section II showed a reverse evaluation results to Section I that this section had poor habitat quality (SVS_{Sum}=12), but displayed good results of bird species (SVS_S=7). The endemic species even have been recorded at good condition (SV_{S3}=3) in this section. As shown in Figure 6.14, the habitat composition is similar from Section II to Section IV. These three sections are covered mainly riverside parks with man-made land use. The results of evaluation echoed the structure and condition of biotope types. Firstly, Section II did not show better biotope conditions than those in the other sections, the sum of scales of values was at scale to poor condition (Figure 6.27). The poor water quality in stream may be getting worse due to the untreated waste water flows directly into the river. The habitats in Section II had strong impacts from the neighbourhoods (SV_{D2-2}=0) and unstable condition of the river channel and its riverbanks (SV_{D1-3}= SV_{D2-3}=1); because the main land-use types of the neighbourhoods are industrial areas (43.56%) and residential areas (21.95%), human activities and industry operation from neighbourhoods particularly increase the water pollution and surface water flow. Besides, this section is nearby the airport, the traffic of planes may disturb the moving routes of bird species. In brief, the impacts from human activities and pollution powerfully affected the habitats of species in this section.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 4
		D 1-2	2	0 4
		D 1-3	1	0 4
	Impact: Riverside	D 2-1	1	0 4
		D 2-2	0	0 4
		D 2-3	1	0 4
State of habitats	Biotope condition	B-1	1	0 4
		B-2	2	0 4
		B-3	1	0 4
		B-4	1	0 4
		B-5	0	0 4
		B-6	1	0 4
Sum of SV (SVS)			12	Section II: Poor (2)

Figure 6.27: Evaluation results of habitat quality in Section II along the lower Keelung River

Though this section did not serve good environment for bird species, there were still many bird species listed in the records. The better situations were particularly represented by “endemic bird species”. In other words, this section might not act as important habitats for bird species. Some bird species, especially the native specific species, may stopover in this section, and therefore, it is important to consider how to establish the diversity of vegetation covers for bird species, to reduce the impacts of human activities on riverbanks, and also to improve the water quality. To review the species-environment-relationship, furthermore, most bird species appeared in this section were resident (51%) and mostly like the habitats of woodland (36%), wetland (34%) and grassland (18%) (Figure 6.28). Since many endemic bird species are observed in this area (e.g. *Urocissa caerulea, Myophonus, Spilornis cheela*, etc), which used to take shrubs and woodland as their habitats. To choose a few target species and review their demands of habitats must be an important analysis for remediation.

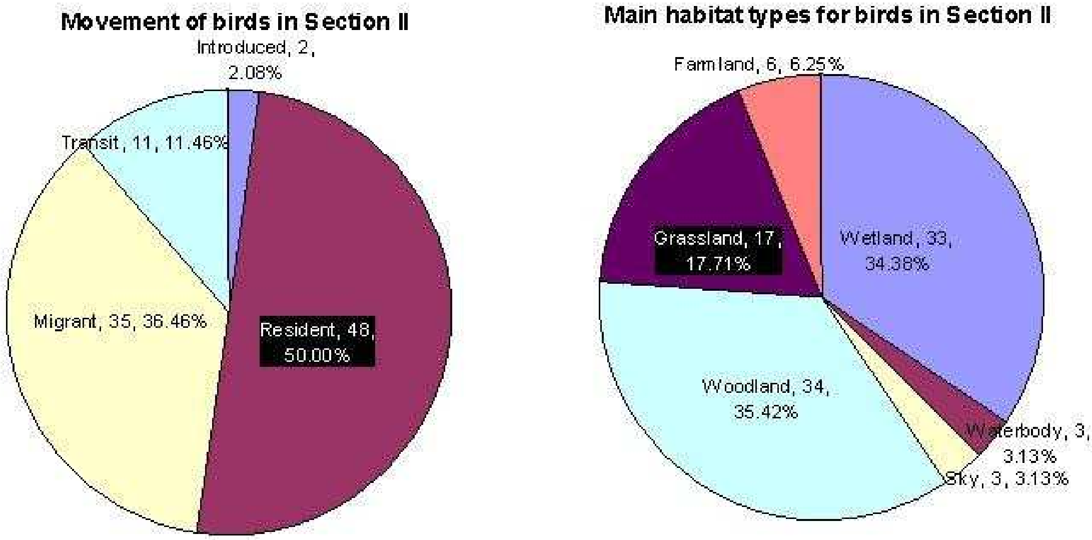


Figure 6.28: Movement of bird species and the main types of their habitats in Section II

6.3.2.3 Habitat Function for Birds in Section III of the lower Keelung River

Section III also had poor condition with most criteria and the scales of values were summed up with 12 points (Figure 6.29). The water bodies and riparian areas were under strong pressure from human activities and urban development (SVS_D=0-1). The untreated waste water usually drained away and might increase the heavy-polluted water quality. Besides, the impacts on flood plains and neighbourhoods were also serious in this section (SV_{D2-1}=SV_{D2-2}=0). The main land-use types on flood plains on both sides were riverside parks, which were covered with grassland (ca. 35.21%) and man-made infrastructures (ca. 19.83%). The regular human activities (sport, sight seeing, etc) in the riparian parks were especially dynamic in the Guanshan riverside park, which is on the left side of Keelung River (SV_{D2-1}=0). The impacts from human activities in the neighbourhoods are also serious due to the high density of infrastructure (e.g. airport; ca. 39%), highway (ca. 29%) and automobile industry (ca. 21%). Furthermore, the main part of this section was straightened channel and deeply excavated. The soil erosion due to rainfall was a serious problem in this section (SV_{D1-3}=1). The lack of vegetation cover might offer slender protection to the riverbanks and increases soil erosion after heavy rainfall (SV_{D2-3}=1).

Moreover, the poor biotope condition represented as unnatural biotopes (SV_{B1}=1). In Section III, the less natural habitats (e.g. rich tall grassland) were disconnected by man-made land-use types and have areas in relatively small sizes. However, some bird species have ever been listed on the right side of the Rainbow Riverside Park. Upgrading the proportion of natural vegetation cover and strengthening the stability of river channel may attempt to enrich the biodiversity of plants to help create a better environment for bird species. Besides, some endemic bird species have been observed at Meiti Riverside Park (e.g. *Spilornis cheela, Myophonus insularis*, etc.), the other temporal sedentary bird species, for example *Bubulcus ibis*, appear often at

Meiti Riverside Park and Rainbow Riverside Park (both on the right side of the lower Keelung River). As shown in Figure 6.30, most bird species listed in Section III were resident (45%), the most residents have their favorite habitats in wetland (39%) and woodland (28%).

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 … 4
		D 1-2	2	0 … 4
		D 1-3	1	0 … 4
	Impact: Riverside	D 2-1	0	0 … 4
		D 2-2	0	0 … 4
		D 2-3	1	0 … 4
State of habitats	Biotope condition	B-1	1	0 … 4
		B-2	2	0 … 4
		B-3	1	0 … 4
		B-4	1	0 … 4
		B-5	1	0 … 4
		B-6	1	0 … 4
Sum of SV (SVS)			12	Section III: Poor (2)

Figure 6.29: Evaluation results of habitat quality in Section III along the lower Keelung River

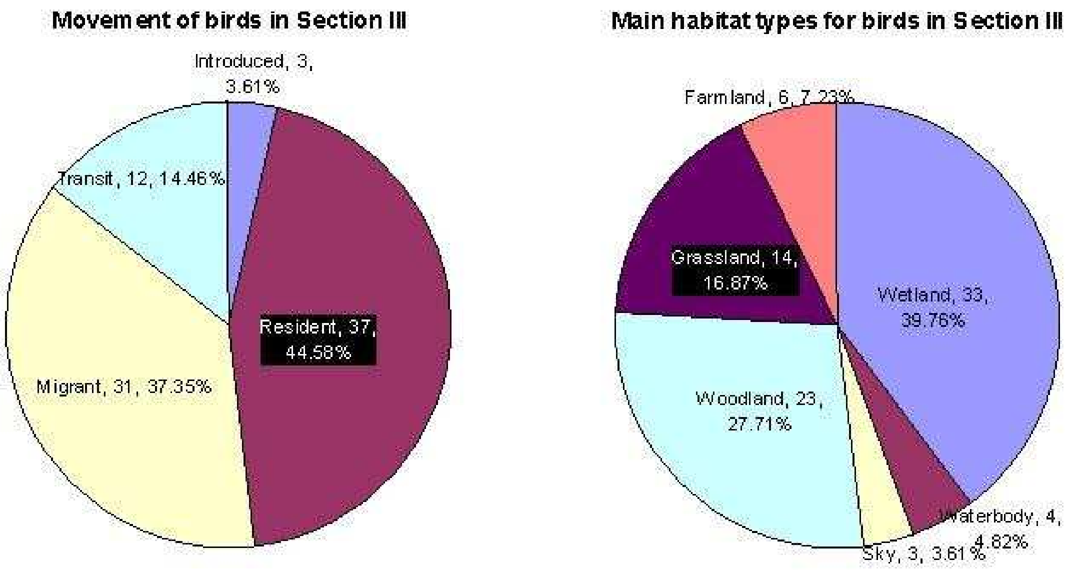


Figure 6.30: Movement of bird species and the main types of their habitats in Section III

6.3.2.4 Habitat Function for Birds in Section IV of the lower Keelung River

In Section IV, the main area-covers were man-made land-use types, such as artificial greensward (ca. 35.07%) and man-made infrastructures (29.30%). The evaluation results give evidence of poor habitat quality (SVS_{sum}=10, Figure 6.31) and represents the worst status in all test sections. It showed the similar problems as in Section III. The worst parts were especially discovered in impact by human activities on flood plains/in neighbourhoods and unstable river channel ($SV_{D1\text{-}3}$=$SV_{D2\text{-}1}$= $SV_{D2\text{-}2}$=0). The core of all the problems indicates the overloading development for human demands and urban planning (e.g. engineering priorities, site-specific activity, etc.). Large areas of flood plains have been even drained and isolated from urban landscape by dikes that the natural vegetation covers were removed and the landscape structures were simplified. The man-made areas (e.g. parking areas and concrete bikeway) cut off the natural biotope types. Such a phenomenon was especially obvious on the left side of the Keelung River which is namely Dajia Riverside Park. This condition may tend to increase surface-water flow and sedimentation of watercourses. These problems appeared conspicuously in the Dajia Riverside Park, a popular recreational area for Taipei citizens. The high intensity of activities may raise and expand the depredation on natural habitats. The fragmental poor vegetation cover did not serve functions of refuge and foraging for bird species. Besides, the main land use in the neighbourhoods at the left side of the Keelung River is airport, the frequent departure and arrival of airplanes may disturb the migrant routes and the roosts of bird species. Generally speaking, the central problems in this section were water pollution, unstable river channel and unnatural habitats due to the intense built-up development on the riverbanks and city planning.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 4
		D 1-2	3	0 4
		D 1-3	0	0 4
	Impact: Riverside	D 2-1	0	0 4
		D 2-2	0	0 4
		D 2-3	1	0 4
State of habitats	Biotope condition	B-1	1	0 4
		B-2	1	0 4
		B-3	1	0 4
		B-4	1	0 4
		B-5	1	0 4
		B-6	0	0 4
Sum of SV (SVS)			10	Section IV: Poor (2)

Figure 6.31: Evaluation results of habitat quality in Section IV along the lower Keelung River

However, some resident bird species, for instance *Bubulcus ibis* (Cattle Egret), have been recorded in a big quantity in this area. On the other hand, the history record displayed a great diversity of bird species in Section IV. Figure 6.32 displays the main bird species with migrants and residents, their favorite habitats were wetland (42%) and woodland (26%).

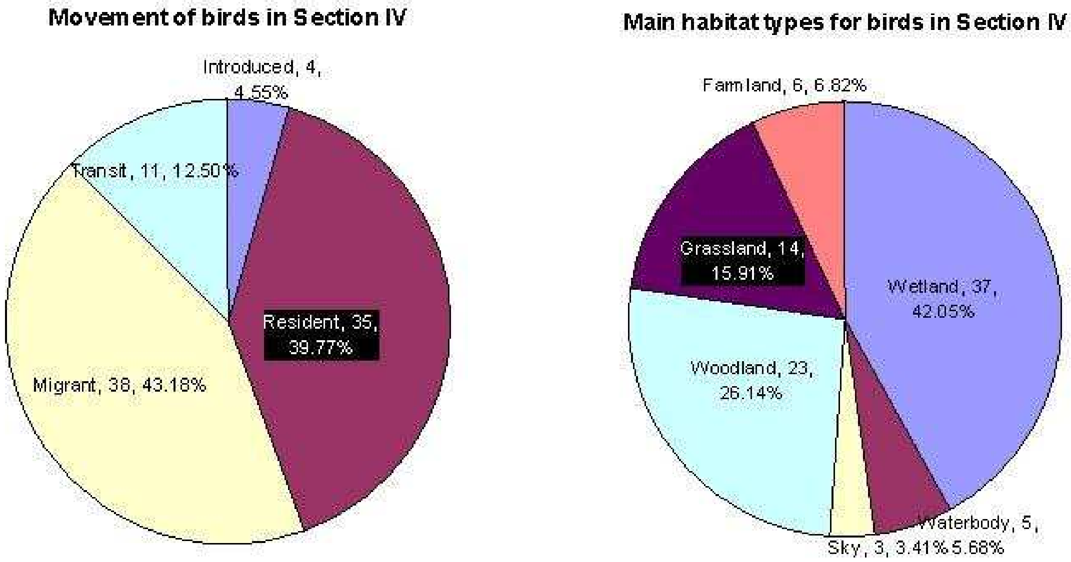


Figure 6.32: Movement of bird species and the main types of their habitats in Section IV

6.3.2.5 Habitat Function for Birds in Section V of the lower Keelung River

The majority biotope types in Section V are channelized river stream (43.37%) and man-made environment (e.g. riparian parks, parking areas, total ca. 40%). Though the biotopes did not present suitable habitats for wildlife, some endemic bird species have ever been observed in this section. The assessment showed moderate-poor status and sumed up the scales of values with 14 (Figure 6.33). The examination showed that the condition of biotope types was mainly poor (SV_B at 1). Although the main matrix in this section was grassland, the main type of grassland was artificial greensward (78.44%), an infertile land cover for bird foraging and bird feeding. The central problem of the poor habitat functions was caused by the impacts and poor habitat condition.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 4
		D 1-2	3	0 4
		D 1-3	1	0 4
	Impact: Riverside	D 2-1	1	0 4
		D 2-2	1	0 4
		D 2-3	1	0 4
State of habitats	Biotope condition	B-1	1	0 4
		B-2	2	0 4
		B-3	1	0 4
		B-4	1	0 4
		B-5	1	0 4
		B-6	0	0 4
Sum of SV (SVS)			14	Section V: Moderate-poor (3)

Figure 6.33: Evaluation results of habitat quality in Section V along the lower Keelung River

The pressure from human activities on water body and flood plains did not show the exception like that in the other sections mentioned above. Many activities of recreation in the riparian parks (e.g. sport and transportation) and high developed land-use types as residential areas, infrastructure (highway) and scenic areas may degrade the quality and diversity of biotopes. Only a few bird species made stopover in this section for a short break. An inference can be drawn that the Yuanshan Scenic Area, which is located on the right side of the lower Keelung River in this section, has more natural environment and multi-structure of landscape with urban forest for functions of forage, refuge and breeding for bird species. Therefore, only a few bird species have been observed in Section V. However, this small amount of bird species showed an important signal in this area that all the bird species are residents; in which most endemic bird species were included. Figure 6.34 illustrates the main types of habitats for residents in Section V. Though the evidence was not compelling, it would still be able to argue that these bird species breed and refuge in Yuanshan Scenic Area, and take a rest along the Keelung River.

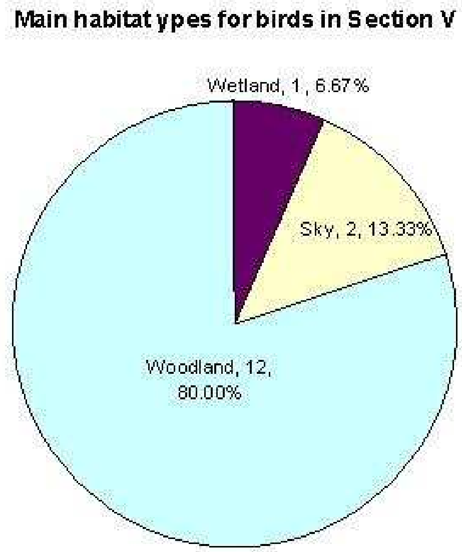


Figure 6.34: The main types of habitats for bird in Section V

6.3.2.6 Habitat Function for Birds in Section VI of the lower Keelung River

This section was assessed the scales of values at moderate-poor scale (SVS=20 shown in Figure 6.35) and ranked at second place of the seven test sections. The habitat condition in Section VI could be surveyed in two parts. The north part (Linung) had more natural and better quality of habitats for bird species. The main patch is grassland (cover areas of 28.18%), which covers biotope of natural, rich grassland about 49.82%; but most natural fields are in the north part. Even though the bird species are observed in great quantities and diversity, this area obviously provided poor habitats for bird species due to built-up environment and strong impacts from human activities.

To put it plainly, the main land-use types in the neighbourhoods are playgrounds, recreation areas and residential areas. The rapid development in the surrounding areas caused water pollution and other negative impacts on the stream ($SV_{D2\text{-}2}$=1). The biotope condition did not reflected the ecological services for wildlife and showed mainly the worst on fragmentation and connection ($SVS_{B\text{-}5}$=0). The other criteria of biotope factor also displayed the poor or fair condition (SV=1-2), since the poor structure of vegetation covers and the composition of cultural landscape.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 … 4
		D 1-2	3	0 … 4
		D 1-3	3	0 … 4
	Impact: Riverside	D 2-1	2	0 … 4
		D 2-2	1	0 … 4
		D 2-3	2	0 … 4
State of habitats	Biotope condition	B-1	1	0 … 4
		B-2	2	0 … 4
		B-3	1	0 … 4
		B-4	2	0 … 4
		B-5	0	0 … 4
		B-6	2	0 … 4
Sum of SV (SVS)			20	Section VI: Moderate-poor (3)

Figure 6.35: Evaluation results of habitat quality in Section VI along the lower Keelung River

The water flow is getting slower from confluent of Shuangxi due to the slope, tide effect and wide river channel, the alluviums spread out at Linung and Shezi. Hence, there are two important perspectives to consider the species-habitat-relationship in this section. Firstly, the endangered species *Platalea minor* (Black-faced Spoonbill) has been observed a few times in the north part during the winter of ‘06/’07, such appearances were meaningful to show that this area could serve places for this threatened species. Therefore, to redesign and rehabilitate this part with Section VII as buffer zone seems a comprehensive implement to improve the habitat quality. Secondly, an introduced alien species *Acridotheres grandis* (White-vented Myna) was often recorded in this section and already threatened the existence of the local species *Acridotheres cristatellu* (Crested Myna) for a few years. This status reflected the change of local food chain, and could be considered as concepts of remediation. In conclusion, the bird species in Section VI were mainly migrant bird species and used to take their perches in the wetland (43%), woodland (19%) and fresh water (17%) (Figure 6.36).

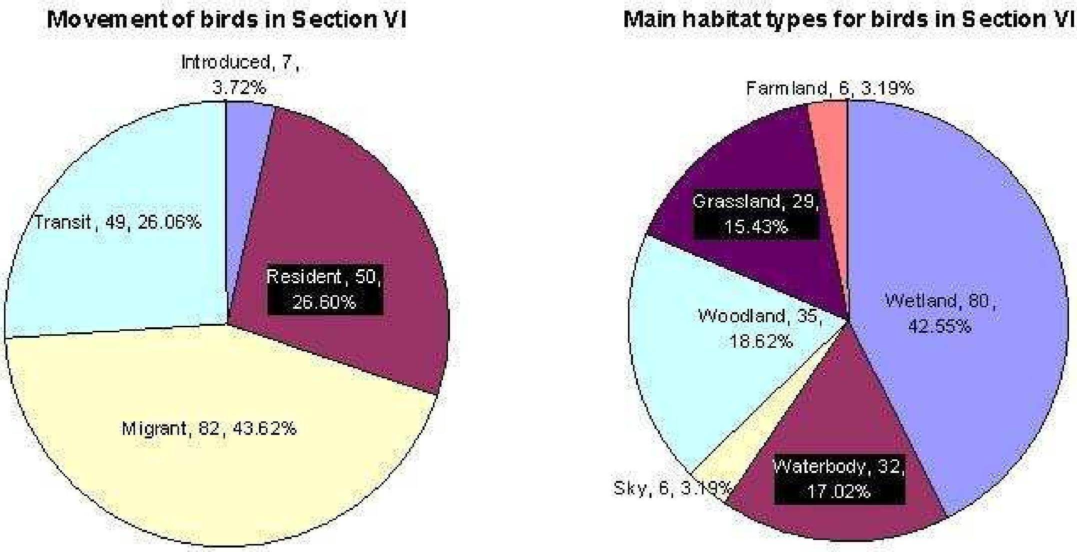


Figure 6.36: Movement of bird species and the main types of their habitats in Section VI

6.3.2.7 Habitat Function for Birds in Section VII of the lower Keelung River

Section VII covers the areas of Guandu wetland, Shezi and a part of Linung, which showed the best habitat quality in the downstream Keelung River (sum SVS with 32, good-moderate scale, Figure 6.37). The composition of biotope was relatively natural and bigger as habitats for wildlife (SV_{B-1}=SV_{B-2}=3). The habitat diversity represented fair condition (SV_{B-3}=SV_{B-4}=2). The flood plains and wetlands within river basin in this section were particularly important to maintain the proper functions of natural water cycle and to reduce the impacts of floods and also to serve as habitats for water fowl. However, the indicators of "plant composition", "habitat variety" and "isolation" represented at fair state (SV_{B-3}=SV_{B-4}=2, SV $_{B-5}$=1), because the natural biotopes were disconnected by man-made infrastructure.

indicators			SV	Bar chart of scales of value (SV)
pressure	Impact: Water	D 1-1	1	0 4
		D 1-2	3	0 4
		D 1-3	4	0 4
	Impact: Riverside	D 2-1	3	0 4
		D 2-2	3	0 4
		D 2-3	3	0 4
State of habitats	Biotope condition	B-1	3	0 4
		B-2	3	0 4
		B-3	2	0 4
		B-4	2	0 4
		B-5	1	0 4
		B-6	4	0 4
Sum of SV (SVS)			32	Section VII: Good-moderate (5)

Figure 6.37: Evaluation results of habitat quality in Section VII along the lower Keelung River

Although the wetland serviced enrich resources for breeding, foraging and feeding functions for fowl, and also played a role as natural revetment to prevent soil erosion and flooding damages, the amount of bird species and types were decreasing gradually due to the worsened quality of habitats and simplex structure of landscape. Yet a great quantity of bird species has been observed using the wetland for resting, foraging and breeding. In which, almost 70% of bird species took stopover in this area (37% of migrants and 32% of transit) and 26.6% of bird species are residents (Figure 6.38). To review the species-environment-relationship with some common "Guests" in this section (e.g. *Anas crecca* (Common Teal) and *Bubulcus ibis* (Cattle Egret)) which were recorded in less quantities in the winter of '06/'07 than those in early years. However, the threatened target species *Platalea minor* (Black-faced Spoonbill), which usually spend winter in the southern Taiwan, has appeared a few times at Guandu during the study period. It is a signal to maintain the habitat for this kind of special species.

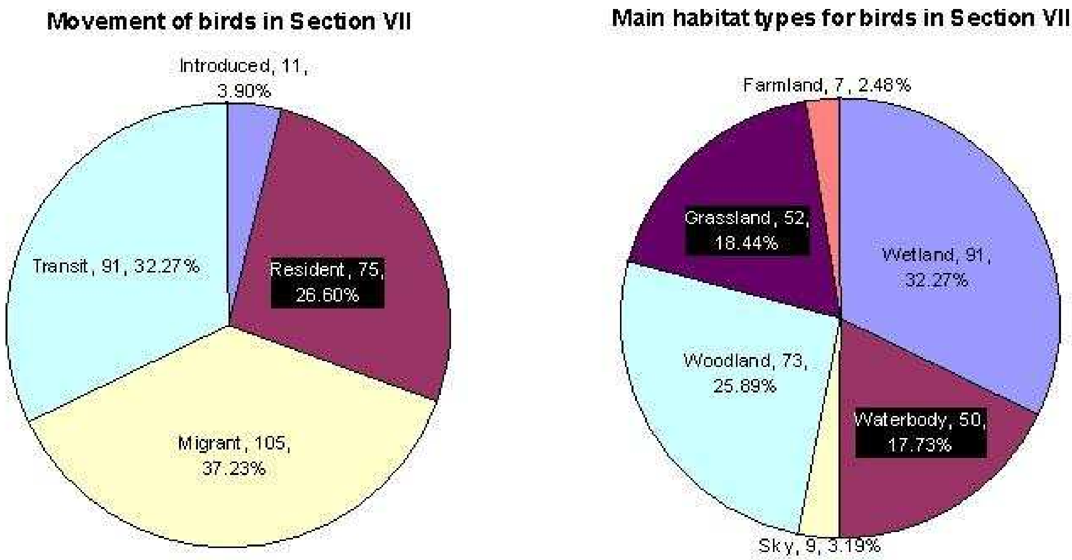


Figure 6.38: Movement of bird species and the main types of their habitats in Section VII

In addition, water impact should be especially mentioned here that the water quality showed the worst condition in the seven test areas (SV_{D1-1}=1). Although the wetland usually helps to dilute the water pollution, the influence of RCC and non-treated discharge may cause problems and interferences in this section. This should be one of the key points to improve the quality of habitats in Section VI. The simple structure of vegetation covers is another perspective to improve the habitat functions, and to upgrade the species diversity of bird species.

In conclusion, Figure 6.39 illustrates the overall condition of habitat functions in the lower Keelung River. The results may further contribute to the decision-making of urban river management and habitat remediation as reference.

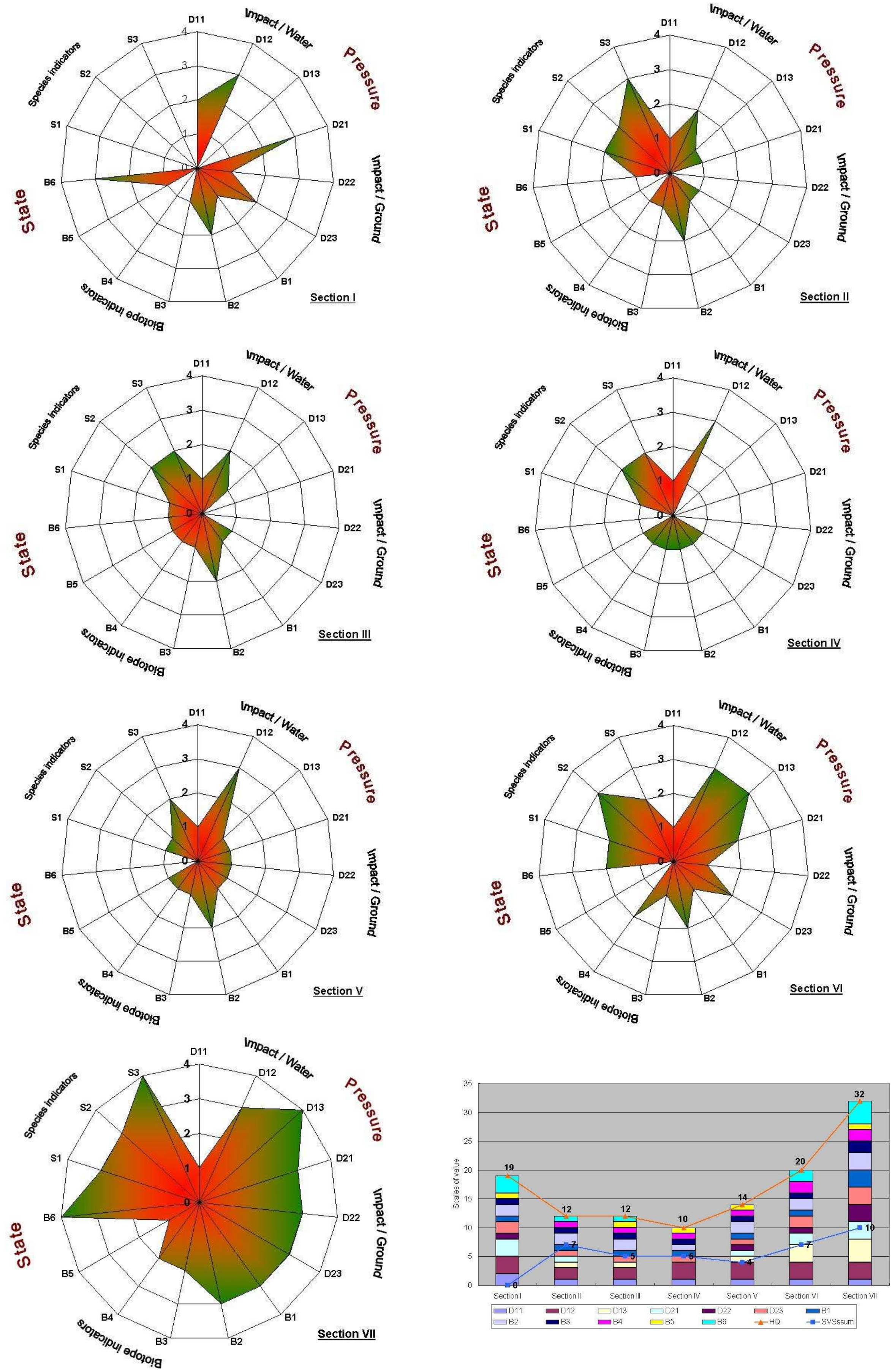


Figure 6.39 Overall displays of scales of values in seven test sections of the lower Keelung River

7. Discussion

There are several research questions addressed in this study, and the principal findings suggested the following ideas. 1) The description of present condition along the lower Keelung River (state) and the causes of impacts (pressure) on river ecosystem were carried out by the PSR framework. The results of the preliminary analysis were adapted both to study targets and concepts of evaluation criteria; 2) The biotope classification not only shows the physical condition of urban river, but also serves as a database for evaluation. The concept may be applied to other studies of biotope mapping in Taiwan, especially for the areas of urban river or urban environment; 3) The evaluation criteria for habitat functions assessed the assets and problems in the lower Keelung River. This methodology may contribute to the assessment of the habitat functions of urban rivers. Moreover, the evaluation results displayed the vulnerability and assets in the lower Keelung River. They can help decision-maker and planner determine rehabilitation priorities; 4) It was difficult to carry out integrated river basin management (IRBM) in this study, but it attempted to propose possible strategies for habitat remediation. It should be concluded that the habitat functions of urban rivers can only develop when the river management is designed according to the river nature instead of human demands. If the river management is not developed and maintained according to nature, the man-made environment may degrade the geodiversity and biodiversity. In conclusion, the measures to improve ecological status (Section 7.1), the limitations of this study (Section 7.2) and the possible application to other studies (Section 7.3) are introduced in the next paragraphs.

7.1 Measures to Improve the Ecological Status of the Keelung River

7.1.1 General Aspects for the Whole Study Areas

The floodplain and wetland along the lower Keelung River should be important green spaces in Taipei City that serve ecological (e.g. habitats), economic (e.g. water supply) and societal (e.g. recreation) functions. The goal of this study has been especially focused on ecological condition and services of urban rivers rather than societal functions (e.g. mitigation of flood damage and transportation of tourism). The main reason is that the evaluation of habitat functions addresses physical and biological condition of the environment, and then assesses the quality of habitat based on physical, biological and environmental states. The results provide information about conservation for decision-making in environmental planning, which may not only benefit the ecological environment, but also the societal context.

However, the channelization and channel straightening works of the river have altered the river’s hydrology and ecosystem; most sections of river channel have been consequently diked and drained. For this reason, there are large areas of flood plains that have been fragmented and isolated by dam and other man-made constructions. Natural vegetation cover has been removed and there is an increase in the surface-water flow and sedimentation of watercourses. In general, degradation of habitat diversity is the core problem that affects the diversity of species in the entire catchment area (i.e. the man-made constructions on the riparian parks), which is in poor condition[1], and the biotopes are not able to behave as normal habitats. Such results indicate that the riverbanks can not provide habitats for wildlife and they also lack of the ability to maintain the functions of the natural water cycle and water quality.

Although almost the whole lower reach of the Keelung River has been altered and has lost the basic habitat functions for wildlife, a small areas of flood plains and the Guandu Wetland at the confluence of the Keelung River and the Danshui River show particular importance for wildlife habitats and for the natural water cycle by reducing the impacts of flooding and soil erosion. These fascinating areas should be considered assets in the river system that serve the life cycles of river animals and reduce the impacts of water pollution and flooding. The diversity of vegetation cover and landscape is therefore a key point to increase the habitat functions in the entire lower Keelung River. Furthermore, the diversity of habitats is relevant to species diversity. Moreover, the stable structure of vegetation on riverbanks would support the channel side stability, reduce soil erosion, and improve the water quality. Not only the environmental condition should be measured, but also the human impact through the use and develop the rivers should be changed. Human activities could be identified as the original cause of natural river ecosystem deterioration; i.e. the human activities limit the valuable functions of the natural environment.

In the further review of the evaluation results, some problems from previous policies and studies should be mentioned. The first problem appeared due to poor knowledge of natural complexity and dynamics in the study area. The confusion over terminology even leads to wrong policies on river management. For instance, many professionals and researchers in Taiwan considered biotope to be associated only with natural environment and argued that there is no biotope in the urban areas. As indicated above, biotope mapping is used as background for spatial planning. It provides important information for communicating with different parties who are involved in urban and regional planning, as well as between different professional categories of environment planning. This platform is an important base of integrated environmental planning to show the updatable status of habitats over time.

[1] Over 85% of the length of streams in the Keelung River catchment in Taipei City is categorized as being in very poor to highly degraded condition. About 80% of the lower Keelung River is in "poor" or "moderate to poor" condition, with over 80% of streams in man-made areas being in this category.

Secondly, a lack of methodology for evaluating the habitat functions causes a lag in showing the habitat-species-relationship in urban river areas. Although some studies have been carried out to assess the river condition in the last years in Taiwan, most of these studies were designed for sites upstream in rural areas or they lack biological information. Some studies have focused on the urban reach of the Keelung River, but mostly paid attention to preventing floods and resulted in suggestions for engineering priorities (e.g. river regulation, excavating river channel, embankments, etc.), which only promote channelization. The mismanagement of river environment leads to increased flooding and fragmented, unnatural habitats on riverbanks.

The third problem, also the core problem, lies in the increasing impact from human activities and urban development. The development on river environment was mostly guided by human demands (e.g. water supply, transportation, recreation, etc). This condition has caused the increase in the impermeable surfaces and surface-water runoff and has enhanced the risk of soil erosion. The natural vegetation cover is fragmented by man-made construction or even removed due to human demands. In brief, most of the studied areas in the lower Keelung River have lost the natural biotopes that provide the basic ecological services. With this in mind, the assets like the Guandu Wetland are central to recovery the river, and help to protect it from impacts. To bring it back to the natural condition as much as possible, i.e. rehabilitation appears to be the central issue in this study.

River rehabilitation is a major subset of river management that maintains or improves the in-stream and riparian environment (Rutherfurd et al., 1999). However, urban rivers are dynamic and unstable environments. The human impacts would continue changing the structure of the rivers. Furthermore, this kind of projects should be addressed by many experts (e.g. engineer, biologist, landscape planner, public-relations officer, etc.) in order to enhance the river condition with legislation, engineering works and long-term monitoring. Therefore, the details of remediation can not be totally dealt with in this study, instead the assets, problems and possible strategies are pointed out. The rehabilitation concepts emphasized that rehabilitation should have priority firstly in the areas with better condition. Therefore, paying attention to the current conditions and problems is a central premise of river rehabilitation.

The usual assumption of remediation is that the most obvious problems in the worst reach should be improved at first; however, an efficient project should be preserve the most biodiversity and natural habitats. That is, it is best to restore the river to its original condition by improving the most important aspects of river environment. When the major assets of the stream have been protected, then it is effective to improve the other stream condition (Lovett and Edgar, 2002). It would be easier to stop the river from deteriorating than it is to fix it. Furthermore, it would be valuable to protect the good river condition than to improve its damaged state. In other words, the areas with "high biological values (high species diversity areas and high quality habitats), imperilment and strategic opportunity" determine the conservation priorities (Efroymson et al., 2008). This concept also reflects to the criteria of habitat assessment. Moreover, the industrial areas with low ecological habitat value and apparently high ecological risk might be of a lower priority for remediation than a more natural area with lower apparent ecological risk but high ecological habitat value (Efroymson et al., 2008). Hence, the key priorities for the Keelung River attempt to preserve special habitats of rare or endangered bird species (some of them should be even protected by legislation), or to enhance and maintain the reaches in good condition at first. For example, the biodiversity and habitat functions would be saved based on this priority.

The downstream Keelung River has been thoroughly altered by dams and man-made constructions to prevent flooding and serve human demands. Hence it is difficult to define the limit, effect and achievable level of rehabilitation. The concepts of rehabilitation may not be appropriate for the river because inputs from the catchment will never support a natural environmental condition. The diversity of the riparian vegetation in the lower reaches has also been reduced. Among these lower sections, there are three sections (Annex C) that have been even straightened. The river ecosystem was consequently severely changed and therefore, it is difficult to restore it to its so-called "original condition". Thus, the requirements should be determined for maintaining or improving the inputs and outputs of the system (e.g. water quality and quantity, vegetation and animals), and for keeping the system in a health condition, not only from upper stream to lower reach, but also from in-stream to riparian areas. Thus, the targets for remediation in this case can be "to avoid increasing further damage to the river ecosystem", "to decrease the impact of rivers" and "to enhance and maintain the enable functions as habitats availability for wildlife".

The core of remediation in the lower Keelung River is, therefore, to return it to the natural state as far as possible, which is determined by the habitat demands for wildlife (e.g. habitat diversity, water quality and stability of channel). This kind of naturalness should be handled with sensitivity to the natural stream, i.e. to work with the stream, not against it. This requires an ongoing adjustment to the dynamic environmental characteristics, which should reflect nature's responses to human intervention in the river channel. The main strategies could be grouped into four parts: enhancement of habitat diversity in the river channel and riparian areas, improvement of water quality, appropriate land uses on the riverbanks (reduction of man-made construction), increase of the ratio of waste water treatment. Furthermore, some river rehabilitation principles should be considered to: "natural development", "free-flowing", "more ecology in settlement areas" and "let nature grow" (Zinke, 2000).

The increase of natural diverse vegetation cover at riversides should be the key aim to protect the river channel, and also to serve natural habitats for wildlife.

From these concepts, the priority categories of remediation on the lower Keelung River are listed in 5 schedules as shown in Table 7.1. They are based on two important principles: 1) The reaches in good condition are already protected and they should be preserved against potential threats and good habitats and species diversity should be maintained. 2) The reaches where endangered species or communities are found should have a higher priority.

Table 7.1: Possible concepts of remediation in the lower Keelung River (altered from Liang, 2001)

Habitat quality		Principles of management	Schedule of management	Strategies
Degree	**Condition**			
7	Excellent	Conservation: maintenance and preserve	Immediately long-term planning	1. set measure of nature conservation with legislation and policy (e.g. nature conservation area) 2. long-term research and monitoring for managing the database
6	Good	Rehabilitation, set measure and monitoring	Immediately long-term planning	1. passive environmental measures of rehabilitation 2. lessen impacts from human activities 3. limited development and land use in the urban river areas and source
5	Good-moderate			
4	Moderate	Rehabilitation and limited land use	Medium-term or short-term planning	1. passive environmental measures of rehabilitation 2. lessen the impacts and destroy from human activities 3. low density of natural resources use
3	Moderate-poor	Remediation and limited land use	Long-term planning	1. active environmental measures of remediation 2. reduce the impacts and destruction from human activities 3. middle density of natural resources use
2	Poor			
1	bad	Temporary discard	No plan temporarily	1. temporary discard of improving natural environment 2. altered and modified with other relevant planning, low priority

7.1.2 General Aspects for Single Sections

Three special cases that should be mentioned in the seven test areas. A moderate condition of habitat quality was indicated in Section I; however, no bird species have been recorded in this section. This causes the integrated assessment to drop on the scale to poor condition. The second special case is at Section II, which has poor habitat condition but represents good species condition. The third one Section V, which is located within the city centre. In this section, the river bears impact from both upstream and the neighbourhoods. Though there is no big quantity of bird species, all of them are residents, which even contain some endemic species. This situation provides a point to study further and creates an attractive environment for these species. The further studies for species-environment-relationship in the three sections should address the connection to the surrounding urban forest. Therefore, the measures to improve the habitat condition in each single section can be shown as follows.

The main requirements for improving the ecological in Section I and Section II are improving the habitat variety, composition of plants and water quality. Habitat diversity is associated with biodiversity, and the water quality is one of the important indexes to estimate the in-stream ecosystem. In Section III, the rehabilitation of the river by using man-made wetland (e.g. at Meiti Riverside Park) and more plant cover with native shrubs and vegetation may serve as a friendly environment for bird species. Regarding Section IV, in order to improve habitat quality, rehabilitation should focus on reducing the percentage of man-made areas and planting diverse native vegetation, as well as improving the water quality. Concerning the central part in Section V, the rehabilitation of the perch in this section could be achieved by improving the water quality and enhancing the biotope diversity for the specific native residents. Close to the confluence, Section VI shows strong characteristics as other tidal sections. Therefore, the water quality can be improved as an important perspective for enhancing the habitat functions. Increase the biotope diversity with replanting native species is also a key issue in Section VI. Section VII has the best asset (Guandu Wetland) in the lower Keelung River. However, water quality and composition of plants remain important for main aspects of rehabilitation for more diverse habitats for wildlife.

7.1.3 Special Aspects for Target Species

In this study, the evaluation of the habitat functions of urban rivers was based on information about bird species and populations. Urban birds are highly heterotrophic, mobile animals. Their multiple demands on places for forage, rest, breeding and refuge display the values of different habitats types (e.g. forage in the sky, wetland, grassland or field; rest on the branches of trees, and refuge from bad weather or floods in the forest) that they need diversity of habitats for their life cycle. The habitat diversity is reflected in the species diversity. The relationship between birds and their habitats, therefore, draws attention to composition and changes in urban ecosystem. The flood plains and wetland along the lower Keelung River may play an important role for wildlife habitats as well as serving other ecological functions, for example to use the natural water cycle to reduce the impacts of flooding, or to maintain the river ecosystem in urban biodiversity. However, the channelization and straightening of the stream have altered the hydrology and ecosystem of the river. For example, large areas of riverbanks have been consequently diked and drained. This construction not only leads to the removal of natural vegetation cover and lowering the landscapes, but they also tend to increase surface-water flow. The habitats are fragmented and isolated by dams and other man-made constructions. More than 70% of the natural flood plains have been lost due to the engineering construction projects. Broadly speaking, the main causes of all the problems in the lower Keelung River are the channelization and the uniformed water flow of the river. Although it is often overlooked, this leads to the degradation of the habitat diversity and further affects the diversity of species in the entire catchment area (i.e. the man-made constructions on the riverside parks). For the purpose of improving habitat functions, some target species can be selected to represent the environmental changes based on the strong species-habitat-relationship. The characteristics of target species and the selecting reasons are listed in Table 7.2.

Table 7.2: Target species for monitoring habitat functions of urban river

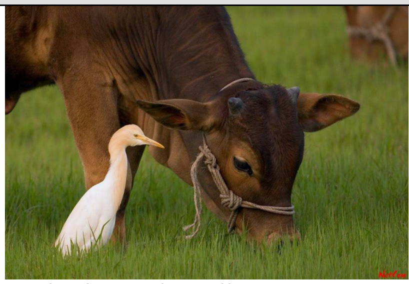
1. Cattle Egret (No. B0042)—test area: Meiti for richness					
Basic Information					
Family:	*Ciconiiformes/ Ardeidae*	**Scientific name:**	*Bubulcus ibis*	**English name:**	Cattle Egret
Residency:	Resident	**Status:**	IUCN: LC BridLife: LC	**Specific in TW:**	no
Population:	common	**Distribution (height):**	0-600 m	**Distribution in KR:**	2, **3**, **4**, 6, **7**
Habitat:	Wetland, farmland, grassland	**Feeding area:**	ground	**Food:**	Fish, insect, amphibian
Photo				**Reasons as target species**	
 Source: Netcam, 03/04/2005 (http://www.lancam.com.tw/v/netcam/)				• active in the entire reach of lower Keelung River • high-level species in food-chain • relationship with humans • bio-control of cattle parasite (e.g. ticks and flies)	
2. Black-faced Spoonbill (No. B0064)—test area: Guandu for rarity					
Basic Information					
Family:	*Ciconiiformes/ Threskiornithidae*	**Scientific name:**	*Platalea minor*	**English name:**	Black-faced Spoonbill
Residency:	Winter migrant	**Status:**	IUCN: EN BridLife: EN TW: ’05 **I**, ’08 **I**	**Specific in TW:**	no
Population:	rare	**Distribution (height):**	0-50 m	**Distribution in KR:**	7
Habitat:	wetland	**Feeding area:**	ground	**Food:**	Fish, insect, amphibian
Photo				**Reasons as target species**	
 Source: Netcam, 01/01/2007 (http://www.lancam.com.tw/v/netcam/)				• endangered species (only 2065 populations in 2008) • easy to watch and differentiate • banded and recorded as high-protected species in Taiwan • high-level species in food-chain	

Table 7.2: Continuance

3. Teal (No. B0071)—test area: Guandu for richness					
Basic Information					
Family:	*Anseriformes/ Anatidae*	**Scientific name:**	*Anas crecca*	**English name:**	Teal
Residency:	Winter migrant	**Status:**	IUCN: LC BridLife: LC	**Specific in TW:**	no
Population:	common	**Distribution (height):**	0-50 m	**Distribution in KR:**	**4, 6, 7**
Habitat:	Waterbody, wetland	**Feeding area:**	Freshwater surface	**Food:**	Aquatics
Photo				**Reasons as target species**	
 Source: Netcam, 05/11/2006 (http://www.lancam.com.tw/v/netcam/)				• first guest of winter migrant in Taiwan. Stay longest as well. (September to Marc of the next year) • easy to watch and differentiate	
4. Black Drongo (No. B0335)—test area: Guandu for uniqueness					
Basic Information					
Family:	*Passeriformes/ Dicruridae*	**Scientific name:**	*Dicrurus macrocercus*	**English name:**	Black Drongo
Residency:	Resident	**Status:**	IUCN: LC BridLife: LC	**Specific in TW:**	yes
Population:	common	**Distribution (height):**	0-50 m	**Distribution in KR:**	2, **3**, **4**, 6, **7**
Habitat:	Waterbody, wetland	**Feeding area:**	Freshwater surface	**Food:**	insect
Photo				**Reasons as target species**	
 Source: by Tsai, 20/04/2003 (http://www.flickr.com/photos/waders/)				• specific native species • higher alertness • human activities have strong impact on its living • easy to watch and differentiate	

Table 7.2: Continuance-2

5. Chinese Bulbul (No. B0381)—test area: Meiti					
Basic Information					
Family:	*Passeriformes/ Pycnonotidae*	**Scientific name:**	*Pycnonotus sinensis*	**English name:**	Chinese Bulbul
Residency:	Resident	**Status:**	IUCN: LC BridLife: LC	**Specific in TW:**	yes
Population:	common	**Distribution (height):**	0-2000 m	**Distribution in KR:**	2, **3**, **4**, **5**, **6**, **7**
Habitat:	Broadleaf forest, orchard, park, woodland	**Feeding area:**	Branch of trees	**Food:**	Seed, fruit, insect
Photo				**Reasons as target species**	
 Source: Netcam, 29/10/2006 (http://www.lancam.com.tw/v/netcam/)				• specific native species • active in cities • easy to watch and differentiate	
6. Crested Myna (No. B0481)—test area: Meiti for uniqueness					
Basic Information					
Family:	*Passeriformes/ Sturnidae*	**Scientific name:**	*Acridotheres cristatellu*	**English name:**	Crested Myna
Residency:	Resident	**Status:**	TW '08	**Specific in TW:**	yes
Population:	common	**Distribution (height):**	0-1000 m	**Distribution in KR:**	2, 3, 4, 6, 7
Habitat:	Town, farmland	**Feeding area:**	Sky, branch of trees	**Food:**	Seed, fruit, insect
Photo				**Reasons as target species**	
 Source: by Tsai, 11/04/2008 (http://www.flickr.com/photos/waders/)				• specific native species • the other same introduced genera cause crisis of this species • pet species since ancient period, the wild state should be observed	

7.1.4 Priority Setting

Based on the results of the seven test sections, the main problems in the lower Keelung River are unnatural biotope condition and vegetation cover low in diversity. The man-made environment appears to be a hostile habitat for wildlife. An overview of improvement recommendations is shown in Table 7.3 and Figure 7.1, which displays that the primary rehabilitation goal along the lower Keelung River is to protect the asset area (Guandu Wetland). It is a perspective to restore the present good state or to recover the river to its original condition in order to make the system useful to humans, flora and fauna. That is to say, the central issues of remediation are improving the ecological condition of rivers and preventing further damage to the river. This is important in order to enable and maintain the ecological functions along the heavily altered urban rivers like the lower Keelung River. Therefore, remediation is the priority in Section VII.

The Guandu Wetland in Section VII, which is a hotspot of bird species, has been preserved as a "core zone" by legislation for long-term observing since 1980's. The species diversity at Guandu is richest in the entire lower Keelung River. However, the rehabilitation project should also consider defining areas adjacent to the core zone as "buffer zones" (e.g. Linung and Shezi), where only limited development is allowed in order to protect the core zone. This hotspot of bird species should be protected tenaciously. It can serve as the major asset of the river ecosystem and should be preserved against potential threats. Moreover, it is an important stopover for migratory species for feeding, staging and resting. The protection of this wetland can: improve water quality and affect other reaches (i.e. adjacent lands and surface water bodies by removing toxicants entering aquatic ecosystems), reduce sediment loads, transform nutrients, and serve as a habitat (breeding, foraging, and resting) for wildlife (King et al., 2000; Rosensteel and Awl, 1995; Efroymson et al., 2008). In brief, the rehabilitation plan for Section VII can increase habitat functions, improve water quality and affect to other reaches.

The second priority goes to maintaining the good condition of the river and improving the deficits in Section VI, which has some good quality habitats close to Guandu but they are gradually deteriorating. The present condition in Section VI is at "moderate-poor". Some poor conditions could be easily fixed which would avoid the further degradation. The north part of this reach is still in moderate condition, where there are natural habitats for wildlife. Therefore, the north part of Section VI can be used as a buffer zone of Section VII, in order to prevent soil erosion and to increase the geodiversity would be the essential concerns.

Section I which ranks the third best condition, has a higher priority than that in the other sections close to the Central Business District (CBD). Nevertheless, no birds have ever been observed in this section. The main issues for this section are to explore the possibility for improving the natural environment for wildlife and to replant more native vegetation.

The evaluation results indicate that there is little benefit of remediation in the other four sections. The influence of urbanization on ecosystem can be grouped into three categories: changes of physical condition (decrease of natural habitats, man-made environment), impacts on flora and fauna (destruction of food chain, degrading of biodiversity, damage of landscape structure) and water pollution (sources from industrial waste water and drains from housing). Therefore, these four sections have similar problems and conditions to other urban rivers: poor water quality, homogeneous environment, poor vegetation cover on riverbanks, straightened channel with sediment deposition in the channel and severe impacts by human activities. The dikes, roads and walkways and the other man-made constructions cause fragmentation of natural habitats for wildlife and increase the proportion of impermeable surfaces. The fragmentation and destruction of habitats, which may decrease the biodiversity, must be addressed in order to improve the biodiversity and diversity of landscape. These two issues appear to be central to the discussion of the ecological functions. They are also at the core of many river management projects. Although the four sections have little value for rehabilitation, improving the poor plant composition and habitat variety with native plants would increase the ecological status. The favorite habitats for birds in the lower Keelung River are wetland, grassland, woodland, fresh water and shrubbery. Setting goals for remediation should address the current deficient state of the river, such as the poor vegetation cover and landscape structure. These may be the important aspects for rebuilding appropriate natural habitats for wildlife. Furthermore, the evaluation results could also reflect the findings of the case studies carried out in the upper stream by Yang (2001) and Lin (2001). Their results together with the findings of this study show that the entire Keelung River has been greatly altered by urban development. The fragmented habitats seem to be a central problem of the river ecosystem upstream as well as downstream.

Because the impacts of human activities have been identified as one of the original causes of the deterioration to natural river ecosystem, strategies should consider ways to change human behaviour that reduce their effects on habitat functions. Diversity of native vegetation cover is another key point for the lower Keelung River. The habitat diversity will increase the richness of species. Moreover, the stable structure of riverbanks would support stable channel sides, reduce soil erosion, as well as improve water quality.

Table 7.3: Proposal for rehabilitation priorities and strategies in the lower Keelung River

Priority	Measure*	State	Aspects to protect	Improvement	Possible strategies for enhancing habitat functions
1 Section VII	Rehabilitation	- good-moderate (32)	- special biotope: wetland - rich bird species, included some rare species	- diversity of vegetation cover (geodiversity) - water quality	- to reduce the unnecessary man-made construction on riverbanks - to increase the ratio of natural native plant species (revegetation) and to create a multifunctional habitat network for bird species - to reduce the impacts from human activities - to set the species-oriented habitat networks for endangered species
2 Section VI	Remediation	- moderate-poor (20)	- rich bird species, included some rare species	- soil erosion - diversity of vegetation cover	- to strengthen the river channel and riverbanks - to increase the ratio of natural native plant species (revegetation) and to create a multifunctional habitat network for bird species - prevent clearing or grazing of native vegetation - control input of fine sediment to the river
3 Section I	Rehabilitation	- moderate-poor (19)	- diversity of biotope types	- waste water treatment - diversity of vegetation cover	- to raise the ratio of waste water treatment. To identify the source and stop the addition of more pollution - to increase the ratio of natural native plant species (revegetation)/ naturalness and to create a multifunctional habitat network for bird species - prevent clearing or grazing of native vegetation
-- Section II	Remediation	- poor (12)	- diversity of bird species	- diversity of vegetation cover - waste water treatment	- to increase the ratio of natural native plant species (revegetation)/ naturalness and to create a multifunctional habitat network for bird species - to raise the ratio of waste water treatment. To identify the source and stop the addition of more pollution - prevent clearing or grazing of native vegetation
-- Section III	Remediation	- poor (12)	- diversity of bird species	- diversity of vegetation cover - soil erosion	- to increase the ratio of natural native plant species (revegetation)/ naturalness and to create a multifunctional habitat network for bird species - to strengthen the river channel and riverbanks - control input of fine sediment to the river
-- Section IV	Remediation	- poor (10)	- diversity of bird species	- diversity of vegetation cover - impact of human activities	- to reduce the unnecessary man-made construction on riverbanks - to increase the ratio of natural native plant species (revegetation)/ naturalness and to create a multifunctional habitat network for bird species - prevent clearing or grazing of native vegetation
-- Section V	Remediation	- moderate-poor (14)	- diversity of bird species - special native bird species	- water quality - diversity of vegetation cover	- to increase the ratio of natural native plant species (revegetation) and to create a multifunctional habitat network for bird species - to control the waste water before discharging into river. To identify the source and stop the addition of more pollution - prevent clearing or grazing of native vegetation - discourage construction of any structures across rivers

* habitat rehabilitation refers to the maintenance or improvement of habitat to its original natural condition (Rutherfurd et al., 1999)
habitat remediation means to treat the habitat returning to a former more favourable condition for wildlife.

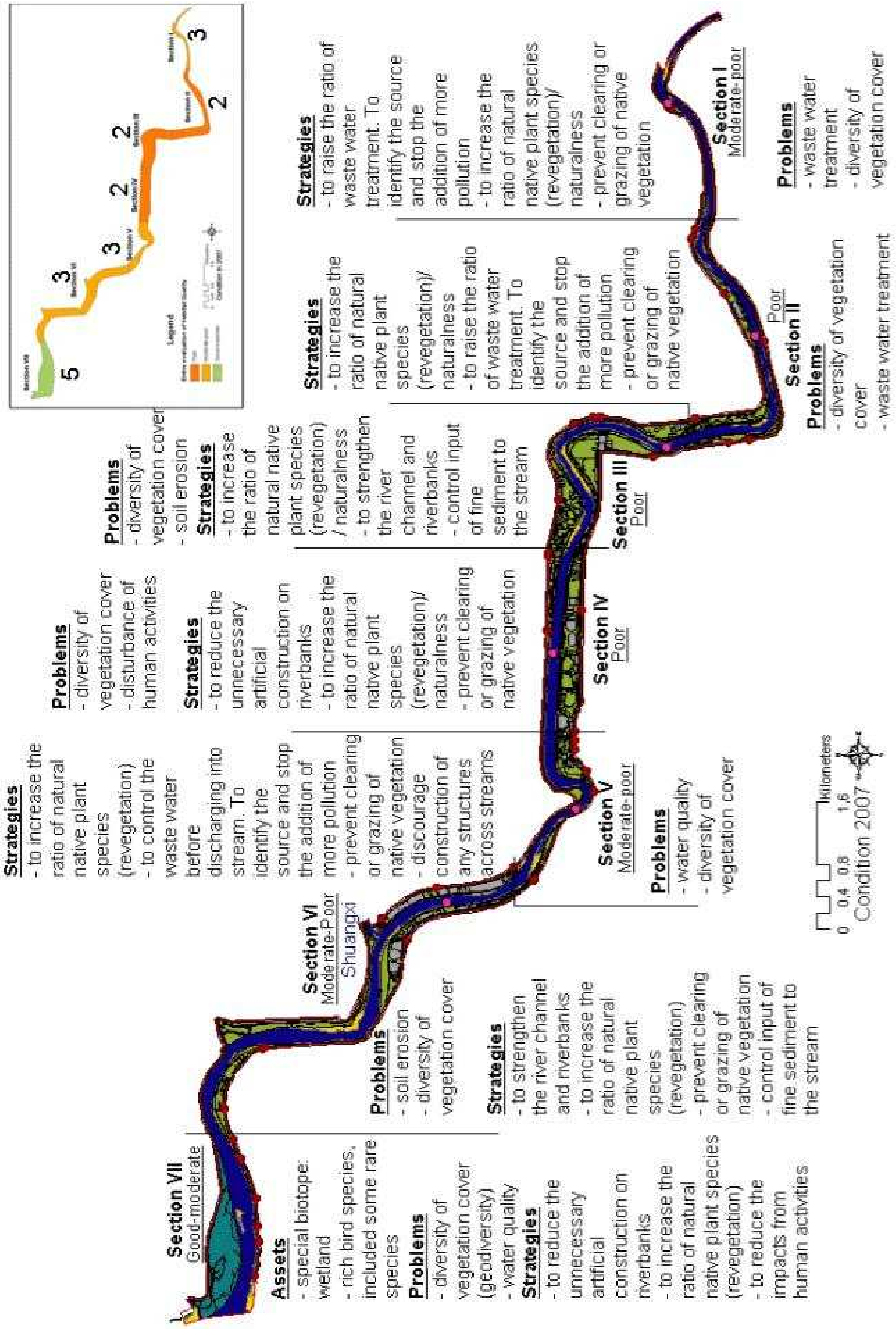


Figure 7.1: Problems, assets and possible strategies for remediation in the lower Keelung River

7.2 Methodological Limitation of the Study

There are several organisational limitations of the study. First, the official aerial photographs were not available due to national defence reasons. Therefore, the base maps were based on the aerial photographs from Google Earth. The impreciseness became apparent when trying to geo-reference the different coordinate systems. Much time was spent trying to alter the results of biotope maps geocoding to overlap with existing digital maps from previous studies. Furthermore, the study lacked sufficient budget and co-workers to carry out the field work. The ground truth could only substantiate rough classifications of data and the information about bird species was acquired from the second-hand data. Due to the data deficits, the spatial component of the results should be verified before using it as a standard. Furthermore, the analysis methodology holds shortcomings which could be systematically developed in future application. Thus, the main drawback is that the relationship of the vegetation structure to the specific species could not be determined in more detail in the study results. Nevertheless, this research provides a methodological approach with both of biotope classification and evaluation criteria, which can be improved and adapted to other similar cases of urban rivers.

The assessment of urban river ecosystem examines the components and changes of the river environment over time. Effective planning proposals require basic information about study areas. Further studies in urban river areas need more detailed information about biotope types, particularly about the structure of vegetation cover. CIR aerial photographs would provide a suitable basis for mapping the structure of vegetation cover. Furthermore, a biotope classification of the entire city is needed in order to establish a database for spatial planning and nature conservation. The essential procedure of biotope classification is listed in Table 7.4.

Table 7.4: Concepts and procedure of biotope mapping in urban area (revised by Müller and Fujiwara, 1998)

Data	Work
Base maps	Mapping of land use by aerial photographs in a larger scale, especially in the high-biodiversity areas
Biotope maps	Representative fauna and flora on the basic maps to show the structure of vegetation cover by field work. Some target species both of plant communities and animal populations can be indicated in this phase.
Evaluation and display	Based on the specific mapping guidelines can show the worth biotopes of protection and the important land use for nature conservation in cities (priority of rehabilitation or preservation). This evaluation can be displayed on biotope maps.
Suggestion	According to the biotope maps and evaluation to recommend the viewpoints of natural conservation and spatial planning. This procedure for suggestion is a dynamic planning process; the detailed may be changed by time and space.

Future studies should also address the development of evaluation criteria. Some of the qualitative indicators used in this study are depended on the results of field work, which may need to be modified for specific cases. Furthermore, more attention needs to be given to the statistical analysis of the quantitative indicators (e.g. correlation coefficient for biodiversity of birds and their habitat condition). However, the approach of PSR framework used in this study could be applied to other similar cases in urban rivers for developing the environmental impacts assessment and its remediation targets.

7.3 Application of the Concept to Other Urban Rivers in Taiwan

Studies of urban ecosystem should address four aspects of environmental planning:

1) to supply information on environmental problems in order to enable policy-makers/planners to evaluate the impacts,

2) to provide policy development and priority setting by identifying the causes of pressure on the environment,

3) to have long-term monitoring on pressures, their impacts and effectiveness of policy responses,

4) to promote public awareness of environmental issues, which is the most difficult and important part to reduce impacts and increase effects of policy responses.

This study supports a new concept of measuring habitat functions in urban river areas. The methodologies of developing a database and evaluation criteria can contribute to further studies and policy development.

For instance, the discussion of biodiversity issue may require new approaches in Taiwan. The findings indicate that biotopes are demarcated areas which represent the cartographic spatial perspective (e.g. characteristics of flora and fauna) and provide ecological context of the landscape. Thus, they can provide a valuable basis for planning decisions (Löfvenhaft et al., 2002). This investigation is a pilot study with a specific focus on a river basin in Taiwan that attempts to establish the biotope classification based on a discussion of the habitat functions of urban rivers. The concepts of biotope mapping serve as a framework to survey the physical condition in urban river areas. Biotope classification can be used to establish a database of an entire river and even in the whole city. The approach of biotope classification could be further developed in Taiwan in order to supplement the existing information with more detailed and systematic mapping of species.

Accordingly, the results of biotope classification can contribute to national projects that support and maintain biodiversity in Taiwan. The central government in Taiwan has begun to recognize the need to protect and increase biodiversity in Taiwan. In 2001 they established a central database about biodiversity which is called TaiBNET[2] (Taiwan Biodiversity National Information Network). The database of TaiBNET is becoming increasingly rich and systematized. The first integrated report was

[2] More data can be found on TaiBNET, available from: http://www.taibif.org.tw.

released in the end of 2008. With the development of this database, the evaluation framework of habitat functions could be altered and updated over time and adapted into difference study areas.

Furthermore, in two main projects, “Species 2000” and “ITIS (Integrated Taxonomic Information system)”, a “Catalogue of Life in Taiwan” was developed by Biodiversity Research Center of Academia Sinica, National Science Council and Council of Agriculture, Executive Yuan in Taiwan from 2004. The TBIF (Taiwan Biodiversity Information Facility) has also been established as a national node of the GBIF (Global Biodiversity Information Facility) and has played an important role in enriching biodiversity and improving ecosystem functions in the past years. Moreover, the evaluation framework and study results may be expected to provide useful information and develop priority setting in decision-making processes for the rehabilitation of the lower Keelung River as well as river basin management in Taiwan. On the basis of urban ecology and river management, the results obtained from this study may have several applications both for biotope classification and ecological assessment of urban rivers. However, the projects of river basin management fall into categories of river resources management, water quality improvement, habitat quality, nature conservation, recreation, flood protection, and other aspects. Successful planning in these areas depends on cooperation with different professionals groups. These results lead to the conclusion that multiple and integrated project needs a team across different parties and specialized fields. The successful projects should be carried out by government foundation.

Finally, the success of a long-term project to maintain urban biodiversity is influenced by impacts from citizen. How people use and develop rivers should be changed. Otherwise, human activities may hinder the rehabilitation of river areas. Therefore, the relationship between human and environment, which influences wildlife habitats, should be considered in order to maintain the valuable ecological functions of urban rivers. Thus, the changes of ecological services may easily affect from one part to other livelihood parts, as well as represented in economic and social benefits (Koehn et al., 2001).

Reference

Apan, A.A., S.R. Raine, M.S. Paterson, (2002), Mapping and analysis of changes in the riparian landscape structure of the Lockyer Valley catchment, Queensland, Australia, Landscape and Urban Planning, Vol. 59, p.p. 43-57.

Biber, E., (2002), Patterns of endemic extinctions among island bird species, *Ecography*, Vol. 25, No., 6, p.p.661-676.

Bierhals, E., O. v. Drachenfels, and M. Rasper, (2004), Wetstufen und Regenerationsfähigkeit der Biotopetypen in Niedersachsen, Inform.d. Naturschutz Niedersachsen, Jg. 24, s. 231-240.

BirdLife International (2003) available from, http://www.birdlife.net

Borja, A., et al., (2006), The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status. Estuar Coast Shelf Sci., Vol., 66, p.p. 84-96.

Bowen, R.E., C. Riley, (2003), Socio-economic indicators and integrated coastal management, Ocean Coast Management, p.p. 299-312.

Bryant, M. M., (2006), Urban landscape conservation and the role of ecological greenways at local and metropolitan scales, Landscape and Urban Planning, Vol. 76, p.p. 23-44.

Bruns, E. (2007), Bewertungs- und Bilanzierungsmethoden in der Eingriffsregelung – Analyse und Systematisierung von Verfahren und Vorgehensweisen des Bundes und der Länder, Ph.D. dissertation, Fakultät VI der Technische Universität Berlin.

Butler, D. R. (2001), Geomorphic process-disturbance corridors: a variation on a principle of landscape ecology, Progress in Physical Geography, Vol. 25, No. 2, 237-248.

Central Weather Bureau, available from: http://www.cwb.gov.tw/V5/index.htm.

Chang, H. S. (2001), A study on development and management of environmental sensitive area in Taiwan, Conference of 21st Century environmental development in south Taiwan, p.p. 392-407.

Chang, W. C. (2004), A Study on of the Urban River renovation policy through All Things on Earth Environmental Symbiosis Concept – A Case study of the Kee Lung river in Taipei City, Master thesis, Institute of Architecture and Urban planning, Chinese Culture University.

Chen, K. T., (2001), A Landscape Ecology Approach to Establishing the Evaluation Method of River Corridor, Master Thesis, Department of Horticulture at National Chung Hsing University, P.77.

Chen, Y. D., (2002), Water Protected Area Planning in Keelung River Based on the Strategy of the Integrated Watershed Management, Master thesis, Institute of Natural Resource Management, National Taipei University.

Chen, S. C., (2008), Ecological Assessment and Integrated Effective Index of Reservoir Watershed, Workshop of conservation and operation in Shihmen Reservoir.

Chiesura, A., (2004), The role of urban parks for the sustainable city, Landscape and Urban Planning, Vol. 68, p.p. 129-138.

Chinese Institute of Landscape Architecture in Taiwan (2003), A Study on Planning of urban ecosystem and principles of ecological design in Taipei City: basic concepts and principles, authorized by Department of Urban Development, Taipei City Government.

Chou, W.-C. and M.-D. Chuang, (2010), Habitat evaluation using suitability index and habitat type diversity: a case study involving a shallow forest stream in central Taiwan, Environmental Monitoring and Assessment

Chu, T. J., (2006), An Approach to stream Integrity Assessment Model, Journal of specific species, Vol. 8: 35-56., Endemic Species Research Institute, Taiwan.

Collar, N.J., (2004), Endemic Subspecies of Taiwan birds – first impression, BirdingASIA No. 2.

Commonwealth of Massachusetts, available from: http://www.mass.gov/?pageID=mg2homepage&L=1&L0=Home&sid=massgov2

Copp, G. H., (1991), Typology of aquatic habitats in the great ouse, a small regulated lowland river, Research and Management, Vol. 6: 125-134.

Connor, D. W. et al., (2004), The marine habitat classification for Britain and Ireland: Introduction (Version 04.05), Institute of coastal and estuarine studies, University of Hull. ISBN: 1 861 07561 8

Cousins, S.A.O., M. Ihse, (1998), A methodological study for biotope and landscape mapping based on CIR aerial photographs, Landscape and Urban Planning Vol.41, p.p. 183-192.

Crosa, G., S. Villa and M. Cotta- Ramusino, (2002), Local versus longitudinal biological variability in a high gradient stream, Hydrobiologia, Vol. 477: 107-114.

Curry, R., (1972), Rivers – a Geomorphic and Chemical Overview, p.p. 9-31, In: River Ecology & Man, Academic Press, NY.

Dauber, J. and V. Wolters, (2004), Edge effects on ant community structure and species richness in an agricultural landscape, Biodiversity and Conservation 13: 901–915.

Department of Urban Development, Taipei City Government, available from: http://www.udd.taipei.gov.tw/PlanWeb/Index.aspx

Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (DVWK) (Hrsg.), (1996), *Fluss und Landschaft, Ökologische Entwicklungskonzepte*, Ergebnisse des Verbundforschungsvorhabens „Modellhafte Erarbeitung ökologisch begründeter Sanierungskonzepte für kleine Fließgewässer“, Bonn.

Digital Museum of Zoology, National Taiwan University, available from: http://archive.zo.ntu.edu.tw/index1.htm

Drachenfels, O. von (2004), Kartierschlösser für Biotoptypen in Niedersachsen, Naturschutz und Landschaftspflege in Niedersachsen.

Duel., H., G.E.M. van der Lee, W.E. Penning and M.J. Baptist, (2003), Habitat Modeling of Rivers and Lakes in the Netherlands: an Ecosystem Approach, Canadian Water Resources Journal Vol., 28: 1-17

Dunn H. (2000), Identifying and Protecting Rivers of high Ecological Value, LWRRDC Occasional Paper 01/00, Australia.

Efroymson, R. A. et al., (2008), Investigating habitat value to inform contaminant remediation options: Approach, Journal of Environmental Management, Vol. 88: 1436-1451.

Endemic Species Research Institute, available from, http://www.tesri.gov.tw

Eng, M., (1997), Spatial Patterns and Landscape Ecology, Implications for Biodiversity, Management Concepts in Landscape Ecology, Ministry of Forests Research Program, British Columbia.

Endemic Species Research Institute, available from: http://tesri.coa.gov.tw/show_index.php

Environment Protection Administration, Taiwan, available from: http://wq.epa.gov.tw/wq/Public2/ImageBasin.asp

Environment Protection Data in Taiwan, available from: http://edb.epa.gov.tw/engenvdb2/

European Union available from: http://ec.europa.eu

Environmental Water Quality Monitoring and Information System, Taiwan, available from: http://wqshow.epa.gov.tw/

Eric J. Gustafson, George R. Parker, (1994), Using an index of habitat patch proximity for landscaped design, Landscape and Urban Planning, 29: 117- 130

European Environment Agency (EEA), (2002), DPSIR framework for State of Environment Reporting, based on Global International Waters Assessment (GIWA), 2001, Copenhagen.

Findlay, S. J. and M. P. Taylor (2006), why rehabilitate urban river systems?, Journal Area, Vol. 38: 312-325.

Forestry Bureau, (2008), Schedule of Protected Species, http://conservation.forest.gov.tw/mp.asp

Forman, R.T.T. and Godron, M. 1986. Landscape ecology. John Wiley & Sons Inc., New York.

Forman, R.T.T, (1995), Some general principles of landscape and regional ecology. *Landscape. Ecol.* 10 (1995), pp. 133–142.

Fu, B. J. et al., (2006), Evaluating change in agricultural landscape pattern between 1980 and 2000 in the Loess hilly region of Ansai County, China, Agriculture, Ecosystems and Environment, Vol. 114, p.p. 387-396.

Fang, W. T., K. S. Loh, T. K. Chang, (2005), A Pondscape Design of Wintering Avian Refuges on Rice Fields, Conference of Agriculture Engineering.

Gabrielsen, P. and P. Bosch, (2003), Environmental Indicators: Typology and Use in Reporting, EEA Internal Working Paper, European Environment Agency.

Getzner, M. and M. Jungmeier, (2002), Conservation policy and the regional economy: the regional economic impact of Natura 2000 conservation sites in Austria, Journal for Nature Conservation, Vol. 10, p.p. 25-34.

Glaser, F. F., M. Düvel, G. Weyer, T. Frey, (1994), Beschreibung der Kartiereinheiten und Luftbildinterpretationsschlüssel Freistaat Sachsen, Gesellschaft für Luftbildinterpretation mbH, Büro Dresden.

Glossary by National Geographic (2001), available from: http://www.nationalgeographic.com/

Grabherr, G., G. Koch, H. Kirchmeir, K. Reiter, (1999), HEMEROBY OF AUSTRIAN FOREST ECOSYSTEMS, Uni. Wien.

Gregory, R. D. et al., (2005), Developing indicators for European birds, Phil. Trans. R. Soc. B, 360: p.p. 269-288.

Groot, R. de, (2006), Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes, Landscape and Urban Planning, Vol. 75, Issue 3-4, p.p. 175-186.

Gustafson, E., G. R. Parker, (1994), Using an index of habitat patch proximity for landscape design, Landscape and Urban Planning, Vol. 29, p.p. 117-130.

Guth, J., T. Kucera, (2005), Natura 2000 habitat mapping in the Czech Republic: Methods and general results, Ekológia, vol. 24, p.p. 39-51.

Haaren, C. v. (Hrsg.), (2004), Landschaftsplanung, P.528, Ulmer UTB.

Haaren, C. v. and M. Reich, (2006), Tue German way to greenways and habitat networks, Landscape and Urban Planning, Vol. 76, p.p. 7-22.

Haasnoot, M., H. Duel, G.E.M. van der Lee, M.J. Baptist, D.T. van der Molen & M. Platteeuw, (2004), Impact of climate change and anticipating flood management strategy on floodplain ecosystems of the river Rhine, The Netherlands. In D Garcia de Jalon & P Vizcaino Martinez (Eds.), Proceedings of the 5th International Symposium on Ecohydraulics (pp. 1389-1393). Madrid, Spain: IAHR.

Haeupler, H. (2002), Die Biotope Deutschland, In *Schriftenreihe für Vegetationskunde*, p.p. 247-272, Bundesamt für Naturschuz, Bonn.

Hartley, S. and W. E. Kunin, (2003), Scale Dependency of Rarity, Extinction Risk, and Conservation Priority, Conservation Biology, Vol. 17, p.p. 1559-1570.

Heggem, D. T., C. M. Edmonds, A. C. Neale, L. Bice and K. B. Jones, (2000), A Landscape Ecology Assessment of the Tensas River Basin, Environmental Monitoring and Assessment, Vol. 64, p.p.41-54.

Heink, U. and I. Kowarik, (2010), What are indicators? On the definition of indicators in ecology and environmental planning, Ecological Indicators, Vol. 10, p.p. 584-593.

Henle, K. et al., (2006), Study Design for Assessing Species Environment Relationships and Developing Indicator Systems for Ecological Changes in Floodplains – The Approach of the RIVA Project, Internat Rev. Hydrobiol. Vol. 91 Issue 4, p.p. 292-313.

Hess, G. R., R. A. Fisher, (2001), Communicating clearly about Conservation Corridors, Landscape and Urban Planning Vol. 55, p.p. 195-208.

Hill, M. O., D. B. Roy, K. Thompson, (2002), Hemeroby, Urbanity and Ruderality: Bioindicators of Disturbance and Human Impact, The Journal of Applied Ecology, Vol. 39, No. 5, p.p. 708-720

Hobbs, R., (1997), Future landscapes and the future of landscape ecology, Landscape and Urban Planning, Vol. 37, p.p. 1-9.

Hong, S. K. et al., (2004), Ecotope mapping for landscape ecological assessment of habitat and ecosystem, Ecological Research Vol. 19, p.p. 131-139.

Hong, S.K., et al., (2005), Application of biotope mapping for spatial environmental planning and policy: case studies in urban ecosystem in Korea, Landscape Ecology, p.p. 101-112.

Hydraulic Engineering Office, Taipei City Government, available from: http://english.taipei.gov.tw/heo/

Ignatieva, M., C. D. Meurk and C. Newell, (2000), Urban biotopes: The typical and unique habitats of city environments and their natural analogues, In G. H. Stewart and M.E. Ignatieva (Eds.), *Urban biodiversity and ecology as a basis for holistic planning and design: Proceedings of a workshop held at Lincoln University*, 28-29 October 2000, p.p. 46-53. Christchurch, New Zealand: Wickliffe Press.

Integrated Management of Keelung River, available from: http://keelung.wra.gov.tw/

International Association of Landscape Ecology (IALE), available from: http://www.landscape-ecology.org/

IUCN (2006), Guideline for Using the IUCN Red List Categories and Criteria, Version 6.1.

Jago-On, et al., (2009), Urbanization and subsurface environmental issues: An attempt at DPSIR model application in Asian cities, Science of the Total Environment, p.p. 2089-3104.

Jarvis, P.J. and C. H. Young, (2005), The Mapping of Urban Habitat and its Evaluation, A Discussion Paper prepared for the Urban Forum of the United Kingdom Man and the Biosphere Programme, School of Applied Sciences University of Wolverhampton.

Jax, Kurt (2005), Function and "Functioning" in ecology: what does it mean?, OIKOS, Vol. 111, p.p. 641-648.

Jian, J. Sh..and F. L. Fong (2002), Analysis on long-term landscape pattern in areas of Guandao River, Research of Specific Species, Vol. 4, p.p. 75-85.

Jim C. Y. and W. Y. Chen, (2008), Pattern and divergence of tree communities in Taipei's main urban green spaces, Landscape and Urban Planning, Vol. 84, p.p. 312-323.

Jongman, R. H.G., (1995), Nature conservation planning in Europe: developing ecological networks, Landscape and Urban Planning, Vol. 32, p.p. 169-183.

Jongman, R. H.G., M. Külvik, I. Kristiansen, (2004), European ecological networks and greenways, Landscape and Urban Planning, Vol. 68, p.p. 305-319.

Karr, J. R. and D. R. Dudley, (1981), Ecological perspective on water quality goals, Environmental Management, Vol. 5, p.p. 55-68.

Kim, H. O. *et al.*, (2005), Different Approaches for Urban Habitat Type Mapping – The Case Study of Berlin and Seoul, Proceedings of the ISPRS joint conference.

Kim, H. O., (2007), Beitrag sehr hochauflösender Satellitenfernerkundungsdaten zur Aktualisierung der Biotop- und Nutzungstypenkartierung in Stadtgebieten – Dargestellt am Beispiel von Seoul, Doktoranden Dissertation, TU Berlin, P.153

Kim, Y. M. (2001), Untersuchung von Flora, Vegetation und Biotoptypen in der dörflichen Kulturlandschaft Koreas, Doktoranden Dissertation, TU Berlin, P. 223

Koehn, J.D. et al. (2001), River Restoration Framework, Water Australia Occasional Paper 01/01, The National Rivers Consortium, Australia.

Koh, C.-N., P.-F. Lee and Ch.-R. Chiou, (2008), Influences of Fragment Size, Isolation and Habitat Heterogeneity on Bird Assemblage Composition in Urban Landscapes – A Case Study of Taipei Parks and Green Areas, Journal of City and Planning Vol. 35, No.2, p.p. 141-154.

Kowarik, I. (1988): Zum menschlichen Einfluß auf Flora und Vegetation. Theoretische Konzepte und ein Quantifizierungsansatz am Beispiel von Berlin (West). Landschaftsentwicklung und Umweltforschung 56, 280 S.

Kommissionsvertrieb Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH (1996), Fluss und Landschaft- Ökologische Entwicklungskonzepte, Bonn.

Kristensen, P., (2004), The DPSIR Framework, Oral presentation at Workshop on a Comprehensive/detailed Assessment of the Vulnerability of Water Resources to Environmental Change in Africa using River basin Approach, Nairobi, Kenya. P.10.

Kuebler, K., U. Ammer, P. Reinartz and R. Mueller, (1991), Classification of biotope types with airborne multispectral scanner data, IEEE.

Kurz, H. (1998), Aktuelle Entwicklungen in der Bewertung von Biotoptypen, Vortrag gehalten auf dem VSÖ-Seminar „Aktuelle Bewertungssysteme in der Naturschutzfachlichen Planung", Büro für Biologische Bestandsaufnahmen.

Langanke, T., C. Burnett , S. Lang, (2006), Assessing the mire conservation status of a raised bog site in Salzburg using object-based monitoring and structural analysis, Landscape and Urban Planning, Vol. 79, p.p. 160-169.

Large, A.R.G. and G.E. Petts, (1996), Historical channel-floodplain dynamics along the river Trent: Implications for river rehabilitation, Applied Geography, Vol. 16, p.p. 191-209.

Laws and Regulations Database of The Republic of China, available from: http://law.moj.gov.tw/eng/

Legal Intelligence of the Digital Age, available from: http://www.lawbank.com.tw/index.php.

Lee, S. W. et al., (2008), Relationship between landscape structure and neighborhood satisfaction in urbanized areas, Landscape and Urban Planning, Vol. 85, p.p. 60-70.

Leitao A. B., (2002), Applying landscape ecological concepts and metrics in sustainable landscape planning, Landscape and Urban Planning, 59: 65-93.

Lin, Y. F. et al., (2000), A Study on the Cultural Environment of Keelung River in Taipei, practical project at Graduate Institute of Urban Planning, National Taipei University, Taiwan (granted by Taipei City Government)

Li, Y.-S. (2007), Assessment of the Healthy River Habitat in Urban Area: A Case Study on Fazih River, Master Thesis, Graduate School of Architecture and urban Design, Chaoyang University of Technology.

Li, M. H. and N. Kräuchi (2004), Using a combined index of native and non-native plant diversity for estimating ecosystem and environmental change over time and space, Bridging Scales and Epistemologies Conference, Millennium Ecosystem Assessment Alexandria, Egypt (CD-ROM): 1-20. Online available: www.millenniumassessment.org/documents/bridging/papers/li.maihe.pdf

Lin, J. Y., Y. Ch. Chen, M. Sh. Wu (2004), Stream Ecological Engineering Methods, Mingwen Bookshop, Taipei

Lin, Shin-Hwei, J. J. Chang (2005), Landscape Ecology and Vegetation Engineering, Mingwen Bookshop, Taipei

Lin, SH. Y. (2005), A Landscape Ecology Approach to Leisure Agriculture Planning in Keelung River Basin, Master Thesis, Institute of Natural Resource Management, National Taipei University.

Lin, T. P. (2001), A Study on Urban Water Cycle─The Investigation on the Percentage of Imperviousness and the Experimental Analysis of Surface Runoff, PhD Dissertation, Department of Architecture, National Chen-Kung University.

Lin, W. J. (2001), River Corridor Planning Based on Ecological Perspectives – A Case Study on Keelung River, Master Thesis, Institute of Natural Resource Management, National Taipei University.

Lin, Y. F. (2002), *A Study on the Measurement of Bio-cybernetic Evaluation of Sensitivity Model*, Master Thesis, National Taipei University, Taiwan. p.165.

Liro, A. (1999), The Linkages between NATURA 2000, ECONET/PEEN and rural development plans, NATURA 2000, Rural development and ecological networks, Warsaw.

Literature Database of Native Plants in Taiwan, available from: http://db1n.sinica.edu.tw/textdb/hast/literature_q.php, http://webgis.sinica.edu.tw/website/plant/viewer.htm

Local Environmental Database (Taiwan), available from: http://edb.epa.gov.tw/localenvdb/index.asp?theme=blue

Löfvenhaft, K., C. Björn, M. Ihse (2002), Biotope patterns in urban areas: a conceptual model integrating biodiversity issues in spatial planning, Landscape and Urban Planning, Vol. 58, p.p. 223-240.

Lovett, S. and B. Edgar, (2002), Planning for river restoration, Fact Sheet 9, Land and Water Australia, Canberra

Lu, A. H., C. Chen, (2006), A Study on Bird Diversity and Landscape Diversity: Case Study on rural Ditch Landscape in Wuggo Village, Pingtung, Journal of Architecture, No. 57, p.p. 123-141, Taiwan.

Machado, A., (2004), An index of naturalness, Journal for Nature Conservation, 12: 95-110

Maddock, I., (1999), The importance of physical habitat assessment for evaluating river health, Freshwate Biology, Vol. 41, p.p. 373-391.

Mander Ü. et al., (2005), Earth observation methods for habitat mapping and spatial indicators for nature conservation in Europe, Journal for Nature Conservation, Vol. 13, p.p. 69-73.

Mason, B., R. Knight, (2002), Sensitive Habitat Inventory and Mapping, Community Mapping Network, Vancouver, British Columbia, M. Johannes, Editor.

McCleary, K. and G. Mowat, (2002), Using forest structural diversity to inventory habitat diversity of forest-dwelling wildlife in the West Kootenay region of British Columbia, B.C. Journal of Ecosystems and Management, Vol. 2, No. 2, p.p. 1-13.

McConnachie, D.P. et al., (2002), Mapping Biotopes of Regulated River Corridors using GIS, Remote Sensing, and Decision Tree Analysis, Kungl Tekniska Högskolan, Master Thesis, p.73.

McConnachie, D. (2002), Mapping Biotopes of Regulated River Corridors using GIS, Satellite Remote Sensing and Decision Tree Analysis, Master Thesis, Royal Institute of Technology in Stockholm.

McLea, M., (2000), Using River Habitat Classification in Regional Plans, Ministry for the Environment, New Zealand. (available from: www.mfe.govt.nz/publications/water/river-habitat-mar00/index.html)

Mueller, N. (1998), Assessment of Habitats for Nature Conservation in Japanese Cities – Procedure of a Pilot Study on Biotope Mapping in the Urban Agglomeration of Tokyo, In: Breuste, J., H. Feldmann, O. Uhlmann (Eds.) Urban Ecology.

Mueller, N., K. Fujiwara (1998), Biotope Mapping and Nature Conservation in Cities – Part 2: Results of Pilot Study in the Urban Agglomeration of Tokyo (Yokohama City), Bull. Inst. Environ. Science & Technology, Yokohama Nat. Univ. 24/1 : 97-119.

Multilateral (1992), Convention on Biological Diversity, concluded on 5. June 1992, registered on 29. December 1993.

Müssner, R. and H. Plachter, (2002), Methodological standards for nature conservation: case-study landscape planning, Journal for Nature Conservation, Vol. 10, p.p. 3-23.

Newson, Malcolm, (1992), Land, Water and Development: River Basin Szstems and their sustainable Management, Rouledge, London.

Newson, M.D., and C.L. Newson, (2000), Geomorphology, ecology and river channel habitat: mesoscale approaches to basin-scale challenges, Progress in Physical Geography, Vol. 24: 195-217.

Niemelä, J., (1999), Ecology and urban planning, Biodiversity and Conservation, Vol. 8, p.p. 119-131.

Niemelä, J., (2000), Biodiversity monitoring for decision-making, Ann. Zool. Fennici., Vol. 37, p.p. 307-317.

O'Brien, R., (1999), GIS techniques for developing a habitat classification for rivers, the 11th Annual Colloquium of the Spatial Information Research Centre, University of Otago, Dunedin, New Zealand.

Olenin S. and D. Daunys, (2004), Coastal typology based on benthic biotope and community data: The Lithuanian case study, In: G. Schernewski and M. Wielgat (eds.): Baltic Sea Typology, p.p. 65-83.

Olenin, S. and J.-P. Ducrotoy, (2006), The concept of biotope in marine ecology and coastal management, Marine Pollution Bulletin, Vol. 53: 20-29.

O'Brien, R., (1999), GIS techniques for developing a habitat classification for rivers, Presented at SIRC 99: The 11th Annual Colloquium of the Spatial Information Research Centre University of Otago, Dunedin, New Zealand.

Paul, M. J. and J. L. Meyer, (2001), Streams in the Urban Landscape, Annual Review of Ecology and Systematics, Vol. 32, p.p. 333-365.

Pellaud, M., (2007), Ecological response of a multi-purpose river development project using macro-invertebrates richness and fish habitat value, doctoral dissertation, University of Genève.

Peter Berthold, (2007), *Vogelzug: Eine aktuelle Gesamtübersicht*, 5. Aufl., Darmstadt.

Pickett, S. T.A. *et al.*, (2001), Urban Ecological System: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas, Annual Review of Ecology and Systematics, Vol. 32, p.p. 127-157.

Pintér, L, K. Zahedi and D.R. Cressman, (2000), Capacity Building for Integrated Environmental Assessment and Reporting, United Nations Environment Programme, International Institute for Sustainable Development, Pages158.

Platt, R. H., (2006), Urban Watershed Management – sustainability, one stream at a time, Environment, Vol., 48, Number 4, p.p. 26-42.

Poff, N.L., M.M. Brinson, J.W. Day, Jr., (2002), Potential impacts on inland freshwater and coastal wetland ecosystems in the United States, Prepared for the Pew Center on Global Climate Change, U. S.

Roy, D. B., M. O. Hill, P. Rothery, (1999), Effects of Urban Land Cover on the Local Species Pool in Britain, Ecography, Vol. 22, No. 5, p.p. 507-515

Rutherfurd, I. D., D. Jerie and N. Marsh, (2000), A Rehabilitation Manual for Australian Streams Vol. 1, Land and Water Resources Research and Development Corporation, Clayton, Australia,

Rutherfurd, I. D., D. Jerie and N. Marsh, (2000), A Rehabilitation Manual for Australian Streams Vol. 2, Land and Water Resources Research and Development Corporation, Clayton, Australia,

Sandström, U. G., P. Angelstam, G. Mikusinski, (2006), Ecological diversity of birds in relation to the structure of urban green space, Landscape and Urban Planning, Vol. 77, p.p. 39-53.

Schneiderbruber, M., M. Cierna and T. Jones, (2004), *Living with floods*: Achieving ecologically sustainable flood management in Europe, Policy Briefing, WWF European Policy Office, Belgium.

Sewage Systems office, Taipei City Government, available from: http://english.taipei.gov.tw/sewage/index.jsp

Shiao, available from, http://www.lancam.com.tw/v/netcam/

Stream Ecosystem Education Website, Taiwan, available from: http://www.ecowindow.com.tw/river/index.htm

Source of birds Netcam, available from: http://www.lancam.com.tw/v/netcam/

Su, Ying-Ming, H. Y. Lian, (2005), The Study of the Planning Authority of Accessible Waterfront from the Viewpoint of Sustainability, Learned Journal of National Taipei Technical University Vol. 38, Issue 2, p.p. 55-76.

Sukopp, H., S. Weiler, (1988), Biotope Mapping and Nature Conservation Strategies in Urban Areas of the Federal Republic of Germany, Landscape and Urban Planning, Vol. 15, p.p. 39-58.

Sustainable Management of Urban Rivers and Floodplains (SMURF), available from: http://www.smurf-project.info/index.html

Tang, T. T. (1997), Assessment Framework for River Ecological Quality based on Ecosystem Integrity, Master Thesis, Institute of Natural Resource Management, National Taipei University.

Taiwan Biodiversity Network, available from: http://www.tbn.org.tw/

Taiwan Endemic Species Research Institute, available from: http://cec.tesri.gov.tw/cec/index.php

Tanner, C. D. and R. C. Clark, Jr., (1999), Restoration of Habitat Functions in an Urban Esturary: Progress and Lessons from Elliott Bay, OCEANS '99 MTS/IEEE. Riding the Crest into the 21st Century, Vol.2, p.p. 817- 821.

Technical Laboratory of Department of Environmental Protection in Taipei City, available from: http://211.79.130.66/c_index/c_index.htm

10^{th} River management office, WRA, Taiwan, available from: http://www.wra10.gov.tw/index.asp

The fish Database of Taiwan, available from, http://fishdb.sinica.edu.tw/

The Tennessee Valley Authority, (2004), An Economic Evaluation of Proposed Flood Protection Plans on the Upper Mississippi River and Illinois Waterway, The Rock Island District, U.S. Army Corps of Engineers.

Tsai, Chia-Yang, Changhua Coast Conservation Action's photostream, available from: http://www.flickr.com/photos/waders/

Urban river basin enhancement methods, available from: http://www.urbem.net/

Vannote, R. L. *et al.*, (1980), The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

Venn, S., (2001), Development of Urban Green Spaces to Improve the Quality of Life in Cities and Urban Regions – Ecological Criteria, Deliverable 7.

Vreugdenhil, D., J. Terborgh, A.M. Cleef, M. Sinitsyn, G.D. Boere, V.L. Archaga, H.H.T. Prins, (2003), *Comprehensive Protected Areas System Composition and Monitoring*, WICE, USA, Shepherdstown, 106 pages.

Wang, C.M. (1999), Biological diversity of river and ecological conservation, Environmental Education Quarterly, Vol. 38, p.p.34-44.

Wang, X. et al., (1987), Ecotourism at Guandu, Wild Bird Society of Taipei.

Wang, X., H. F. Lei (1994), Go! Let’s visit the Keelung River! Natural quarterly, p.p. 8-13. Taiwan

Ward, J.V., F. Malard and K. Tockner, (2002), Landscape ecology: a framework for integrating pattern and process in river corridors, Landscape Ecology, Vol. 17, p.p. 35-46.

Water Resources Bureau, Taiwan, available from: http://www.cis.nctu.edu.tw/~is83072/Work/mainpage.html

Water Resources Agency, Ministry of Economic Affairs, Taiwan, available from: http://www.wra.gov.tw/

Wiens, J. A., (2002), Riverine landscapes: taking landscape ecology into the water, Freshwater Biology, Vol. 47, p.p. 501-515.

Wilcox, D.B., (1993), An Aquatic Habitat Classification system for the Upper Mississippi River System, Environmental Management Technical Center, Onalaska, Wisconsin, U.S.

Wild Bird Federation Taiwan (1992), Wetland Birds Studies on the Tamsui River I, Series of Bird Conservation, 1, Taipei

Wild Bird Federation Taiwan (1993), Wetland Birds Studies on the Tamsui River II, Series of Bird Conservation, 5, Taipei

Wild Bird Federation Taiwan (1996), Wetland Birds Studies on the Tamsui River III, Series of Bird Conservation, 14, Taipei

Wildlife Habitat Incentives Program (WHIP) by Natural Resources Conservation Service (NRCS), USA. Available from: http://www.md.nrcs.usda.gov/programs/whip/whip.html.

Willis, M., S. Zerbe, W. Breitung. (2006), Habitat survey, mapping, and assessment in the Mai Po Nature Reserve, Hong Kong (China), Archiv für Naturschutz und Landschaftsforschung.

Wheater, C. P., (1999), *Urban Habitats*, Routledge, USA.

WL | Delft Hydraulics, available from: www.wldelft.nl

Wong, J. L. (2001), Watershed Planning Based on the Ecosystem Management Concept - A Case Study for the Keelung River in Taiwan, Master Thesis, Institute of Natural Resource Management, National Taipei University.

Wu, H. H. (2003), A Study on Ecological Engineering for River Management of Keelung River, Journal of Taiwan Water Conservancy, Vol. 51, No. 4, p.p.1-6.

Huang, S. L. et al., 2007, Stream order, hierarchy, and energy convergence of land use, ecological modelling Vol.205, p.p. 255–264.

Yang, P. J. (2001), Landscape Ecology in City Planning: Urban Development, Landscape Change and Hydrological Effect in Taipei's Keelung River Basin 1980-2000, PhD Dissertation, Graduate Institute of Building and Planning, National Taiwan University.

Zhang, L., H. Wang, (2006), Planning an ecological network of Xiamen Island (China) using landscape metrics and network analysis, Landscape and Urban Planning, Vol. 78, p.p. 449-456.

Zinke, A., The new Management of Rivers and Wetlands in Central Europe, Seeking Public Works Projects for the 21st Century, International Symposium, Tokyo, Japan.

Annex

Annex A: Biological Status along the Keelung River

A. Flora

Section	**Upper stream**	**Middle stream**	**Lower stream**	**confluence**
	Hotungjiesho bridge – Dahua bridge (Pingxi – Rifang)	Dahua bridge – Nanhu bridge (Rifang – Nangang)	Nanhu bridge – confluence (Nangang – Guandu)	Guandu wetland
Woody plants	*Machilus zuihoensis, Schefflera octophylla, Machilus thunbergii, Ficus fistulosa Reinw. Ex Blume, Machilus japonica Sieb., Smilax china L., Mallotus japonicus, Erigeron bonariensis L., Morus australis Poir., Trema virgata, Acacia confusa Merr., Michelia compressa, Bambusa lodhamii Munro Ficus septica Burm. F.*	*Ricinus communis L., Acacia confusa Merr., Machilus thunbergii, Lagerstroemia subcostata Koehne, Ficus septica Burm. F., Mallotus japonicus, Ficus septica Burm. F., Bambusa lodhamii Munro*	*Ficus septica Burm. F.*	*Hibiscus tiliaceus L., Kandelia candel.*
Herb	*Paspalum conjugatum, Formosan Raspberry, Miscanthus floridulus, Hydrocotyle sibthorpioides Lam., Commelina auriculata Blume, Elatostema platyphylloides Shih & Yang, Ageratum conyzoides L., Cryptotaenia Canadensis, Polygonum chinense L., Setaria palmifolia (J. Konig.) Stapf, Hedychium coronarium, Impatiens walleriana Hook. F., Alocasia macrorrhiza, Mazua miquelii*	*Miscanthus floridulus, Hedychium coronarium, Ipomoea cairica (L.) Sweet, Stephania cephalantha Hay.*	*Bidens pilosa L. var. minor, Wedelia chinensis, Brachiaria mutica (Forsk.) Stapf, Commelina auriculata Blume, Lycianthes biflora （Lour）Bitter., Pennisetum purpureum Schumach., Ludwigia hyssopifolia, Miscanthus floridulus, Amaranthus spinosus L., Ipomoea cairica(L.) Sweet, Eclipta prostrata L., Eleusine indica, Emilia sonchifolia (L.) DC. var. javanica (Burm. f.) Mattfeld, Soliva anthemifolia R. Br., Polygonum plebeium R.Br., Euphorbia hirta L., Commelina communis L., Phagmites communis (L.)Trin., Polygonum longisetum De Bruyn, Carex brunnea Thunb., Ageratum conyzoides L., Erigeron bonariensis L., Cyperus pilosus Vahl., Rμmex acetasa L., Kyllinga brevifolia Rottb., Alternanthera philoxeroides, Ludwigia epilobioides Maxim., Polygonum sagittatum L.*	*Paspalum distichum L., Phragmites communis (L.)Trin., Cyperus malaccensis Lam, Typha angustifolia L., Miscanthus floridulus*
Fern	*Alsophila spinulosa, Microlepia strigosa (Thunb.) Presl, Asplenium antiquum Makino, Miscanthus floridulus*	*Alsophila spinulosa, Blechnum orientale L., Cyperus pilosus Vahl., Humulus japonicus, Phyllanthus urinaria L., Pennisetum purpureum*		
Aquatic vegetation		*Eichhornia crassipes, Potamogeton malaianus Miq., Hydrilla verticillata*	*Eichhornia crassipes, Potamogeton malaianus Miq., Hydrilla verticillata*	
			Study areas	

(Source: Lin, 2002; http://databook.fhk.gov.tw/plant)

B. Fauna

Section	Upper stream	Middle stream	Lower stream	confluence
	Hotungjiesho bridge – Dahua bridge (Pingxi – Rifang)	Dahua bridge – Nanhu bridge (Rifang – Nangang)	Nanhu bridge – confluence (Nangang – Guandu)	Guandu wetland
Birds	*Myiophonus insularis, Alcedo atthis, Egretta garzetta, Butorides striatus, Spilornis cheela, Urocissa caerulea, Rhyacornis fuliginosus, Motacilla cinerea, Dendrocitta formosae, Hypsipetes leucocephalus, Pomatorhinus ruficollis, Dicrurus macrocercus*	*Alcedo atthis, Motacilla alba**, *Motacilla cinerea,** *Egretta garzetta, Butorides striatus, Spilornis cheela, Milvus migrans, Pycnonotus sinensis, Megalaima oorti*	*Ixobrychus cinnamomeus, Gallinula chloropus, Amaurornis phoenicurus, Egretta garzetta, Hirundo tahitica, Anas crecca, Phasianus colchicus, Larus ridibundus, Milvus migrans, Podiceps ruficollis, Nycticorax nycticorax, Hirundo rustica**, *Passer montanus, Zosterops japonicus, Pycnonotus sinensis*	**Raptor**: *Falco tinnunculus**, *Circus spilonotus**, *Pandion haliaetus** **Family Ardeidae**: *Nycticorax nycticorax, Bubulcus ibis**, *Ardea cinerea**, *Casmerodius albus**, *Egretta garzetta, Ixobrychus cinnamomeus* **Family Phalaropodidae**: *Phalaropus lobatus**, *Tringa cinerea**, *Tringa brevipes**, *Tringa nebularia**, *Limosa lapponica**, *Calidris tenuirostris**, *Calidris alpina**, *Calidris ruficollis**, *Arenaria interpres**, *Tringa glareola**, *Gallinago gallinago, Rostratula benghalensis, Tringa hypoleucos**, *Calidris acuminate, Calidris ferruginea**, *Tringa erythropus* **Family Charadriidae**: *Charadrius leschenaultii**, *Charadrius alexandrinus**, *Pluvialis fulva**, etc. **Family Anatidae**: *Anas crecca **, *Anas poecilorhyncha** **Family Hirundinidae**: *Riparia paludicola, Hirundo rustica**, **Family Sylviidae**: *Prinia inornata, Prinia flaviventris* **Family Rallidae**: *Porzana fusca, Gallinula chloropus* **Family Motacillidae**: *Motacilla alba, Motacilla cinerea,*

				*Motacilla flava** **Others**: *Ciconia ciconia**, *Vanellus cinereus**, *Anser fabalis**(rare transit bird), *Streptopelia tranquebarica, Larus ridibundus**, *Cisticola juncidis, Zosterops japonicus, Alcedo atthis*
Fishes	*Rhinogobius brunneus, Crossostoma lacustre,* Acrossocheilus paradoxus, *Zacco pachycephalus, Zacco platypus,* Zacco temmincki, *Microphysogobio brevirostris, Varicorhinus barbatulus,* Pseudorasbora parva, *Cobitis taenia, Crossostoma,* Parasilurus asotus, Anguilla japonica, *Rhinogobius candidianus,* Rhinogobius giurinus *(Rhinogobius giurinus)*	*Rhinogobius brunneus, Zacco pachycephalus, Zacco platypus,* Zacco temmincki, *Microphysogobio brevirostris, Acrossocheilus paradoxus, Carassius auratus auratus, Varicorhinus barbatulus, Hemibarbus labeo, Pseudorasbora parva, Misgurnus anguillicaudatus, Cobitis taenia, Hypostomus placostomus,* Anguilla japonica, *Rhinogobius candidianus, Cyprinus carpio, Tilapia zillii, Oreochromis mossambicus, Oreochromis sp, Misgurnus anguillicaudatus, Crossostoma lacustre, Clarias fuscus, Parasilurus asotus, Pseudobagrus adiposalis, Sinibrama macrops, Rhodeus spinalis, Liza macrolepsis, Kuhlia marginata, Channa sp., Channa asiatica, Gambusia affinis*	*Channa sp., Pangasius sutchi, Megalops cyprinoides, Oreochromis niloticus niloticus, Oreochromis mossambicus, Oreochromis sp, Tilapia zillii, Liza macrolepsis, Mugil tade, Liza carinata, Clarias fuscus, Gambusia affinis, Misgurnus anguillicaudatus, Periophthalmus cantonensis*	*Boleophthalmus chinensis, Periophthalmus cantonensis, Megalops cyprinoides,* Elops hawaiensis, *Chanos chanos, Liza affinis, Liza macrolepsis, Mugil cephalus, Valamugil formosae, Terapon jarbua, Acanthopagrus schlegeli, Pangasius sutchi, Liza macrolepsis, Mugil tade, Liza carinata, Gerres filamentosus, Gerres abbreviatus, Scatophagus argus, Oreochromis spp*

Explaination: * means migrant bird; Endemic Species Research Institute, http://www.tesri.gov.tw; Digital Museum of Zoology, National Taiwan University: http://archive.zo.ntu.edu.tw/index1.htm; The fish Database of Taiwan, http://fishdb.sinica.edu.tw/

Annex B: Bird Species in the lower Keelung River

A. Overall

	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII
Family	0	35	32	32	11	39	52
Species	0	96	83	88	15	188	282

	Section I	Section II	Section III	Section IV	Sction V	Section VI	Section VII
Anseriformes/Anatidae	0	0	0	2	0	18	23
Apodiformes/Apodidae	0	1	1	1	1	2	2
Caprimulgiformes/Caprimulgidae	0	1	1	1	0	0	1
Charadriiformes/Charadriidae	0	6	6	7	0	9	9
Charadriiformes/Glareolidae	0	1	1	1	0	1	1
Charadriiformes/Jacanidae	0	0	0	0	0	0	1
Charadriiformes/Laridae	0	1	1	1	0	8	16
Charadriiformes/Phalaropodidae	0	0	0	0	0	0	1
Charadriiformes/Recurvirostridae	0	0	0	0	0	2	2
Charadriiformes/Rostratulidae	0	3	3	3	0	5	5
Charadriiformes/scolopacidae	0	9	9	9	0	31	37
Ciconiiformes/Accipitridae	0	0	0	0	0	0	1
Ciconiiformes/Ardeidae	0	7	8	9	1	13	16
Ciconiiformes/Ciconiidae	0	0	0	0	0	1	1
ciconiiformes/threskiornithidae	0	0	0	0	0	2	4
Columbiformes/Columbidae	0	4	4	4	0	3	5
Coraciiformes/Alcedinidae	0	1	2	2	0	1	3
Coraciiformes/Upupidae	0	0	1	1	0	0	1
Cuculiformes/Cuculidae	0	2	0	0	0	2	4
Falconiformes/Accipitridae	0	3	1	1	1	11	16
Falconiformes/falconidae	0	1	1	1	0	2	3
Falconiformes/Pandionidae	0	1	1	1	0	1	1
Galliformes/Phasianidae	0	1	0	0	1	2	3
Gruiformes/Rallidae	0	1	1	1	0	5	7
Gruiformes/Turnicidae	0	1	1	1	0	2	3
Passeriformes/Alaudidae	0	1	1	1	0	1	1
Passeriformes/Bombycillidae	0	0	0	0	0	0	1
Passeriformes/Corvidae	0	2	0	1	1	1	4
Passeriformes/Dicruridae	0	1	1	1	0	1	2
Passeriformes/Emberizidae	0	1	1	1	0	5	11
Passeriformes/Fringllidae	0	0	0	0	0	1	7
Passeriformes/Hirundinidae	0	2	2	2	1	5	7
Passeriformes/Laniidae	0	2	2	2	0	2	4
Passeriformes/Motacillidae	0	7	7	7	0	10	10
Passeriformes/Musciapidae	0	1	1	0	1	1	1
Passeriformes/Oriolidae	0	0	0	0	0	0	1
Passeriformes/Paradoxornithidae	0	1	0	0	0	1	1
Passeriformes/Ploceidae	0	3	3	3	0	5	7
Passeriformes/Pycnonotidae	0	2	2	2	2	3	4
Passeriformes/Remizidae	0	0	0	0	0	0	1
Passeriformes/Sturnidae	0	5	5	4	0	9	12
Passeriformes/Sylviidae	0	6	3	4	0	9	15
Passeriformes/Timaliidae	0	6	2	4	4	1	6
Passeriformes/Turdidae	0	6	5	5	0	8	11
Passeriformes/Zosteropidae	0	1	1	1	1	1	1
Piciformes/Capitonidae	0	1	1	0	1	0	1
Piciformes/Cacida	0	0	0	0	0	0	1
Podicipediformes/Podicipedidae	0	0	0	0	0	2	2
Procellariiformes/Fregatidae	0	0	0	0	0	0	1
Procellariiformes/Phalacrocoracidae	0	0	0	0	0	1	1
Stericorariidae/Laridae	0	0	0	0	0	0	1
Strigiformes/Strigidae	0	4	4	4	0	0	2
TOTAL SPECIES	**0**	**96**	**83**	**88**	**15**	**188**	**282**

B. By migrant Migration strategy

	Introduced	Resident	Migrant			Transit, vagrant	TOTAL
			Summer migrant	Winter migrant	SUM		
Anseriformes/Anatidae	0	1	0	11	11	11	**23**
Apodiformes/Apodidae	0	1	0	0	0	1	**2**
Caprimulgiformes/Caprimulgidae	0	1	0	0	0	0	**1**
Charadriiformes/Charadriidae	0	0	0	7	7	4	**11**
Charadriiformes/Glareolidae	0	0	1	0	1	0	**1**
Charadriiformes/Jacanidae	0	1	0	0	0	0	**1**
Charadriiformes/Laridae	0	3	3	8	11	2	**16**
Charadriiformes/Phalaropodidae	0	0	0	0	0	1	**1**
Charadriiformes/Recurvirostridae	0	0	0	0	0	2	**2**
Charadriiformes/Rostratulidae	0	0	1	4	5	0	**5**
Charadriiformes/scolopacidae	0	0	0	22	22	15	**37**
Ciconiiformes/Accipitridae	0	0	0	0	0	1	**1**
Ciconiiformes/Ardeidae	0	8	0	5	5	4	**17**
Ciconiiformes/Ciconiidae	0	0	0	0	0	1	**1**
ciconiiformes/threskiornithidae	1	0	0	1	1	2	**4**
Columbiformes/Columbidae	0	4	0	0	0	1	**5**
Coraciiformes/Alcedinidae	0	1	0	0	0	3	**4**
Coraciiformes/Upupidae	0	0	0	0	0	1	**1**
Cuculiformes/Cuculidae	0	1	3	0	3	0	**4**
Falconiformes/Accipitridae	0	4	0	0	0	12	**16**
Falconiformes/falconidae	0	0	0	1	1	2	**3**
Falconiformes/Pandionidae	0	1	0	0	0	0	**1**
Galliformes/Phasianidae	0	2	0	0	0	1	**3**
Gruiformes/Rallidae	0	3	1	1	2	2	**7**
Gruiformes/Turnicidae	0	3	0	0	0	0	**3**
Passeriformes/Alaudidae	0	1	0	0	0	0	**1**
Passeriformes/Bombycillidae	0	0	0	0	0	1	**1**
Passeriformes/Corvidae	0	3	0	0	0	1	**4**
Passeriformes/Dicruridae	0	2	0	0	0	0	**2**
Passeriformes/Emberizidae	0	0	0	5	5	6	**11**
Passeriformes/Fringllidae	2	0	1	4	5	0	**7**
Passeriformes/Hirundinidae	0	5	0	0	0	2	**7**
Passeriformes/Laniidae	0	1	0	1	1	2	**4**
Passeriformes/Motacillidae	0	0	0	9	9	2	**11**
Passeriformes/Musciapidae	0	1	0	0	0	0	**1**

Passeriformes/Oriolidae	0	1	0	0	0	0	**1**
Passeriformes/Paradoxornithidae	0	1	0	0	0	0	**1**
Passeriformes/Ploceidae	3	4	0	0	0	0	**7**
Passeriformes/Pycnonotidae	0	4	0	0	0	0	**4**
Passeriformes/Remizidae	0	0	0	0	0	1	**1**
Passeriformes/Sturnidae	5	2	1	0	1	4	**12**
Passeriformes/Sylviidae	0	7	0	5	5	4	**16**
Passeriformes/Timaliidae	0	7	0	0	0	0	**7**
Passeriformes/Turdidae	0	1	0	10	10	2	**13**
Passeriformes/Zosteropidae	0	1	0	0	0	0	**1**
Piciformes/Capitonidae	0	1	0	0	0	0	**1**
Piciformes/Cacida	0	0	0	0	0	1	**1**
Podicipediformes/Podicipedidae	0	1	0	0	0	1	**2**
Procellariiformes/Fregatidae	0	0	0	0	0	1	**1**
Procellariiformes/Phalacrocoracidae	0	0	0	1	1	0	**1**
Stericorariidae/Laridae	0	1	0	0	0	0	**1**
Strigiformes/Strigidae	0	2	0	2	2	0	**4**
TOTAL	**11**	**80**	**11**	**97**	**108**	**94**	**293**
%	**(3.75)**	**(27.3)**	**(3.75)**	**(33.11)**	**(36.86)**	**(32.08)**	**(100)**

C. By Family

Anseriformes/Anatidae (23)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0082	Anser cygnoides	EN, A2bcd+3bcd, ver 3.1 (2001)	VU, 2004		transit (rare)	waterbody, wetland	7,6
B0107	Tadorna tadorna	LC, ver 3.1 (2001)			transit (rare)	waterbody, wetland	7,6
B0106	Tadorna ferruginea	LC, ver 3.1 (2001)			transit (rare)	waterbody, wetland	7
B0092	Bucephala clangula	LC, ver 3.1 (2001)	LC, 2004		vagrant	waterbody, wetland	7
B0088	Aythya marila	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	waterbody, wetland	7,6
B0087	Aythya fuligula	LC, ver 3.1 (2001)	LC, 2004		winter migrant (partial area)	waterbody, wetland	7,6
B0086	Aythya ferina	LC, ver 3.1 (2001)	LC, 2004		vagrant	waterbody, wetland	7,6
B0084	Anser fabalis	LC, ver 3.1 (2001)	LC, 2004		transit (rare), vagrant	waterbody, wetland	7,6
B0080	Anser albifrons	LC, ver 3.1 (2001)	LC, 2004		vagrant	waterbody, wetland	7,6
B0079	Anas strepera	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	waterbody, wetland	7,6
B0078	Anas querquedula	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6

B0077	Anas poecilorhyncha	LC, ver 3.1 (2001)	LC, 2004		winter migrant, resident (rare)	waterbody, wetland	7,6
B0076	Anas platyrhynchos	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6
B0075	Anas penelope	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6
B0071	Anas crecca	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6,4
B0070	Anas clypeata	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6
B0068	*Aix galericulata*	*LC, ver 3.1 (2001)*	*LC, 2004*	*TW, '05, II; TW, '08, II*	*Resident (uncommon)*	*freshwater*	*7*
B0069	Anas acuta	LC, ver 3.1 (2001)	LC, 2004		winter migrant	waterbody, wetland	7,6
B0072	Anas falcata	NT, ver 3.1 (2001)	NT, 2004		winter migrant (rare)	waterbody, wetland	7,6
B0073	Anas formosa	VU A3c, ver 3.1 (2001)		TW, '05, II; TW, '08, II	winter migrant (rare)	wetland	7,6,4
B0083	Anser erythropus	VU, A2bcd+3bcd, ver 3.1 (2001)			vagrant	waterbody, wetland	7
B0085	Aythya baeri	VU, A2cd+3cd, ver 3.1 (2001)	EN, 2004		vagrant	waterbody, wetland	7,6
B0081	Anser anser				vagrant	waterbody, wetland	7

Apodiformes/Apodidae (2)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0305	Apus pacificus	LC, ver 3.1 (2001)	LC, 2004		transit, resident (uncommon)	sky	7,6
B0304	Apus nipalensis	LC, ver 3.1 (2001)	LC, 2004		resident	sky	7,6,5,4,3,2

Caprimulgiformes/Caprimulgidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0302	Caprimulgus affinis	LC, ver 3.1 (2001)	LC, 2004		resident (rare)	woodland	7,4,3,2

Charadriiformes/Charadriidae (11)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0188	Vanellus vanellus	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon)	wetland	7,6,4,3,2
B0187	Pluvialis squatarola	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	7,6

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0186	Pluvialis fulva	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**,**3**,2
B0185	Vanellus cinereus	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,**4**,**3**,2
B0184	Charadrius placidus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	wetland	6
B0183	Charadrius mongolus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**
B0182	Charadrius leschenaultii	LC, ver 3.1 (2001)	LC, 2004		winter migrant, transit	wetland	**7**,**6**
B0181	Charadrius hiaticula	LC, ver 3.1 (2001)			transit (rare)	wetland	**7**,6
B0180	Charadrius dubius	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**,**3**,2
B0179	Charadrius veredus	LC, ver 3.1 (2001)			transit (rare)	wetland	4,**3**,2
B0178	Charadrius alexandrinus	LC, ver 3.1 (2001)	LC, 2004		winter migrant, summer migrant (uncommon)	wetland	**7**,6,**4**,**3**,2

Charadriiformes/Glareolidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0238	Glareola maldivarum	LC, ver 3.1 (2001)	LC, 2004	**TW, '05, II; TW, '08, III**	summer migrant (uncommon)	wetland	**7**,6,**4**,**3**,2

Charadriiformes/Jacanidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0175	Hydrophasianus chirurgis	LC, ver 3.1 (2001)		TW, '05, II; TW, '08, II	resident (uncommon)	wetland	7

Charadriiformes/Laridae (16)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0251	Sterna albifrons	LC (watching list), ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident, summer migrant (partial area)	waterbody	**7**,6
B0261	Sterna caspia	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	waterbody	7
B0259	Sterna nilotica	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	waterbody	**7**,6
B0258	Chlidonias leucopterus	LC, ver 3.1 (2001)	LC, 2004		transit	waterbody	**7**,6
B0257	Chlidonias hybridus	LC, ver 3.1 (2001)			transit	waterbody	**7**,6

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0256	Sterna hirundo	LC, ver 3.1 (2001)	LC, 2004		winter migrant (partial area)	waterbody	**7**,6,**4**,3,2
B0255	Sterna fuscata	LC, ver 3.1 (2001)	LC, 2004		summer migrant (rare)	waterbody	**7**,6
B0253	Sterna bergii	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	summer migrant (partial area)	waterbody	7
B0248	Larus ridibundus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (partial area)	waterbody	**7**,6
B0245	Larus crassirostris	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	waterbody	7
B0243	Larus argentatus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	waterbody	7
B0260	Sterna sumatrana	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident, summer migrant (partial area)	waterbody	7
B0252	Sterna anaetheta (anaethetus)	LC, ver 3.1 (2001)		TW, '05, II; TW, '08, II	summer migrant (partial area)	waterbody	7
B0249	Larus saundersi	VU, A3c, ver 3.1 (2001)	VU, 2004	**TW, '08, II**	winter migrant (uncommon)	waterbody	**7**,6
B0254	Sterna dougallii		LC, 2004	**TW, '08, II**	resident, summer migrant (rare)	waterbody	7
B0250	Larus schistisagus				winter migrant (rare)	waterbody	7

Charadriiformes/Phalaropodidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0236	Phalaropus fulicaria	LC, ver 3.1 (2001)			vagrant	wetland	7

Charadriiformes/Recurvirostridae (2)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0235	Recurvirostra avosetta	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,6
B0234	Himantopus himantopus	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon	wetland	**7**,6

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Charadriiformes/Rostratulidae (5)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0221	Actitis hypoleucos / Tringa hypoleucos	LC, ver 3.1 (2001)	LC, 2004		winter migrant, resident	wetland	**7**,**6**,**4**,**3**,2
B0218	Tringa erythropus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon, rare)	wetland	**7**,6
B0193	Calidris ferruginea	LC, ver 3.1 (2001)	LC, 2004		winter migrant, transit	wetland	**7**,3
B0190	Calidris acuminata	LC, ver 3.1 (2001)	LC, 2004		winter migrant, transit	wetland	**7**,6,**4**,**3**,2
B0176	Rostratula benghalensis	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	summer migrant, resident (partial area)	wetland	**7**,**6**,**4**,**3**,2

Charadriiformes/scolopacidae (37)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0220	Tringa guttifer	EN C2a(i), ver 3.1 (2001)	EN, 2004	**TW, '08, I**	transit (rare)	wetland	**7**,6
B0200	Eurynorhynchus pygmeus	EN, C1+2a(ii), ver 3.1 (2001)	CR, 2004	**TW, '08, III**	transit (rare)	waterbody	7
B0237	Phalaropus lobatus	LC, ver 3.1 (2001)	LC, 2004		winter migrant, transit	wetland	**7**,6,**4**,**3**,2
B0231	Micropalama himantopus	LC, ver 3.1 (2001)			winter migrant	wetland	7
B0228	Xenus cinereus / Tringa cinerea	LC, ver 3.1 (2001)	LC, 2004		winter migrant(common), transit (uncommon)	wetland	**7**,6
B0226	Tringa totanus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,2
B0225	Tringa stagnatilis	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0224	Tringa ochropus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**,**3**,2
B0223	Tringa nebularia	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,**6**
B0219	Tringa glareola	LC, ver 3.1 (2001)	LC, 2004		Winter migrant	wetland	**7**,6

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0217	Heteroscelus brevipes / Tringa brevipes	LC, ver 3.1 (2001)	LC, 2004		winter migrant, transit	wetland	**7**,6
B0216	Scolopax rusticola	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,**4**,**3**,2
B0215	Philomachus pugnax	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,6
B0213	Numenius phaeopus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6
B0212	Numenius minutus	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon)	wetland	**7**,6,**4**,**3**,2
B0211	Numenius madagascariensis	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0210	Numenius arquata	LC, ver 3.1 (2001)	NT, 2004	**TW, '08, III**	winter migrant (partial area)	wetland	**7**,6
B0209	Lymnocryptes minimus	LC, ver 3.1 (2001)	LC, 2004		vagrant	wetland	**7**,6
B0207	Limosa lapponica	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,6
B0205	Limicola falcinellus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0204	Gallinago stenura	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,6,**4**,**3**,2
B0203	Gallinago megala	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland	**7**,**4**,**3**,2
B0202	Gallinago hardwickii	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, III**	vagrant	wetland	**7**,**4**,**3**,2
B0201	Gallinago gallinago	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**,**3**,2
B0199	Calidris alba	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0198	Calidris tenuirostris	LC, ver 3.1 (2001)	LC, 2004		winter migrant(uncommon), Transit	wetland	**7**,6
B0197	Calidris temminckii	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0196	Calidris subminuta	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,**4**,**3**,2
B0195	Calidris ruficollis	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,**6**
B0192	Calidris canutus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0191	Calidris alpina	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6

B0189	Arenaria interpres	LC, ver 3.1 (2001)	LC, 2004		Transit, winter migrant (partial area)	wetland	**7**,6
B0227	Tryngites subruficollis	NT, ver 3.1 (2001)			vagrant	wetland	7
B0208	Limosa limosa	NT, ver 3.1 (2001)	NT, 2004		transit (rare)	wetland	**7**,6
B0206	Limnodromus semipalmatus	NT, ver 3.1 (2001)	NT, 2004	**TW, '08, III**	vagrant	wetland	**7**,6
B0229	Limnodromus scolopaceus				winter migrant	wetland	**7**,6
B0222	Tringa incana				vagrant	wetland	**7**,6

Ciconiiformes/Accipitridae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0131	*Pernis ptilorhyncus*	*LC, ver 3.1 (2001)*	*LC, 2004*		*Transit (rare)*	*wetland*	*7*

Ciconiiformes/Ardeidae (17)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0058	Nycticorax nycticorax	LC, ver 3.1 (2001)	LC, 2004		resident	wetland	**7**,**6**,4,**3**,2
B0056	Ixobrychus sinensis	LC, ver 3.1 (2001)	LC, 2004		resident (uncommon)	wetland, grassland	**7**,6,**4**,**3**
B0055	Ixobrychus eurhythmus	LC, ver 3.1 (2001)	LC, 2004		vagrant	wetland, grassland	7
B0053	*Gorsachius melanolophus*	*LC, ver 3.1 (2001)*	*LC, 2004*		*Resident (rare)*	*Wetland, grassland*	*7*
B0050	Egretta sacra	LC, ver 3.1 (2001)	LC, 2004		resident (partial area)	waterbody	7
B0051	Gorsachius goisagi	EN, C2a(i), ver 3.1 (2001)	EN, 2004	**TW, '08, III**	transit (rare)	wetland, grassland	4,**3**,2
B0048	Mesophoyx intermedia	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,4,**3**,2
B0045	Casmerodius albus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,6,4,**3**,2
B0043	Butorides striatus	LC, ver 3.1 (2001)			resident, transit (rare)	waterbody	**7**,6
B0041	Botaurus stellaris	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	wetland, grassland	**7**,**6**
B0040	Ardeola bacchus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland, farmland	**7**,6,**4**
B0039	Ardea purpurea	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	wetland	**7**,**6**

B0046	Egretta eulophotes	VU C2a(i), ver 3.1 (2001)	VU, 2004	TW, '05, II; TW, '08, II	transit (uncommon)	wetland	**7**,6
B0054	Ixobrychus cinnamomeus	LC, ver 3.1 (2001)	LC, 2004		resident	wetland, grassland	**7**,**6**
B0047	Egretta Garzetta	LC, ver 3.1 (2001)	LC, 2004		resident	wetland, grassland, farmland	**7**,**6**,**5**,**4**,**3**,2
B0042	Bubulcus ibis	LC, ver 3.1 (2001)	LC, 2004		resident summer migrant, winter migrant (uncommon)	wetland, grassland, farmland	**7**,6,**4**,**3**,2
B0038	Ardea cinerea	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland	**7**,**6**,4,**3**,2

Ciconiiformes/Ciconiidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0059	Ciconia boyciana	EN C2a(ii), ver 3.1 (2001)	EN, 2004	TW, '05, I; TW, '08, I	vagrant	wetland	**7**,6

ciconiiformes/threskiornithidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0064	Platalea minor	EN C2a(i), ver 3.1 (2001)	EN, 2004	TW, '05, I; TW, '08, I	winter migrant	wetland	**7**,6
B0063	Platalea leucorodia	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	vagrant	wetland	7
B0067	Threskiornis melanocephalus	NT, ver 3.1 (2001)		TW, '05, II; TW, '08, II	transit (rare)	wetland	7
B0066	Threskiornis aethiopicus				introduced (uncommon)	wetland	**7**,6

Columbiformes/Columbidae (5)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0275	Streptopelia tranquebarica	LC, ver 3.1 (2001)	LC, 2004		resident	woodland, grassland	**7**,6,**4**,**3**,2
B0274	Streptopelia orientalis	LC, ver 3.1 (2001)	LC, 2004		resident	woodland, grassland	**7**,6,**4**,**3**,2
B0269	Columba livia	LC, ver 3.1 (2001)	LC, 2004		resident	woodland, grassland	7,**4**,**3**,2
B0276	Treron bicincta				vagrant	woodland	7
B0273	Streptopelia chinensis				resident	woodland, grassland	**7**,6,**4**,**3**,2

Coraciiformes/Alcedinidae (4)

Code	Scientific	IUCN RL	BirdLife	Taiwan	Migration	Habitat	Section

	Name		RL	RL	strategy		
B0310	Halcyon smyrnensis	LC, ver 3.1 (2001)			vagrant	waterbody	7
B0309	Halcyon pileata	LC, ver 3.1 (2001)			transit (rare)	waterbody	7
B0308	Halcyon coromanda	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	waterbody	**4**,**3**,2
B0307	Alcedo atthis	LC, ver 3.1 (2001)	LC, 2004		resident	waterbody	**7**,6,**4**,3

Coraciiformes/Upupidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0314	Upupa epops	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	grassland	**7**,**4**,3

Cuculiformes/Cuculidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0287	Cuculus sparverioides	LC, ver 3.1 (2001)	LC, 2004		summer migrant	woodland	7
B0286	Cuculus saturatus	LC, ver 3.1 (2001)	LC, 2004		summer migrant	woodland	**7**,**6**,2
B0285	Cuculus poliocephalus				summer migrant (rare)	woodland	7
B0279	Centropus bengalensis				resident	grassland, woodland	**7**,6,2

Falconiformes/Accipitridae (16)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0130	Milvus migrans	EN A2c, C2a(i), D1, ver 3.1 (2001)		TW, '05, II; TW, '08, II	resident	woodland	**7**,6
B0134	Accipiter gularis	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	transit (rare)	woodland	7
B0126	Haliaeetus leucogaster	LC, ver 3.1 (2001)			vagrant (rare)	waterbody	**7**,6
B0124	Circus melanoleucos	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	transit (rare)	woodland	7
B0123	Circus cyaneus	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	transit (rare)	woodland	**7**,6
B0122	Circus spilonotus	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	transit, winter migrant (rare)	woodland	**7**,**6**
B0121	Buteo lagopus	LC, ver 3.1 (2001)	LC, 2004		vagrant	woodland	**7**,6
B0119	Buteo buteo	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	vagrant	woodland	**7**,**4**
B0111	Accipiter virgatus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident (uncommon)	woodland	**7**,6,2

B0112	Accipiter soloensis	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	transit	woodland	**7**,6
B0113	Accipiter trivirgatus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident (uncommon)	woodland	**7**,6,2
B0118	Butastur indicus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	transit	woodland	**7**,6
B0132	Spilornis cheela	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident	woodland	**7**,**6**,**5**,**3**,2
B0110	Accipiter nisus	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	vagrant	woodland	**7**,6
B0115	Aquila clanga	VU, C2a(ii), ver 3.1 (2001)	VU, 2004		vagrant	woodland	7
B0120	Buteo hemilasius				vagrant (rare)	woodland	7

Falconiformes/falconidae (3)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0141	Falco tinnunculus	LC, ver 3.1 (2001)	LC, 2004	**TW, '08, II**	winter migrant	grassland	**7**,6,**4**,**3**,2
B0138	Falco peregrinus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, I; TW, '08, I	transit (rare)	grassland	7,6
B0137	Falco columbarius				vagrant	grassland	7

Falconiformes/Pandionidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0135	Pandion haliaetus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident (partial area)	waterside	**7**,6,**4**,**3**,2

Galliformes/Phasianidae (3)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0147	Bambusicola thoracica	LC, ver 3.1 (2001)			resident	woodland	**7**,6,**5**,2
B0151	Phasianus colchicus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident	grassland	7
B0149	Coturnix japonica				transit (rare)	grassland	**7**,6

Gruiformes/Rallidae (7)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0169	Gallirallus striatus	LC, ver 3.1 (2001)	LC, 2004		resident (rare)	wetland	7
B0168	Rallus aquaticus	LC, ver 3.1 (2001)	LC, 2004		transit, resident (rare)	wetland	**7**,**6**
B0166	Rallina eurizonoides	LC, ver 3.1 (2001)	LC, 2004		resident (rare)	wetland	7
B0165	Porzana	LC, ver 3.1			vagrant	wetland	**7**,6

	pusilla	(2001)					
B0161	Gallicrex cinerea	LC, ver 3.1 (2001)	LC, 2004		summer migrant (uncommon)	wetland	**7**,6
B0160	Fulica atra	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland	**7**,6
B0159	Amaurornis phoenicurus	LC, ver 3.1 (2001)	LC, 2004		resident	wetland	**7**,6,**4**,**3**,2

Gruiformes/Turnicidae (3)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0164	Porzana fusca	LC, ver 3.1 (2001)	LC, 2004		resident	wetland	**7**,6
B0162	Gallinula chloropus	LC, ver 3.1 (2001)	LC, 2004		resident	wetland	**7**,**6**,**4**,**3**,2
B0153	Turnix suscitator	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	7

Passeriformes/Alaudidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0321	Alauda gulgula	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	**7**,**6**,**4**,**3**,2

Passeriformes/Bombycillidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0474	Bombycilla japonica	NT, ver 3.1 (2001)	NT, 2004		vagrant	woodland	**7**

Passeriformes/Corvidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0347	Dendrocitta formosae	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**,6,5,4,2
B0342	Corvus frugilegus	LC, ver 3.1 (2001)			vagrant	woodland	**7**
B0350	Pica pica	LC, ver 3.1 (2001)	LC, 2004	**TW, '05, III**	resident	woodland, grassland	**7**
B0351	Urocissa caerulea	LC, ver 3.1 (2001)	LC, 2004	**TW, '05, II; TW, '08, III**	resident	woodland	**7**,2

Passeriformes/Dicruridae (2)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0335	Dicrurus macrocercus	LC, ver 3.1 (2001)	LC, 2004		resident	town, farmland	**7**,6,**4**,**3**,2
B0333	Dicrurus aeneus	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**

Passeriformes/Emberizidae (11)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0534	Emberiza tristrami	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	**7**
B0532	Emberiza spodocephala	LC, ver 3.1 (2001)	LC, 2004		winter migrant	grassland	**7**,6,**4**,**3**,2
B0530	Emberiza rutila	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	grassland	**7**
B0529	Emberiza rustica	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	grassland	**7**,6
B0528	Emberiza pusilla	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	grassland	**7**,6
B0527	Emberiza pallasi	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	**7**
B0525	Emberiza elegans	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	grassland	**7**,6
B0522	Emberiza aureola	NT, ver 3.1 (2001)	VU, 2004		transit (rare)	grassland	**7**,6
B0533	Emberiza sulphurata	VU, C2a(ii), ver 3.1 (2001)	VU, 2004	TW, '08, II	winter migrant (uncommon)	grassland	**7**
B0536	Melophus lathami				vagrant	grassland	7
B0526	Emberiza fucata				vagrant	grassland	**7**

Passeriformes/Fringllidae (7)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0515	Fringilla montifringilla	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	**7**
B0513	Eophona migratoria	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	**7**
B0512	Coccothraustes coccothraustes	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	7
B0520	Serinus mozabicus				introduced	woodland	**7**,6
B0519	Uragus sibiricus				migrant	woodland	**7**
B0508	Carduelis sinica				winter migrant (rare)	woodland	**7**
B0507	Estrilda astrild				introduced	woodland	**7**

Passeriformes/Hirundinidae (7)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section

B0328	*Hirundo daurica*	*LC, ver 3.1 (2001)*	*LC, 2004*		*transit*	*sky*	*7*
B0327	Riparia riparia	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	sky	7,6
B0326	Riparia paludicola	LC, ver 3.1 (2001)	LC, 2004		resident	sky	7,6
B0325	Hirundo tahitica	LC, ver 3.1 (2001)	LC, 2004		resident	sky	7,6,4,3,2
B0324	Hirundo striolata	LC, ver 3.1 (2001)	LC, 2004		resident, transit	sky	7,6
B0323	Hirundo rustica	LC, ver 3.1 (2001)	LC, 2004		resident, summer migrant, winter migrant (rare)	sky	7,6,5,4,3,2
B0322	Delichon dasypus	LC, ver 3.1 (2001)	LC, 2004		resident	sky	7

Passeriformes/Laniidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0480	Acridotheres cristatellus	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	7
B0475	Lanius bucephalus	LC, ver 3.1 (2001)			vagrant	grassland	7
B0476	Lanius criMigration strategy	LC, ver 3.1 (2001)	LC, 2004	TW, '05, III; TW, '08, III	winter migrant	grassland	7,6,4,3,2
B0478	Lanius sphenocercus				resident	farmland, grassland	7,6,4,3,2

Passeriformes/Motacillidae (11)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0472	Motacilla grandis	LC, ver 3.1 (2001)	LC, 2004		vagrant	wetland, waterbody	7,6
B0471	Motacilla flava	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland, waterbody	7,6,4,3,2
B0470	Motacilla citreola	LC, ver 3.1 (2001)			winter migrant (rare)	wetland, waterbody	6
B0469	Motacilla cinerea	LC, ver 3.1 (2001)	LC, 2004		winter migrant	wetland, waterbody	7,6,4,3,2
B0468	Motacilla alba	LC, ver 3.1 (2001)	LC, 2004		winter migrant, resident	wetland, waterbody	7,6,4,3,2
B0467	Dendronanthus indicus	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland, woodland	7,6
B0466	Anthus spinoletta	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	wetland, waterbody	7,6
B0465	Anthus richardi	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	wetland, waterbody	7,6,4,3,2
B0464	Anthus hodgsoni	LC, ver 3.1 (2001)	LC, 2004		winter migrant	grassland, woodland	7,6,4,3,2

B0463	Anthus gustavi	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	woodland, grassland	7,4,3,2
B0462	Anthus cervinus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	farmland, wetland	7,6,4,3,2

Passeriformes/Musciapidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0453	Hypothymis azurea				resident	woodland	7,6,5,3,2

Passeriformes/Oriolidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0337	Oriolus chinensis	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, I	resident, transit (rare)	woodland	7

Passeriformes/Paradoxornithidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0353	Paradoxornis webbianus	LC, ver 3.1 (2001)	LC, 2004		resident	woodland, grassland	7,6,2

Passeriformes/Ploceidae (7)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0537	Passer montanus	LC, ver 3.1 (2001)	LC, 2004		resident	town, grassland, farmland	7,6,4,3,2
B0503	Lonchura striata	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	7,6,2
B0502	Lonchura punctulata	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	7,6,4,3,2
B0506	Lonchura maja				introduced (rare)	grassland	7,4,3
B0505	Amandava amandava				introduced (rare)	grassland	7
B0504	Padda oryzivora				introduced (uncommon)	grassland	7,6
B0501	Lonchura malacca				resident	grassland	7,6

Passeriformes/Pycnonotidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0383	Spizixos semitorques	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	7,6
B0381	Pycnonotus sinensis	LC, ver 3.1 (2001)	LC, 2004		resident	woodland, orchard, park, forest	7,6,5,4,3,2
B0380	Hypsipetes leucocephalus	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	7,6,5,4,3,2
B0384	Pycnonotus jocosus				resident	woodland	7

Passeriformes/Remizidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0354	Remiz consobrinus				vagrant	grassland	**7**

Passeriformes/Sturnidae (12)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0491	Acridotheres ginginianus	LC, ver 3.1 (2001)	LC, 2004		introduced (rare)	grassland	7,6
B0489	Sturnus sturninus	LC, ver 3.1 (2001)	LC, 2004		migrant	grassland	7
B0488	Sturnus sericeus	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	7,6
B0487	Sturnus sinensis	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon)	grassland	7,6
B0486	Sturnus philippensis	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon)	grassland	7
B0485	Sturnus cineraceus	LC, ver 3.1 (2001)	LC, 2004		transit, winter migrant (uncommon)	grassland	7,6,3,2
B0493	Acridotheres fuscus				introduced (rare)	grassland	7,6
B0492	Acridotheres javanicus				introduced (rare)	grassland	7,6,4,3,2
B0484	Sturnus nigricollis				resident	grassland	7,6,4,3,2
B0482	Acridotheres tristis				introduced (uncommon)	farmland, grassland	7,6,4,3,2
B0481	Acridotheres cristatellu			**TW, '08, II**	resident	farmland, grassland	7,6,4,3,2
B0600	*Acridotheres grandis*				*introduced*	*town, farmland*	*7*

Passeriformes/Sylviidae (16)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0442	Prinia inornata / Prinia subflava	LC, ver 3.1 (2001)	LC, 2004		resident	grassland, shrubbery	**7**,6,**4**,**3**,2
B0441	Prinia flaviventris	LC, ver 3.1 (2001)	LC, 2004		resident	grassland, shrubbery	**7**,6,**4**,**3**,2
B0440	Prinia criniger	LC, ver 3.1 (2001)			resident	grassland	**4**,**3**,2
B0437	Phylloscopus inornatus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	**7**
B0436	Phylloscopus fuscatus	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	**7**,6

B0434	Phylloscopus borealis	LC, ver 3.1 (2001)	LC, 2004		winter migrant	woodland	**7**,2
B0433	Locustella ochotensis	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	7
B0432	Locustella lanceolata	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	**7**,**6**
B0430	Cisticola juncidis	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	**7**,6,**4**,2
B0429	Cisticola exilis	LC, ver 3.1 (2001)	LC, 2004		resident	grassland	**7**,6
B0428	Urosphena squameiceps	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	grassland	**7**
B0424	Bradypterus alishanensis	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**
B0423	Acrocephalus bistrigiceps	LC, ver 3.1 (2001)	LC, 2004		vagrant	grassland	**7**,6
B0421	Abroscopus albogularis	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**
B0426	Cettia canturians				winter migrant	woodland	**7**,6,2
B0422	Acrocephalus arundinaceus				winter migrant	grassland	**7**,6

Passeriformes/Timaliidae (7)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0375	Stachyris ruficeps	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**,**5**,4,3,2
B0377	Yuhina zantholeuca	LC, ver 3.1 (2001)			resident	woodland	**5**,4,2
B0374	Pomatorhinus ruficollis	LC, ver 3.1 (2001)			resident	woodland	**7**,2
B0373	Pomatorhinus erythrocnemis	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**,**5**,4,2
B0365	Alcippe morrisonia	LC, ver 3.1 (2001)	LC, 2004		resident	woodland	**7**,**5**,4,3,2
B0370	Heterophasia auricularis	LC, ver 3.1 (2001)	LC, 2004	**TW, '05, III**	resident	woodland	**7**
B0367	Garrulax canorus	LC, ver 3.1 (2001)		TW, '05, II; TW, '08, II	resident (uncommon)	woodland	**7**,6,2

Passeriformes/Turdidae (13)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0413	Turdus pallidus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	woodland	**7**,6,2
B0412	Turdus obscurus	LC, ver 3.1 (2001)	LC, 2004		transit (uncommon)	woodland	**7**
B0411	Turdus naumanni	LC, ver 3.1 (2001)	LC, 2004		winter migrant	woodland	**7**,6,**4**,**3**,2
B0408	Zoothera dauma		LC, 2004		winter migrant, resident (uncommon)	woodland	**4**,**3**,2

B0407	Turdus chrysolaus	LC, ver 3.1 (2001)	LC, 2004		winter migrant	woodland	**7**,**6**,**4**,**3**,2
B0402	Saxicola torquata	LC, ver 3.1 (2001)			winter migrant (rare)	woodland	**7**,6
B0401	Saxicola ferrea	LC, ver 3.1 (2001)			vagrant	woodland	**7**
B0399	Phoenicurus auroreus	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	**7**,**6**,**4**,3
B0396	Myophonus insularis	LC, ver 3.1 (2001)	LC, 2004	**TW, '05, III**	resident	woodland, waterbody	**3**,2
B0394	Monticola solitarius	LC, ver 3.1 (2001)	LC, 2004		winter migrant, resident	woodland	**7**,6,**4**
B0393	Luscinia calliope	LC, ver 3.1 (2001)	LC, 2004		winter migrant (uncommon)	woodland	**7**,6,2
B0390	Luscinia svecica	LC, ver 3.1 (2001)			winter migrant (rare)	grassland	**7**,6
B0403	Tarsiger cyanurus		LC, 2004		winter migrant (uncommon)	woodland	**7**

Passeriformes/Zosteropidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0499	Zosterops japonicus				resident	woodland, town, farmland	**7**,**6**,**5**,**4**,**3**,**2**

Piciformes/Capitonidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0315	Megalaima oorti	LC, ver 3.1 (2001)			resident	woodland	**7**,**5**,3,2

Piciformes/Cacida (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0318	*Jynx torquilla*	*LC, ver 3.1 (2001)*			*vagrant*	*woodland*	*7*

Podicipediformes/Podicipedidae (2)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0007	Podiceps criMigration strategy	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	freshwater	**7**,6
B0003	Tachybaptus ruficollis	LC, ver 3.1 (2001)	LC, 2004		resident	freshwater	**7**,6

Procellariiformes/Fregatidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0036	Fregata ariel	LC, ver 3.1 (2001)	LC, 2004		transit (rare)	freshwater	7

Procellariiformes/Phalacrocoracidae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0032	Phalacrocorax carbo	LC, ver 3.1 (2001)	LC, 2004		winter migrant (rare)	waterbody	**7**,6

Stericorariidae/Laridae (1)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0242	Anous stolidus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident, summer migrant (partial area)	waterbody	7

Strigiformes/Strigidae (4)

Code	Scientific Name	IUCN RL	BirdLife RL	Taiwan RL	Migration strategy	Habitat	Section
B0296	Otus bakkamoena	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident (uncommon)	woodland	7,**4**,**3**,2
B0299	Otus spilocephalus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	resident (uncommon)	woodland	**4**,**3**,2
B0291	Asio flammeus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	winter migrant (rare)	woodland, grassland	**7**,**4**,**3**,2
B0292	Asio otus	LC, ver 3.1 (2001)	LC, 2004	TW, '05, II; TW, '08, II	winter migrant (rare)	woodland, grassland	**4**,3,2

Annex C: Flood Control Works along the lower Keelung River

(Source: Taipei City Government; Lin, 2001)

I. History and Contents of Works

The government has ever studied and tried to define the causes of floods in the early 1960's. Unfortunately, people at that time knew nothing about river management. Meanwhile, the technique of channelization (1950-1970) from U.S. was firstly introduced into Taiwan; thus the government decided to build embankments for preventing floods. The first project was so-called 'conservation areas', which was just separated the rivers from their neighbourhoods by banks. This project only provided a temporary solution to flooding problem, and changed the cultural landscape of downtown. Many conservation areas were still suffered from heavy typhoons. Taking *Lynn* Typhoon in 1987, for example, resulted in a flooding area more than 1,000 ha. Accordingly, the authorities concerned beginning to establish more water control works since the 1990's. These works were designed to reduce water pollution and prevent floods at the same time (flood recurrence period of 200 years) (Wong, 2001). In addition to building more embankments, they gradually adopted changing the course of the Keelung River as one of the water control methods. In which, there are three big projects in the lower section.

II. First straightening work of the Keelung River

It was one part of the Danshui River project in the 1960's. This project straightened the section between Zhongshan Bridge and Shezi and dredged a new channel about 1,828 meters in length and 150 meters in width to solve the flood problem in Shilin and Shezi. The land reclaimed from the river is Keeho Road and Shishan Road nowadays (Figure C-1).

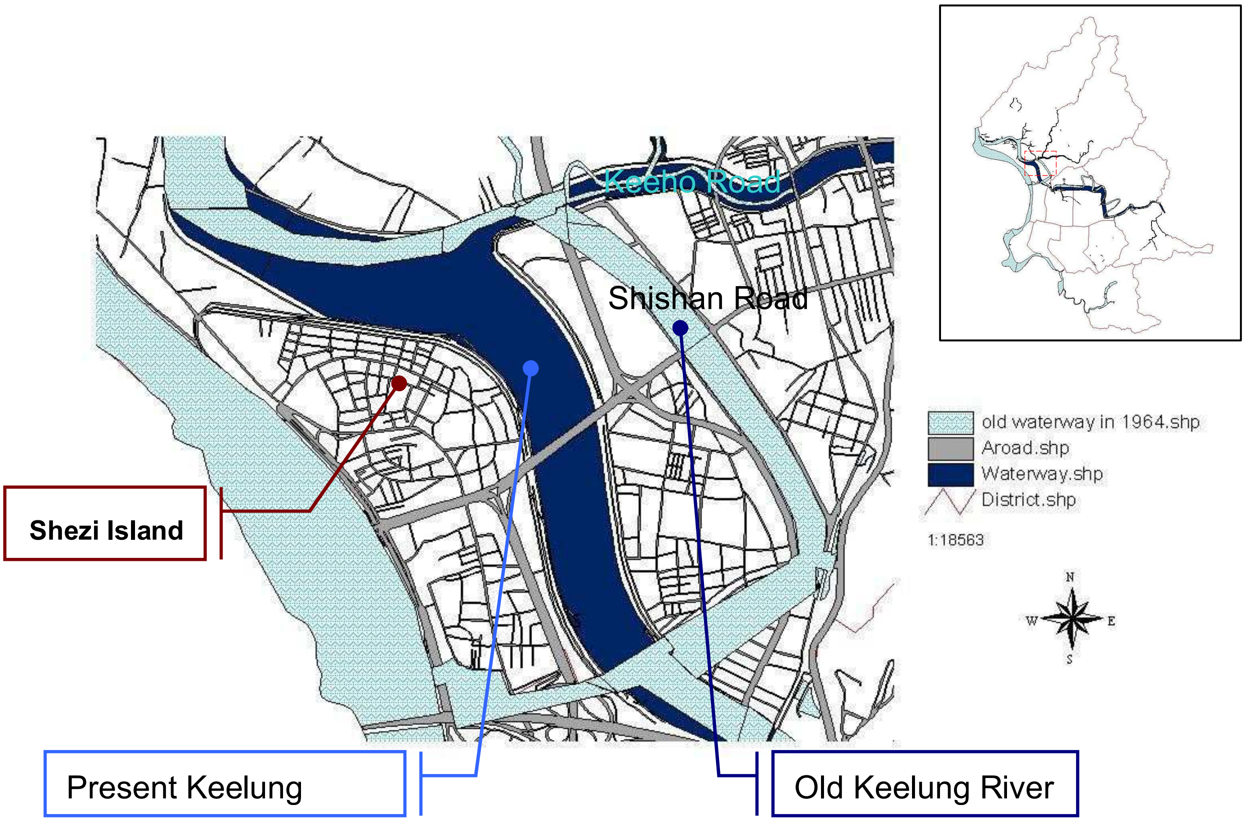


Figure C-1: First straightening work of The Keelung River (Base maps: NORTH, 2000)

A. Background and planning process

The flood procures the loss of habitats at Zhongshan, Dazhi, Shongsang, Shilin and Beito which were the CBD (central business district) of Taipei City. Therefore, the original idea was decreasing the damages caused by floods. After discussing with the American engineers, they proposed to straighten the zigzag channel between Chengde Bridge and Shuanxi.

B. Target and Scope

The main target was reducing the flood disaster of all Danshui Basin, especially the middle section of lower The Keelung River (Shongshan and Shilin).

C. Contents and Phases

The relevant impacts included: a) dredging the estuary of Danshui River. b) broadening the channel of The Keelung River between Shezi and Guandu, and straightening the channel between Chengde bridge and Shuangxi. c) changing the route of The Keelung River. d) building up embankment along The Keelung River next to Shezi, Shilin, Shongshan, Dazhi, and Yuchen. f) setting up 200 years as the flood recurrence period for the main stream and tributaries of The Keelung River, which is the standard in Taipei City up to now. At the same time, the concept of river management was also set.

All works were gradually finished in three steps. It took two years to finish the first part of the project, focusing on Guandu area and the embankment between Shilin and Shuangxi on the left side of The Keelung River. The second step was the embankments around Shongshan on the left side of the Keelung River, Dazhi on the right side of the Keelung River, and changing the course of the Keelung River. This part had been done for four years. The last phase was establishing Yuchen embankment on the left side of the Keelung River and the embankment along the tributaries (Nanyaxi and Huangxi) for four years.

D. Effect

The new channel between Bailin Bridge and Shuangxi has been totally altered. There was a large area of land reclaimed from the Keelung River in Shilin (between Keeho road and Shishan road). The landscape were also totally changed. Afterward, due to the establishment of super highway (1971-1978), which was built across the Keelung River, the Shezi Island was transformed from a sandbank into a peninsula next to the Keelung River.

III. Second straightening work of the Keelung River

A. Background and planning process

The first straightening work did not really solve the flooding problem. While torrential rainfall occurred, the water still overflowed and the seawater even flowed backward to the middle stream of the Keelung River due to tidal effect. Moreover, along the lower Keelung River, many illegal and disordered buildings or constructions in the neighbourhoods and the agriculture on riverbanks caused the poor drainage. Consequently, the water quality was getting worse in the 1980s.

The authorities tried to modify this situation in the 1980s; however, there was still no comprehensive plan to treat these illegal resident areas on riverbanks. In 1987, the *Lynn* Typhoon heavily hit this area and almost destroyed Nehu, Shongshan and Nangang. Thus, Taipei City Government announced to build new embankments along the Keelung River in 1991 and started to do the second straightening work between Chengmei Bridge and Zhongshan Bridge.

B. Target and Scope

This project wanted to solve the flooding problems, water pollution and illegal buildings at the same time and included two sections of straightening channel: a) the section between Chengmei Bridge and Zhongshan Bridge was the so-called big curve section, which included two parts: Jintai section (Shongshan embankment to Dazhi pumping station) and Jiozong section (Maishuai 1st bridge to Mingqian bridge). b) the other part of plan-to-change route, the so-called small curve section, which was between Nanhu Bridge and Chengmei Bridge, was cut from 3.3 kilometers down to 0.8 kilometers (Figure C-2).

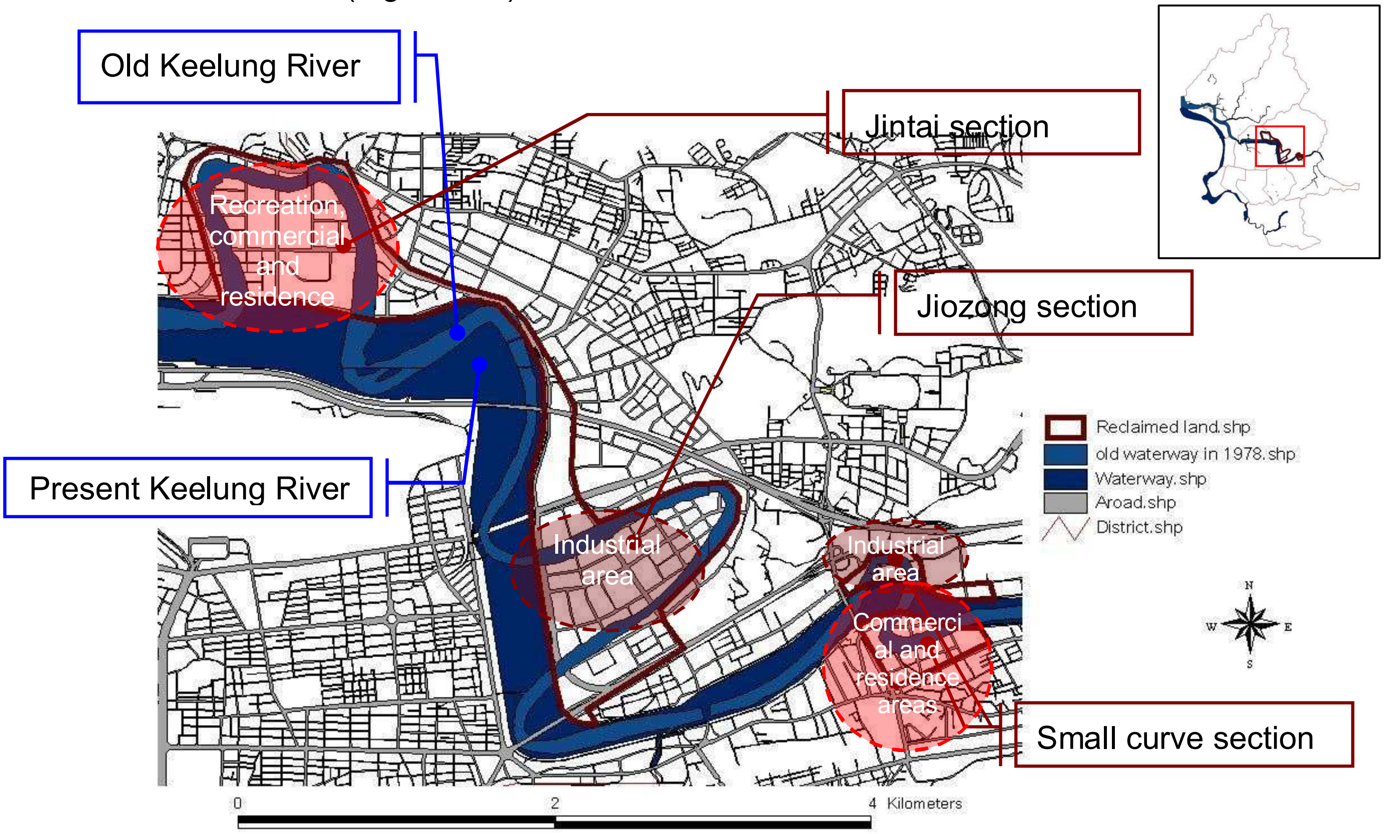


Figure C-2: Second straightening work of the Keelung River (Base maps: NORTH, 2000)

C. Contents and Phases

Moreover, this project also heightened the embankments on the left side of the Keelung River and established the new embankments on the right side. The soil preparation for the new reclaimed land was directly reused from the Keelung River in order to reduce the impact of the change of river course (ca. 242 ha). Thus, the soil of new land could consist with the previous slope of channel for sure with this important measure. This project is introduced with two parts in more details as follows:

a) Chengmei Bridge to Zhongshan Bridge: it spent about four years for changing the river route (1992-1995). The channel length was shortened from 4.2 kilometers down to 1.9 kilometers in Jintai section (Shongshan embankment to Dazhi pumping station). Jiozong section (Maishuai 1st Bridge to Mingqian Bridge) was shortened from 4.4 kilometers to 1.8 kilometer. Meanwhile, the new embankments have length of about 5,640 meters, including construction on the left side, such as Yuchen embankment, Fuyuan retaining wall and Shongshan embankment. Nehu embankment and Dazhi embankment were built at the right side. The reclaimed land has entire area of 555 ha and was separated from the Keelung River by embankments. The land use on riverbanks and the neighbourhoods was determined as residential area or commercial area (ca. 237.55 ha). For draining flooded fields, new pumping stations were also built at Beian, Huanshan, Gangqian, Yiangguang, and Mingquan.

b) Nanhu Bridge to Chengmei Bridge: the channel was shortened from 3.3 kilometers to 0.8 kilometers. The new riverbank has an area of 90 ha. The new embankments spread 6600 meters long. There were five new pumping stations at Nanhu, Nangang, Changsho, Chenggong, and Chengmei. The reclaimed land in neighbourhoods has an area of 34.98 ha and determined as high-tech industry region.

D. Effect

The second straightening work seemed to ease the flood problem of the Keelung River; the new transportation construction was also convenient to move across the Keelung River. However, preventing floods should not be the one and only target of river management. The landscape structure, environmental health and ecosystem functions should be also considered. Many important habitats on riverbanks just destroyed due to the straightening works, thus the whole urban ecosystem was changed.

IV. Integral management of the Keelung River

A. Background and planning process

The flooding problem occurred once in a while after heavy typhoons hitting Taiwan. Most disaster areas were in the middle and lower Keelung River. The Ministry of Economic Affairs started to develop an integrated management of the Keelung River due to great amounts of damage caused by Xangsane Typhoon and Nari Typhoon in 2000. This project covers almost 70% of the entire Keelung River (from Hotongjiesho Bridge to confluence, ca. 59.5 kilometers.), but most constructions have mainly carried out in the middle stream. The first phase was finished in 2005, and the second phase is supposed to be done in June of 2008.

B. Target and Scope

This project firstly planed to calculate the regular discharge capacity in the entire Keelung River, and then devised the regulatory flood-diversion channel to reduce the pleasure of flood (the flood recurrence period of 200 years). The project targets are mitigating the discharge while encountering the flood peak and improving the environment of flooded areas by urban renewal at the same time. The main work of this project aims at rebuilding embankments along the middle section and reconstructing Zhongshan Bridge crossing the lower Keelung River.

C. Contents and Phases

The construction includes Yuanshanzi flood-diversion channel, channel dredging works, drainage works, bridges, embankment, neighbourhood renewal, flooding forecast and alarm system and hillside preservation. The main constructions are concluded as follows:

a) Yuanshanzi flood-diversion channel: A flood-diversion channel was built at Yuanshanzi in the upper Keelung River, in which the partial flood water flows into East Sea with control device. It works both for flood control and also for discharge of rainfall. It covers and area of 90 square kilometres (18% of the drainage area).

b) Flood control works: There are 11 sub-projects in order to prevent floods and for recreation in the middle and lower Keelung River. For instance, embankments (the flood recurrence period of 200 years), pumping stations and discharge works were redesigned along the riverbanks. There are four sub-projects in Taipei City, which are embankments along Negoxi (a branch of The Keelung River), rebuild of Zhongshan bridge, renovation of Huangxi (a tributary of The Keelung River), and broadening the narrowest channel (Yuanshan) from 100 meters to 140 meters.

D. Effect

This project tried to enhance the ecological environment and prevent the flood water at the same time. With renovating the environment on riverbanks and in the neighbourhood, it would show positive feedback to promote the economical development. Though it emphasized that all works were designed and built with ecological engineering, there was no ecological database and without any basic study as the construction supports. The government tried to solve all problems with engineering only, which consequently may not really improve the riparian environment as the other previous projects.

Annex D: Relevant Laws of Riparian Space and River Management in Taiwan

Law	§	contents
Water Act (Amended on July 11. 2007)	46	The construction, alteration, or removal of any of the following structures for a water work shall have the prior approval of the authority-in-charge: 1. flood control structure; 2. water conveying structure; 3. reservoir structure; 4. drainage structure; 5. ground water extraction structure; 6. navigation related structure; 7. hydro-power related structure; and 8. other hydraulic structures. For construction or alternation of any structures enumerated above, the proprietor shall submit detailed plans, drawings, and descriptions for the approval of authority-in-charge. Where it is necessary to amend or alter the approved plans or drawings due to special circumstances, the proprietor shall show cause and submit the modified plans or drawings for approval to effect the alteration. However, for the sake of hazard prevention or temporary relief, the proprietor may proceed with change of plan without prior approval and file with the authority-in-charge afterwards. The authority-in-charge may issue an order of alteration or demolition of any hydraulic structure built without its prior approval.
	47	The authority-in-charge may revoke or restrict the approval granted to a water work in any of the following events; if necessary, the authority-in-charge may order an alteration or demolition: 1. construction not in compliance with the approved plan or exceeding the scope of approval; 2. poor working method that adversely affects public interests; 3. working procedures not in compliance with laws and regulations; Failure to commence or complete work within the permitted duration unless an extension is granted by the authority-in-charge under special circumstances.
	51	When the construction of a water work has an impact on flood control, the authority-in-charge may order the proprietor to construct proper flood control structures.
	55	When a water work proprietor develops new water sources for waterway in connection with a hydraulic construction, said proprietor has the priority to apply for right of use and collecting income derived from the water source, provided the vested interests in water use of the downstream water right holders are not affected. The vested interests as referred to in the preceding paragraph shall mean the natural flow of water not exceeding the volume under the registered water right before the new water sources are developed.
	57	When a water work proprietor's use of land interferes with a land owner's ingress and egress or blocks the gutters or waterways, the proprietor shall, with consent of such landowner, build bridge, culvert, aqueduct, or other structures, or provide comparable compensation.
	61	When a water work adversely affects the cleanness of a water source, the authority-in-charge may place restrictions on or ban such a project.
	63	When a water work involves matters under the jurisdiction of other government agencies, the authorities-in-charge under this Act will carry out the coordination. When matters under the jurisdiction of other government agencies involve water works, the consent of the authorities-in-charge under this Act shall be obtained.
	63-3	The following conducts or activities are prohibited within the confines of irrigation facilities as delineated by its proprietor, and approved and publicly announced by the authority-in-charge: 1. filling canal channel; 2. damaging pond, canal channel or accessory structures thereto; 3. opening, closing, moving or damaging water gate or its auxiliary facilities; 4. dumping waste soil or other waste; 5. quarrying or stacking soil and stone; 6. planting or harvesting vegetation, or raising livestock, or breeding aquatic products; or 7. engaging in activities that impedes the safety of irrigation facilities. The activities of discharging wastewater into or drawing water from canal channel, or building structures on pond or canal facilities or within the boundaries of pond or canal are not allowed unless with the approval of authority-in-charge.
	65	To mitigate flood damages, the authority-in-charge may restrict use of land in the vicinity reached by flood through zoning regulation. The authority-in charge shall formulate and implement the restriction and zoning regulation under preceding paragraph based on flood history records and forecasts after the approval and public announcement by the superior authority.
	68	Wastewater from factories and mines or urban sewerage shall be discharged into properly selected locations after adequate treatment. If such wastewater or sewerage adversely affects water quality, human health, public interests, or interests of a third party, the authority-in-charge may place restrictions on or prohibit the discharge thereof, and those who suffer damages may claim compensations.
	78	The following conducts or activities are prohibited in the river area: 1. filling the river waterway; 2. damaging or altering river flood control structures, equipment or stone and other materials for flood control or use in flooding emergency; 3. opening, closing, moving or damaging water gate or its auxiliary facilities; 4. building factory or house; 5. dumping waste soil or other debris that will block flow of water; 6. driving on roads other than designated ones; or 7. engaging in other activities that impede river protection.
	78-1	To engage in the following conducts or activities in river area shall obtain prior approval from the authority: 1. installing, rebuilding, repairing or demolishing structures; 2. discharging wastewater or drawing water; 3. quarrying or stacking soil and stone; 4. planting vegetation; 5. engaging in excavation, burying/filling or other activities that alter the existing patterns in the river area; 6. building fish pond, growing oyster or raising livestock; or 7. other river management related activities as announced by the authority-in-charge.
	78-2	The central authority-in-charge will set forth regulations governing river management that stipulates the planning and facilities of watershed management, safety inspection and maintenance of river embankment, river flood control and flooding emergency, zoning, approval announcement of river area, river usage and management and other provisions.
	78-3	The following conducts or activities are prohibited within the range of drainage facilities: 1. filling the drainage channel; 2. damaging or altering drainage facilities; 3. opening, closing, moving or damaging water gate or its auxiliary facilities; 4. dumping waste soil or other waste; 5. raising livestock or engaging in other breeding activities; or 6. engaging in other activities that impedes drainage. To engage in the following conducts or activities within the range of drainage facilities shall obtain prior approval from the authority: 1. installing, rebuilding, repairing or demolishing structures; 2. discharging wastewater; 3. quarrying or stacking soil and stone; 4. planting vegetation; or 5. engaging in excavation, burying/filling or other activities that alter the existing patterns in the range of drainage facilities;
	79	The authority-in-charge may, after obtaining approval from its superior authority, order a party to modify, relocate, or demolish any plants grown or structures built on the riparian land of waterways that in the judgment of the authority-in-charge have

		interfered with water flow, provided that appropriate compensation will be provided for. The riparian land referred to under the preceding paragraph shall mean the land along waterways without dike and stretching to the outer reach of normal flood water.
	80	Reeds, aquatic grasses, willows or other vegetations growing in the area between a dike and river banks and having the utility of wind and wave control, regardless of being privately or publicly owned, shall not be mowed down without permission unless off the flood control season or with permission from the authority-in-charge.
	81	No enclosing of a sandbank or beach of a waterway for cultivation is allowed unless the authority-in-charge deems such enclosure is not detrimental to water flow or flood control and approval from its superior authority has been obtained.
	82	Land lying within the line of a waterway management plan or the designated dike line may be requisitioned by the government according to law after the authority-in-charge submits its plan to the superior authority for approval and public announcement. As to such land not requisitioned, the authority-in-charge may restrict its use for the purpose of flood control, but cannot proceed with partition registration.
	83	Land situated within areas under normal flood submerge level may not be privately owned. Such land already held under private ownership may be requisitioned by the government according to law. As to such land not requisitioned, the authority-in-charge may restrict its use for the purpose of flood control, but cannot proceed with partition registration. The authority-in-charge shall submit the areas under normal flood submerge level under preceding paragraph for approval and public announcement by its superior authority.
Enforcement Rule for Water Act (Amended on Sep. 17. 2004)	4	The term "waterway" depicted in the Act refers to areas run through by rivers, lakes, reservoir storage area, drainage facility area, canal, distributary, detention pond or waterflow of diversion route.
	47	The "flood" depicted in Article 64 of the Act refers to inundation and pooling of water; "inundation" is defined as an overflowing of water in the waterway that surpasses the possible accommodation and discharge limits of waterway and suffices to spill over and cause disaster; "pooling of water" is defined as a body of standing water on ground surface from rain or melted snow and enough to cause damages of flood submergence. The "distributary" depicted in Article 64 of the Act refers to another waterway constructed to divert the overflow in certain section of the main channel and merge the diverted flow back into the main channel at a proper downstream location or discharge the diverted flow into a lake or ocean, or store it temporarily in a low-lying area. The "newly constructed waterways" depicted in Article 64 of the Act refers to new waterways constructed to divert or discharge water for the purpose of flood control; a waterway that is also used for navigation is regarded as a canal.
	53	The "scope of waterway protection" depicted in the first paragraph, Article 75 of the Act refers to river area, range of drainage facilities or areas reached by the flow of waterway.
	56	The "area between a dike and river banks" depicted in Article 80 of the Act refers to the area between the dike line on the water side of the dike and the line on the water side of the river bank.
	57	The "sandbank or beach of a waterway" depicted in Article 81 of the Act refers to an area with access prohibited or restricted due to obstruction of water flow or flood control, including swamp, reclaimed land and delta at estuary, and designated flood discharge area.
	58	The "line of waterway management plan" depicted in Article 82 of the Act refers to tue water-side dike shoulder lines or lines bordering the width of water surface under the waterway management plan; the "designated dike line" refers to the line starting from the outer dike line, including the boundary lines of dike foundation, flood barrier roads, land reserved for maintenance and repair, and land for safety control.
	59	The "normal flood submerge level" depicted in Article 83 of the Act refers to the flood level corresponding to the runoff peak flow with two-year return period; the "areas under normal flood submerge level" refers to areas covering the land-adjoining side of two banks facing the normal flood submerge level plus a certain area.

Water Pollution Control Act (Amended on May 22. 2002)	6	The central competent authority shall delineate water zones and determine water body classifications and water quality standards based on the special characteristics and on-site conditions of water bodies. The central competent authority may delegate the delineation of water zones and the determination of water body classifications and water quality standards in the foregoing paragraph to special municipality, county or city competent authorities. The competent authority in consultation with units related to the use of water bodies shall make determinations for the delineation of water zones.
	27	When there is concern of the serious endangerment of human health, agricultural or aquacultural production, or drinking water sources due to the discharge of wastewater or sewage by an enterprise or sewage system, the statutory responsible person shall adopt emergency response measures promptly and notify the local competent authority within three hours. The central competent authority shall determine the circumstances of the serious endangerment of human health, agricultural or aquacultural production, or drinking water sources referred to in the foregoing paragraph. The central competent authority shall determine the content and implementation methods for the emergency response measures in Paragraph 1. Under the circumstances in Paragraph 1, in addition to ordering the adoption of necessary control measures, the competent authority may, for those serious circumstances, also order the suspension of business or the partial or complete suspension of work.
	28	Maintenance and preventive measures shall be adopted for those circumstances in which there is concern of the leakage through negligence of pollutants or wastewater or sewage into a water body from the conveyance or storage equipment installed by an enterprise or sewage system; for those circumstances in which leakage through negligence causes the pollution of a water body, emergency response measures shall be adopted promptly and the local competent authority notified within three hours of the occurrence of the accident. The central competent authority shall determine the content and implementation methods for the emergency response measures in the foregoing paragraph.
	30	The following acts are prohibited within water pollution control zones. 1. The use of agricultural chemicals or chemical fertilizers that causes concern of polluting water bodies designated by the competent authority 2. The dumping of garbage, nightsoil, sludge, acidic or basic liquid waste, construction waste or other pollutants in water bodies or within a designated distance from their shorelines 3. The use of toxins, drugs or electric current to catch or kill aquatic organisms 4. The raising of poultry or livestock in water bodies designated by the competent authority or within a designated distance from their shorelines 5. Other behavior sufficient to cause water pollution officially announced as prohibited by the competent authority. The competent authority shall, depending on actual requirements, officially announce the designated water bodies and designated distance referred to in Paragraph 1, Subparagraphs 1, 2 and 4. However, for those circumstances in which the central competent authority has other regulations, the regulations of the central competent authority shall be followed.
	2	The river in this Regulation refers to the waterway that has been announced a significant water system subject to the development of water resources, homeland preservation, or local area development recognized by the central authority. The river in the preceding paragraph can be categorized into three kinds according to different managements: the central controlled river, the municipal controlled river and the county controlled river.

Regulation govering River Management (Amended on Jan. 17. 2007)	3	The river management in this Regulation refers to the following: 1. Planning, designing, and constructing the river management plan.2. Demarcating and modifying the river districts. 3. Demarcating the quarry districts. 4. Drafting the plan of river environment plan. 5. Managing the river flood-protection construction. 6. Baning and punishing the events of river patrol and illegally harming to rivers. 7. Accepting, reviewing, approving, abolishing, revocating the application of using river and collecting the usage fees. 8. Acquiring the lands for the management plan. 9. Controlling flood and flooding emergency. 10. Other related administrative matters concerning river management
	4	The authorities of central, municipality and county levels shall conduct the river management matters in accordance with the preceding article provided that the flood control and flooding emergency administrated by the central government provided in the preceding 9th item shall administrate by the municipality and county governments. The authority stated in the preceding paragraph refers to the Water Resource Agency, Ministry of Economic Affairs (hereinafter "the Agency") at the central level, and the river management offices under the Agency (hereinafter "the Office") execute the river management matters.
	5	The Agency may commission the river management matters regarding the river administrated by the central government provided in the fifth to eighth items and the tenth item in Article 3 to municipality and county governments. Those authorities may commission the abovementioned matters to rural townships, urban townships, cities and districts or other public entities. Each level of authority may commission the river management matters regarding the upstream river to the competent authorities or resevoir agencies.
	6	The terms in the Regulation are defined as follows: 1. Rive Zone: It refers to the outfall zone and one of the following lands: (1) The land that does not include in the river management plan or does not demarcate the lines of waterway or the proposed line of the dike under the preventive plan announced in accordance with Article 82 belongs to the common flood draining area of Article 83 and has been announced demarcation; provided that the broader one prevails either the anticipated line of the dike according to the river management plan (i.e. the range line of the land in the waterway preventive plan) or the line of waterway preventive plan and such demarcation shall be announced. (2) The lands that are demarcated in accordance with the scope of flood-protection construction, which is completed within a certain river segment according to the river management plan, and that are reserved for preparatory use when the flood-protection construction is in need of maintenance after the announcement of demarcation. (3) The land of the river segment that is not announced in accordance with Item (1) has been ascertained by the authorities after reviewing actual coverage of the river, the usage and ownership of the land and other relevant materials. 2. Dike Land: It refers to the proposed land for the dike or the land that has been constructed the dike, and its adjunctive construction and emergence flood-protection roads thereon. 3. Emergence Flood-Protection Road: It refers to the road and its side trench that is convenient for the flood protection and emergent transportation, and is a portion of the dike. 4. Outfall Zone: It refers to the zone that covers from the linkage of river zone line and high water line of sea shore to the sea stretching for 150 meters; however, the stretching distance shall be limited to the isobath at the attitude of -5 meters if the isobath at the attitude is beyond -5 meters. 5. Inner of Dike: It refers to land surface of the dike (i.e. rear side of dike). 6. Outer of Dike: It refers to water surface of the dike (i.e. front side of dike). 7. Public Land of River: It refers to the public owned land, including registered and non-registered. 8. Reclaimed Land: It refers to the land out of river zone due to the transition of rivers or the establishment of river control construction and shall be announced.

	6	9. Flood-Protection Construction: It refers to the construction for the purpose of flood protection, including the dike, revetment, groyne, check dam, submerged dam, consolidation work, water gate of the facility attached to dike and other river preventive construction.10. River Map Information: It refers to the illustrations of the river zone, the line of waterway and the line of land for waterway management plan that are demarcated by the authorities pursuant to this regulation. 11. Flooding Emergency: It refers to the emergent rescue measure for preventing the danger or damage to the flood-protection construction caused by the act of God from enlarging its scope of damage. 12. Emergency Repair: It refers to the emergent measure in order to prevent the unrecovered flood-protection construction from enlarging its scope of damage while the threat of act of God has been lessened.
	12	The authorities shall conduct a general check on every river in its jurisdiction jointly with other competent authorities before the end of December each year. The items to be checked are as follow: 1. the condition of damage to the flood-protection construction and the measure to be reinforced or improved. 2. the construction attached to the dike and the flexibility effect of the water gates along the river and the gates of watercourses, and the coordination of each responsible person among different agencies . 3. the use that hinders the river protection or endangers the safety of flooding protection. The check indicated in preceding subparagraph 1 or 2 shall complete the repair before the flooding period of each year; if subparagraph 3, shall be conducted immediately.
	13	The river management plan shall be worked out in accordance with each water system or several water systems with correlations by a single authority.
	27	The authority may draw up the management plan of river environment according to the river management plan with reference to water and soil resources, ecological environment, nature landscape, development of the land along the river side and other related matters, and submit the plan for the competent authorities for approval. The authority shall, subject to each river environment management plan indicated in the preceding paragraph, announce the scope and items of sub-zones and the use that may apply for use permit. If the use has already been permitted, any alteration shall wait after the expiration of time. If the use is for the planting, the alteration may be made after the expiration of second extension. The authority may command the user to clean or recover the land, which has been permitted to use indicated in the preceding paragraph, when the permit has been expired, revoked, or annulled. If the user does not clean or recover the land in accordance with the deadline, the authority may make a decision against the user pursuant to Article 95 of this regulation. If the public land of the river meets the requirement of permission, the authority may announce the application for use permit within a designated period.
	28	Other uses that relate to the river management stated in subparagraph 7 of Article 78-1 are as follow: 1. small amount for self use purpose under Article 3, paragraph 1, subparagraph 1 of Sand and Gravel Excavation Act. 2. the act prescribed in Article 19, paragraph 1, subparagraph 3 of Aboriginal Basic Law. 3. the use that is across above or beneath the river zone to a certain degree. 4. the ancillary facility that is necessary for the permitted use or other uses. 5. the long-term use at a fixed location that does not alter the original shape of river by means of a temporary, non-fixed facility or levelling on the spot. 6. the temporary use for a large event or rescue exercise.
	37	Permission is not allowed where the planting is within 20 meters from the water surface close to dike foundation, flood control wall, revetment or construction attached to the dike; provided that the plant is belong to herbaceous or liana plant and its attitude is under 50 centimetres and no supporting pergola is established, The regulation governing the planting nearby the river zone shall be mandated by the competent authority.

38	Those who apply for constructing a fish farm shall be limited to the outfall area with width of over 300 meters or the tidal river section that does not affect the waterway area, and the following areas shall not be allowed: 1. The area of within 80 meters of the outer dike foundation, flood control wall, revetment or construction attached to the dike. 2. The area of one-third of the width of river, between the lines of river management of two banks, calculated from the center of frequent waterway area to banks of both side. 3. The area of upsteam or downstream 500 meters from the construction of Article 72 or Article 72-1 or the water intake point, or upstream 1000 meters/downstream 400 meters from the water intake facility. The area of applying for constructing a fish farm, which the width in total shall not be larger than the width of one-third of the river zone; the bottom of farm shall be higher than the riverbed of the plan and not be lower than 150 centimetres of the average ground level of the spot in application; the bank of the farm shall be constructed not be higher than 50 centimetres of the average ground level and constructed by the soils and rocks on current river area. The soils and rocks excavated from the farm pool indicated in the preceding paragraph shall be conducted according to the manner mandated by the competent authority.
39	Those who apply for growing oyster shall be limited to the outfall area or the tidal river section that does not affect the waterway area, where one-sixth of the width of river, between the lines of river management of two banks, calculated from the centre of frequent waterway area to banks of both side shall be reserved for the use of drainage section.
40	Those who are allowed to use the public land of river may cooperatively run the agricultural business with the farmers whose lands are adjacent to the public land or the neighbour farmers subject to related regulations.
41	The authority shall allow taking soil sand and gravel under the goal of river management plan on the premise of stabling riverbed and not affecting the direction of waterway and mark out the permissible taking area and make the priority order of taking depending on the geomorphological change of riverbed, drainage section and other factors and report to the competent authority for approval and announcement. However, the following areas shall not be marked out as permissible taking area: 1. The area of within 80 meters of the outer dike foundation, flood control wall, revetment or construction attached to the dike. 2. The area of upsteam or downstream 500 meters from the construction of Article 72 or Article 72-1 or the water intake point, or upstream 1000 meters/downstream 400 meters from the water intake facility.
42	The industry competent authority of the construction indicated in subparagraph 2 of the preceding Article may, in consideration of safety, produce a written explanation for reducing the permissible taking area and submit it to the authority. After agreed by the authority, the written explanation shall be submitted to the competent authority for approval to reduce the permissible taking area. The industry competent authority shall, based on the industry safety and in need of dredging a river, implement the matter within the scope of preceding paragraph after approval by the river management authority.
45	The local government may map out a plan, which is submitted to the authority and then be approved by the competent authority, to allow taking soil sand and gravel when the authority of the central controlled rivers is in need of dredging rivers or managing river ways. The scope of permission in the preceding paragraph shall not be limited to the proviso of Article 41.

	50	Those who apply for more than two kinds of permissible use for recreational purpose and one of the use indicated in Article 78-1 shall be limited to the following: 1. A car racetrack, bikeway, or paintball field. 2. A golf driving range. 3. An ultralight aircraft drome. 4. A ball game field or other athletic field. 5. A water park. The facility indicated in the preceding paragraph shall be limited to temporary and removable use. The applicant shall be responsible for the maintenance and management work and adopt those into the use plan, which shall include the following matters: 1. A written consent issued by the owner or legal occupant of the private land, or a certificate issued by the administration agency of the public land. 2. A written consent by the industry competent authority. 3. A use management plan shall list the following items: (1) Impact assessment of flood-discharging function on the facility managing the water level of river within the use scope. (2) Measure of managing the original objects on the ground. (3) Facility deployment, divisions, circulation of use and frequency forecast. (4) Access road, hygiene equipment and other supporting measures. (5) Safety protection and enhanced measures for night use. (6) Maintenance measures and organization. (7) Anticipated time schedule of construction and operation periods. (8) Other matters assisting the river management. 4. The contingency plan during the high-water season shall contain the following matters: (1) Establishment of warning and alarm systems and emergency evacuation measure. (2) Measures governing the blocking of divisions. (3) Preparation of flood-control equipment. (4) Disassembly and temporary place of non-fixed facility. (5) Organization of contingency misssion. The applicant shall, before beginning the construction, prepare the related documentation and written consent issued by the competent authority of environment if environment impact assessment is needed in accordance with the Environment Impact Assessment Act, and the permissible use certificate shall be issued after the approval by the river management authority.
	51	Other governmental agencies may, in line with utilization of land along the banks of river or other overall planning, map out a use plan, which combines the functions of river ecology protection and recreation, without hindering the safety of river control, and report it to the river management authority for approval.
	65	The matter of the river under the same water system, which drifts among different municipalities and counties (cities), authorized to the governments of municipality or county (city) before establishment of the special agency shall be managed in accordance with this regulation.
Special Act Governing the Management of Keelung River Basin (promulgated on Oct. 31, 2001)	3	The term "central authority" depicted herein refers to the Ministry of Economic Affairs.
	4	The term "Keelung River and Keelung River Basin" depicted herein refer to sections and reaches within the Keelung River watershed covering the administrative regions of Taipei City, Taipei County and Keelung City.
	6	In order to expedite the improvement of drainage and flood control functions of Keelung River, the government may, for the purpose of bypassing restrictions provided under other laws, execute the management program in accordance with the provisions of the Temporary Act for Post-921 Quake Reconstruction.
	8	This Act shall be in force from the date of promulgation for a period of ten years.

Regulation Governing the Land Use of Flooded Area of Keelung River (promulgated on Jan. 8, 2003)	2	The flooded areas of Keelung River Basin indicated in this regulation refers to the following areas: 1. The land within the scope line of Keelung River management basic plan announced in accordance with Article 82 of Water Act. 2. The detention basin established in accordance with the Overall Management Plan of Keelung River. 3. The low area adjacent to the land of management plan with risk of flood before completion of the Overall Management Plan of Keelung River. 4. The area with risk of frequent flood due to the low-lying land or other factors before completion of the Overall Management Plan of Keelung River.
	7	Building houses, dumping debris or waste soil, taking rocks and sands without permission, constructing fish farms, growing oysters or other breeding acts are not allowed in the flooded area of restricted area of first degree. Otherwise stated in the preceding paragraph, any establishing, remodelling, repairing, demolishing the construction or planting or other acts that may alter the original terrain shall apply to the 10th Bureau of Agency for approval in accordance with Article 28 of the Regulation Governing River Management.
	9	The house in the flooded area of restricted area of second degree shall be constructed two-floor or above, and the owner of the ground floor shall be the same as the second floor; provided that any owner of above the second floor may provide written consent to the user of first floor for the short-term use of evacuation against flood. The house indicated in the preceding paragraph is a temporary single-story house shall equip necessary evacuation facility; if the building has basement, in addition that the user of basement is the same as the ground floor, shall be only for joint use. The machine and equipments of the factories situated in the restricted area of the paragraph 1 that are not easy to be removed or are the viable facility shall be installed at the floor that could keep from the flood. The house indicated in paragraph 1 refers to the building fixed on the land, in accordance with subparagraph 1 of Article 2 of House Tax Statute, for business or residential purpose. The construction refers to the acts of newly constructing, annexing, remodelling or repairing.
	10	The bureau may, after surveying the originally legal house located in flooded area of restrict area of first degree, report to the Agency for requesting the construction competent authority to annul the construction license and order to demolish the building within the time limit; the same effect shall apply to the situation that the building with license is about to construct or is constructing. The bureau may, after surveying and confirming that the construction other than the originally legal house, plants or other things that may alter the terrain situated in the restricted area indicated in the preceding paragraph, report to the Agency transferring to MOEA for ordering the owner or user to demolish, improve or remove on one's own; the same effect shall apply to the situation that the house or plant is allowed to be constructed or planted but yet not constructed or planted or even is constructing or planting.
	11	The bureau may, after surveying and confirming that the originally legal building situated in the flooded area of restricted area of second degree does not meet the review standard stated in Article 8, report to Agency for requesting the construction competent authority to annul or alter the construction license and order to demolish or improve the building within the time limit; the same effect shall apply to the situation that the building with license is about to construct or is constructing. The bureau may, after surveying and confirming that the originally illegal building situated in the restricted area indicated in the preceding paragraph that does not meet the review standard in Article 8, report to the Agency for requesting the construction competent authority to order, at its discretion, to demolish the building, in whole or in part.

Soil and Water Conservation Law (Amended on Dec. 17. 2003)	9	The competent authority and relevant government departments involved with the plan will work together to implement a plan for watershed area protection, focusing on soil and water conservation and proper use. The competent authority and relevant departments will develop medium-term and long-term plans. After plans have been approved by the competent authority of the central government, each agency, department or the obligator of soil and water conservation will carry out the aims designated within the plan. Watershed areas of rivers will be designated jointly by the competent authority and relevant departments of the central government.
	16	The following areas are hereby designated as soil and water conservation zones: 1. Reservoir watershed areas. 2. Watershed areas located in river basins or in rivers that need special protection. 3. Sea shores, lake shores, and the banks of waterways that need special protection. 4. Sand dune areas, beaches, and other areas that are especially susceptible to wind erosion. 5. Slopeland areas in which the slopes are steep enough to pose a threat to public safety. 6. Other areas that seriously affect soil and water conservation. The areas mentioned above have to be managed by departments created or assigned by the central, municipal, and county / city competent authority.
	17	Designated soil and water conservation zones that cross the boundaries of a municipality or counties will be delimited by the competent authority of the central government, which will also announce that delimitation. Within a municipality, municipality competent authority will delimit zones, and such delimitation will be approved and announced by the competent authority of the central government. The criteria to be followed in delimiting the above areas will be established by the competent authority of the central government.
	18	The competent authority must have a long-term soil and water conservation plan for the area. Every five years, the said authority must review and revise the plan based on current conditions. If there is a need to change the plan, the competent authority will through official channels, submit the planned change to the central government for approval.
	19	The areas of focus of the long-term soil and water conservation plans for designated soil and water conservation zones are as follows: 1. Reservoir and watershed areas: Conservation of water resources, prevention of erosion, landslides, and debris flow, improvement of water quality and preservation of the natural ecology. 2. Watershed areas in major river basins: Preservation of soil and water resources, prevention and control of erosion and landslides, prevention of floods and preservation of the natural ecology. 3. Sea shores, lake shores, and the banks of waterways: Prevention of landslides and erosion, preservation of the natural ecology and protection of adjacent land. 4. Sand dunes and beaches: Wind erosion control and sand stabilization. 5. Other areas: Conservation items are designated by the competent authority. No development activity will be allowed in any of the designated soil and water conservation zones, with the exception of major water resources projects or natural recreation areas requiring only a limited extent of change in landscape and having secured an approved environmental impact statement issued by the competent authority of the central government. The criteria for defining the limited extent of charge in landscape will be designed by the competent authority of the central government and relevant authorities.

Regulations Governing Water Recreation Activities (Promulgated on Feb. 11. 2004)	3	The term "water recreation activities" as used in these Regulations means the following water-related activities: 1. Swimming, surfing, and diving 2. Operating equipment for wind surfing, water-skiing, parasailing, jetskiing, canoeing, rafting, banana boating, and other such activities 3. Other water recreation activities as announced by the Responsible Authority
	4	The water management authorities referred to in these Regulations are as follows: 1. For water recreation activities within the jurisdictional boundaries of designated scenic areas and national parks, the designated management authorities thereof; 2. For water recreation activities outside the ambit of the preceding subsection, the municipal or county (city) government with jurisdiction over the location concerned. The aforementioned water management authorities shall, for the purposes of managing water recreation activities in accordance with these Regulations, publicly announce and impose penalties as prescribed by the Act.
	8	Those engaging in water recreation activities should abide by the following: 1. Shall not disregard public notices by the water management authorities indicating areas in which activities are prohibited. 2. Shall not disregard public notices by the water management authorities indicating restrictions on the types, scope, time, and conduct of activities. 3. Shall not engage in activities that are detrimental to public safety or endanger other people. 4. Shall not cause water pollution or damage the natural environment or natural landscape. 5. Shall not consume narcotic or hallucinogenic substances or abuse controlled drugs.
	12	The water management authorities shall designate personal watercraft activity zones according to the conditions of each location. When personal watercraft activity is taking place simultaneously with other water activities at the same location, the water management authority must confine the personal watercraft activity to an area of water between two hundred meters and one kilometer offshore as measured from the territorial-water base line or the bank. The aforementioned water management authority must put up clearly visible signs at the activity zone; from land or entry point, the waterway of the activity zone should be at least thirty meters in width and marked by clearly visible signs. Personal watercraft activity must not take place at the same time and location as diving, swimming or other non-motorized water recreation activities.
	1	To excavate earth and rock resources rationally, protect natural environments, integrate administrative system, and prevent inappropriate earth and rock excavation that may result in related hazards, this Act is then made accordingly for the purpose of achieving sustained national development. Provisions of other Acts shall apply when such are not included in this Act.

Earth and Rock Excavation Act (Promulgated on Feb. 06. 2003)	4	The definitions used in this Act are as follows: 1. "Earth and rock" means natural resources such as soil (including clay and silt), sand, gravel and rock, etc. which are not included in Article 2 of Mining Act along with other minerals. 2. "Land earth and rock" means the earth and rock deposited in land. 3. "River and lake earth and rock" means the earth and rock deposited in river and lake. 4. "Coastal and marine earth and rock" means the earth and rock deposited along the coastal line and outside of coastal line. 5. "Earth and rock excavation area" means the area that is approved for earth and rock excavation by Authority. 6. "Earth and rock excavation field" means the site that is used for earth and rock excavation, storage, and its related operations such as handling, crushing, washing and beneficiation. 7. "Permittee" means a person or entity who hold the earth and rock Excavation Permit. 8. "Operator" means a person who actually in charge of the overall management the earth and rock excavation field. 9. "Technical manager" means the technical person who managing the technical and safety aspects of the earth and rock excavation field. 10. "Total quantity control" means the restrictive measures imposed to control the total quantity of earth and rock excavation for a specific area.
	6	The duration for earth and rock excavation permit is limited to 3 years for river and lake earth and rock and 10 years for land and coastal and marine earth and rock. For applying permit extension, the duration approved shall be limited to the period between elapsed time from the date of obtaining excavation permit and the date declaration of commencing the excavation work.
	7	For excavating earth and rock , the application area shall be not greater than 20 hectares for river and water earth and rock, 100 hectares for both coastal and marine earth and rock and land earth and rock. Within the earth and rock excavation permitted area, the excavation is allowed only to the permitted depth measured from the surface excavation boundary line vertically downward. The criteria for the depth of excavation shall be announced through Central Authority after consulting with related Government Authorities.
	8	Municipal or County (city) Authority shall, after receiving the applications of earth and rock excavation and river use, invite River Management Office with application forms and drawings to conduct jointly the site investigation. After obtaining the river use permit issued from River Management Office, Municipal or County (City) Authority shall process and transmit to the applicant. For the works of river and reservoir dredging and maintaining waterway conducted by Water Resources Agency, the excavation of earth and rock complying with Water Resources Act shall be exempted from the restrictions listed in the provisions of this Act.

Special Act for Flood Management (Promulgated on Jan. 27. 2006)	33	In order to protect water resources, water conservancy, traffic safety, urban development, environment and landscape or other public benefits, Central Authority may designate an earth and rock excavation prohibited area, as duty required or applied by the purpose governmental authority. The permittee suffered loss or damage from such designation of prohibited area may claim comparable compensation from the Central Authority or the purpose governmental authorities which ordering or requesting such designation. Disputing over compensation between the permittee and the purpose governmental authorities applied for the designation prohibited area shall be reconciled by the Central Authority. After designated an earth and rock excavation prohibited area, the Municipal Governments or County (City) Authority shall revoke the earth and rock excavation permission, in whole or in part of the excavation area located within the designated prohibited area. The residual earth and rock excavation area after designating for prohibited area, which worth to and the permittee has the intention to continue operating, the permittee shall re-submit earth and rock excavation plan and drawings for the residual area to the Municipal or County (City) Authority to apply for a new earth and rock excavation permit and a new earth and rock excavation field registration certificate. The valid period shall be limited to the period originally granted. The requirements of earth and rock excavation plan and drawings for applying the residual earth and rock excavation area as mentioned above shall be allowed under Article 11.
	2	The central authority under this Act is the Ministry of Economic Affairs; the central executive agencies under this Act are relevant government agencies responsible for budget preparation. To expedite flood management and flood prevention in flood-prone areas, the central executive agencies may proceed to undertake works relating to the management of flood-prone areas under this Act without being subject to the restrictions of "act on behalf" proceeding and assumption of outlay as provided in Article 76 of the Local Government Act. The central executive agencies may commission municipal government, county (city) government, or irrigation association to perform the tasks under this Act. The central authority will undertake the following tasks: 1. Planning and promoting policies concerning flood management in flood-prone areas. 2. Drafting and promoting flood-prone area flood management plan and implementation plans for each phase. 3. Reviewing and approving the implementation programs proposed by the central executive agencies. The central executive agencies will undertake the following tasks: 1. Preparing special budget for the flood-prone area flood management plan. 2. Drafting, promoting and executing the implementation programs for each phase. 3. Commissioning and overseeing the execution of tasks under this Act by municipal government or county (city) government. 4. Approving the workplans proposed by municipal government or county (city) government. The municipal government, county (city) government or irrigation association will undertake the following tasks: 1. Acquiring the land for the management works under this Act. 2. Dredging of rivers, drainage systems and rainwater sewage systems, and carrying out related emergency works. 3. Executing tasks under this Act as commissioned by the central executive agencies.

	10	Except for ongoing remediation work, the management and maintenance of county (city)-governed rivers, regional drainage systems, enterprise-built sea dikes, farmland drainage, rainwater sewage systems, and related soil preservation works shall be undertaken by the local competent authorities. Notwithstanding the foregoing, farmland drainage facilities within the business district of an irrigation association shall be managed and maintained by the irrigation association. The local competent authorities or irrigation associations shall complete the takeover of structures built under this Act in a time period specified by the central executive agencies. Subsequent to taking over the structure, the local competent authorities or irrigation associations shall prepare budget on a yearly basis for the maintenance and management work. Where the local competent authorities fail to allocate sufficient budget for the maintenance/management work, the central executive agencies may pay for the work on its behalf and deduct the expenses from tax revenue or subsidy to be allocated to said local competent authorities in the following year.
Wildlife Conservation Act (Amended on July 11, 2007)	3	Definition of terms: 1.Wildlife: in common circumstances, any animal living in a natural habitat, including mammals, birds, reptiles, amphibians, fish, insects and other kinds of animals; 2.Population size: the number of the same species of wildlife living in a particular space at a particular time; 3.Endangered Species: those wildlife species whose population size is at or below a critical level so that their survival is in jeopardy; 4.Rare and Valuable Species: endemic species or those species with a very low total population; 5.Other Conservation-Deserving Wildlife: species which do not necessarily have a very low total population, but their survival remains in jeopardy; 6.Wildlife products: animal carcasses, bones, horns, teeth, skin, hair, eggs or internal organs in whole, partial or processed form; 7.Habitat: the natural living environment necessary for the survival of plants and animals; 8.Conservation: any protection, restoration or management of wildlife based on the principles of species diversity and natural ecological balance; 9.Utilization: the use of wildlife for cultural, educational, academic or economic benefit in such a way or form scientifically determined not to be detrimental to the natural ecological balance; 10.Disturbance: any behaviour involving the use of drugs, tools or any other means so as to interfere with wildlife; 11.Abuse: the use of violence, unsuitable drugs or other methods to harm wildlife so they cannot maintain their normal physiological condition; 12.Hunting: the use of drugs, hunting equipment or other tools or methods to catch or kill wildlife; 13.Processing: the use of wildlife carcasses, bones, horns, teeth, skins, hair, eggs or organs in their whole or partial form as or to make other products; 14.Display: placement of wildlife or wildlife products in public areas for people to view.

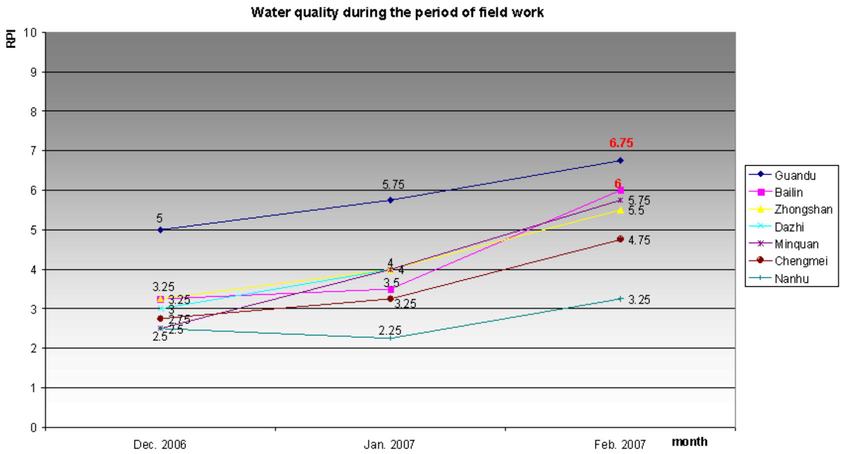
	8	Any construction and land use in Major Wildlife Habitats should be carried out in ways and areas which least affects the habitat, and the original ecological functions of the habitat should not be harmed. If necessary, the Authorities shall ask the owners, users or occupants of a land use project to conduct an Environmental Impact Assessment. Any farming, forestry, fishery or animal husbandry development utilization; mine exploration, earth or rock removal or related works; repair or construction of railroads, public roads or other roads; construction; establishment of parks or cemeteries; utilization of land for recreation, sporting or forest recreation areas, waste disposal or other utilization of Major Wildlife Habitats may begin only after application to the proper local authorities and after approval by the NPA. Only then can an application for such development be made to the relevant target business authorities. Existing facilities, land utilization or development activities have a significant impact on the wildlife in the area, the NPA may require the relevant person or target business authority to put forth a plan for improvements within a certain time limit. The type and area of the Major Wildlife Habitats referred to above shall be determined and announced by the NPA, as shall any changes in designation.
	9	If land use proceeds before the Environmental Impact Assessment referred to in Article 8, Paragraph 1, the Authorities shall inform and consult immediately with other appropriate responsible government agencies to halt the project. If destruction of the wildlife habitat has taken place, the Authorities and other appropriate government agencies shall request the responsible parties to put forward a rehabilitation plan within a certain time limit and should monitor this process. If the responsible parties do not put forward a rehabilitation plan, or in case of emergency, the Authorities may require that any resultant costs of necessary rehabilitation procedures be borne by the responsible parties.
	10	Local authorities may establish Wildlife Refuges for Major Wildlife Habitats with special conservation needs, as well as formulate and carry out conservation plans in those areas. If necessary, they may commission other agencies or organizations to carry out the plans. Establishment of a Wildlife Refuge, its modification or elimination shall be authorized and announced by the NPA after an on-site public hearing on the plan is held and the opinions of local residents have been heard and approval from the Wildlife Conservation Advisory Committee. In emergency or necessary situations, the NPA may, with the approval of the Wildlife Conservation Advisory Committee, designate or modify Wildlife Refuges. In the conservation plan for the Wildlife Refuge, the Authorities may announce restrictive measures regarding the following: 1. Disturbance, abuse, hunting or killing of General Wildlife, etc. 2. Collection or cutting of plants, etc. 3. Pollution or destruction of the environment, etc. 4. Other prohibited or approved actions, etc.
	13	In areas which have received utilization approval per Article 8, Paragraph 2, but still experience damage to wildlife habitats, the Authorities shall order the developer to put forth a plan for rehabilitation within a certain time limit and monitor this process. If the damage occurs in areas where utilization approval was not granted, in addition to measures in the above paragraph, the Authorities may use emergency methods, which are to be paid for by the party responsible for the damage.
	14	Lost or wild animals which are not endemic to Taiwan may be dealt with by the Authorities if found to be damaging Taiwan's plant or animal habitats. The NPA shall determine which animals are not endemic to Taiwan.

	27	In the case of exotic wildlife which is not endemic to Taiwan imported for the first time, the applicant shall provide the NPA with all relevant information concerning that species and an Impact Assessment Report to address that animal's effect upon native fauna and flora. Such wildlife may be imported only after the approval of the NPA. The municipal city or county (city) authorities of the areas where the above-mentioned wildlife is located shall investigate and monitor these imported wildlife regularly. If it is found that their importation has had an impact on the habitat of native fauna or flora, the authorities shall order the owners or users to put forth a plan for prevention or rehabilitation within a certain time limit and shall monitor this process. In addition, the situation shall be referred to the NPA for handling.
Environmental Impact Assessment Working Standards (Amended on Dec. 20, 2006)	11	Developing organization(s) shall submit a sheet of water utilization plan to apply for approval regarding the water utilization during the period of construction and operation. If the water is provided for drinking, the water source quality shall conform to the drinking water source quality standards. The development activity in the preceding paragraph which is located at the restricted area of groundwater shall be conducted in accordance with the Water Act and Regulations on Groundwater Conservation when drawing groundwater is necessary. Anyone who draws groundwater shall inspect the level and water quality of groundwater in the development site and bring up an effective measure to prevent the pollution of groundwater and ground subsidence.
	12	The stationary and non-stationary pollution generated by the development activity during the period of construction and operation shall be prevented and controlled, and proper countermeasures shall be made accordingly. The sewage may be discharged before appropriate treatment. The treatment that indicates to discharge the sewage into the existing sewage system(s) shall attach the approval documentation made by the authorities concerned. The self-establishment of sewage treatment facility shall jointly conduct the on-site inspection, analysis and impact evaluation and promise to complete the trial operation according to the plan or before bringing in the pollution source. The development activity that generates wastewater or sewage discharging into the river, ocean, lake, reservoir or into the irrigation or drainage system shall assess the impact to the water quality and aquatic ecology and shall make the countermeasure accordingly.

Source: Laws and Regulations Database of Tue Republic of China, http://law.moj.gov.tw/eng/

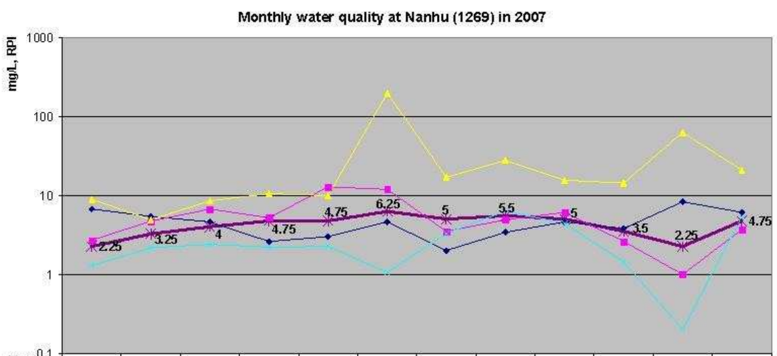
Annex E: Water Quality in the lower Keelung River

I. Water quality during period of field survey



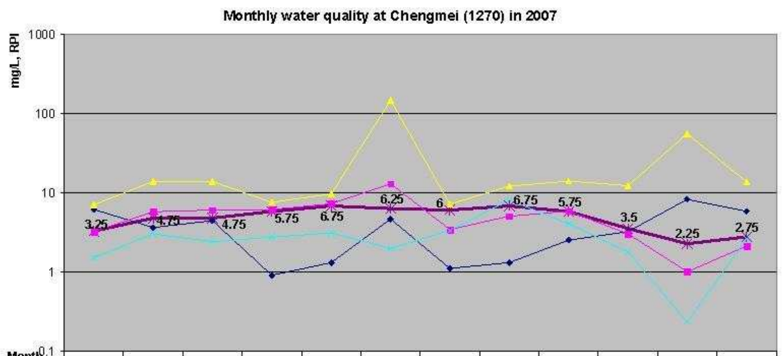
II. Water quality in 2007 in the lower Keelung River

1. Section I



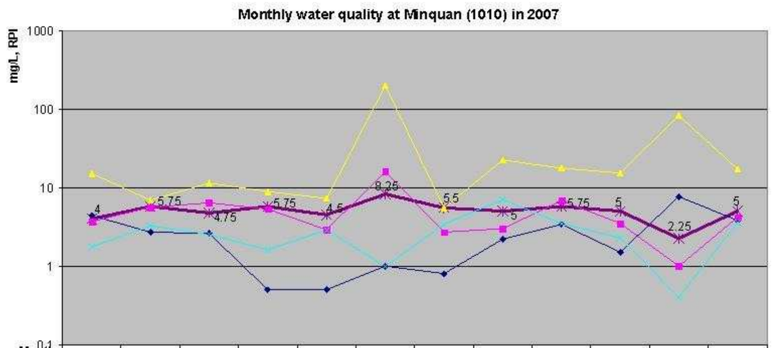
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	2.25	3.25	4	4.75	4.75	6.25	5	5.5	5	3.5	2.25	4.75
DO (mg/L)	6.7	5.4	4.6	2.6	3	4.6	2	3.4	4.6	3.8	8.3	6.1
BOD (mg/L)	2.7	4.7	6.7	5.2	12.8	11.9	3.5	4.9	6.1	2.6	1	3.7
SS (mg/L)	8.9	4.9	8.5	10.5	9.9	198	17	27.8	15.5	14.3	62.7	20.9
Amonia (mg/L)	1.28	2.17	2.39	2.2	2.25	1.06	3.3	6.3	4.41	1.43	0.2	5.31

2. Section II



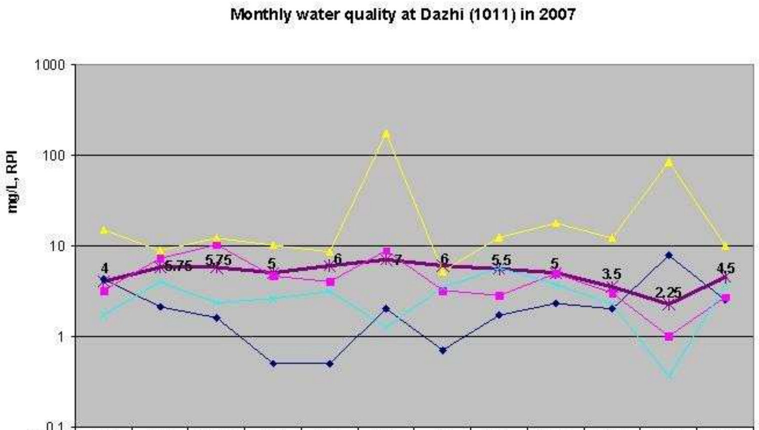
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	3.25	4.75	4.75	5.75	6.75	6.25	6	6.75	5.75	3.5	2.25	2.75
DO (mg/L)	6.1	3.6	4.4	0.9	1.3	4.6	1.1	1.3	2.5	3.2	8.2	5.8
BOD (mg/L)	3.2	5.7	6	6.1	7.2	12.9	3.4	5	5.8	3	1	2.1
SS (mg/L)	7	13.8	13.7	7.5	9.6	146	7.1	12	13.9	12.2	55	13.6
Amonia (mg/L)	1.5	3	2.39	2.72	3.09	1.96	3.32	8.01	4.01	1.77	0.23	2.6

3. Section III



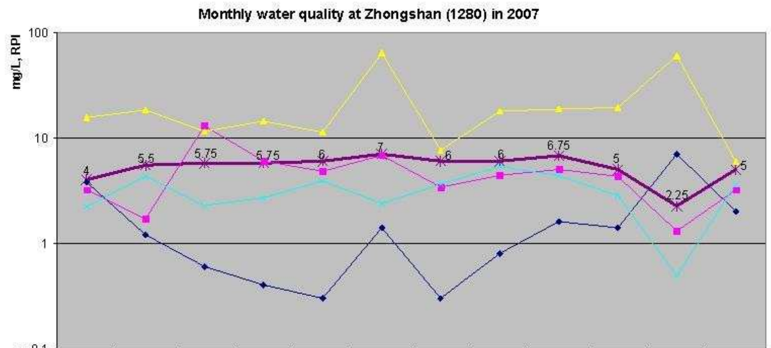
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	4	5.75	4.75	5.75	4.5	8.25	5.5	5	5.75	5	2.25	5
DO (mg/L)	4.4	2.7	2.6	0.5	0.5	1	0.8	2.2	3.4	1.5	7.7	3.8
BOD (mg/L)	3.7	5.6	6.4	5.3	2.9	16.1	2.7	3	6.8	3.5	1	4.2
SS (mg/L)	15.2	6.9	11.4	8.9	7.3	199	5.5	22.4	17.7	15.3	83.2	17.2
Amonia (mg/L)	1.75	3.26	2.53	1.61	2.88	0.99	3.41	7.06	3.48	2.28	0.4	3.56

4. Section IV



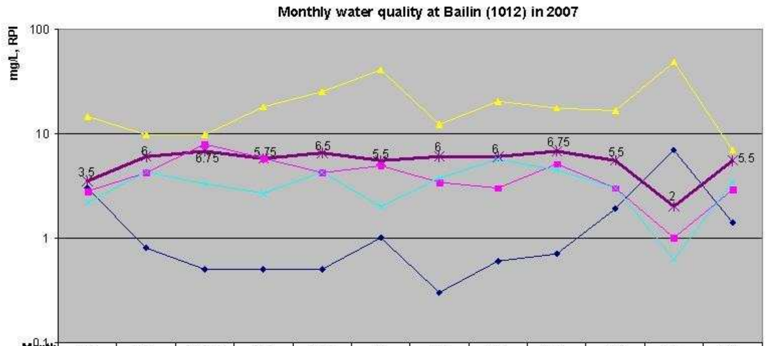
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	4	5.75	5.75	5	6	7	6	5.5	5	3.5	2.25	4.5
DO (mg/L)	4.3	2.1	1.6	0.5	0.5	2	0.7	1.7	2.3	2	7.8	2.5
BOD (mg/L)	3.2	7.2	10.2	4.6	4	8.8	3.2	2.8	4.9	3	1	2.7
SS (mg/L)	14.9	8.8	12.1	10.1	8.5	174	5.2	12.3	17.6	12.1	84.2	9.9
Amonia (mg/L)	1.72	3.98	2.33	2.6	3.13	1.26	3.44	5.66	3.72	2.25	0.36	3.63

5. Section V



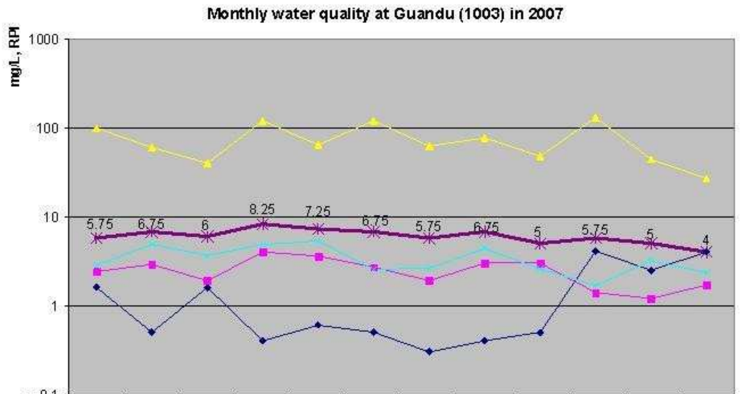
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	4	5.5	5.75	5.75	6	7	6	6	6.75	5	2.25	5
DO (mg/L)	3.8	1.2	0.6	0.4	0.3	1.4	0.3	0.8	1.6	1.4	7	2
BOD (mg/L)	3.2	1.7	13	6	4.8	6.8	3.4	4.4	5	4.3	1.3	3.2
SS (mg/L)	15.6	18.4	11.5	14.4	11.3	63.8	7.6	17.9	18.7	19.4	60.2	5.9
Amonia (mg/L)	2.22	4.34	2.27	2.7	3.9	2.38	3.62	5.34	4.38	2.83	0.49	3.65

6. Section VI



Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	3.5	6	6.75	5.75	6.5	5.5	6	6	6.75	5.5	2	5.5
DO (mg/L)	3	0.8	0.5	0.5	0.5	1	0.3	0.6	0.7	1.9	6.9	1.4
BOD (mg/L)	2.8	4.2	7.9	5.8	4.2	4.9	3.4	3	5.1	3	1	2.9
SS (mg/L)	14.6	9.7	9.7	18	25.1	40.7	12.2	20.3	17.5	16.5	48.4	6.9
Amonia (mg/L)	2.17	4.28	3.3	2.67	4.25	1.99	3.73	5.66	4.46	3.01	0.62	3.43

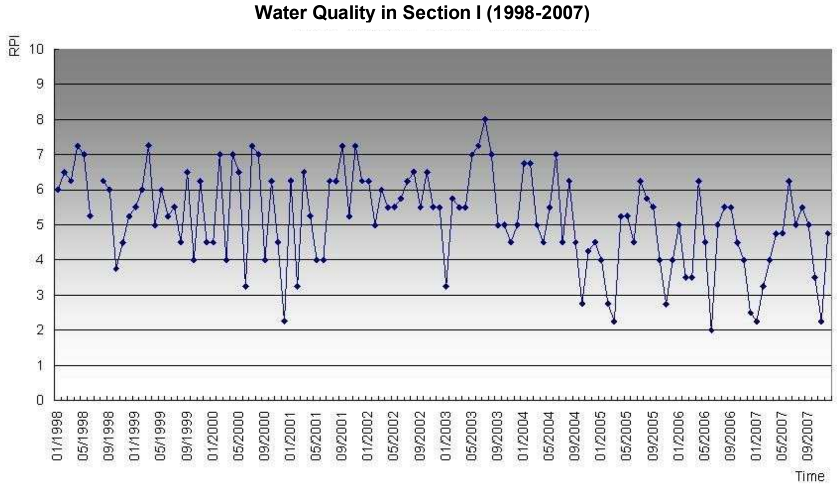
7. Section VII



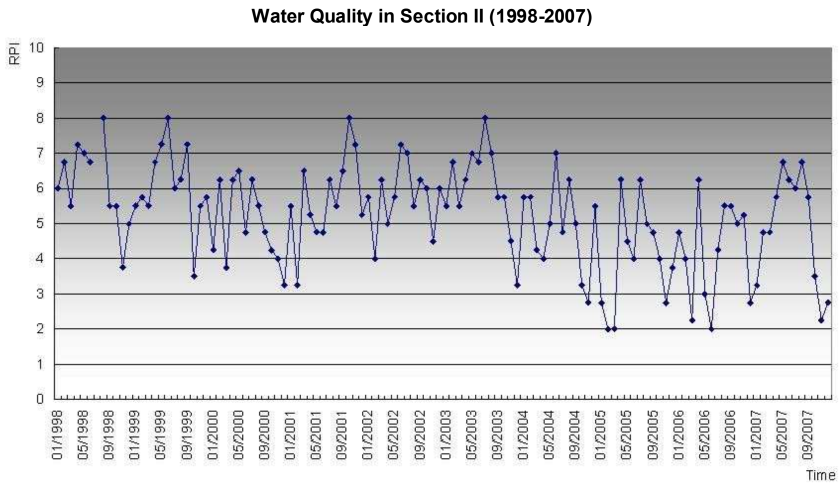
Month	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RPI	5.75	6.75	6	8.25	7.25	6.75	5.75	6.75	5	5.75	5	4
DO (mg/L)	1.6	0.5	1.6	0.4	0.6	0.5	0.3	0.4	0.5	4.1	2.5	4
BOD (mg/L)	2.4	2.9	1.9	4	3.6	2.7	1.9	3	3	1.4	1.2	1.7
SS (mg/L)	99.1	60	40.1	120	64.4	120	62.4	76.7	47.9	131	44	26.8
Amonia (mg/L)	2.82	4.89	3.66	4.86	5.32	2.55	2.63	4.38	2.58	1.67	3.21	2.34

III. Water quality from 1998 to 2007 in the lower Keelung River

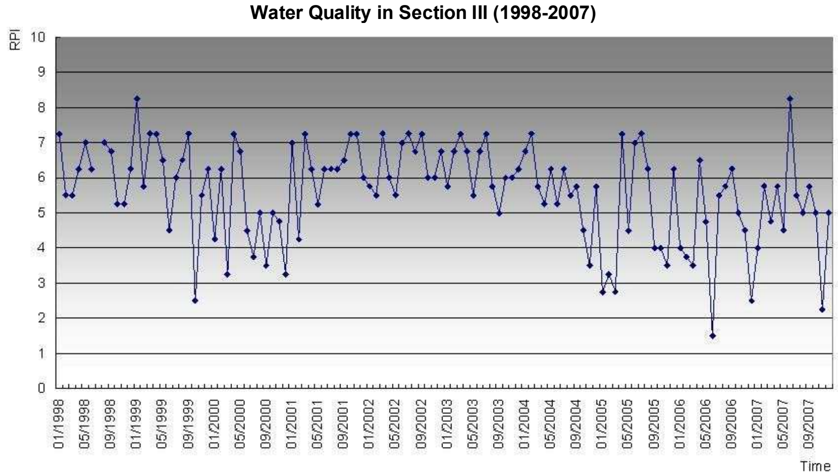
1. Section I



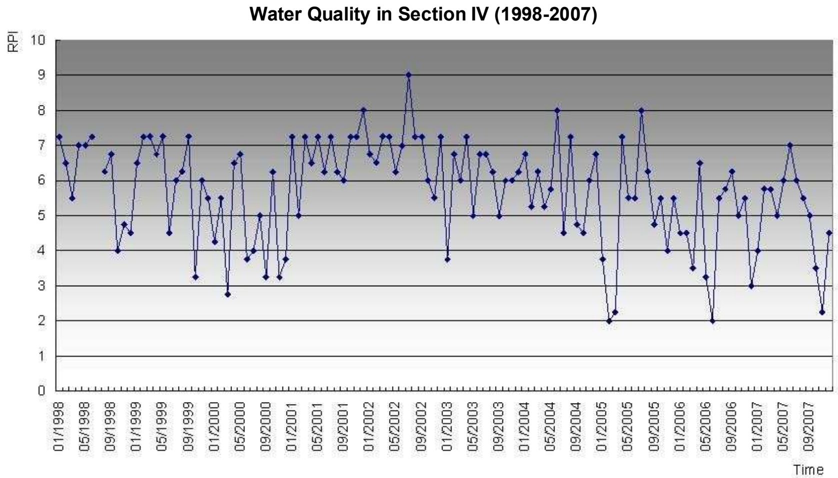
2. Section II



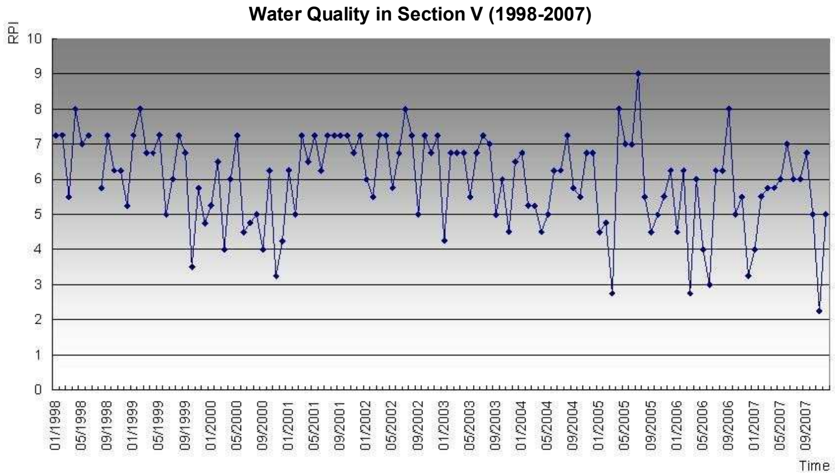
3. Section III



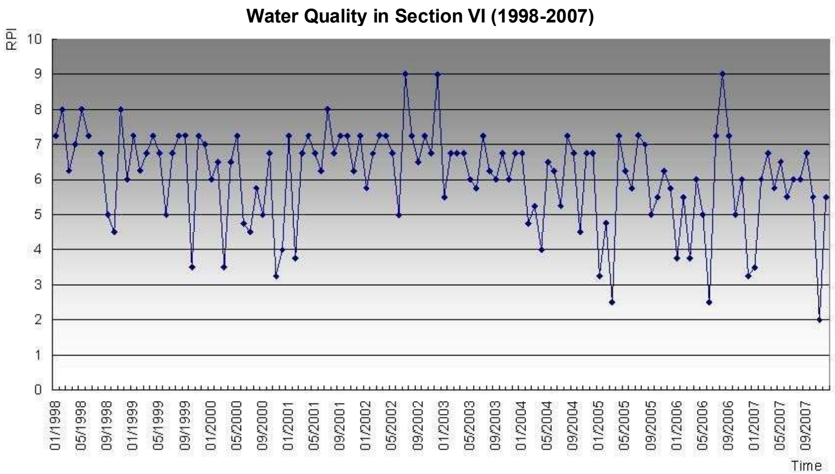
4. Section IV



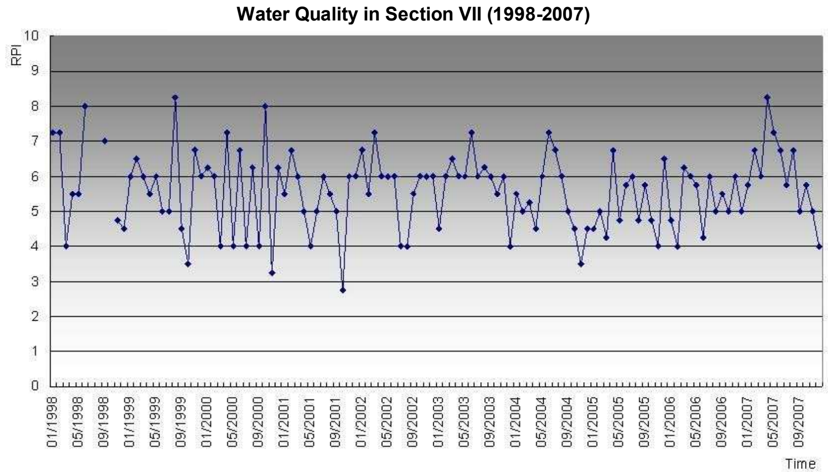
5. Section V



6. Section VI



7. Section VII



Annex F: Evaluation of Biotope Naturalness in the lower Keelung River

I. Section I

CODE	Data	0	1	2	TOTAL
A110	Count of code	0			0
	Sum of area (m^2)	7774.29			7774.29
A120	Count of code	0			0
	Sum of area (m^2)	10479.55			10479.55
A250	Count of code	0			0
	Sum of area (m^2)	1130.33			1130.33
A320	Count of code	0			0
	Sum of area (m^2)	2475.71			2475.71
A330	Count of code	0			0
	Sum of area (m^2)	13597.27			13597.27
A610	Count of code	0			0
	Sum of area (m^2)	1067.33			1067.33
G100	Count of code			4	4
	Sum of area (m^2)			29743.99	29743.99
G200	Count of code		8		8
	Sum of area (m^2)		34122.37		34122.37
U200	Count of code		3		3
	Sum of area (m^2)		19943.13		19943.13
U400	Count of code	0			0
	Sum of area (m^2)	21736.16			21736.16
W220	Count of code		1		1
	Sum of area (m^2)		97031.5		97031.5
W230	Count of code		1		1
	Sum of area (m^2)		114516.6		114516.58
W400	Count of code		2		2
	Sum of area (m^2)		840.8		840.8
X100	Count of code	0			0
	Sum of area (m^2)	1734.5			1734.5
TOTAL_Count of code		0	15	4	19
TOTAL_Sum of area (m^2)		59995.14	266454.4	29743.99	356193.51
		0.1684341	0.748061	0.0835051	
		0	1	2	

B1: **0.92**

II. Section II

CODE	Data	0	1	2	TOTAL
A110	Count of code	0			0
	Sum of area (m^2)	28574.33			28574.33
A120	Count of code	0			0
	Sum of area (m^2)	9656.81			9656.81
A130	Count of code	0			0
	Sum of area (m^2)	12533.79			12533.79
A250	Count of code	0			0
	Sum of area (m^2)	7311.19			7311.19
A310	Count of code	0			0
	Sum of area (m^2)	560.47			560.47
A320	Count of code	0			0
	Sum of area (m^2)	16081.8			16081.8
A330	Count of code	0			0
	Sum of area (m^2)	38771.83			38771.83
A410	Count of code	0	6		6
	Sum of area (m^2)	7226.88	20532.98		27759.86
A420	Count of code	0			0
	Sum of area (m^2)	1337.11			1337.11
A520	Count of code	0			0
	Sum of area (m^2)	169.98			169.98
A530	Count of code	0			0
	Sum of area (m^2)	739.71			739.71
A610	Count of code	0			0
	Sum of area (m^2)	28165.35			28165.35
A620	Count of code	0			0
	Sum of area (m^2)	4668.91			4668.91
A650	Count of code	0			0
	Sum of area (m^2)	94.38			94.38
A710	Count of code	0			0
	Sum of area (m^2)	412.03			412.03
G100	Count of code			32	32
	Sum of area (m^2)			51489.78	51489.78
G200	Count of code		71		71
	Sum of area (m^2)		271890.51		271890.51
G300	Count of code			6	6
	Sum of area (m^2)			3176.43	3176.43
S100	Count of code			310	310
	Sum of area (m^2)			5773.7	5773.7
U100	Count of code	0			0

	Sum of area (m²)	1797.19			1797.19
U200	Count of code		11		11
	Sum of area (m²)		39926.72		39926.72
U400	Count of code	0			0
	Sum of area (m²)	4461.65			4461.65
W220	Count of code		1		1
	Sum of area (m²)		223099.85		223099.85
W230	Count of code		1		1
	Sum of area (m²)		150644.78		150644.78
W400	Count of code		9		9
	Sum of area (m²)		5628.64		5628.64
X100	Count of code	0			0
	Sum of area (m²)	680.44			680.44
TOTAL_Count of code		0	99	348	447
TOTAL_Sum of area (m²)		163243.85	711723.48	60439.91	935407.24
		0.1745163	0.7608702	0.064613	
		0	1	2	
				B1:	**0.89**

III. Section III

CODE	Data	0	1	2	3	TOTAL
A110	Count of code	0				0
	Sum of area (m²)	44267.26				44267.26
A130	Count of code	0				0
	Sum of area (m²)	46567.75				46567.75
A250	Count of code	0				0
	Sum of area (m²)	3914.41				3914.41
A310	Count of code	0				0
	Sum of area (m²)	59338.22				59338.22
A330	Count of code	0				0
	Sum of area (m²)	12451.82				12451.82
A410	Count of code	0				0
	Sum of area (m²)	32793.08				32793.08
A520	Count of code	0				0
	Sum of area (m²)	187.89				187.89
A610	Count of code	0				0
	Sum of area (m²)	48090.81				48090.81
A620	Count of code	0				0
	Sum of area (m²)	27893.1				27893.1
A650	Count of code	0				0
	Sum of area (m²)	454.25				454.25
G100	Count of code			36		36
	Sum of area (m²)			96980.97		96980.97
G200	Count of code		68			68
	Sum of area (m²)		490057.6			490057.59
G300	Count of code			4		4
	Sum of area (m²)			1023.76		1023.76
S100	Count of code			394		394
	Sum of area (m²)			8398.55		8398.55
U100	Count of code	0				0
	Sum of area (m²)	18963.39				18963.39
U200	Count of code		4			4
	Sum of area (m²)		99015.65			99015.65
U400	Count of code	0				0
	Sum of area (m²)	861.82				861.82
W220	Count of code		1			1
	Sum of area (m²)		30319.82			30319.82
W230	Count of code		2			2
	Sum of area (m²)		360313.9			360313.91
W400	Count of code		7			7

	Sum of area (m^2)		5614.34			5614.34
W510 A110	Count of code				3	3
	Sum of area (m^2)				4347.71	4347.71
TOTAL_Count of code		0	82	434	3	519
TOTAL_Sum of area (m^2)		295783.8	985321.3	106403.3	4347.71	1391856.1
		0.21251	0.707919	0.076447	0.003124	
		0	1	2	3	

B1: **0.87**

IV. Section IV

CODE	Data	0	1	2	TOTAL
A130	Count of code	0			0
	Sum of area (m^2)	17021.39			17021.39
A250	Count of code	0			0
	Sum of area (m^2)	8542.2			8542.2
A310	Count of code	0			0
	Sum of area (m^2)	20002.9			20002.9
A330	Count of code	0			0
	Sum of area (m^2)	41499.99			41499.99
A410	Count of code	0			0
	Sum of area (m^2)	64697.14			64697.14
A610	Count of code	0			0
	Sum of area (m^2)	58676.86			58676.86
A620	Count of code	0			0
	Sum of area (m^2)	40013.18			40013.18
A630	Count of code	0			0
	Sum of area (m^2)	7904.98			7904.98
A650	Count of code	0			0
	Sum of area (m^2)	378.02			378.02
A710	Count of code	0			0
	Sum of area (m^2)	194.76			194.76
G100	Count of code			14	14
	Sum of area (m^2)			51475.05	51475.05
G200	Count of code		83		83
	Sum of area (m^2)		354332.2		354332.2
G300	Count of code			12	12
	Sum of area (m^2)			6845.92	6845.92
S100	Count of code			706	706
	Sum of area (m^2)			8055.52	8055.52
U100	Count of code	0			0
	Sum of area (m^2)	13614.24			13614.24
U200	Count of code		1		1
	Sum of area (m^2)		1893.69		1893.69
U400	Count of code	0			0
	Sum of area (m^2)	19134.31			19134.31
W220	Count of code		1		1
	Sum of area (m^2)		128831.46		128831.46
W230	Count of code		1		1
	Sum of area (m^2)		150880.36		150880.36
W400	Count of code		8		8

	Sum of area (m^2)		7649.44		7649.44
W520	Count of code			2	2
	Sum of area (m^2)			8637.52	8637.52
TOTAL_Count of code		0	94	734	828
TOTAL_Sum of area (m^2)		291679.97	643587.15	75014.01	1010281.1
		0.2887117	0.6370377	0.074251	
		0	1	2	
				B1:	**0.79**

V. Section V

CODE	Data	0	1	2	3	TOTAL
A210	Count of code	0				0
	Sum of area (m^2)	10801.9				10801.9
A250	Count of code	0				0
	Sum of area (m^2)	1701.65				1701.65
A310	Count of code	0				0
	Sum of area (m^2)	3485.77				3485.77
A320	Count of code	0				0
	Sum of area (m^2)	5681.87				5681.87
A330	Count of code	0				0
	Sum of area (m^2)	32681.92				32681.92
A410	Count of code	0				0
	Sum of area (m^2)	7937.43				7937.43
A510	Count of code	0				0
	Sum of area (m^2)	91.36				91.36
A520	Count of code	0				0
	Sum of area (m^2)	29.8				29.8
A610	Count of code	0				0
	Sum of area (m^2)	15555.4				15555.4
A620	Count of code	0				0
	Sum of area (m^2)	3846.09				3846.09
A630	Count of code	0				0
	Sum of area (m^2)	1970.2				1970.2
A650	Count of code	0				0
	Sum of area (m^2)	1276.36				1276.36
G100	Count of code			12		12
	Sum of area (m^2)			22780.85		22780.85
G200	Count of code		41			41
	Sum of area (m^2)		188723.2			188723.2 2
G300	Count of code			24		24
	Sum of area (m^2)			13852.39		13852.39
S100	Count of code			210	15	225
	Sum of area (m^2)			10861.49	26429.66	37291.15
U100	Count of code	0				0
	Sum of area (m^2)	10494.31				10494.31
U200	Count of code		2			2
	Sum of area (m^2)		29109.95			29109.95
U400	Count of code	0				0
	Sum of area (m^2)	10701.5				10701.5
W220	Count of code		2			2

	Sum of area (m²)		129681.6			129681.64
W230	Count of code		1			1
	Sum of area (m²)		163794.4			163794.44
W300	Count of code		1			1
	Sum of area (m²)		5402.24			5402.24
W400	Count of code		3			3
	Sum of area (m²)		6202.07			6202.07
W520	Count of code			2		2
	Sum of area (m²)			1057.76		1057.76
X100	Count of code	0				0
	Sum of area (m²)	1716.72				1716.72
TOTAL Count of code		0	50	248	15	313
TOTAL_Sum of area (m²)		107972.28	522913.6	48552.49	26429.66	705868.0
		0.1529638	0.740809	0.068784	0.037443	
		0	1	2	3	

B1: **0.99**

VI. Section VI

CODE	Data	0	1	2	3	TOTAL
A210	Sum of area (m²)	130443.79				130443.79
	Count of code	0				0
A220	Sum of area (m²)	19465.38				19465.38
	Count of code	0				0
A250	Sum of area (m²)	1082.55				1082.55
	Count of code	0				0
A320	Sum of area (m²)	7967.98				7967.98
	Count of code	0				0
A330	Sum of area (m²)	72299.72				72299.72
	Count of code	0				0
A340	Sum of area (m²)	4004.75				4004.75
	Count of code	0				0
A410	Sum of area (m²)	16721.66	150154.76			166876.42
	Count of code	0	14			14
A520	Sum of area (m²)	0.83				0.83
	Count of code	0				0
A530		615.61				615.61
		0				0
A610	Sum of area (m²)	25496.27				25496.27
	Count of code	0				0
A620	Sum of area (m²)	11687.45				11687.45
	Count of code	0				0
A650	Sum of area (m²)	185.65				185.65
	Count of code	0				0
A710	Sum of area (m²)	1694.24				1694.24
	Count of code	0				0
G100	Sum of area (m²)			300151.61		300151.61
	Count of code			42		42
G200	Sum of area (m²)		299996.11			299996.11
	Count of code		38			38
G300	Sum of area (m²)			2316.49		2316.49
	Count of code			4		4
S100	Sum of area (m²)			12978.25	6070.36	19048.61
	Count of code			370	42	412
U100	Sum of area (m²)	14732.43				14732.43
	Count of code	0				0
U200	Sum of area (m²)		131035.29			131035.29
	Count of code		21			21
U300	Sum of area (m²)		2052.26			2052.26

	Count of code		1			1
U400	Sum of area (m^2)	775.14				775.14
	Count of code	0				0
W110	Sum of area (m^2)			5667.89		5667.89
	Count of code			2		2
W120	Sum of area (m^2)		23660			23660
	Count of code		2			2
W210	Sum of area (m^2)			142746.41		142746.41
	Count of code			2		2
W220	Sum of area (m^2)		725172.79			725172.79
	Count of code		2			2
W300	Sum of area (m^2)				7150.68	7150.68
	Count of code				3	3
W400	Sum of area (m^2)		14588.15			14588.15
	Count of code		10			10
W510	Sum of area (m^2)				6210.35	6210.35
	Count of code				39	39
W600	Sum of area (m^2)			548.85		548.85
	Count of code			2		2
TOTAL_Sum of area (m^2)		307173.45	1346659.4	464409.5	19431.39	2137673.7
TOTAL_Count of code		0	88	422	84	594
		0.1436952	0.6299649	0.2172499	0.00909	
		0	1	2	3	

B1: **1.09**

VII. Section VII

CODE	Data	0	1	2	3	4	TOTAL
A220	Sum of area (m^2)	11257.4					11257.4
	Count of code	0					0
A330	Sum of area (m^2)	9249.08					9249.08
	Count of code	0					0
A340	Sum of area (m^2)	11773.81					11773.81
	Count of code	0					0
A610	Sum of area (m^2)	1436.71					1436.71
	Count of code	0					0
A620	Sum of area (m^2)	250.34					250.34
	Count of code	0					0
A630	Sum of area (m^2)	1461.03					1461.03
	Count of code	0					0
G100	Sum of area (m^2)			32300.47			32300.47
	Count of code			12			12
G200	Sum of area (m^2)			3844.52			3844.52
	Count of code			2			2
U100	Sum of area (m^2)	17439.22					17439.22
	Count of code	0					0
U200	Sum of area (m^2)		48185.8				48185.8
	Count of code		10				10
U300	Sum of area (m^2)		11349.94				11349.94
	Count of code		1				1
U400	Sum of area (m^2)	9855.83					9855.83
	Count of code	0					0
W110	Sum of area (m^2)			9107.78			9107.78
	Count of code			2			2
W120	Sum of area (m^2)		180.27				180.27
	Count of code		1				1
W210	Sum of area (m^2)			513152.93			513152.93
	Count of code			2			2
W300	Sum of area (m^2)				4421.61		4421.61
	Count of code				3		3
W400	Sum of area (m^2)		549.22				549.22
	Count of code		2				2
We110	Sum of area (m^2)					375058.42	375058.42
	Count of code					24	24
We210	Sum of area (m^2)				140000.98		140000.98
	Count of code				9		9
We220	Sum of area (m^2)				5657.09		5657.09

	Count of code				3		3
TOTAL_Sum of area (m^2)		62723.42	60265.23	558405.7	150079.68	375058.42	1206532.5
TOTAL_Count of code		0	14	18	15	24	71
		0.0519865	0.0499491	0.4628186	0.1243893	0.3108565	
		0	1	2	3	4	

B1: **2.59**

Annex G: Evaluation of Patch Size in the lower Keelung River

I. Section I

CODE	Data	0	1	2	3	TOTAL
A110	Count of code	0				0
	Sum of area (m^2)	7774.29				7774.29
A120	Count of code	0				0
	Sum of area (m^2)	10479.55				10479.55
A250	Count of code	0				0
	Sum of area (m^2)	1130.33				1130.33
A320	Count of code	0				0
	Sum of area (m^2)	2475.71				2475.71
A330	Count of code	0				0
	Sum of area (m^2)	13597.27				13597.27
A610	Count of code	0				0
	Sum of area (m^2)	1067.33				1067.33
G100	Count of code			4		4
	Sum of area (m^2)			29743.99		29743.99
G200	Count of code	0	6	2		8
	Sum of area (m^2)	264.79	23942.54	9915.04		34122.37
U200	Count of code		2	2		4
	Sum of area (m^2)		5374.36	14568.77		19943.13
U400	Count of code	0	1	2		3
	Sum of area (m^2)	568.01	6996.31	14171.84		21736.16
W220	Count of code				3	3
	Sum of area (m^2)				97031.5	97031.5
W230	Count of code				3	3
	Sum of area (m^2)				114516.58	114516.58
W400	Count of code	0				0
	Sum of area (m^2)	840.8				840.8
X100	Count of code	0				0
	Sum of area (m^2)	1734.5				1734.5
TOTAL_Count of code		0	9	10	6	25
TOTAL_Sum of area (m^2)		39932.58	36313.21	68399.64	211548.08	356193.51
		0.1121092	0.101948	0.192029	0.5939133	
		0	1	2	3	

B2: **2.27**

II. Section II

CODE	Data	0	1	2	3	TOTAL
A110	Count of code	0				0
	Sum of area (m^2)	28574.33				28574.33
A120	Count of code	0				0
	Sum of area (m^2)	9656.81				9656.81
A130	Count of code	0				0
	Sum of area (m^2)	12533.79				12533.79
A250	Count of code	0				0
	Sum of area (m^2)	7311.19				7311.19
A310	Count of code	0				0
	Sum of area (m^2)	560.47				560.47
A320	Count of code	0				0
	Sum of area (m^2)	16081.8				16081.8
A330	Count of code	0				0
	Sum of area (m^2)	38771.83				38771.83
A410	Count of code	0				0
	Sum of area (m^2)	27759.86				27759.86
A420	Count of code	0				0
	Sum of area (m^2)	1337.11				1337.11
A520	Count of code	0				0
	Sum of area (m^2)	169.98				169.98
A530	Count of code	0				0
	Sum of area (m^2)	739.71				739.71
A610	Count of code	0				0
	Sum of area (m^2)	28165.35				28165.35
A620	Count of code	0				0
	Sum of area (m^2)	4668.91				4668.91
A650	Count of code	0				0
	Sum of area (m^2)	94.38				94.38
A710	Count of code	0				0
	Sum of area (m^2)	412.03				412.03
G100	Count of code	0	10	2		12
	Sum of area (m^2)	3548.05	37567.33	10374.4		51489.78
G200	Count of code	0	41	14	3	58
	Sum of area (m^2)	10617.56	114371.4	146224.05	677.5	271890.51
G300	Count of code	0	1			1
	Sum of area (m^2)	1219.39	1957.04			3176.43
S100	Count of code	0	1			1
	Sum of area (m^2)	5563.57	210.13			5773.7
U100	Count of code		1			1

	Sum of area (m^2)		1797.19			1797.19
U200	Count of code	0	8	2		10
	Sum of area (m^2)	1316.5	24829.33	13780.89		39926.72
U400	Count of code	0	1			1
	Sum of area (m^2)	1211.9	3249.75			4461.65
W220	Count of code				3	3
	Sum of area (m^2)				223099.85	223099.85
W230	Count of code				3	3
	Sum of area (m^2)				150644.78	150644.78
W400	Count of code	0	1			1
	Sum of area (m^2)	2808.87	2819.77			5628.64
X100	Count of code	0				0
	Sum of area (m^2)	680.44				680.44
TOTAL_Count of code		0	64	18	9	91
TOTAL_Sum of area (m^2)		203803.83	186801.94	170379.34	374422.13	935407.24
		0.2178771	0.1997012	0.1821446	0.4002771	
		0	1	2	3	
				B2:	**1.76**	

III. Section III

CODE	Data	0	1	2	3	TOTAL
A110	Count of code	0				0
	Sum of area (m^2)	44267.26				44267.26
A130	Count of code	0				0
	Sum of area (m^2)	46567.75				46567.75
A250	Count of code	0				0
	Sum of area (m^2)	3914.41				3914.41
A310	Count of code	0				0
	Sum of area (m^2)	59338.22				59338.22
A330	Count of code	0				0
	Sum of area (m^2)	12451.82				12451.82
A410	Count of code	0				0
	Sum of area (m^2)	32793.08				32793.08
A520	Count of code	0				0
	Sum of area (m^2)	187.89				187.89
A610	Count of code	0				0
	Sum of area (m^2)	48090.81				48090.81
A620	Count of code	0				0
	Sum of area (m^2)	27893.1				27893.1
A650	Count of code	0				0
	Sum of area (m^2)	454.25				454.25
G100	Count of code	0	7	8		15
	Sum of area (m^2)	4097.97	28051.54	64831.46		96980.97
G200	Count of code	0	36	14	9	59
	Sum of area (m^2)	9240.07	129493.05	149713.44	201611.03	490057.59
G300	Count of code	0				0
	Sum of area (m^2)	1023.76				1023.76
S100	Count of code	0	2			2
	Sum of area (m^2)	3218.12	5180.43			8398.55
U100	Count of code	0	4			4
	Sum of area (m^2)	1066.86	17896.53			18963.39
U200	Count of code		1	6		7
	Sum of area (m^2)		8050.03	90965.62		99015.65
U400	Count of code	0				0
	Sum of area (m^2)	861.82				861.82
W220	Count of code				3	3
	Sum of area (m^2)				30319.82	30319.82
W230	Count of code				6	6
	Sum of area (m^2)				360313.91	360313.91
W400	Count of code	0	2			2

	Sum of area (m²)	2408.34	3206			5614.34
W510	Count of code		1			1
A110	Sum of area (m²)		4347.71			4347.71
TOTAL_Count of code		0	53	28	18	99
TOTAL_Sum of area (m²)		297875.53	196225.29	305510.52	592244.76	1391856.1
		0.2140132	0.140981	0.2194986	0.4255072	
		0	1	2	3	

B2: **1.86**

IV. Section IV

CODE	Data	0	1	2	3	TOTAL
A130	Count of code	0				0
	Sum of area (m²)	17021.39				17021.39
A250	Count of code	0				0
	Sum of area (m²)	8542.2				8542.2
A310	Count of code	0				0
	Sum of area (m²)	20002.9				20002.9
A330	Count of code	0				0
	Sum of area (m²)	41499.99				41499.99
A410	Count of code	0				0
	Sum of area (m²)	64697.14				64697.14
A610	Count of code	0				0
	Sum of area (m²)	58676.86				58676.86
A620	Count of code	0				0
	Sum of area (m²)	40013.18				40013.18
A630	Count of code	0				0
	Sum of area (m²)	7904.98				7904.98
A650	Count of code	0				0
	Sum of area (m²)	378.02				378.02
A710	Count of code	0				0
	Sum of area (m²)	194.76				194.76
G100	Count of code		5	4		9
	Sum of area (m²)		14903.43	36571.62		51475.05
G200	Count of code	0	45	18		63
	Sum of area (m²)	13083.41	163021.76	178227.03		354332.2
G300	Count of code	0	4			4
	Sum of area (m²)	1165.77	5680.15			6845.92
S100	Count of code	0				0
	Sum of area (m²)	8055.52				8055.52
U100	Count of code	0	3			3
	Sum of area (m²)	1003.38	12610.86			13614.24
U200	Count of code			2		2
	Sum of area (m²)			1893.69		1893.69
U400	Count of code	0	6			6
	Sum of area (m²)	3767.71	15366.6			19134.31
W220	Count of code				3	3
	Sum of area (m²)				128831.46	128831.46
W230	Count of code				3	3
	Sum of area (m²)				150880.36	150880.36
W400	Count of code	0	3			3

CODE	Data	0	1	2	3	TOTAL
	Sum of area (m²)	1928.68	5720.76			7649.44
W520	Count of code		1			1
	Sum of area (m²)		8637.52			8637.52
TOTAL_Count of code		0	67	24	6	97
TOTAL_Sum of area (m²)		287935.89	225941.08	216692.34	279711.82	1010281.1
		0.2850057	0.2236418	0.2144872	0.2768653	
		0	1	2	3	

B2: **1.48**

V. Section V

CODE	Data	0	1	2	3	TOTAL
A210	Count of code	0				0
	Sum of area (m²)	10801.9				10801.9
A250	Count of code	0				0
	Sum of area (m²)	1701.65				1701.65
A310	Count of code	0				0
	Sum of area (m²)	3485.77				3485.77
A320	Count of code	0				0
	Sum of area (m²)	5681.87				5681.87
A330	Count of code	0				0
	Sum of area (m²)	32681.92				32681.92
A410	Count of code	0				0
	Sum of area (m²)	7937.43				7937.43
A510	Count of code	0				0
	Sum of area (m²)	91.36				91.36
A520	Count of code	0				0
	Sum of area (m²)	29.8				29.8
A610	Count of code	0				0
	Sum of area (m²)	15555.4				15555.4
A620	Count of code	0				0
	Sum of area (m²)	3846.09				3846.09
A630	Count of code	0				0
	Sum of area (m²)	1970.2				1970.2
A650	Count of code	0				0
	Sum of area (m²)	1276.36				1276.36
G100	Count of code	0	3	4		7
	Sum of area (m²)	390.59	9506.48	12883.78		22780.85
G200	Count of code	0	24	10		34
	Sum of area (m²)	4088.83	77271.8	107362.6		188723.22
G300	Count of code	0	7			7
	Sum of area (m²)	2091.2	11761.19			13852.39
S100	Count of code	0	8			8
	Sum of area (m²)	5626.17	31664.98			37291.15
U100	Count of code	0	5			5
	Sum of area (m²)	238.06	10256.25			10494.31
U200	Count of code		1	2		3
	Sum of area (m²)		4212.71	24897.24		29109.95
U400	Count of code	0	4			4
	Sum of area (m²)	474.88	10226.62			10701.5
W220	Count of code				6	6

	Sum of area (m^2)				129681.6	129681.6 4
W230	Count of code				3	3
	Sum of area (m^2)				163794.4	163794.4 4
W300	Count of code		1			1
	Sum of area (m^2)		5402.24			5402.24
W400	Count of code		3			3
	Sum of area (m^2)		6202.07			6202.07
W520	Count of code		1			1
	Sum of area (m^2)		1057.76			1057.76
X100	Count of code	0				0
	Sum of area (m^2)	1716.72				1716.72
TOTAL_Count of code		0	57	16	9	82
TOTAL_Sum of area (m^2)		99686.2	167562.1	145143.6	293476.1	705868.0
		0.141225	0.237384	0.205624	0.415766	
		0	1	2	3	

B2: **1.90**

VI. Section VI

CODE	Data	0	1	2	3	4	TOTAL
A210	Sum of area (m^2)	130443.79					130443.79
	Count of code	0					0
A220	Sum of area (m^2)	19465.38					19465.38
	Count of code	0					0
A250	Sum of area (m^2)	1082.55					1082.55
	Count of code	0					0
A320	Sum of area (m^2)	7967.98					7967.98
	Count of code	0					0
A330	Sum of area (m^2)	72299.72					72299.72
	Count of code	0					0
A340	Sum of area (m^2)	4004.75					4004.75
	Count of code	0					0
A410	Sum of area (m^2)	166876.42					166876.42
	Count of code	0					0
A520	Sum of area (m^2)	0.83					0.83
	Count of code	0					0
A530	Sum of area (m^2)	615.61					615.61
	Count of code	0					0
A610	Sum of area (m^2)	25496.27					25496.27
	Count of code	0					0
A620		11687.45					11687.45
		0					0
A650	Sum of area (m^2)	185.65					185.65
	Count of code	0					0
A710	Sum of area (m^2)	1694.24					1694.24
	Count of code	0					0
G100	Sum of area (m^2)	1407.99	52513.03	115776.39	130454.2		300151.61
	Count of code	0	10	14	6		30
G200	Sum of area (m^2)	6473.75	65508.43	151026.38	76987.55		299996.11
	Count of code	0	17	14	3		34
G300	Sum of area (m^2)		2316.49				2316.49
	Count of code		2				2
S100	Sum of area (m^2)	11463.16	7585.45				19048.61
	Count of code	0	5				5
U100	Sum of area (m^2)	2306.77	12425.66				14732.43
	Count of code	0	5				5
U200	Sum of area (m^2)	2314.04	26895.4	44898.64	56927.21		131035.29
	Count of code	0	11	6	3		20
U300	Sum of area (m^2)		2052.26				2052.26

	Count of code		1				1
U400	Sum of area (m^2)	775.14					775.14
	Count of code	0					0
W110	Sum of area (m^2)		5667.89				5667.89
	Count of code		1				1
W120	Sum of area (m^2)	22		23638			23660
	Count of code	0		2			2
W210	Sum of area (m^2)					142746.41	142746.41
	Count of code					4	4
W220	Sum of area (m^2)				725172.8		725172.79
	Count of code				6		6
W300	Sum of area (m^2)		7150.68				7150.68
	Count of code		1				1
W400	Sum of area (m^2)	2656.44	11931.71				14588.15
	Count of code	0	3				3
W510	Sum of area (m^2)	2482.6	3727.75				6210.35
	Count of code	0	3				3
W600	Sum of area (m^2)	548.85					548.85
	Count of code	0					0
TOTAL_Sum of area (m^2)		347827.4	580832.6	1028190	174690.2	6133.7	2137673.7
TOTAL_Count of code		81	85	26	200	15	407
		0.2209277	0.0925187	0.1568712	0.462906	0.0667765	
		0	1	2	3	4	

B2: **2.06**

VII. Section VII

CODE	Data	0	1	2	3	4	TOTAL
A220	Sum of area (m^2)	11257.4					11257.4
	Count of code	0					0
A330	Sum of area (m^2)	9249.08					9249.08
	Count of code	0					0
A340	Sum of area (m^2)	11773.81					11773.81
	Count of code	0					0
A610	Sum of area (m^2)	1436.71					1436.71
	Count of code	0					0
A620	Sum of area (m^2)	250.34					250.34
	Count of code	0					0
A630	Sum of area (m^2)	1461.03					1461.03
	Count of code	0					0
G100	Sum of area (m^2)		14535.86	17764.61			32300.47
	Count of code		3	6			9
G200	Sum of area (m^2)		3844.52				3844.52
	Count of code		1				1
U100	Sum of area (m^2)	617.44	16821.78				17439.22
	Count of code	0	2				2
U200	Sum of area (m^2)	690.1	12191.22	35304.48			48185.8
	Count of code	0	6	4			10
U300	Sum of area (m^2)			11349.94			11349.94
	Count of code			2			2
U400	Sum of area (m^2)		9855.83				9855.83
	Count of code		1				1
W110	Sum of area (m^2)		9107.78				9107.78
	Count of code		1				1
W120	Sum of area (m^2)	180.27					180.27
	Count of code	0					0
W210	Sum of area (m^2)					513152.93	513152.93
	Count of code					4	4
W300	Sum of area (m^2)		4421.61				4421.61
	Count of code		1				1
W400	Sum of area (m^2)	549.22					549.22
	Count of code	0					0
We110	Sum of area (m^2)	911.37	6414.27	30434.09	337298.69		375058.42
	Count of code	0	3	2	3		8
We210	Sum of area (m^2)		2538.89	28468.33	108993.76		140000.98
	Count of code		1	2	3		6
We220	Sum of area (m^2)		5657.09				5657.09

	Count of code		1				1
TOTAL_Sum of area (m^2)		38376.77	85388.85	123321.5	446292.45	513152.93	1206532.5
TOTAL_Count of code		0	20	16	6	4	46
		0.031807	0.070772	0.102211	0.3698968	0.4253122	
		0	1	2	3	4	

B2: **3.09**

Annex H: Evaluation of Plant Composition in the lower Keelung River

I. Section I

CODE	Data	0	1	2	TOTAL
A110	Sum of area (m^2)	7774.29			7774.29
	Count of code	0			0
A120	Sum of area (m^2)	10479.55			10479.55
	Count of code	0			0
A250	Sum of area (m^2)	1130.33			1130.33
	Count of code	0			0
A320	Sum of area (m^2)	2475.71			2475.71
	Count of code	0			0
A330	Sum of area (m^2)	13597.27			13597.27
	Count of code	0			0
A610	Sum of area (m^2)	1067.33			1067.33
	Count of code	0			0
G100	Sum of area (m^2)			29743.99	29743.99
	Count of code			4	4
G200	Sum of area (m^2)		34122.37		34122.37
	Count of code		8		8
U200	Sum of area (m^2)	19943.13			19943.13
	Count of code	0			0
U400	Sum of area (m^2)	21736.16			21736.16
	Count of code	0			0
W220	Sum of area (m^2)			97031.5	97031.5
	Count of code			2	2
W230	Sum of area (m^2)			114516.58	114516.58
	Count of code			2	2
W400	Sum of area (m^2)		840.8		840.8
	Count of code		2		2
X100	Sum of area (m^2)	1734.5			1734.5
	Count of code	0			0
TOTAL_Sum of area (m^2)		79938.27	34963.17	241292.07	356193.51
TOTAL_Count of code		0	10	8	18
		0.22442371	0.0981578	0.67741849	
		0	1	2	

B3: **1.45**

II. Section II

CODE	Data	0	1	2	3	TOTAL
A110	Sum of area (m^2)	28574.33				28574.33
	Count of code	0				0
A120	Sum of area (m^2)	9656.81				9656.81
	Count of code	0				0
A130	Sum of area (m^2)	12533.79				12533.79
	Count of code	0				0
A250	Sum of area (m^2)	7311.19				7311.19
	Count of code	0				0
A310	Sum of area (m^2)	560.47				560.47
	Count of code	0				0
A320	Sum of area (m^2)	16081.8				16081.8
	Count of code	0				0
A330	Sum of area (m^2)	38771.83				38771.83
	Count of code	0				0
A410	Sum of area (m^2)	27759.86				27759.86
	Count of code	0				0
A420	Sum of area (m^2)	1337.11				1337.11
	Count of code	0				0
A520	Sum of area (m^2)	169.98				169.98
	Count of code	0				0
A530	Sum of area (m^2)	739.71				739.71
	Count of code	0				0
A610	Sum of area (m^2)	28165.35				28165.35
	Count of code	0				0
A620	Sum of area (m^2)	4668.91				4668.91
	Count of code	0				0
A650	Sum of area (m^2)	94.38				94.38
	Count of code	0				0
A710	Sum of area (m^2)	412.03				412.03
	Count of code	0				0
G100	Sum of area (m^2)		9464.35	42025.43		51489.78
	Count of code		4	24		28
G200	Sum of area (m^2)		271890.51			271890.51
	Count of code		71			71
G300	Sum of area (m^2)		3176.43			3176.43
	Count of code		3			3
S100	Sum of area (m^2)				5773.7	5773.7
	Count of code				465	465
U100	Sum of area (m^2)	1797.19				1797.19

	Count of code	0				0
U200	Sum of area (m^2)	39926.72				39926.72
	Count of code	0				0
U400	Sum of area (m^2)	4461.65				4461.65
	Count of code	0				0
W220	Sum of area (m^2)			223099.85		223099.85
	Count of code			2		2
W230	Sum of area (m^2)			150644.78		150644.78
	Count of code			2		2
W400	Sum of area (m^2)		5628.64			5628.64
	Count of code		9			9
X100	Sum of area (m^2)	680.44				680.44
	Count of code	0				0
TOTAL_ Sum of area (m^2)		223703.55	290159.93	415770.06	5773.7	935407.24
TOTAL_Count of code		0	87	28	465	580
		0.239151	0.3101964	0.4444803	0.0061724	
		0	1	2	3	

B3: **1.22**

III. Section III

CODE	Data	0	1	2	3	TOTAL
A110	Sum of area (m^2)	44267.26				44267.26
	Count of code	0				0
A130	Sum of area (m^2)	46567.75				46567.75
	Count of code	0				0
A250	Sum of area (m^2)	3914.41				3914.41
	Count of code	0				0
A310	Sum of area (m^2)	59338.22				59338.22
	Count of code	0				0
A330	Sum of area (m^2)	12451.82				12451.82
	Count of code	0				0
A410	Sum of area (m^2)	32793.08				32793.08
	Count of code	0				0
A520	Sum of area (m^2)	187.89				187.89
	Count of code	0				0
A610	Sum of area (m^2)	48090.81				48090.81
	Count of code	0				0
A620	Sum of area (m^2)	27893.1				27893.1
	Count of code	0				0
A650	Sum of area (m^2)	454.25				454.25
	Count of code	0				0
G100	Sum of area (m^2)		49549.62	47431.35		96980.97
	Count of code		7	22		29
G200	Sum of area (m^2)		490057.59			490057.59
	Count of code		68			68
G300	Sum of area (m^2)		1023.76			1023.76
	Count of code		2			2
S100	Sum of area (m^2)				8398.55	8398.55
	Count of code				591	591
U100	Sum of area (m^2)	18963.39				18963.39
	Count of code	0				0
U200	Sum of area (m^2)	99015.65				99015.65
	Count of code	0				0
U400	Sum of area (m^2)	861.82				861.82
	Count of code	0				0
W220	Sum of area (m^2)			30319.82		30319.82
	Count of code			2		2
W230	Sum of area (m^2)			360313.91		360313.91
	Count of code			4		4
W400	Sum of area (m^2)		5614.34			5614.34

	Count of code		7			7
W510	Sum of area (m²)			4347.71		4347.71
A110	Count of code			2		2
TOTAL_Sum of area (m²)		394799.45	546245.31	442412.79	8398.55	1391856.1
TOTAL_Count of code		0	84	30	591	705
		0.2836496	0.3924582	0.3178581	0.0060341	
		0	1	2	3	
					B3:	**1.05**

IV. Section IV

CODE	Data	0	1	2	3	TOTAL
A130	Sum of area (m²)	17021.39				17021.39
	Count of code	0				0
A250	Sum of area (m²)	8542.2				8542.2
	Count of code	0				0
A310	Sum of area (m²)	20002.9				20002.9
	Count of code	0				0
A330	Sum of area (m²)	41499.99				41499.99
	Count of code	0				0
A410	Sum of area (m²)	64697.14				64697.14
	Count of code	0				0
A610	Sum of area (m²)	58676.86				58676.86
	Count of code	0				0
A620	Sum of area (m²)	40013.18				40013.18
	Count of code	0				0
A630	Sum of area (m²)	7904.98				7904.98
	Count of code	0				0
A650	Sum of area (m²)	378.02				378.02
	Count of code	0				0
A710	Sum of area (m²)	194.76				194.76
	Count of code	0				0
G100	Sum of area (m²)		4638.18	46836.87		51475.05
	Count of code		2	10		12
G200	Sum of area (m²)		354332.2			354332.2
	Count of code		83			83
G300	Sum of area (m²)		6845.92			6845.92
	Count of code		6			6
S100	Sum of area (m²)				8055.52	8055.52
	Count of code				1059	1059
U100	Sum of area (m²)	13614.24				13614.24
	Count of code	0				0
U200	Sum of area (m²)	1893.69				1893.69
	Count of code	0				0
U400	Sum of area (m²)	19134.31				19134.31
	Count of code	0				0
W220	Sum of area (m²)			128831.46		128831.46
	Count of code			2		2
W230	Sum of area (m²)			150880.36		150880.36
	Count of code			2		2
W400	Sum of area (m²)		7649.44			7649.44

	Count of code		8			8
W520	Sum of area (m^2)	8637.52				8637.52
	Count of code	0				0
TOTAL_Sum of area (m^2)		302211.18	373465.74	326548.69	8055.52	1010281.1
TOTAL_Count of code		0	99	14	1059	1172
		0.2991357	0.3696652	0.3232256	0.0079735	
		0	1	2	3	

B3: **1.04**

V. Section V

CODE	Data	0	1	2	3	TOTAL
A210	Sum of area (m^2)	10801.9				10801.9
	Count of code	0				0
A250	Sum of area (m^2)	1701.65				1701.65
	Count of code	0				0
A310	Sum of area (m^2)	3485.77				3485.77
	Count of code	0				0
A320	Sum of area (m^2)	5681.87				5681.87
	Count of code	0				0
A330	Sum of area (m^2)	32681.92				32681.92
	Count of code	0				0
A410		7937.43				7937.43
		0				0
A510		91.36				91.36
		0				0
A520	Sum of area (m^2)	29.8				29.8
	Count of code	0				0
A610	Sum of area (m^2)	15555.4				15555.4
	Count of code	0				0
A620	Sum of area (m^2)	3846.09				3846.09
	Count of code	0				0
A630	Sum of area (m^2)	1970.2				1970.2
	Count of code	0				0
A650	Sum of area (m^2)	1276.36				1276.36
	Count of code	0				0
G100	Sum of area (m^2)			22780.85		22780.85
	Count of code			12		12
G200	Sum of area (m^2)		188723.2			188723.2 2
	Count of code		41			41
G300	Sum of area (m^2)		13852.39			13852.39
	Count of code		12			12
S100	Sum of area (m^2)				37291.15	37291.15
	Count of code				330	330
U100	Sum of area (m^2)	10494.31				10494.31
	Count of code	0				0
U200	Sum of area (m^2)	29109.95				29109.95
	Count of code	0				0
U400	Sum of area (m^2)	10701.5				10701.5
	Count of code	0				0
W220	Sum of area (m^2)			129681.6		129681.6

						4
	Count of code			4		4
W230	Sum of area (m^2)			163794.4		163794.4 4
	Count of code			2		2
W300	Sum of area (m^2)		5402.24			5402.24
	Count of code		1			1
W400	Sum of area (m^2)		6202.07			6202.07
	Count of code		3			3
W520	Sum of area (m^2)	1057.76				1057.76
	Count of code	0				0
X100	Sum of area (m^2)	1716.72				1716.72
	Count of code	0				0
TOTAL_Sum of area (m^2)		138139.99	214179.9	316256.9	37291.15	705868.0
TOTAL_Count of code		0	57	18	330	405
		0.1957023	0.303428	0.44804	0.0528302	
		0	1	2	3	

B3: **1.36**

VI. Section VI

CODE	Data	0	1	2	3	TOTAL
A210	Sum of area (m^2)	130443.79				130443.79
	Count of code	0				0
A220	Sum of area (m^2)	19465.38				19465.38
	Count of code	0				0
A250	Sum of area (m^2)	1082.55				1082.55
	Count of code	0				0
A320	Sum of area (m^2)	7967.98				7967.98
	Count of code	0				0
A330	Sum of area (m^2)	72299.72				72299.72
	Count of code	0				0
A340	Sum of area (m^2)	4004.75				4004.75
	Count of code	0				0
A410	Sum of area (m^2)	166876.42				166876.42
	Count of code	0				0
A520		0.83				0.83
		0				0
A530	Sum of area (m^2)	615.61				615.61
	Count of code	0				0
A610	Sum of area (m^2)	25496.27				25496.27
	Count of code	0				0
A620	Sum of area (m^2)	11687.45				11687.45
	Count of code	0				0
A650	Sum of area (m^2)	185.65				185.65
	Count of code	0				0
A710	Sum of area (m^2)	1694.24				1694.24
	Count of code	0				0
G100	Sum of area (m^2)			300151.61		300151.61
	Count of code			42		42
G200	Sum of area (m^2)		299996.11			299996.11
	Count of code		38			38
G300	Sum of area (m^2)		2316.49			2316.49
	Count of code		2			2
S100	Sum of area (m^2)				19048.61	19048.61
	Count of code				597	597
U100	Sum of area (m^2)	14732.43				14732.43
	Count of code	0				0
U200	Sum of area (m^2)	131035.29				131035.29
	Count of code	0				0
U300	Sum of area (m^2)	2052.26				2052.26

	Count of code	0				0
U400	Sum of area (m^2)	775.14				775.14
	Count of code	0				0
W110	Sum of area (m^2)			5667.89		5667.89
	Count of code			2		2
W120	Sum of area (m^2)	22	23638			23660
	Count of code	0	1			1
W210	Sum of area (m^2)			142746.41		142746.41
	Count of code			2		2
W220	Sum of area (m^2)			725172.79		725172.79
	Count of code			4		4
W300	Sum of area (m^2)			7150.68		7150.68
	Count of code			2		2
W400	Sum of area (m^2)		14588.15			14588.15
	Count of code		10			10
W510	Sum of area (m^2)			6210.35		6210.35
	Count of code			26		26
W600	Sum of area (m^2)			548.85		548.85
	Count of code			2		2
TOTAL_Sum of area (m^2)		590437.76	340538.75	1187648.6	19048.61	2137673.7
TOTAL_Count of code		0	51	80	597	728
		0.2762058	0.1593034	0.5555799	0.0089109 06	
		0	1	2	3	
					B3:	**1.30**

VII. Section VII

CODE	Data	0	1	2	3	4	TOTAL
A220	Count of code	0				0	0
	Sum of area (m^2)	11257.4				11257.4	11257.4
A330	Count of code	0				0	0
	Sum of area (m^2)	9249.08				9249.08	9249.08
A340	Count of code	0				0	0
	Sum of area (m^2)	11773.81				11773.81	11773.81
A610	Count of code	0				0	0
	Sum of area (m^2)	1436.71				1436.71	1436.71
A620	Count of code	0				0	0
	Sum of area (m^2)	250.34				250.34	250.34
A630	Count of code	0				0	0
	Sum of area (m^2)	1461.03				1461.03	1461.03
G100	Count of code			12		12	
	Sum of area (m^2)			32300.47		32300.47	
G200	Count of code		1			1	
	Sum of area (m^2)		3844.52			3844.52	
U100	Count of code	0				0	0
	Sum of area (m^2)	17439.22				17439.22	17439.22
U200	Count of code	0				0	0
	Sum of area (m^2)	48185.8				48185.8	48185.8
U300	Count of code	0				0	0
	Sum of area (m^2)	11349.94				11349.94	11349.94
U400	Count of code	0				0	0
	Sum of area (m^2)	9855.83				9855.83	9855.83
W110	Count of code			2		2	
	Sum of area (m^2)			9107.78		9107.78	
W120	Count of code	0				0	0
	Sum of area (m^2)	180.27				180.27	180.27
W210	Count of code			2		2	
	Sum of area (m^2)			513152.93		513152.93	
W300	Count of code			2		2	
	Sum of area (m^2)			4421.61		4421.61	
W400	Count of code		2			2	
	Sum of area (m^2)		549.22			549.22	
We110	Count of code				24	24	
	Sum of area (m^2)				375058.42	375058.42	
We210	Count of code			6		6	
	Sum of area (m^2)			140000.98		140000.98	
We220	Count of code			2		2	

	Sum of area (m^2)			5657.09		5657.09	
TOTAL_Count of code		0	3	26	24	53	0
TOTAL_Sum of area (m^2)		122439.43	4393.74	704640.86	375058.42	1206532.5	122439.43
		0.1014804	0.0036416	0.5840215	0.3108565	0.1014804	
		0	1	2	3	4	

B3: **2.42**