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1 INTRODUCTION

1.1 INTRODUCTION

The Sustainable Development Division (SDD) of the Hong Kong Special Administrative Region Government (HKSAR) commissioned **ERM-Hong Kong Ltd (ERM)** to undertake a study entitled *2008 Update of Terrestrial Habitat Mapping and Ranking Based on Conservation Value*. ERM worked in association with the **Institute of Space and Earth Information Science (ISEIS)**, Chinese University of Hong Kong (CUHK), an acknowledged team with satellite imagery processing and analysis specialists, and **Winson Engineering Survey Co** who brought to the team expertise with qualified land surveyors. This study, awarded under the Tender Ref SD 08-056, is henceforth referred to as "the Present Study".

The Present Study commenced on 5 September 2008. This *Final Report* is the fourth and the final deliverable of the Present Study to present all the data and findings of the 2008 Study as required in *Clause 3e v* of the *Tender Services Specification*.

1.2 BACKGROUND TO THE PRESENT STUDY

This consultancy is a continued study of *Environmental Baseline Survey on Terrestrial Habitat Mapping and Ranking Based on Conservation Value* (the "2000 survey") commissioned by the Planning Department (PlanD) and the three studies commissioned by the then Sustainable Development Unit (SDU) of the Administration Wing (currently known as the Sustainable Development Division (SDD) of the Environment Bureau) including the study on *Terrestrial Habitat Mapping and Ranking Based on Conservation Value* completed in 2003 (the "2003 Study"), the study on *2004 Update of Terrestrial Habitat Mapping and Ranking Based on Conservation Value* completed in 2005 (the "2005 Study") and the study on *2006 Update of Terrestrial Habitat Mapping and Ranking Based on Conservation Value* completed in 2007 (the "2007 Study"). The "2000 Survey" and these three studies are hereinafter collectively referred to as the "Previous Studies".

In June 1998, the 2000 Survey was commissioned by the PlanD of the Hong Kong Government, under a Supplementary Agreement to the *Study of Sustainable Development 21st Century* (SUSDEV 21). The 2000 Survey, conducted by ERM, was designed to update an existing Hong Kong-wide vegetation map, to expand the coverage to include new categories, and to present the results in an interactive Geographic Information System (GIS). The survey was also designed to develop a system for ranking the conservation value of areas of Hong Kong, to supplement the compilation of existing conservation data through field truthing surveys, and to present the results in a GIS.

The mapping and ranking exercise that was carried out under the SUSDEV 21 baseline survey produced a comprehensive and robust habitat mapping system. The baseline data were then incorporated into the Computer-aided Sustainability Evaluation Tool (CASET) system to help assessing different Government proposals and visualize the impacts associated with those proposals. The habitat mapping system was particularly useful in acting as a tool for quantification and assessment of existing natural habitats. The conservation ranking information provided in the system facilitated sustainable development planning by highlighting important areas for protection and evaluating the existing baseline conditions against any indicators (developed under the SUSDEV 21 Study) involving the area of land with various levels of conservation status. The survey was completed in August 2000 and the key findings were documented.

In October 2002, SDU commissioned ERM to carry out the 2003 Study, to review and update the findings of the previous 2000 Survey using the latest data (including aerial photographs) and field truthing surveys by ecology specialists (for a total of 200 days) to obtain necessary field information. The field data collected were validated and analysed and updated the interactive GIS habitat and conservation value maps contained in the CASET.

In October 2004, SDU commissioned Scott Wilson in association with Joint Laboratory for Geoinformation Science, CUHK (currently known as ISEIS) to carry out the 2005 Study. They updated the terrestrial habitat mapping and ranking, updated the GIS map in CASET and carried out remote sensing analysis using the latest satellite images and higher spatial resolution data along with a more advanced non-parametric classification method, as well as doing desktop truthing and 50 days of field truthing surveys.

In September 2006, SDU commissioned ERM to update the findings of the Previous Studies and the associated terrestrial habitat and ecological baseline database including the maps contained in the CASET, to fill any essential information gap and to maintain the data integrity through (i) remote sensing analysis using up-to-date satellite images; (ii) desktop truthing orthophotos; and (iii) 50 days of field truthing surveys. The study was completed in 2007.

1.3 OBJECTIVES OF THE PRESENT STUDY

The Present Study has several main requirements which are listed as follows:

Review the Previous Studies – Information provided in the Previous Studies, and contained in the relevant terrestrial habitat and ecological baseline database, the terrestrial habitat map and the conservation assessment map were reviewed. The Present Study was required to adopt habitat categorization methodology, conservation values assessment criteria and ranking system that were consistent with the Previous Studies. Where necessary, appropriate minor modifications to the methodology, to suit the purpose of the 2008 Update, were identified during the review.

Propose Methodology and a Work Programme – The Present Study was required to update the findings of the Previous Studies and the existing terrestrial habitat and ecological baseline database by using an appropriate methodology and work programme, to fill any essential information gaps and to maintain the data integrity through (i) remote sensing analysis using up-to-date satellite images; (ii) desktop truthing using orthophotos; and (iii) field truthing surveys.

Conduct Remote Sensing Analysis and Desktop Truthing – The Present Study was required to use up-to-date and suitable satellite images (which were taken no earlier than November 2008) for remote sensing analysis of terrestrial habitats to determine the changes in various habitat coverage, their respective ecological values and produce a preliminary terrestrial habitat map. Desktop Truthing was used to refine the terrestrial habitat map using orthophotos and supplementary ancillary data.

Conduct Field Truthing Surveys - Based on the outcome of the Review of the Previous Studies, Remote Sensing Analysis and Desktop Truthing mentioned above, the Present Study aimed to identify discrepancies, uncertainties and outstanding information gaps, and verify all these by conducting 80 days of field truthing surveys.

Analyse Information Collected and Update the Existing Habitat Map and Conservation Evaluation - The Present Study was required to update the habitat and conservation assessment maps by examining, verifying and combining collected information in a review of all available data on habitats, including field observations and records.

Compare Findings with the Previous 2007 Study to Identify any Changes in the Habitat Map and Conservation Assessment Map - The results of the updated habitat maps of the Present Study were required to be compared with the previous 2007 Study to determine changes in the habitat map and conservation assessment map between the 2007 Study and the Present Study.

1.4 REPORT STRUCTURE

The remainder of the report is set out as follows:

Section 2 Presents the results of the review of the existing database and findings of the previous 2000, 2003, 2005 and 2007 Studies with details on the study approach, habitat categorisation and indication of ecological values;

Section 3 Presents the methodologies and results of the remote sensing analysis;

Section 4 Presents the methodologies and results of desktop truthing and the preliminary refined habitat map;

Section 5 Describes the allocation of survey effort for each habitat category;

Section 6 Presents the survey methodology employed for each habitat type with specifications on the information to be collected;

Section 7 Summarises the results of the field truthing survey;

Section 8 Updates the habitat map and conservation assessment map; and

Section 9 Presents the summaries and conclusions of the *Final Report*.

This report has been prepared solely for this Present Study and its use by 3rd parties should be in the context of this Present Study's stated goals and objectives. The contents in this Report, including but not limited to the CASET application, methodologies, definitions, Habitat and Conservation Value Maps and vegetation coverage data used are only applicable to this Present Study.

2.1 INTRODUCTION

This *Section* provides information from a review of the existing databases produced in the Previous Studies. All the available reports (including *Review Reports*, *Inception Reports*, *Topic Reports* and *Final Reports*), GIS baseline database, the terrestrial habitat map and the conservation assessment map produced under the previous 2000, 2003, 2005 and 2007 Studies have been thoroughly reviewed. The focus of the review was on the study approach, methodology and specifically the habitat categorisation method and the conservation value ranking system. In the *Topic Report* and *Final Report* of each of the previous 2000, 2003, 2005 and 2007 Studies, recommendations were provided which highlighted information gaps that had yet to be filled. Other available existing information on terrestrial habitat identification and conservation value obtained from, for example, consultancy studies were also noted during the course of the Present Study as these studies were potentially useful to fill part of the information gap identified. Appropriate specialists were also consulted during the review process to ensure that identification of outstanding information gaps and discrepancies was comprehensive. The results of the review are provided below.

2.1.1 *Study Approach*

The 2000 Survey involved delineating terrestrial and coastal habitats on the basis of satellite images and aerial photographs, and assigning an ecological value to each of those habitats based on field survey findings and existing information. For terrestrial habitats, which were above the low tide mark, an ecological baseline database was compiled, and a terrestrial habitat map and a conservation assessment map were produced. The baseline database and the maps, which were also presented in an interactive GIS format, were incorporated into the CASET to help assess impacts of the Government's proposals on, among other aspects, the terrestrial ecology of, and area of, countryside in Hong Kong. The objectives of the subsequent 2003, 2005 and 2007 Studies were used to update the findings of the 2000 Survey.

The 2000 Survey classified the land area of Hong Kong into 25 habitat categories that were subsequently used for mapping. The definitions used for habitat mapping categories are presented in *Table 2.1*. Habitat categories were developed based on a list of land use categories plotted on the WWF habitat map and refined based on the comments received at the time from Government Departments, and consultation with HKU Biodiversity Survey Team specialists and satellite imagery/aerial photograph experts.

Table 2.1 ***Definitions of Habitat Mapping Categories Adopted in 2000, 2003, 2005 & 2007 Studies***

Habitat/Feature Type	Mapping Category	Definitions
Natural Terrestrial Habitats	Bare Rock or Soil	Naturally open rock faces or disturbed lands, or "badlands" denuded of vegetation.
	Grassland	Lands covered predominantly (50% or more) by grasses with no visible woody plants.
	Shrubby Grassland	Lands covered predominantly (50% or more) by grasses and contained visible woody plants covering up to 50% of the area. Definition of Shrubby Grassland was revised to include *Baeckea* Shrubland in the 2003, 2005 and 2007 Studies.
	Mixed Shrubland	Lands covered with less than 50% grasses with shrubs the major woody life form.
	Baeckea Shrubland	Lands covered with less than 50% grasses with the genus *Baeckea* (Myrtaceae) the predominant plant group. Definition of Shrubby Grassland was revised to include *Baeckea* Shrubland in the 2003 Study. This mapping category was removed in the 2003, 2005 and 2007 Studies.
	Fung Shui Forest	Lands covered with natural forests over 60 years old and dominated by native species. Often located behind villages, in valleys or near water. The definition of Fung Shui forest was revised to incorporate the Fung Shui elements in the 2003, 2005 and 2007 Studies.
	Montane Forest	Lands covered with natural forests above 600m above sea level.
	Lowland forest	Lands covered with natural forests below 600m above sea level.
	Plantation or Plantation /Mixed Forest	Lands covered with tree species varying in size from low saplings to mature trees which are in recognizable rows from the air. In areas where the definition "in recognizable rows from the air" cannot apply (eg plantations have become mixed plantation forests and intermingled with other spectrally and visually habitats, making identification using satellite imagery and aerial photos impossible) and field truthing surveys are required to supplement the mapping, the pattern and type of plant species used for tree planting, formed the basis for justification of this habitat.
Natural/Artificial Freshwater and Intertidal Habitats – revised to Natural/ Artificial Freshwater in the 2005 Study	Natural Watercourse	Consists of rivers and streams experiencing natural flow patterns in unchannelised beds and banks.

Habitat/Feature Type	Mapping Category	Definitions
	Modified Watercourse	Consists of channelised rivers, streams and other waterbodies, which are often without natural banks and beds, and are not subject to a natural flow patterns (eg drainage channels, nullahs and reservoirs). Rivers with substantial abstraction of water for irrigation or domestic use. Watercourse with "very bad" water quality identified by EPD (1).
Natural/Artificial Freshwater and Intertidal Habitats – revised to Natural/ Artificial Wetland in the 2005 Study	Freshwater/Brackish Wetland	Lands covered with shallow waters and dominated by emergent hydrophytes (i.e. reedbed).
	Fishpond/Gei Wai	Fishponds are small artificial lakes that have been constructed for the purposes of growing freshwater fish. Gei Wais are small artificial lakes which contain brackish water and are often flushed through tidal action.
	Mangrove	Highly productive intertidal areas that support high biological diversity and which are know as breeding and nursery grounds for a range fauna.
	Intertidal Mudflat	Areas of fine-grained sediment (i.e. silt or finer) which lie between the high and low tide marks and which are not covered by seagrasses, mangroves or typical wetland vegetation.
	Seagrass Bed	Shallow intertidal or subtidal areas dominated by one or more species of specialised marine grasses.
	Sandy Shore	Areas of sandy sediment (coarser than silt and up to and including cobble-sized rocks) between the high and low tide marks, and areas with 50% or more of the area consists of exposed sand or rocks equal to or smaller than cobbles.
	Rocky Shore	Areas of stable (non-mobile) rocks larger than cobbles between the high and low tide marks, covering more than 50% of the area.
	Artificial Rocky/Hard Shoreline	Man-made intertidal hard shore habitats, eg seawalls, jetties, groins and piers.
Disturbed Areas which Provide Some Habitat	Cultivation	Lands currently under cultivation, i.e. actively agricultural land (eg rice paddies or areas farmed for vegetables), and lands not currently under cultivation and/or abandoned for cultivation.

(1) Classification of watercourse based on the most recent EPD River Water Quality data.

Habitat/Feature Type	Mapping Category	Definitions
	Golf Course/Urban Park	Areas which consist of existing golf courses and urban parks, and areas under development for golf courses and urban parks. Urban parks include all recreational parks under the governmental management of the Provisional Urban council and the Provisional Regional Council, and the non-governmental management of private enterprise.
Disturbed Areas which Provide Little if any Habitat	Rural Industrial Storage/Containers	Areas in which large number of containers or other commercial/industrial materials are stored (generally considered as "black spot" areas by the Government).
	Quarry	Areas which are being or have been excavated for rock.
	Landfill	Areas used for disposal of solid waste and may be either active or inactive.
	Other	Areas occupied by urban or other highly modified habitats, including scattered buildings mixed with cultivation, abandoned cultivation and/or forest.

In the 2003 Study, in general, the definitions used for habitat categories were not modified, except that the definition of Shrubby Grassland was revised to include *Baeckea* Shrubland as the *Baeckea* Shrubland showed a comparatively low mapping accuracy and the same ecological value as the Shrubby Grassland. The definition of Fung Shui forest was also revised to incorporate the Fung Shui elements in the 2003 Study. The resulting habitat map thus showed a total of 24 habitat categories.

In the 2005 Study, the definition of habitat categories used for 2003 Study was retained with only one minor rearrangement of habitat classification scheme, which was to reclassify the mapping categories of Natural/Artificial Freshwater and Intertidal Habitats as Natural/Artificial Freshwater and Natural/Artificial Wetlands. Nine general land cover types that were more spectrally distinct were classified using the SPOT 5 data imagery and were detailed as:

- Grasslands
- Forest (including low and high land forest and other type of trees)
- Shrubby Grassland (grassland with some shrubs)
- Mixed Shrubland (tall and low shrublands)
- Natural and Artificial Wetlands (including fishpond, coastal wetlands and other lands with water or saturated soils)
- Mangrove

- Cultivation
- Bare and modified lands (all bare ground with different land use)
- Water (natural and man-made)

The same 24 habitat classes used in the 2003 Study were used in 2005 Study and were mapped using both satellite images and geospatial ancillary data.

In the 2007 Study, the broad land cover was reclassified (from 9 to 10 classes) as follows:

- Grasslands (Pure grassland)
- Forest (including low and high land forest and other type of trees)
- Shrubby Grassland (grassland with some shrubs)
- Mixed Shrubland (tall and low shrublands)
- Natural and Artificial Wetlands (including fishpond, coastal wetlands and other lands with water or saturated soils)
- Mangrove
- Bare soil (rocky area, shore, badland and high albedo artificial materials)
- Others (urban, other highly modified area and low albedo artificial materials)
- Water (natural and man-made)
- Cloud (thick cloud)

Seven of the general land cover types, including Grassland, Forest, Shrubby Grassland, Mixed Shrubland, Natural and Artificial Wetlands, Mangrove and Water, remained unchanged.

Due to the presence of cloud cover in the SPOT 5 employed in the 2007 Study (which was absent in the SPOT 5 employed in the 2005 Study), a new class called "Cloud" was also created as a class instead of masking it out because there is no guaranteed method for filtering the cloud even using the SWIR (Short-Wave Infrared) Band. In addition, the "bare and modified lands (all bare ground with different land use)" class in the 2005 Study was divided into two distinctive classes: "Bare soil" and "Others". The "Bare soil" was defined as "bare soil and high albedo urban material". The "Others" was defined as "low albedo urban material and building". The "Cultivation" class that existed in the broad land cover classification of the 2005 Study was removed due to the fact that it was spectrally similar with the Shrubby Grassland. It could be mapped in the post-classification stage using decision rules. This classification was believed to be more compatible with the

spectral characteristics of SPOT 5 which had a much narrower band width when compared with Landsat data products.

The same 24 habitat classes were finally generated from the 10 classes in the 2007 Study.

2.2 *INDICATIVE DESIGNATION OF ECOLOGICAL VALUE*

As proposed in *Topic Report 1* of the 2000 Survey, each identified habitat type was assigned an indicative ecological value of high, medium, low or negligible. These ecological values are defined with reference to elements of *Annex 8: Criteria for Evaluating Ecological Impact, EPD Technical Memorandum on the Environmental Impact Assessment Process* (*EIAO TM*). The definitions of high, medium, low and negligible ecological value habitats are provided below:

High ecological value habitat is defined as:

- areas that support the highest known biodiversity values for Hong Kong; or
- areas that are documented to function as important breeding, nursery or key foraging habitats; or
- areas that contain habitats that are regionally rare or threatened or provide documented critical habitat for "rare" species; or
- areas that contain unusually large-sized, valuable and generally undisturbed habitat.

Medium ecological value habitat is defined as:

- areas that support intermediate biodiversity values for Hong Kong; or
- areas that may provide critical habitat for "rare" species but for which such use is not documented; or
- areas that may function as important breeding, nursery or key foraging habitats but for which such use is not documented; or
- areas that contain unusually large-sized and valuable habitats which have been fragmented or otherwise disturbed such that habitat potential has diminished; or
- areas that have potential to develop into high value habitat but do not meet the criteria for high ecological value at present.

Low ecological value habitat is defined as:

- areas that support low biodiversity values for Hong Kong; or

- areas that are not likely to provide critical habitat for "rare" species; or
- areas that are not likely to function as important breeding, nursery or key foraging habitats; or
- areas that contain habitats that have been degraded or modified by human activities such that habitat potential is low but that can be recolonized by the original floral/faunal assemblage; or
- areas that have potential to develop into medium value habitat but do not meet the criteria for medium ecological value at present.

Negligible ecological value habitat is defined as:

- areas that support negligible biodiversity values for Hong Kong; or
- areas that do not provide critical habitat for "rare" species; or
- areas that do not function as important breeding, nursery or key foraging habitats; or
- areas that contain habitats that have been severely degraded or extensively modified by human activities such that habitat potential is negligible and recolonization by the original floral/faunal assemblage is unlikely; or
- areas that do not have potential for developing into high, medium or low value habitat in the foreseeable future.

In assigning each of the habitat categories either a value of high, medium, low or negligible ecological, a number of criteria such as their biodiversity, occurrence of rare species, ecological function, rarity, vulnerability, size and potential were assessed. However, the overall assessment was based on the classification that best represented the habitat type rather than on strict compliance with each of the criteria under a particular classification. It was also acknowledged that specific sites within a given habitat category could vary in ecological value. This variation, within habitat, has been addressed in the later stages of mapping, performed under the field truthing surveys and plotting of detailed existing information.

The habitats proposed for an indicative designation as of high value ecological habitat (in the absence of further information) include:

- Fung Shui Forest;
- Montane Forest;
- Lowland Forest;
- Mixed Shrubland;

- Freshwater/Brackish Wetland;
- Natural Watercourse;
- Mangrove;
- Seagrass Bed; and,
- Intertidal Mudflat.

The habitats proposed for an indicative designation as of medium value ecological habitat (in the absence of further information) include:

- Shrubby Grassland (including *Baeckea* Shrubland);
- Plantation or Plantation/Mixed Forest;
- Fishpond/Gei Wai;
- Sandy Shore;
- Rocky Shore; and,
- Cultivation.

The habitats proposed for an indicative designation as of low value ecological habitat (in the absence of further information) include:

- Bare Rock or Soil;
- Grassland;
- Modified Watercourse;
- Artificial Rocky/Hard Shoreline;
- Golf Course/Urban Park; and,
- Quarry.

The habitats proposed for an indicative designation as of negligible value ecological habitat (in the absence of further information) include:

- Rural industrial storage/containers;
- Landfill; and,
- Other.

This classification of ecological value was adopted in the 2003, 2005 and 2007 Studies. It was considered appropriate to maintain the indicative ecological value assigned to each of the mapped habitat categories as in the Previous

Studies and, therefore, no modification to the indicative designation was deemed necessary for the Present Study.

2.3 METHODOLOGY OF REMOTE SENSING ANALYSIS

2.3.1 Satellite Data Employed in Previous Projects

In 2000, two sources of satellite imagery: Landsat 4 Thematic Mapper (TM) Multispectral data and SPOT 5 panchromatic (SPOT PAN) data were used. TM was used because it had a wider spectral resolution while SPOT PAN, was acquired to improve the spatial resolution of the Landsat TM imagery through merging. SPOT 5 Multi-spectral satellite data with a ground resolution of 20-m were also available but were not used because they had a narrower spectrum than TM and operated only in red, green and infrared band. Totally 6 bands from two imageries were employed: 4 bands of TM including the visible, near infrared, middle infrared, and thermal infrared spectral regions and 2 bands of SPOT PAN containing the visible (green) and near infrared spectrum. The review of the 2000 Survey indicated that while the qualities of most habitat classes mapped were good, the mapping accuracy of some classes such as Wetland and Shrubby Grassland was rather low (<40%).

The 2003 Study did not involve any remote sensing analysis. The update of the habitat map was dependent on data collected from ecological field surveys. In the 2005 Study, SPOT 5 panchromatic and multispectral imageries were used. Both the spatial and spectral resolution of SPOT 5 had been greatly improved. The spatial resolution of multispectral reached 10-m while panchromatic offered two resolutions: 2.5-m and 5-m. The lower spatial resolution of SPOT 5 was compensated by the panchromatic data. Geometric and ortho-rectification were applied to the two imageries separately to correct the positional and displacement error. Both procedures require high quality Ground Control Points (GCPs) and Digital Terrain Elevation models (DEM).

In the 2007 Study, since good satellite imagery providing full coverage of Hong Kong, with 80% cloud free coverage, was not available, two SPOT 5 imageries of two different dates were sought. The two multispectral data imageries were merged (using a mosaic technique) with two panchromatic data imageries after ortho-rectification correction. Pixel balancing and histogram adjustment were applied to merge the two images into one without any visible seams. Where cloud cover areas still existed in the two mosaic imageries, these areas were replaced with a new set of data by making reference to the 2003 habitat map, 2005 habitat map and also DOP5000. The fidelity of this data was further assessed using ground truthing data.

2.3.2 Satellite Image Analysis

In the 2000, 2005 and 2007 Studies, a two-step process was taken to create the preliminary habitat maps.

- The first step was to consider the limitation of spectral distinction among detailed habitat classes in using satellite data. Ten general land covers (the 2000 Survey used 9 general land covers) that were spectrally distinct were classified using the SPOT 5 data.

- The second step was to refine and split the general land cover classes into finer habitat types using decision rules and a suite of ancillary data (both spatial and non-spatial).

These two steps involved a process of sorting pixels into a finite number of individual classes, or categories of data, based on their data values. If a pixel satisfied a certain set of criteria, the pixel was assigned to the class that corresponded to that set of criteria. This process is termed multispectral classification.

Multispectral Classification

The 2000 Survey used a supervised classification called Maximum Likelihood to define broad land cover classes. Before the classification, 902 training sites were analysed to ensure that they were not composed of any outlying pixels, whose spectral values were uncharacteristic of that class. The Maximum Likelihood Classifier accounts for the mean and covariance of each class by estimating the likelihood of a class at any digital value. To be acceptable for classification, a level of 90% correctly classified training pixels in each class was set. In addition to the six multi-spectral channels of data included in the classification, two additional principal component bands were generated from the merged data. Principal component analysis is a technique employed to reduce the correlation between bands of data and enhance features that are unique to each band. This classification led to the generation of nine thematic classes. Manual interpretation of orthophotos served as a cross-reference for the identification of more refined categories. The result from this process was a digital map containing 25 habitat categories.

The 2005 Study used a classification called See5 Decision Tree (DT) algorithm to classify the data into broad land cover uses. See5 DT excels in other multispectral classification by two advanced features: boosting and cross-validation. Boosting is a technique for improving classification accuracy while cross-validation can provide a certain level of estimation regarding the land cover classification quality. The parameters used to run See5 were mainly based on a 10-fold boosting with 25% pruning in order to generate a set of classification rules on 902 training data into a specific habitat class. An example of this classification rule was: IF spectral reflectance in SPOT 5 band 3 > 140 and that of SOPT 5 band 1 < 50 and Elevation < 400, then classify as lowland forest. This approach had finally generated 10 preliminary land covers. The preliminary habitat map of 24 classes was derived from ten general land covers using geospatial ancillary data and the manual interpretation with reference to high-resolution aerial photos and SPOT 5 panchromatic images.

In the 2007 Study, a total of 1,091 training samples were selected from the 10 classes (including 3 sites from cloud cover class) to guarantee enough samples for the classification. The selection of these 1,091 training samples was based on various authors' (1) recommendation that the total sample size for data training should be between 10*n* and 30*n*, where *n* is the number of spectral bands. Since there were four SPOT 5 multispectral bands (green, red, near IR and shortwave), a sample size of between 40 (i.e. 10 x 4 SPOT 5 multispectral bands) and 120 (i.e. 30 x 4 SPOT 5 multispectral bands) training sites per class were required. As there were 10 land use covers, about 400 to 1200 training sites were considered to be sufficient. Finally, 1091 training sites were randomly selected from different locations of the 10 land cover classes. Aside from the sampling number, all samples were selected based on the following logic:

1. Locations of well-defined spectral characteristics,

2. Locations of well-defined features as identified from higher resolution aerial photos, and

3. Based on the needs, field visits were also carried out for certain types of questionable training sites.

The principle on the training samples selection used for the 2007 Study (also used in the Present Study) is summarised as follows:

- Select sites with spectral characteristics representing a unique signature for a habitat class enabling unknown data to be discernible from the rest of the data.

- Select site(s) which is already identified with a habitat type. This identification is acquired through previous studies, analysis of aerial photography, professional (experienced ecologists) experience and reliable GIS data (either from ERM in-house or Government). ERM is aware of the time difference among the data sources and the latest satellite imagery to be acquired. This issue is resolved by cross-checking with all available reliable data sources to ensure the habitat type of the interested areas which are consistent over time are selected. Any training sites of inconsistency will not be used.

- For site(s) which indicate uncertainty (after comparison of different data sources), ERM may request the Lands Department to provide it with the latest orthophoto DOP 5000 for cross-referencing with that particular site(s).

- If doubts still persist, pre-classification field truthing will be conducted for the questionable training sites. The number of days for the field truthing will be subject to agreement with SDD.

(1) Lillesand . T. M. and Kiefer . R. W. (1994). Remote Sensing & Images Interpretation. New York, John Wiley & Sons. Inc. 3rd Edition.

After the training sites selection, training sites were delineated on-screen. Maximum Likelihood Classification was implemented in the 2007 Study, where 1091 training data were used to classify 10 broad classes including Grassland, Mixed Shrubland, Shrubby Grassland, Soil, Mangrove, Wetland, Forest, Water, Cloud and Others. The rationale of Maximum Likelihood Classification is to calculate the posterior probability of each pixel with respect to each training class. For example, it calculates the probabilities of pixel A being classified as Forest (P=0.8), as Grass (P=0.1), as Shrubland (P=0.1) etc, then finding the maximum probability (P=0.8) and assigning it to that class (Forest). A majority filter was also included as part of the classification to remove isolated pixels from the classed output. In order to provide a 24 habitat class map from these 10 land covers, a post-classification technique was used in the Present Study. Post classification discrimination used decision rules to refine the classification by re-assigning classified pixels with reference to the existing information. Decision rules were applied in conjunction with known regions defining the extent of a habitat at that location. For example:

- IF pixels were classified as *Bare / Modified* AND falling within the boundary of a known *Quarry*,
- THEN it was re-assigned as the *Quarry Habitat*

Post classification discrimination resulted in significant changes to the raw image classification. The nine land covers (except cloud) were reclassified into 24 finer habitat classes.

A low accuracy was often observed between Shrubland and Grassland in Previous Studies. ISEIS of CUHK project team purchased a new full range spectrum analyzer in 2007 which was employed in the Present Study. If the classification accuracy for Grassland and Shrubland were found to be low, the Project Team used the new equipment and carried out an in-depth analysis for the spectral characteristics for Grassland and Shrubland. The analysis results could be incorporated to the See5 DT so as to improve the classification accuracies. The availability of these high quality data should have enabled a more accurate multispectral classification. A discussion of these data products and the methodology of remote sensing analysis for the 2008 Update is reported in *Section 3*.

2.4 METHODOLOGY OF DESKTOP TRUTHING AND POST CLASSIFICATION

The objective of the desktop truthing was to assess the quality of the preliminary habitat map. The process was performed on the preliminary habitat map (24 habitat classes) and involved mainly orthophotos supplemented by ancillary data to enhance the accuracy of the classification.

In the 2000 Survey, the preliminary habitat map was examined with the aerial photographs taken in January 1997 at an elevation of 20,000 feet with a camera lens of focal length 6 inches (0.5 feet), which translated to a scale of 1:40,000

(20,000 / 0.5) in the captured images. The accuracy of the mapping for each habitat type was assessed with regard to both the habitat type (i.e. is the area actually Grassland or Shrubby Grassland?) and the habitat boundary (i.e. is the boundary between adjoining grassland and shrubby habitats drawn correctly?). Based on these considerations, confidence levels of high, medium or low were assigned to each habitat category. Mixed Shrubland, *Baeckea* Shrubland, Lowland Forest and Freshwater Brackish Wetland were rated as having a low confidence value while Bare Rock or Soil, Plantation or Plantation / Mixed Forest, Fishpond / Gei Wai were rated as having a high confidence value.

In the 2005 Study, high spatial resolution (50cm) ortho-rectified aerial photographs of 2001-2004 provided by Lands Department were employed to conduct the desktop truthing. Photo interpretation of habitat class using fuzzy logic was first conducted. 480 Samples from the habitat map were drawn and overlaid on the high resolution photos to assess their accuracy of the 24 classes (20 samples per habitat class). The overall accuracy of the habitat classification was 81%. Montane Forest, Wetlands, Mixed Shrublands reached an accuracy of 80% to 90%. Bare Rock, Rocky Shore and Sandy Shore had a commission error of 40% to less than 60%, while Bare Rock, Grassland and Lowland Forest had an omission error of less than 60%.

In the 2007 Study, a moderate accuracy (83%) was achieved for the preliminary map when compared manually with a wide range of datasets such as DOP5000, Lands' series of topographic data: 1:1000, 1:5000, 1:10000, 1:20000, Landsat 7 ETM+ Landscape Value Map published by Planning Department, HKSAR, 2005 and ERM's GIS data collected from various EIA projects. A comparison matrix was generated to show the accuracy rate. Fung Shui Forest, Montane Forest and Golf Course almost attained 100% user accuracy. Mudflat, Mangrove, Plantation, Seagrass also had higher user accuracy (>90%). Shrubby Grassland, Grassland and Mixed Shrubland only achieved moderate accuracy (>65% in average). Areas of low accuracy in Previous Studies were outlined for further revision using field truthing survey findings.

2.5 METHODOLOGY OF FIELD TRUTHING SURVEYS

All of the Previous Studies included habitat verification, supplemental verification and ecological value assessment. Additional tasks including estimation of mapping accuracy based on previous field survey results and area coverage of habitats were included in the 2003, 2005 and 2007 Studies.

2.5.1 *Strategy on Allocating Field Truthing Sites*

The 2003 Study involved 200 field truthing survey days and a total of 1,015 sites were visited. The survey effort was mainly allocated to habitat classes with a higher conservation value. Based on the resulting survey effort allocation, a total of 151 field survey days were assigned to seven habitat categories that were of high indicative ecological value (Fung Shui Forest,

Lowland Forest, Mixed Shrubland, Freshwater/Brackish Wetland, Natural Watercourse, Mangrove and Intertidal Mudflat). A total of 49 days were given to four medium indicative ecological value habitats (Shrubby Grassland including *Baeckea* Shrubland, Sandy Shore, Rocky Shore, Cultivation). Habitat mapping of Fishpond/Gei Wai was updated through desktop mapping verification using the latest available aerial photographs

Both the 2005 and 2007 Studies involved the use of remote sensing analysis to create the preliminary habitat map. The desktop truthing which employed many ancillary data for verification helped to boost the accuracy of the classification generated by remote sensing analysis. The desktop truthing, on the other hand, had also outlined habitat types that required immediate attention due to their low accuracy in classification.

In the 2005 Study, site-allocation strategies took into account these site allocation logics:

1) the verification of habitat areas with classification uncertainties;

2) areas with high and medium ecological value; and

3) availability of existing information on the habitat.

Out of the total 370 sites visited, 123 sites were selected because of discrepancies with orthophotos based on the desktop truthing exercise. The remaining 247 sites were selected through stratified random sampling on the 2004 preliminary habitat map. 12 habitat classes with high or medium ecological value including Lowland Forests, Mixed Shrubland, Freshwater/Brackish Wetland, Nature Watercourse, Fung Shui Forest, Mangrove, Intertidal Mudflat, Cultivation, Shrubby Grassland, Plantation or Plantation / Mixed Forest, Sandy Shore, Rocky Shore were the focus for the field truthing surveys. Data on Montane Forest was derived from image analysis. Two habitat categories including Fishpond and Seagrass were excluded due to, as advised by the Government representatives, the limited area of these classes and/or that the relevant information is readily available and the data were provided by Agriculture, Fisheries and Conservation Department (AFCD).

In the 2007 Study, a total of 370 sites were also selected. Of these, 100 sites were selected for uncertain areas based on the result of remote sensing analysis and desktop truthing. In addition to the factors considered in the 2005 Study for site allocation (as mentioned above), the 2007 study used other strategies as well to allocate the survey sites. The remaining 270 of 370 survey sites were selected with the following considerations:

- General verification – attempted to confirm the accuracy of the habitat classification defined by desktop truthing. 12 days of field survey effort were allocated under this category.

- Supplemental verification – assigned to habitats which had been mapped with a medium to low level of mapping confidence. 13 days of field survey effort were allocated under this category.

- Ecological value assessment – priorities were given to habitats of "high and medium ecological value" and high variability within a given habitat type and boundary. 4 days of field survey effort were allocated under this category.

- Low mapping accuracy based on previous field truthing survey results. 14 days of field survey effort were allocated under this category.

- Additional effort based on high coverage – for high ecological value habitats that also had a high coverage in Hong Kong (Lowland Forest and Mixed Shrubland had the highest coverage in the 2005 Study). 2 days of field survey effort were allocated under this category.

- Re-adjustment of field truthing survey effort – readjust the survey effort from habitat sites of high certainty to habitats of less certainty. 5 days of field survey effort from Sandy Shore and Rocky Shore were shifted to other habitats of less certainty.

The Field truthing exercise in the 2007 Study also reserved 230 backup sites to replace sites which were remote and not reasonably accessible by transport and hiking routes. Both the 2005 and 2007 Studies required the field truthing surveys to be completed for 50 days.

2.5.2 Field Truthing Surveys

The field truthing surveys for the Previous Studies, including verifying the habitat location, type and boundaries, were undertaken by qualified ecologists. All the Previous Studies used a GPS system and ArcPad (installed with a reasonably high resolution base map with adequate location indicators) for field data recording during the field truthing surveys.

In the 2005 Study, two sets of Differential GPS (product of Leica Inc. Geosystem500) were employed which could boost the position accuracy to within 10 meters, which is the pixel dimension of the SPOT 5 multispectral image. The following measures were also taken to ensure data quality:

- All surveyors and crew leaders were trained before the actual survey.

- Each survey team consisted of three surveyors – at least one with training in botany / vegetation, and one with training in ecology / geography. The team members would crosscheck the collected information with each other to ensure the accuracy.

- The survey team used GPS to check their current location. It helped to ensure that the correct survey site was located.

- All field data, including GPS raw data and the collected attributes, were

updated to the desktop computer for record. The hard-copy survey records were used for double-checking.

In the 2007 Study, ground truthing of the habitat was achieved by checking the habitat type, location and boundary against the preliminary habitat map using a hand held Window's CE PC with ArcPad linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the Lowland Forest in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat. The following measures were also taken to ensure data quality:

- A one day pre-trip was conducted before the field truthing trips, to allow team members to become familiarised with the field equipment and the survey methodology.

- During the field truthing surveys, the accuracy of habitat identifications and delineation of their land cover boundaries was checked by the land survey specialist and assisted by the use of GPS.

- A 'light' version of GIS software (known as ESRI's ArcPAD) was installed onto a hand held Windows CE. A digital proforma was created as an easy-to-use interface to allow the surveyors to collect ecological data systematically and consistently into the Arcpad. This also ensured validation of the data at point of collection, elimination of double entry and the use of GPS units, which greatly assisted surveyors in locating their position in the field.

- The number of available satellites and the Geometric Dilution of Precision (GDOP) to show the configuration of available GPSs were recorded for each site to locate the selected survey site.

This field truthing survey methodology was adopted in the 2003, 2005 and 2007 Studies and obtained useful datasets for the assessment. A detailed methodology of field truthing for the 2008 Update is reported in *Section 3*.

2.6 *PRESENTATION OF FINDINGS OF SURVEY RESULTS*

The major findings on habitat mapping accuracy and ecological value ranking of individual habitat types of the 2003, 2005 and 2007 Studies are discussed in subsequent sections. Information gaps are also mentioned in each discussed habitat type. As the 2005 Study was surveyed as a spot site, instead of polygon area, it is not recommended to compare the 2005 Study information directly with the 2003 and 2007 Studies. Instead it should be used as reference only. Discussion of the information gaps from the 2005 Study cannot be provided here because it was not discussed in their Final report. The total area surveyed for each habitat category in the 2003, 2005 and 2007 Study is shown in *Table 2.2*.

Table 2.2 ***Total Areas Surveyed for Each Habitat Category Selected for Field Surveys in the 2003, 2005 and 2007 Study***

Habitat Type	2003	2005	2007
	Total Area Surveyed (ha) (% Area Surveyed)	No. of Sites Surveyed*	Total Area Surveyed (ha) (% Area Surveyed)
Indicative Ecological Value – High			
Lowland Forest	1,113.0 (6.1)	98	1,142.5 (8.8)
Mixed Shrubland	867.1 (5.3)	47	6,373.5 (22.8)
Freshwater/Brackish Wetland	229.8 (19.6)	45	26.2 (2.9)
Natural Watercourse	34.1 (4.2)	34	11.5 (1.2)
Intertidal Mudflat	43.0 (2.6)	8	135.8 (9.2)
Indicative Ecological Value – Medium			
Plantation or Plantation Mixed Forest^ ##	--	19	109.5 (12.8)
Shrubby Grassland	319.8 (2.2)	60	750.4 (3.4)
Sandy Shore	14.7 (9.8)#	7	47.5 (19.2)
Rocky Shore	33.8 (4.7)#	7	21.2 (21.2)
Cultivation	219.2 (5.1)	27	75.8 (1.1)
Fung Shui Forest##	93.5 (N/A**)	9	--
Mangrove##	103.5 (36.8)	9	--

Notes:

^ Information of both plantation services inside country parks and plantation managed by Agriculture, Fisheries and Conservation Department (AFCD) outside country parks were given by AFCD as reference material. The Plantation data contained 179 plantation patches constituting approximately 532.3 hectares within the HKSAR and was used as reference in all the Previous Studies.

* As the 2005 Study was surveyed as a spot site, instead of polygon area, it is not recommended to compare the 2005 Study information directly with the 2003 and 2007 Studies. Instead it should be used as reference only.

** The majority of Fung Shui Forest in 2003 was initially represented as dot locations on the habitat map and therefore was not applicable for spatial calculation.

The habitat of Sandy Shore and Rocky Shore in 2003 was mapped as a linear component, the total "area" surveyed for the habitat is represented by the length (km) of the habitat.

Digital data on the locations and boundaries of these habitats were provided courtesy of the Agriculture, Fisheries and Conservation Department (AFCD).

2.6.1 Mapping Accuracy of Habitat in Previous Studies

The mapping accuracy compared between the 2003, 2005 and 2007 Studies is shown in *Table 2.3*.

Table 2.3 *Mapping Accuracy of each Surveyed Habitat Category for the Previous Studies*

Habitat Category	2003 Mapping Accuracy of the Surveyed Area (%)	2005 Mapping Accuracy of the Surveyed Area* (%)	2007 Mapping Accuracy of the Surveyed Area (%)
Lowland Forest	79.2	70	98.6
Mixed Shrubland	83.5	67	99.0
Freshwater/Brackish Wetland	57.0	64	66.6
Natural Watercourse	64.4	24	96.0
Intertidal Mudflat	86.3	100	85.3
Plantation or Plantation Mixed Forest#	--	57	100
Shrubby Grassland	34.9	67	56.2
Sandy Shore	92.1	29	100
Rocky Shore	95.9	71	73.7
Cultivation	57.3	78	
Fung Shui Forest#	--	9	--
Mangrove#	49.7	89	--

Notes:

* As the 2005 Study was surveyed as a spot site, instead of polygon area, it is not recommended to compare the 2005 Study directly with the 2003 and 2007 Studies. Instead it should be used as reference only.

\# Information of plantation services inside country parks, Plantation managed by AFCD outside country parks, Fung Shui forest and Mangroves were provided courtesy of the Agriculture, Fisheries and Conservation Department (AFCD).

2.6.2 *The Areal Change of Habitat Categories in Previous Studies*

The series of habitat mapping studies that have been conducted to date have spanned a number of years (from 2000 to 2007). Over this time, some changes in the areal extent of different habitats are evident.

As shown in *Table 2.4*, over time, there has been a general trend of increase in total habitat areas for Mixed Shrubland, Cultivation, Shrubby Grassland, Plantation and Bare Rock & Soil. For instance, Mixed Shrubland, Shrubby Grassland and Plantation/Plantation with Mixed Forest have increased by over 30% when comparing results from the 2007 and 2000 Studies. The significant increases in Mixed Shrubland (69.57%) and Shrubby Grassland (51.95%) were interpreted as likely due to the succession from Grassland habitats. On the other hand, the size of Cultivation habitat area fluctuated between Previous Study years. This was probably related to mis-classifications of this habitat, which has similar spectral qualities to Shrubby Grassland.

Some of the habitats experienced a general reduction in their total area based on a comparison of Studies between 2000 and 2007. Such habitats were Grassland, Lowland Forest, Golf Course/Urban Pak, Montane Forest, Intertidal Mudflat and Fishpond/Gei Wai. Of these, Fishpond/Gei Wai experienced the greatest reduction (-68.32% between the 2000 and 2007 Studies). Reduction in the areal extent of Grassland was associated with

conversion of such habitat into developed land, natural succession to Mixed Shrubland or tree planting following hill fire events.

In the 2007 Study, the areal extent of Lowland Forest was recorded to be 30.75% less than that of the 2000 Survey. Factors contributing to the reduction in the size of Lowland Forest cover could be related to reclassification of Lowland Forest into Plantation/Plantation with Mixed Forest or losses due to the occurrence of hill fire over this period.

Along the coastline, the areal extent of coastal habitats (Rocky Shore, Sandy Shore, Artificial/Hard Shore, Intertidal Mudflat, Brackish Wetland, Seagrass Bed, Mangrove and Intertidal Mudflat) exhibited variation in size based on the findings of Previous Studies. These variations were likely related to differences in the height of the tides on images used for the remote sensing analysis.

Table 2.4 Habitat Area Mapped for the Previous Study

Type	2000 Study (ha)	% of total area (2000)	2003 Study (ha)	% of total area (2003)	2005 Study (ha)	% of total area (2005)	2007 Study (ha)	% of total area (2007)
Grassland	26,081.30	22.15	25,752.80	22.82	21,572.70	19.38	15,439.90	13.81
Other	18,819.90	15.99	18,910.00	16.76	12,656.30	11.37	13,936.50	12.47
Lowland Forest	18,225.40	15.48	17,904.40	15.87	18,318.30	16.46	12,621.70	11.29
Mixed Shrubland	16,477.70*	14.00	16,607.10	14.72	15,196.50	13.65	27,941.40	25.00
Shrubby Grassland	14,679.70	12.47	14,332.10	12.70	24,674.80	22.17	22,305.30	19.95
Cultivation	5,976.90	5.08	4,450.60	3.94	3,838.30	3.45	6,300.70	5.64
Modified Watercourse	4,381.00	3.72	2,835.10	2.51	2,384.10	2.14	2,819.90	2.52
Fishpond/Gei Wai	2,827.00	2.40	1,754.60	1.55	1,031.70	0.93	895.50	0.80
Intertidal Mudflat	1,835.70	1.56	1,520.60	1.35	656.10	0.59	745.70	0.67
Bare Rock or Soil	1,563.90	1.33	1,431.50	1.27	5,101.80	4.58	2,029.80	1.82
Freshwater/Brackish Wetland	1,440.00	1.22	930.40	0.82	130.10	0.12	897.40	0.80
Rural Industrial Storage/Containers	1,030.50	0.88	1,006.90	0.89	1,379.20	1.24	1,043.70	0.93
Golf Course/Urban Park	1,007.70	0.86	1,006.70	0.89	1,398.30	1.26	1,158.20	1.04
Natural Watercourse	1,006.70	0.86	751.50	0.67	803.90	0.72	860.60	0.77
Landfill	783.40	0.67	397.70	0.35	404.30	0.36	303.10	0.27
Mangrove	397.70	0.34	383.40	0.34	343.10	0.31	456.80	0.41
Quarry	326.50	0.28	217.40	0.19	168.60	0.15	245.60	0.22
Plantation or Plantation/Mixed Forest	228.90	0.19	980.50	0.87	417.00	0.37	926.00	0.83
Fung Shui Forest	206.40	0.18	210.70	0.19	106.30	0.10	211.20	0.19
Montane Forest	180.00	0.15	59.60	0.05	123.40	0.11	109.50	0.10
Seagrass Bed	111.70	0.09	43.00	0.04	5.40	0.00	6.60	0.01
Rocky Shore**		0.00	708.80	0.63	94.20	0.08	90.60	0.08
Artificial Rocky/Hard Shoreline**		0.00	273.00	0.24	315.40	0.28	230.90	0.21
Sandy Shore (spatial)	145.00	0.12	368.00	0.33	179.60	0.16	211.00	0.19

Notes:

* The value involved both the mapped area of Shrubby Grassland and *Baeckea* Shrubland. In the 2000 Study, they were separated categories. However, in the 2003 Study, these two habitat types were combined to form the Shrubby Grassland.

** Rocky Shore, Artificial Rocky/Hard Shoreline and the majority of Sandy Shore habitats in the 2000 Study are represented as a linear component on the habitat map. Spatial calculation for these habitats was not applicable.

The areal extent of habitat types by ecological value is presented in *Table 2.5*. In the 2007 Study, the areal extent of "High" ecological value habitats was greater than that in the Previous Studies. This increase was likely mainly a result of increased cover of Mixed Shrubland habitat, which is a high ecological value habitat. The area of "Low" and "Negligible" ecological value habitats generally became less during the course of the habitat mapping studies. This was likely due to tree planting at the sites where hill fires occurred, to form medium value Plantation habitat as well as natural succession which converted areas of low ecological value Grassland into medium ecological value Shrubby Grassland. As a result of these changes to medium ecological value, between the time of the 2000 Study and the 2007 Study, the areal extent of "Medium" ecological value habitat area was also observed to increase.

Table 2.5 ***Total Area of Habitats Assigned Ecological Value of High, Medium, Low and Negligible reported in Previous Studies***

Ecological Value	2000 Study	2003 Study	2005 Study	2007 Study
High	40,095	39,813.5	35,683	43,849
Medium	19,926	20,417.9	30,236	30,707
Low	31,466	31,194.5	30,941	21,949
Negligible	20,224	20,271.6	14,440	15,283

The presentation of findings adopted in the Previous Studies was considered appropriate and therefore no modification was deemed necessary.

3.1 TASK 1 - DESCRIPTION OF META DATA

By following the method proposed in the Inception Report (IR) and the understanding of the current available satellite data, one SPOT 5 High-resolution Visible infrared (HRVIR) imagery, acquired on 21 November 2008 (Level 1A), was purchased from an official SPOT data distributor and used for land cover and habitat mapping (*Figure 3.1*). The SPOT 5 HRVIR is a linear array push-broom system, with 60 km swath and Equatorial crossing time around 10:30 a.m. The spatial resolution of the SPOT 5 HRVIR Panchromatic Band (0.48-0.7um) is 5-m. For HRVIR Multi-spectral data, three bands are invisible and near infrared (NIR) (0.50-0.59 um, 0.61-0.68 um, 0.79-0.89 um) with 10-m spatial resolution, and one is a short-wavelength infrared (SWIR) band (1.58 – 1.75 um) with 20-m resolution. With improved spatial resolution, the SPOT 5 data are an ideal medium resolution source for land cover and vegetation mapping at approximately 1:20,000 that is required by the SDD for the cartographic scale of the final deliverables.

The format of the data is in Digital Image Map (DIMAP), which includes a GeoTIFF image file and XML metadata file. For Level 1A data, detector normalization was performed in each spectral band for radiometric corrections. The Level 1A data were the least processed form of data with no geometric corrections applied. The scene was oriented along the satellite's orbital path, not in a map projection (*Table 3.1*).

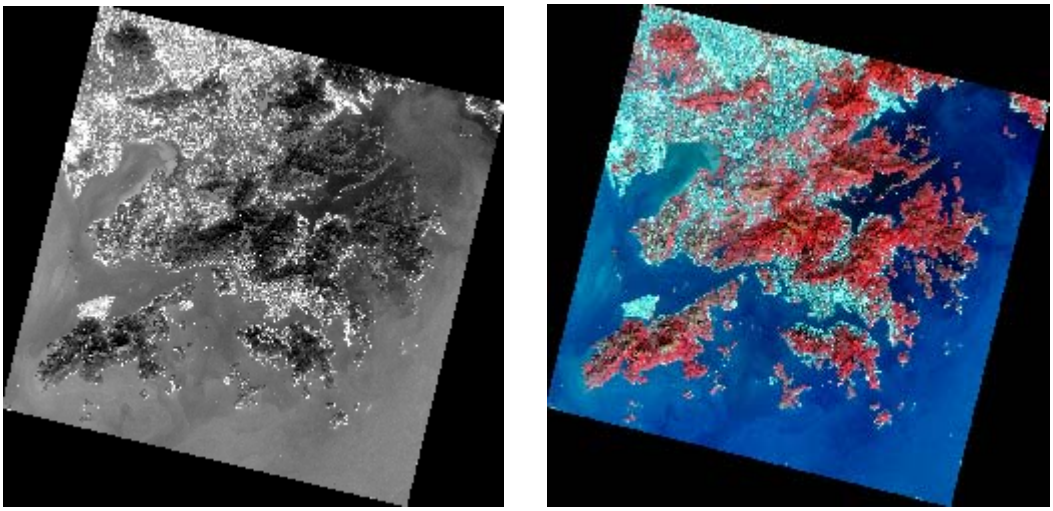
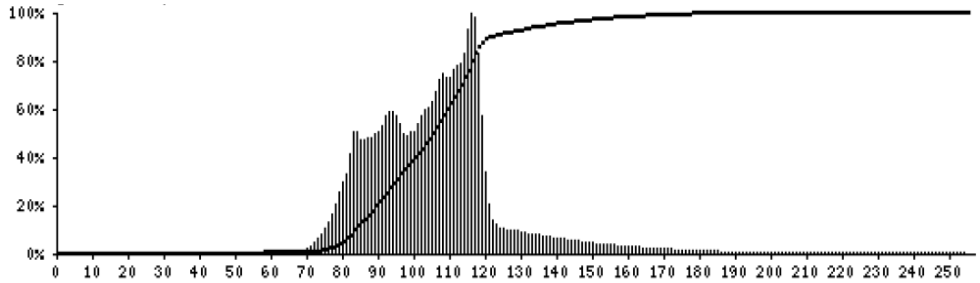


Figure 3.1 SPOT 5 Panchromatic and Multispectral bands imagery of Hong Kong and adjacent areas acquired on 21 November 2008

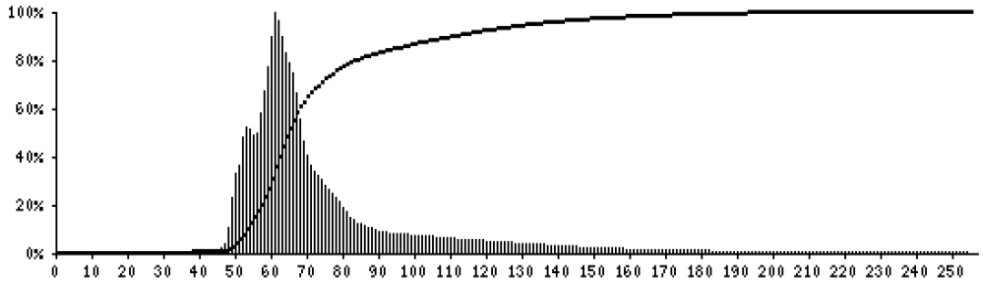
Table 3.1 ***Acquisition Dates of SPOT 5 Panchromatic and Multispectral Images used for Land Cover Classification of Hong Kong***

Date	Scene_ID
21/11/2008	5 286-305/2 08/11/21 02:52:00 1 J

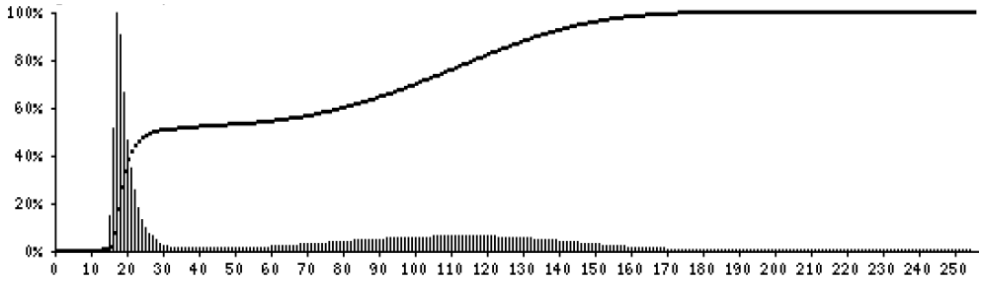
Histograms of each spectral band image were examined to ascertain whether the shapes were relative to scene contents, as well as to uncover any continuous or noticeable dropouts. The following are the histograms of multispectral and panchromatic bands (*Figure 3.2* and *Figure 3.3*). From the histograms, most of the pixel values were normally distributed which suggests the quality of images were fit for use in the Present Study:



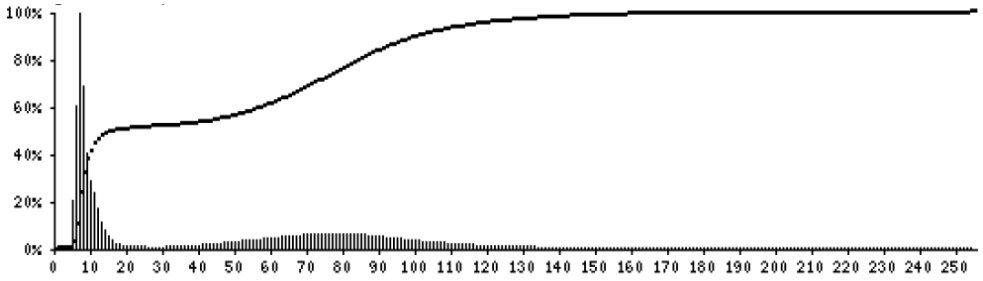
Histogram of NIR band



Histogram of Red band



Histogram of Green band



Histogram of SWIR band

Figure 3.2 ***Histograms of NIR, Red, Green and SWIR Bands***

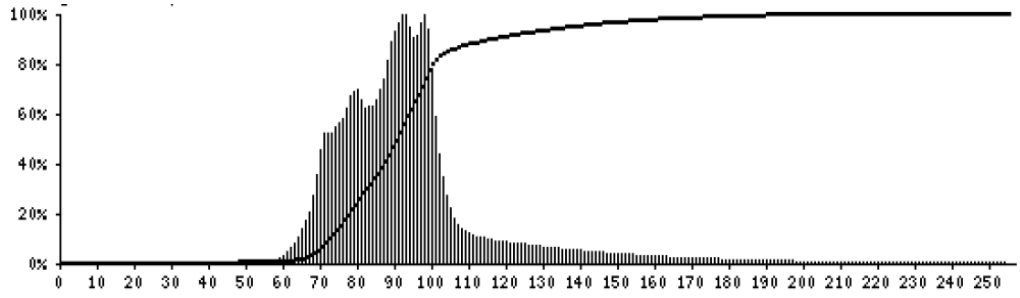


Figure 3.3 Histogram of Panchromatic Band

3.2 TASK 2 – PRE-PROCESSING OF THE DATA

3.2.1 Geometric correction

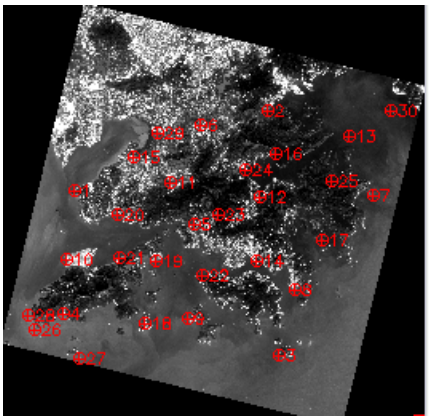
Georeference and ortho-rectification corrections were applied to the SPOT 5 imagery using ENVI and PCI Software. The geometric correction was conducted separately for Panchromatic and for Multispectral bands as recommended by the SPOT 5 data distributor. For each correction, at least 25 Ground Control Points (GCP) were selected throughout the SPOT 5 image. The GCP points were manually chosen from the 0.5m resolution DOP5000 aerial photographs and the corresponding points from the SPOT 5 Panchromatic (or Multispectral) image. The images were geometrically-corrected using "Rational Model" (as an advanced model of second order polynomial) for geometric corrections and used "Bilinear resampling" for data re-sampling. The Root Mean Square (RMS) error of the georeference results for the panchromatic band was less than +/-5-m, and was less than +/-15-m for the Multi-spectral bands. The detailed map projection information for processed SPOT 5 images of Hong Kong is listed in *Table 3.2* and the RMS errors of geometric correction is listed in *Table 3.3*.

Table 3.2 Projection Information for SPOT 5 Images of Hong Kong

Projection Information:
Projected Coordinate System: Transverse Mercator Projection: Transverse_Mercator False_Easting: 836694.05000000 False_Northing: 819069.80000000 Central_Meridian: 114.17855560 Scale_Factor: 1.00000000 Latitude_Of_Origin: 22.31213333 Datum: D_WGS_1984
Image File Size
Number of Lines (rows): 14594 (pan), 7286 (multispectral) Number of Samples(columns): 14607(pan), 7302(multispectral) Pixel size: 5 meter (Pan) 10 meters (multispectral)

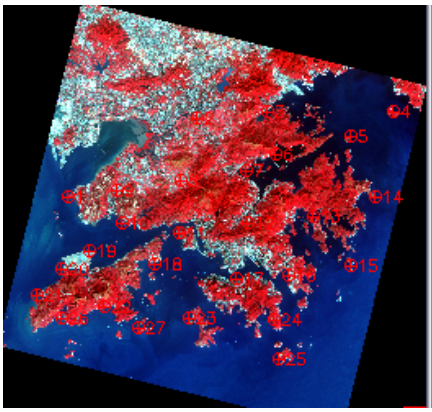
Table 3.3 ***RMS Errors of GCPs Points***

Image	Number of GCPs	X RMS	Y RMS	Overall RMS
Panchromatic Image	30	2.5m	3.0m	4.01m
Multispectral Image	27	2.7m	4.8m	5.7m



	Map X	Map Y	Image X	Image Y	Predict X	Predi
#1+	808432.27	830312.57	2537.00	6458.00	2536.5070	6458.
#2+	841491.11	844633.66	9205.91	3717.27	9205.3134	3717.
#3+	844109.73	802761.38	9573.18	12105.36	9572.4594	1210
#4+	807129.12	809067.72	2196.45	10703.73	2195.9831	1070
#5+	829110.18	824889.55	6654.36	7621.55	6653.8758	7621.
#6+	829962.13	841985.00	6889.00	4203.25	6888.4434	4203.
#7+	859858.85	830445.25	12827.50	6625.75	12827.590	6625.
#8+	846695.95	813954.37	10132.00	9876.00	10131.902	9875.
#9+	828418.83	808904.48	6456.56	10819.00	6455.6017	1081
#10+	807394.66	818492.35	2284.67	8821.67	2284.5025	8820.
#11+	825081.37	831945.45	5874.67	6193.83	5874.1568	6194.
#12+	840436.41	829856.24	8938.88	6670.50	8938.9051	6670.
#13+	855385.25	840420.13	11970.00	4612.00	11969.746	4612.

F: GCP selection of Panchromatic Image



	Base X	Base Y	Warp X	Warp Y	Predict X	Predi
#1+	2550.75	6813.00	1216.50	3307.00	1217.3004	3307.
#2+	6884.25	4102.25	3410.50	1992.00	3410.6391	1991.
#3+	9267.00	3817.25	4605.75	1871.50	4605.3509	1871.
#4+	13502.50	3731.25	6725.00	1868.00	6725.0913	1867.
#5+	12094.75	4618.50	6012.75	2298.50	6012.4960	2298.
#6+	9544.25	5284.50	4731.00	2608.25	4730.2919	2607.
#7+	8554.25	5824.25	4230.25	2868.75	4229.9575	2868.
#8+	6355.00	6203.00	3126.00	3038.25	3126.1788	3037.
#9+	4185.50	6580.50	2037.75	3205.75	2037.2986	3206.
#10+	4382.25	7669.25	2125.50	3753.25	2125.5287	3752.
#11+	6311.25	8008.00	3086.75	3940.25	3087.3758	3940.
#12+	8663.50	7611.75	4268.50	3763.25	4267.8510	3763.
#13+	10894.75	7374.25	5386.25	3665.50	5386.3082	3665.

F: GCP selection of Multispectral Image

Figure 3.4 ***Ground Control Points (GCP) were selected throughout the SPOT 5 image (Please refer to Table C1 of* Annex C *for the list of GCPs)***

3.2.2 Ortho-rectification

For the image ortho-rectification process, the latest version of 1:5,000 Digital Elevation Model (DEM) provided by the Hong Kong Government was used. Based on the metadata compiled by the Civil Engineering and Development Department, the accuracy of the DEM data were:

1) for horizontal accuracy: the linear features were generalized with no more than 10 percent of the points tested having error by more than 0.8mm, which corresponded to 8 m of actual ground distance at a 1:10,000 scale (0.8 mm x 10,000 =8,000 mm = 8 m). In other words, 90% or more points tested should have had a horizontal accuracy within 8 m of the ground distance; and

2) for vertical (height) accuracy, no more than 10 percent of the points tested should have been in error of more than one-half of the contour interval.

For the 1:5,000 DEM, a 2-meter grid cell DEM data were provided in ARC/INFO GRID format. The grid was then re-sampled into 5 meters in order to match the spatial resolution of the SPOT 5 image. The DEM data were inputted into the PCI image processing software (Ortho-Engine module) for image ortho-rectification. The accuracy of the 1:5,000 DEM was compatible with that of the SPOT Panchromatic data (5-m). Hence, using these data ensured the quality of the ortho-rectification.

3.3 TASK 3 – CREATING A COMPOSITE MAP

In order to obtain an optimum level of detail for the classification process, a composition of multispectral SPOT 5 images and SPOT 5 panchromatic images was produced as the inputs to image classifications. The multispectral images (10-m) were resampled with panchromatic images (5-m) to create a composite map at 5-m resolution. The "bilinear re-sampling" method had been used for the data re-sampling, comparing with other data re-sampling methods provided by PCI Software (nearest neighbour & cubic re-sampling method). The bilinear re-sampling method examines the values from 16 nearest neighbours and provides the best balance of data re-sampling quality and computation duration. It should be remembered that in the 2007 Study this process was performed after the multispectral classification (1). In the Present Study, this process was carried out prior to the multispectral classification. This is because the resampling process preserves the spectral properties of five individual bands including red, green, NIR, SWIR and panchromatic bands. These five bands still remain separable from each other after resampling (they will not be inter-mixed to alter their inherent electromagnetic spectrum) and spectral characteristics can be masked out from them to define a unique signature for each habitat class. Moreover, the composite map of higher resolution allows better visualization and interpretation. In selecting the training samples in multispectral classification, the analyst could now employ a wide range of visual cues such as texture, pattern, size, shape and spatial arrangement to identify reliable and representative samples. For instance, Cultivation is usually regarded as difficult to be determined by multispectral classification due to its spectral resemblance with other vegetation cover such as Shrubby Grassland. However, the cultivation field's regular shape, homogenous nature and low- or flat-land based position can easily lend to its identification and interpretation on the satellite image. The classification is now not solely dependent on spectral qualities but also on its visual and spatial properties.

(1) In the 2007 Study, the composite map which we named here was called the fusion map. We changed the name because "fusion" is a confusing word implying that the spectral properties of the band were merged together to alter their inherent electromagnetic spectrum. In fact, as explained in the note, all the bands (red, green, NIR, SWIR and panchromatic band) will remain separate and unchanged in the composite map after resampling. The classification can still perform on these individual bands to extract their spectral characteristics to define representative habitat classes. The name "composite map" is more appropriate, because it denotes that it just combines (or superimposes) the maps with one another without them being intermixed (or blended or merged).

PCI Geomatics's resampling algorithm was used to resample the high resolution panchromatic and lower-resolution multispectral imagery to create a high resolution colour image (Please refer to *Annex C* for the parameter settings of resampling program in PCI). The high-resolution colour image preserves the original colour fidelity and allows for better visualization and interpretation.

Figure 3.5 and *Figure 3.6* show the example of images before image- and after image-resampling respectively (The red rectangle represents the common area in the images).

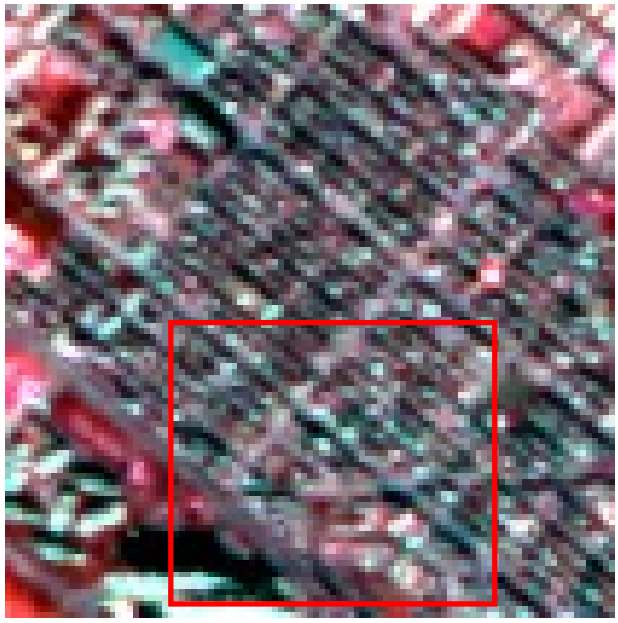


Figure 3.5 Example of Image Before Image Re-sampling

Figure 3.6 Example of Image After Image Re-sampling

3.4 TASK 4 - MULTISPECTRAL CLASSIFICATION

3.4.1 Classification algorithm

The nine general land cover classifications were achieved by the use of a Decision Tree (DT). The Decision Tree (DT) is a supervised classification method (similar to Maximum Likelihood Classification, MLC) which requires

extensive spatially and categorically well-balanced training data. DT is a machine learning algorithm; based on the training data, DT conducts a binary recursive partitioning and generates a set of IF-THEN rules to assign a class to an individual pixel. An example of the IF-THEN as follows:

```
If Band 3<= 56
    If Band 2 <=11
        If Band 1 <=109
            Then Class 6
If Band 1 >=110
    Then Class 4
```

As a non-parametric classifier, DT can handle a mixture of nominal, ordinal and quantitative data. Unlike MLC, DT does not require the considerations of the statistical distribution of training data. The Project Team employed See5/C5 (a classification software based on DT) in the Present Study (http://www.rulequest.com/see5-win.html#CLASSIFIERS).

See5/C5 can simplify the complex tree structure by replacing one or more subtrees by their leaves using an error-based pruning method at a given confidence level. Moreover, to reduce data redundancy, See5/C5 can also determine a subset of pre-selected classes from an abundance of attributes in constructing the decision tree (or rule sets). Another advanced feature of See5/C5 is its ability to estimate the predictive accuracy by N-fold cross-validations. In this feature, the training data are divided into N blocks with almost equal size and uniform class distribution. For each block, a classifier is built from the remaining blocks and tested using the hold-out blocks. The average error rate over the N classifiers would be the final accuracy of the decision tree (http://www.rulequest.com/see5-win.html#XVAL).

Comparing with MLC, DT possesses the following unique characteristics theoretically:

1. DT is a non-parametric method and, therefore, it is independent from the distribution of class signature;

2. DT can handle both continuous and nominal data;

3. DT generates interpretable classification rules; and

4. Comparing with other classification methods (eg MLC, Parallelepiped, Minimum distance, Mahalanobis distance, etc.), DT requires less processing time and yields accurate results as other classifiers do.

The input data for DT are the SPOT 5 image spectral bands and the Normalized Difference Vegetation Index (NDVI). The specific DT program employed is called See5, which implements a gain ratio criterion in classification tree development and pruning. The See5 also provides several advanced features that can aid and improve land cover classification, including boosting and cross-validation. Boosting is a technique for improving classification accuracy, while cross-validation can provide a certain

level of estimation regarding the land cover classification quality. In addition, See5 can generate a confidence estimate for each classified pixel and record the associated classification logic in a text file that can be readily interpreted and incorporated into a metadata system.

Figure 3.7 illustrates the general workflow of the See5 in development of the land cover classification. Firstly, training data and other related information, including the previous habitat map and GIS data, are used as the inputs to the classification. The classification model which establishes the relationships between training data and the individual class is developed. The model is used to classify the original satellite image and produces the preliminary classification. Some misclassified pixels may be found in the preliminary product (i.e. the classified pixel cannot be spectrally represented by the training data set). If so, more training data were added and the entire map was re-classified again. When all the classified pixels were found to be spectrally represented by the training data, these pixels were recoded and edited and eventually the final classification map was produced.

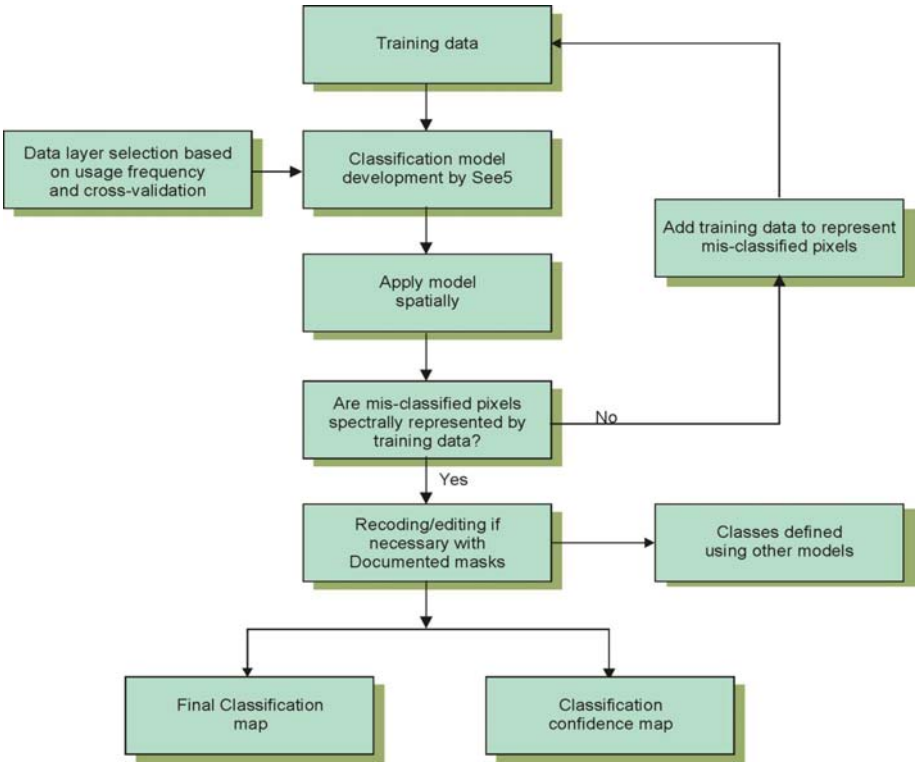


Figure 3.7 Overall Land Cover Classification Procedure

The following are the definitions of these broad classes:

- Grasslands (Pure grassland)
- Forest (Including Lowland and Montane Forest and other type of trees)
- Shrubby Grassland (Grassland with some shrubs)
- Mixed Shrubland (Tall and low shrublands)

- Natural and Artificial Wetlands (including Fishponds, Coastal Wetlands and other lands with water or saturated soils)
- Mangrove
- Bare Soil (Rocky areas, shore, badland and high albedo artificial materials)
- Water (Natural and man-made)
- Others (Urban, other highly modified area and low albedo artificial materials)

3.4.2 Training Site Selection

Training is the process of sorting sample pixels and defining criteria by which meaningfully spectral patterns in data are recognised. In supervised training, the prior (already known) information about the training data must be obtained in order to help the system determine the statistical criteria (signature) for data classification. This prior information of the data was substantiated through analysis of aerial photography, personal experience, previous field work and studies and reliable GIS data (either available from in-house or Government). In particular, Orthophoto and digital maps from the Lands Department provided the prior information.

The selection of training data usually involves two considerations:

- How much should be selected?
- How are they selected?

Studies conducted by various authors (1) were referenced regarding the first question. It was recommended that the total sample size for data training should be between 10*n* and 30*n*, where *n* is the number of spectral bands. Four SPOT 5 multispectral bands (green, red, near IR and shortwave) and 1 panchromatic band were used in the classification SPOT 5, so a sample size of between 50 (i.e. 10 x 5 SPOT 5 multispectral and panchromatic bands) and 150 (i.e. 30 x 5 SPOT 5 multispectral and panchromatic bands) training sites per class was required. The actual sample size for each class depended on the presence of suitable training sites in the imagery and their spectral homogeneity. A spatial resolution of 10-m was possible by using 10-m multispectral. This meant that a total area of between 500 and 1500 m^2 per class was drawn for training the classification taken from nine land cover classes. Around 1,080 (120 samples x 9 classes) training samples were drawn from all classes to guarantee enough samples for the classification.

Regarding the second question on how to select the training sites, the following logic was used:

(1) Lillesand T.M. and R.W. Kiefer (1994). Remote Sensing and Image Interpretation (Third-Edition), John Wiley & Sons, Inc.

1. Select sites with spectral characteristics representing a unique signature for a habitat class enabling unknown data to be discernible from the rest of the data (1).

2. Select site(s) which is already identified with a habitat type. This identification is acquired through previous studies, analysis of aerial photography, professional (experienced ecologists) experience and reliable GIS data (either from ERM in-house or Government). ERM is aware of the time difference among the data sources and the latest satellite imagery acquired (no earlier than November 2008). This issue was resolved by cross-checking with all available reliable data sources to ensure the habitat types of the interested areas which are consistent over time were selected. Any training sites of inconsistency were not used.

3. For sites which indicate uncertainty (after comparison of different data sources), the latest orthophoto DOP 5000 was used for cross-referencing with those particular sites.

4. Still doubtful sites, were simply discarded and data with habitat traits which provided certainty were selected. Details on these training samples, in terms of their site coordinates, proposed habitat type, resources that have been used for cross-referencing the concerned samples and the requirement of the post-classification field truthing survey are shown in *Table A1* of *Annex A*.

Since the spectral properties of a pixel may not be entirely independent of neighbouring pixels due to spatial autocorrelation, over 1,000 training sites were randomly selected from different locations of the respective land cover classes. If the classification is accurate, the result of training is a set of signatures that defines a training sample or cluster.

Until this point in the Present Study, the assumption had been that the classes for which training sites were identified were spectrally separable. To ascertain whether this was true or not, a decision tree classification was performed and the percentage of correctly classified pixels within each training site was assessed. To be acceptable for classification, a level of 90% correctly classified training pixels in each class was set. Training sites not meeting these criteria were examined as described above.

Table 3.4 shows the allocation of training data over nine habitat classes.
Figure 3.8 shows the distribution of training areas over the images.
Figure 3.9 shows the result of the classification.

(1) Before proceeding with the classification of the imagery, the training sites were analysed to ensure that they were not composed of any outlying pixels, whose digital numbers were uncharacteristic of that class. This was achieved by calculating statistics for each training region and examining the maximum, minimum and standard deviations. If outlying pixels were identified, the boundaries were adjusted or the site was dropped from the training set.

Table 3.4 Land Cover Training Data for Hong Kong

Source	Land cover type	Quantity
Aerial Photos	Bare and modified land (All bare ground with different land use)	89
	Forest (Including low and high forest and other type of trees)	177
	Grasslands	139
	Mangrove	42
	Mixed Shrubland (Tall and low shrublands)	159
	Other	98
	Shrubby Grassland (Grassland with some shrubs)	256
	Water (Natural and man-made)	98
	Natural and artificial wetlands (Including fishpond, coastal wetlands and other lands with water or saturated soils	22
Total:		**1,080**

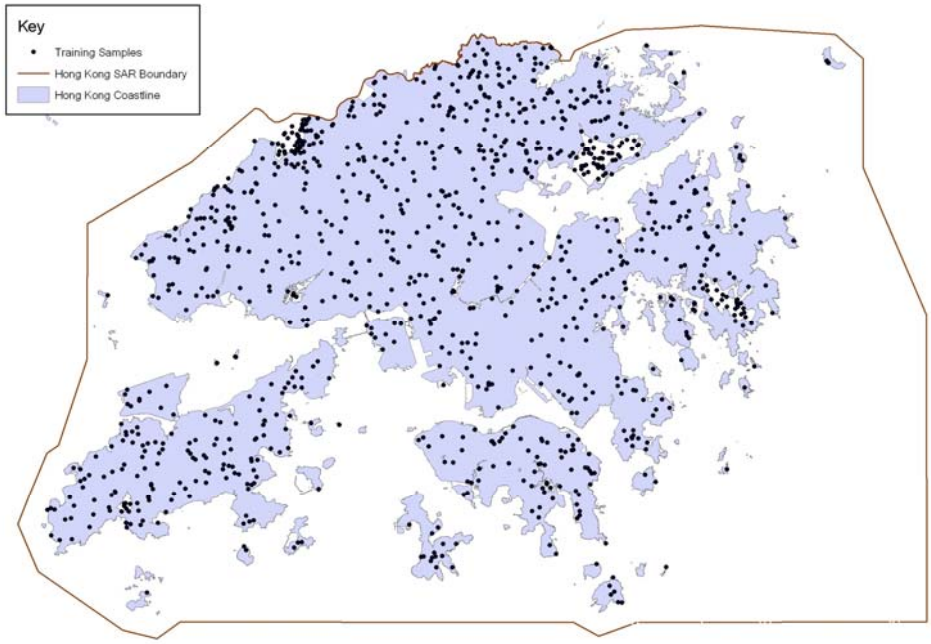


Figure 3.8 Distribution of Training Data for Land Cover Classification

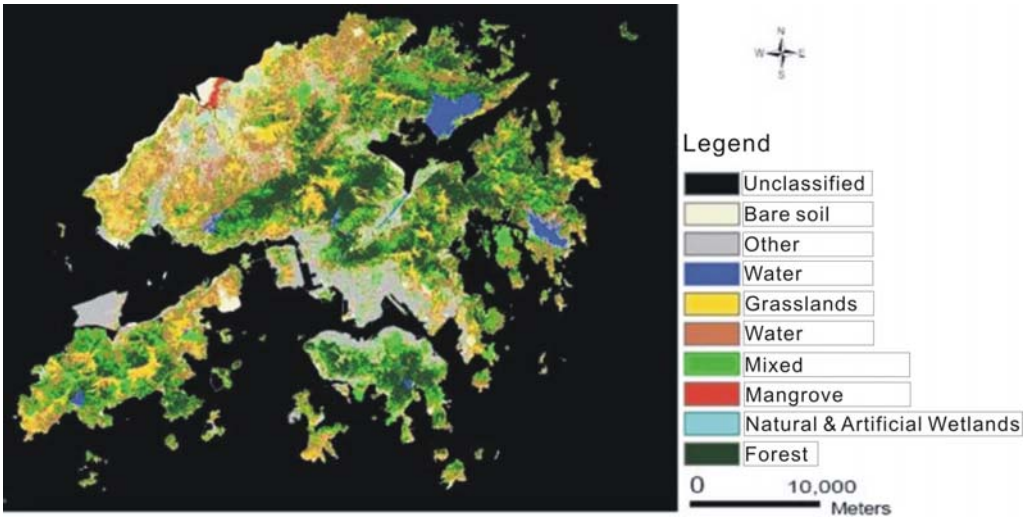


Figure 3.9 ***The Result of Multispectral Classification: the Land Covers Map***

3.4.3 Post Classification

In order to provide a 24 habitat class map, a post-classification technique was used in the Present Study. Post classification discrimination used decision rules to refine the classification by re-assigning classified pixels with reference to the existing information. Decision rules were applied in conjunction with known regions defining the extent of a habitat at that location. For example,

> IF pixels were classified as *Bare/Modified* AND falling within the boundary of a known *Quarry*
>
> THEN they were re-assigned as the *Quarry Habitat*

The habitat categories that were subject to post-classification discrimination and the source of the regions are detailed in *Table 2.1*. The procedures followed to discriminate the habitats are summarised below:

Step 1: Identify reliable data sources of recognised habitat types.

Known data representing 24 identified habitat types were obtained from reliable sources. This could have been obtained from existing GIS data (eg Fung Shui forest, Seagrass and Mangrove was provided by AFCD in the Previous Studies. Plantation [plantation service inside and outside country park] or Plantation/Mixed Forest was provided by AFCD in the Present Study). These data were also identified through cross-referencing with other sources, such as high resolution aerial photos, ground truth data or reliable maps.

Step 2: Rasterize all vector data into raster format.

Step 3: Superimpose these identified layers (known as *overlay*) onto the land cover map (known as *input*).

Step 4: Create decision rules to both layers using IF-THEN logic.

For example, IF the *input (pixel)* identified as Forest and the *overlay (pixel)* identified as Fung Shui, THEN the *output (pixel)* would be reclassified as Fung Shui. More examples of decision rules are shown in *Table 3.5*.

Step 5: Apply the decision rules to the data using ERDAS. About 61% of data were classified by this method.

Step 6: Rerun the Classification for unclassified data

The classification was re-operated for pixels which were still unable to be discriminated by automated decision rules. The signature was first obtained by defining a training sample representing a corresponding habitat, then rerunning the classification to sort unclassified pixels to a class that had a similar signature to the pixel. About 23% of data were classified by this method.

Step 7: For astray pixels that are still left to be determined, cross-reference with other resources or manual interpretation. Around 16% of data are classified by this method.

Table 3.5 Decision Rules used in Post-classification

Categories to be discriminated (Overlay pixel)**	**Input pixel***	**Operation by IF-THEN logic*****
Bare Rock or Soil	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'bare rock or soil'
Quarry	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'quarry'
Landfill	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'landfill'
Other (Urban or Other Highly Modified Area)	Others	IF input and overlay pixel value evaluates TRUE THEN output = 'other'
Fung Shui Forest	Forest	IF input and overlay pixel value evaluates TRUE THEN output = 'Fung Shui forest' ELSE NULL
Plantation/Mixed Forest	Forest	IF input and overlay pixel value evaluates TRUE THEN output = 'plantation/mixed forest ' ELSE NULL
Fishpond/Gei Wai	Water	IF input and overlay pixel value evaluates TRUE THEN output = 'fishpond/gei wai '
Natural Watercourse	Water	IF input and overlay pixel value evaluates TRUE THEN output = 'natural watercourse'
Modified Watercourse	Water	IF input and overlay pixel value evaluates TRUE THEN output = 'modified watercourse'
Rocky Shore	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'rocky shore'
Artificial Rocky/Hard Shoreline	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'artificial rocky/hard shoreline'
Intertidal Mudflat	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'intertidal mudflat'

Categories to be discriminated (Overlay pixel)**	Input pixel*	Operation by IF-THEN logic***
Sandy Shore	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'sandy shore'
Seagrass Bed	Soil	IF input and overlay pixel value evaluates TRUE THEN output = 'seagrass bed'
Golf Course/Urban Park	Shrubland	IF input and overlay pixel value evaluates TRUE THEN output = 'golf course/urban park'
Rural Industrial Storage/Container	Others	IF input and overlay pixel value evaluates TRUE THEN output = 'rural industrial storage/container'
Cultivation	Shrubby Grassland	IF input and overlay pixel value evaluates TRUE THEN output = 'cultivation'
Grassland	Grassland	IF input and overlay pixel value evaluates TRUE THEN output = 'grassland'
Shrubby Grassland	Shrubby grassland	IF input and overlay pixel value evaluates TRUE THEN output = 'shrubby grassland'
Mixed Shrubland	Shrubland	IF input and overlay pixel value evaluates TRUE THEN output = 'mixed shrubland'
Mangrove	Mangrove	IF input and overlay pixel value evaluates TRUE THEN output = 'mangrove ' ELSE NULL
Freshwater/Brackish Wetland	Wetland	IF input and overlay pixel value evaluates TRUE THEN output = 'freshwater/brackish wetland'
Montane Forest	Forest	IF input and overlay pixel value evaluates TRUE THEN output = 'Montane Forest' ELSE 'Lowland Forest'
Lowland Forest	Forest	IF input and overlay pixel value evaluates TRUE THEN output = 'Lowland Forest' ELSE 'Montane Forest'

Notes:

* Input pixel refers to the pixel with habitat value classified from SPOT 5 data

** Overlay pixel refers to the pixel with habitat value determined by other reference GIS data (data provided by AFCD, LIC and ERM's EIA data)

*** Output pixel refers to the resultant pixels

Post classification discrimination resulted in significant changes to the raw image classification. The nine land covers were reclassified into 24 finer habitat classes.

3.4.4 Conversion to Vector Polygons

Since most reference data are in vector format, vectorization was required for changing the raster map of 24 land covers to a vector map. The output from the classification was converted to an ArcInfo Grid and then to an ArcInfo Coverage.

The vectorized data were saved into ArcView shape file format. The attribute table contained the attributes of area, perimeter, and class name.

3.5 TASK 5 - ACCURACY ASSESSMENT OF MULTISPECTRAL CLASSIFICATION

3.5.1 Land Cover Classification Quality Assessment

A quality control (QC) on a land cover classification product is a necessary step. The QC provides a mechanism to systematically document the quality and limitation of the product, and to provide feedback on how to best refine the product. It should be noted that the QC process of the preliminary land cover product described hereafter should not be regarded as a formal accuracy assessment. A statistically based assessment of the habitat map was used for the Present Study through a separate desktop truthing task described in *Section 4.2*. Here only major procedures and components of the QC process implemented for general land cover classification are discussed.

Quality Control of Land Cover Classification (Qualitative Evaluation)

Once a set of classification rules were generated by See5 using training data, the rules are applied spatially to generate a land cover map for all classes of interest. The land cover prediction and the associated rules were reviewed and the corresponding classification map was visually assessed to understand the quality of the classification. This visual assessment checked land cover predictions against the SPOT 5 imagery and/or Digital Orthophoto DOP5000. This process helped to understand the spatial distribution of the classification errors and possible causes of the error. Refinements were then made accordingly, either by modifying training data or through screen editing, to improve the classification.

Quality Control of Land Cover Classification (Quantitative Assessment)

A quantitative assessment of the land cover map was made using a standard error matrix approach, based on classification results obtained from the See5 (*Table 3.6*). These estimates were based on training data used to develop the land cover classification. As is shown in the error matrix in *Table 3.6*, the overall accuracy of the classification was 82.71%. The user's accuracy ranged from 69.52% to 92.31%, while the producer's accuracy varied from 46.67% to 90.12%. Most classes showed a reasonable accuracy. The relatively weak classes were the Mangrove and Wetland classes where omission error was relatively high (i.e. less pixels classified as Mangrove or Wetlands than what it should have been). It should be mentioned that the results shown in *Table 3.6* only provide an initial estimate for the preliminary land cover classification, not for the final edited land cover map. The accuracy of the final land cover product is higher than that reflected in the error matrix because of substantial editing and refinements made on the preliminary land cover map through screen-editing.

Table 3.6 Error Matrix for Preliminary Land Cover Classification

Class	Bare Soil	Other	Water	Grassland	Shrubby Grassland	Mixed Shrubland	Mangrove	Wetland	Forest	Total	*User Acc. (%)*
Bare Soil	**194**	20	0	12	10	3	0	0	0	239	***81.17***
Other	23	**248**	0	5	2	3	2	0	0	283	***87.63***
Water	0	0	**47**	0	0	1	0	5	2	55	***85.45***
Grassland	28	20	3	**368**	0	0	1	2	7	429	***85.78***
Shrubby Grassland	0	11	2	64	**507**	0	3	1	11	599	***84.64***
Mixed Shrubland	0	1	3	7	89	**276**	1	0	20	397	***69.52***
Mangrove	0	0	0	0	0	0	**7**	0	2	9	***77.78***
Wetland	1	0	0	0	0	0	0	**12**	0	13	***92.31***
Forest	0	0	4	3	12	42	1	0	**383**	445	***86.07***
Total	246	300	59	459	620	325	15	20	425	**2469**	
Prod. Acc. (%)	***78.86***	***82.67***	***79.66***	***80.17***	***81.77***	***84.92***	***46.67***	***60.00***	***90.12***		***82.71***

4.1 TASK 6 – DESKTOP TRUTHING

4.1.1 Objective of Desktop Truthing

The purpose of desktop truthing is to assess the quality of the preliminary habitat map. The assessment focused on habitat type delineation. *Figure 4.1* shows a procedure to conduct desktop truthing.

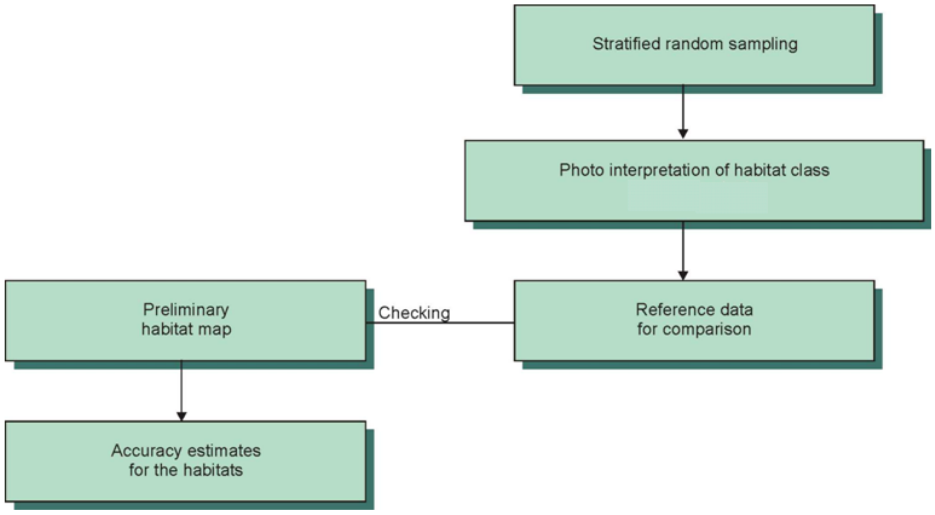


Figure 4.1 A Procedure to Conduct Desktop Truthing

4.1.2 Data used for Desktop Truthing

High spatial resolution (33 cm) ortho-rectified images for desktop truthing were used.

4.1.3 Methodology for Desktop Truthing

Probability based sampling was used to obtain a statistically defensible accuracy estimate for the preliminary habitat map. This accuracy assessment methodology consisted of three primary components: (i) the sampling design, which determined the spatial locations at which the reference data were obtained; (ii) the response design, which detailed how the reference data were obtained; and (iii) the analysis plan for producing the accuracy estimates. The results of this exercise also set the stage for later ground survey planning to focus on areas with classification uncertainty and confusion.

Sampling Design

A stratified random sampling design was used for drawing samples. The stratification was based on mapped habitat classes, and a random sample of 20 pixels was selected independently for each class.

Reference Data Collection

To obtain the reference classification, each sample (pixel) of unknown land cover was located on the high resolution digital photo based on geographic coordinates of sample location. Because all high resolution photos are ortho-rectified, the interpretation can be assured in terms of registration to sampled pixels from the habitat map derived from SPOT 5 image.

Accuracy Assessment using High Resolution Photos

Procedures were implemented so that the reference data (habitat class) was determined along with an interpretation confidence index using a linguistic scale:

The interpretation of the habitat class was:

- absolutely correct;
- most likely correct;
- only a guess; or
- not able to determine.

Estimating Accuracy

Standard error matrix and accompanying summary measures including overall user's and producer's accuracies of the preliminary habitat map were estimated.

4.2 TASK 7 - ACCURACY ASSESSMENT OF DESKTOP TRUTHING

Following the completion of the map, the accuracy of the mapping for each habitat type was assessed based on the following steps:

A stratified random sampling design was adopted for collecting sample data from the preliminary habitat map. The stratification based the mapped habitat classes on randomly drawn 30 pixels independently from each class. Revision and improvement of the preliminary habitat was carried out by means of:

- Comparison with aerial photos, as their higher resolution can help distinguish more spectral refined classes. The following data source was used:
  - Source A: Orthophoto (Dop5000) in ECW format, 2008
- Seeking reference from ERM's past projects related to habitat study. The following data source was used:

- Source B: ERM's EIA projects which involved an extensive study of the habitat types on the study area (eg *2004 Landscape Character Map of Hong Kong and Satellite Image Classification of the Mai Po Inner Deep Bay Ramsar Site and Wetland Buffer Area, 1999-2000*), 2000 - 2006

- GIS data and maps provided by the Government. The following data sources were used:

  - Source C: Land Utilization in Hong Kong (*Sheet No. LUM/HK/75*) 2007 published by Planning Department, 2007

  - Source D: Landscape Character Map of Hong Kong (*Sheet No. LCM/HK/75*) published by Planning Department, 2005

  - Source E: Landscape Value Map of Hong Kong (*Landscape Value Mapping of Hong Kong* published by Planning Department, HKSAR, 2005), 2005

  - Source F: Information provided by Agriculture, Fisheries & Conservation Department, HKSAR.

The details of validation and processing applied to each data source are described in *Table 4.1*.

Table 4.1 Desktop Truthing Processes

Habitats Type	Desktop truthing data sources	Processes of desktop truthing
Bare Rock or Soil	Source A, C, D	Visual identification of bare rock / soil from A, and, according the information extracted from C & D to eliminate other habitat types such as landfills, rocky shores and artificial rocky.
Quarry	Source A, C, D	Visual identification of quarry from A and extract the related information from C & D.
Landfill	Source A, C, D	Visual identification of landfill from A and check the related information from C & D.
Other (Urban or Other Highly Modified Area)	Source A, C, D	Visual identification of Urban / Highly Modified Area from A, eliminate Bare Rock/Soil, Quarry and Landfill and check with C & D.
Fung Shui Forest	Source A, F	Visual identification of Forest from A, and make reference to F.
Plantation Plantation/Mixed Forest	Source A, F	Visual identification of Forest from A, and make reference to F.
Fishpond/Gei Wai	Source A, C, D, F .	Visual identification of water bodies from A, B, and make reference to C, D & F.
Natural Watercourse	Source A	Visual identification of water bodies from A.
Modified Watercourse	Source A, C, D	Visual identification of water bodies from A, and make reference to C & D.

Habitats Type	Desktop truthing data sources	Processes of desktop truthing
Rocky Shore	Source A, C, D	Visual identification of rocky areas from A and make references to C & D.
Artificial Rocky/Hard Shoreline	Source A, D	Visual identification of rocky areas from A and make references to D.
Intertidal Mudflat	Source A, C, E	Visual identification of Mudflat from A and make references to C & E.
Sandy Shore	Source A, B	Visual identification of Sandy Shore from A and make references to B.
Seagrass Bed	Source A, B, C, F	Visual identification of Seagrass Bed from A and make references to B, C & F.
Golf Course/Urban Park	Source A, C, D	Visual identification of Grassland from A and make references to C & D.
Rural Industrial Storage/Containers	Source B, C	Make reference to B & C.
Cultivation	Source A, F	Visual identification of Grassland from A and make references to F.
Grassland	Source A, B, C, D	Visual identification of Grassland from A, eliminate Cultivation class and make reference to B, C & D.
Shrubby Grassland	Source A, B, C, D	By analysing the spectral features of Shrubby Grassland from A, eliminate Cultivation class and make reference to B, C & D.
Mixed Shrubland	Source A, B, C	Visual identification of shrub from A, eliminate Cultivation class and make reference to B & C.
Mangrove	Source A, B, F	Visual identification of Mangrove and Grassland from A, and make reference to B & F.
Freshwater/Brackish Wetland	Source A, B, C	Visual identification of waterbodies from A, and make reference to B & C.
Montane Forest	Source A, B	Visual identification of Forest from A, and make reference to B.
Lowland Forest	Source A, B, C	Visual identification of Forest from A, eliminate Montane Forest and make reference to B & C.

4.2.1 Result of Desktop Truthing

An error matrix, similar to the one created by multispectral classification, is presented in *Table 4.2* to summarize the accuracy level of the classification on the preliminary map. The user and the producer accuracy were determined to identify the error of commission and omission.

Table 4.2 shows the error matrix of the preliminary habitat classification. The 720 samples used to assess the accuracy of the 24 classes (30 samples per habitat classes) were based on a rigorous sampling design,i.e.a stratified sampling procedure. A moderate accuracy (80.14%) was achieved for 24 finer classes compared with digital orthorphoto, aerial photographs and

previous datasets. From the confusion matrix, it could be seen that Rocky Shore, Golf Course /Urban Park, Mangrove and Lowland Forest attained 90% in Producer accuracy. Artificial Rocky/Hard Shoreline, Seagrass, Natural Watercourse and Montane Forest had the highest Producer accuracy (93%). Although the newly developed fine classes performed with higher accuracy, the original broad classes such as Shrubby Grassland, Grassland, Sandy Soil, Intertidal Mudflat, Fung Shui Forest, Plantation or Plantation / Mixed Forest only achieved moderate accuracy (72% on average).

Table 4.2 Error Matrix of the 24 Preliminary Habitat Classes

		C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	*C14*	*C15*	*C16*	*C17*	*C18*	*C19*	*C20*	*C21*	*C22*	*C23*	*C24*	**Total**	**User**
C1	Bare Rock or Soil	**23**	3	4	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	36	64
C2	Quarry	0	**25**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	100
C3	Landfill	0	0	**24**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	100
C4	Other(Urban or Highly Modified Area)	2	0	0	**26**	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	30	87
C5	Fung Shui Forest	0	0	0	0	**21**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	100
C6	Plantation or Plantation/Mixed Forest	0	0	0	0	0	**22**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	100
C7	Fishpond/Gei Wai	0	0	0	0	0	0	**23**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	26	86
C8	Natural Watercourse	0	0	0	0	0	0	3	**28**	2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	11	76
C9	Modified Watercourse	0	0	0	0	0	0	0	2	**25**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	93
C10	Rocky Shore	0	0	0	0	0	0	0	0	0	**27**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	28	96
C11	Artificial Rocky/Hard Shoreline	0	0	2	0	0	0	0	0	0	0	**28**	0	0	0	0	0	0	0	0	0	0	0	0	0	30	93
C12	Intertidal Mudflat	0	0	0	0	0	0	0	0	0	0	0	**22**	0	0	0	0	0	0	0	0	0	0	0	0	22	100
C13	Sandy Shore	0	0	0	0	0	0	0	0	0	0	0	2	**21**	0	0	0	0	0	0	0	0	0	0	0	23	91
C14	Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	**28**	0	0	0	0	0	0	0	0	0	0	28	100
C15	Golf Course/Urban Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**27**	0	0	0	0	0	0	0	0	0	27	100
C16	Rural Industrial Storage/Containers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**18**	0	0	0	0	0	0	0	0	18	100
C17	Cultivation	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	6	**17**	0	0	0	0	0	0	0	25	68
C18	Grassland	5	2	0	2	0	0	0	0	0	2	0	2	7	1	1	6	6	**22**	0	0	0	0	0	0	60	37
C19	Shrubby Grassland	0	0	0	0	1	7	0	0	0	0	0	0	0	0	1	0	6	6	**21**	0	0	0	0	1	49	43
C20	Mixed Shrubland	0	0	0	0	8	0	0	0	0	1	0	0	2	0	1	0	0	1	9	**24**	1	0	0	1	58	41
C21	Mangrove	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**27**	0	1	0	28	96
C22	Freshwater/Brackish Wetland	0	0	0	0	0	0	4	2	3	0	0	0	0	0	0	0	0	0	0	0	0	**23**	0	0	30	77
C23	Montane Forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**28**	1	30	93
C24	Lowland Forest	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	6	1	0	1	**27**	44	61
	Total	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	**720**	
	Producer Accuracy (%)	**77**	**83**	**80**	**87**	**70**	**73**	**77**	**93**	**83**	**90**	**93**	**73**	**70**	**93**	**90**	**60**	**57**	**73**	**70**	**80**	**90**	**77**	**93**	**90**		

4.3 PRELIMINARY HABITAT MAP

The conversion of nine general categories of land cover into 24 more refined habitat classes were supported by ERM's technical expertise in ecology. ERM, with many years of ecological experience, has accumulated a rich reserve of data regarding different habitat types derived directly from field survey and site reconnaissance visits. Self-evidently, such information is an asset which allows high fidelity ground truthing results to be attained. During the post-processing, these datasets played a crucial role to increase the accuracy of the habitat map data. The decision rules developed through this process further helped determine the class of each input pixel of the image. During desktop truthing, the ecological datasets also acted as useful reference to validate the habitat class.

In the sections below, 24 habitat classes are discussed to summarise the basis for their classification on the habitat map from the nine general categories of land cover.

4.3.1 *Bare Soil (Quarry, Landfill, Rocky Shore, Artificial Rocky/Hard Shoreline, Intertidal Mudflat, Seagrass, Sandy Shore & Bare Rock or Soil)*

Around 6.21% of the land area of Hong Kong was classified as the captioned habitat types (*Table 4.3*). The approach taken to derive spectrally similar classes was a progressive refinement approach. Specifically, those classes were obtained through the bare surface mask layer made through very low NDVI values and through visual interpretation of aerial photos. After the initial splitting of all classes, additional manual editing was performed by screen-editing the classification map against the SPOT 5 Panchromatic and multispectral bands/ images to correct any misclassification in order to increase accuracy.

Quarry and Landfill

Landfill and Quarry were identified from the bare surface mask with reference to aerial photos and the 2007 habitat map. Manual editing was carried out to ensure the correct identification of these classes from the bare mask.

Rocky Shore

The Rocky Shore in Hong Kong area is commonly found in limited and narrow shape, and because its spectral features are very similar to that of the other bare surfaces, high resolution aerial photos and the DEM data were relied upon to identify areas of this class. The screen-editing was made within the target coastal areas and with reference to Rocky Shore habitat class from the 2007 Study.

Artificial Rocky/Hard Shoreline

This habitat type was delineated by screen-editing using aerial photos and the previously mapped shoreline. Based on the 2005 and 2007 Studies, it could often be easily distinguished from natural shores because of its relatively

straight coastline. The spatial resolution of the SPOT 5 image enabled mapping of the Artificial Rocky/Hard Shorelines that were often narrow and spatially limited.

Intertidal Mudflat

Intertidal Mudflat areas are often confused with either water or wetland class depending on the depth and quality of coastal waters. This class was screen-digitized from the identified Intertidal Mudflat with reference to existing habitat data, aerial photos and SPOT 5 images. As the Intertidal Mudflat should have little vegetation in it, visual checks of delineated areas against the SPOT NIR and NDVI bands were made to exclude any areas that had some vegetation (eg Mangrove, Seagrass).

Seagrass Bed

0.01% of the land area of Hong Kong was classified as the captioned habitat type (*Table 4.3*). The Seagrass beds are difficult to map through remote sensing data. Primarily existing information from the 2005 and 2007 habitat maps was relied upon, as well as AFCD data. The habitat location was made with reference to images in the shallow intertidal or subtidal areas.

Sandy Shore

Sandy Shore was derived from the bare ground mask with some modifications. The general areas were first identified from the SPOT 5 (5m) images and checked against the high resolution aerial photos for confirmation. The delineation of the class was then made through screen-editing with reference to both SPOT images and the DEM data. The spatial extent of Sandy Shores is mostly narrow except for large beaches. The 5 meter resolution of the SPOT 5 data made it possible to map this class as a spatial unit rather than as a line feature.

Bare Rock or Soil

The Bare Rock and Soil areas were defined from the remaining area of bare surface mask layer.

4.3.2 Others (Rural Industrial Storage/Containers & Other (Urban or Other Highly Modified Area))

Approximately 11.49% of the land area of Hong Kong was classified as the captioned habitat types (*Table 4.3*). From the definition of Rural Industrial Storage/Containers category, it refers to blocks of multi-coloured containers and/or plain-coloured commercial/industrial materials intermingled with concrete paths. This feature made it a mixed pixel which has mixed spectral features that could not be easily classified by using spectral data. To identify these areas, previously mapped classes and high resolution aerial photos using Aerial Photo interpretation (API) and manual discrimination methods were relied upon. Further refinements were made using aerial photos as an independent source for verification of the mapped class. The Urban and

highly disturbed areas or reclaimed lands (Urban and Other class) were delineated from known urban areas.

4.3.3 Water (Natural Watercourse, Modified Watercourse & Fishpond/Gei Wai)

About 3.65% of the land area of Hong Kong was classified as the captioned habitat types.

Natural Watercourse

The Natural Watercourses consisted primarily of rivers identified from the GIS data of the Lands Department.

Modified Watercourse

Modified Watercourse was defined as channelized rivers, streams and other water bodies, often without natural bands and beds, and not subject to a natural flow. For identifying this class, the previously mapped class and the 1:5,000 topographic data were referenced, and this class was manually isolated by screen-editing. The shape and the regular patterns of the watercourses (reservoirs and waterworks) were also identified from the images.

Fishpond/Gei Wai

The Fishpond/Gei Wai (Producer accuracy of 77%) is a land use class so it is not possible to obtain this class from a direct spectral classification. The Gei Wais are classified as water in most cases, and the spectral feature of fishponds can vary from time to time depending on if they contain water or not. Visual interpretation of the SPOT 5 Panchromatic and multispectral images were relied upon with reference to the mapped Gei Wai habitats from the 2007 map. The screen-editing from water and wetland classes was made to delineate this habitat class. Further refinement against the aerial photos improved the quality of the final mapping of the habitat.

4.3.4 Grassland

Roughly 16.17% of the land area of Hong Kong was classified as Grassland (*Table 4.3*). The initial classification using training data through See5 was accurate (73%). A minor problem was found in areas where some Grassland was mixed with cultivated lands located nearby the towns and villages. To correct this misclassification, the cultivated areas identified from the GIS data provided by the Lands Department and related aerial photos were referenced to change the Grassland areas to Cultivation.

4.3.5 Shrubby Grassland (Shrubby Grassland and Cultivation)

Around 22.67% of the land area of Hong Kong was classified as the captioned habitat types.

Shrubby Grassland

Around 20.78% of the land area of Hong Kong was classified as Shrubby Grassland (*Table 4.3*). The supervised classification result was also quite satisfactory (70%). Some confusion of localized areas with Shrubby Grassland and open forest lands was anticipated because of their spectral similarity and the transition from Shrubby Grassland to other woody vegetation classes. To minimize the confusion, several land cover classifications were made by modifying training data in areas where Shrubby Grassland transited into forest land. By examining the spatial predicted classes from the See5, a better decision tree and associated spatial classification was used to generate the final Shrubby Grassland class. This iterative supervised classification improved the accuracy of the class. Nevertheless, some uncertainties were still found in areas where the mixed grass and woody components were found. This class was further refined through screen-editing by reference to the high-resolution aerial photos.

Cultivation

1.89% of the land area of Hong Kong was classified as the captioned habitat type (*Table 4.3*). The Cultivation class was one of the more challenging types to map accurately with spectral data. The variation in type and growth stage caused difficulty in mapping the class confidently. To improve the chance of success, two steps were taken to tackle this:

i) using aerial photos to identify spectral signatures of areas that were very likely to be Cultivation with high confidence;

ii) the 2007 habitat map was referenced.

Because of spectral confusion with other categories (eg Grassland and Shrubby Grassland), the Cultivation class had to be identified through manual discrimination in order to distinguish it from the other spectrally similar but non-cultivated classes.

4.3.6 Mixed Shrubland (Mixed Shrubland and Golf Course/Urban Park)

Around 17.19% of the land area of Hong Kong was classified as the captioned habitat types (*Table 4.3*).

Mixed Shrubland

About 15.96% of the land area of Hong Kong was classified as Mixed Shrubland (*Table 4.3*). Mixed Shrubland was mapped with a high level of producer's accuracy (80%). Similar to the strategy taken for refinement of Shrubby Grassland, several classifications were made by modifying training data and by examining the spatial predicted classes from the See5.

To avoid under-estimation of the Mixed Shrubland as in the Previous Studies, more screen-editing was conducted using aerial photos. For areas where they were on transition between Shrubby Grassland and Mixed Shrubland,

they were labelled in favour of Mixed Shrubland rather than Shrubby Grassland.

Golf Course/Urban Park

1.23% of the land area of Hong Kong was classified as the captioned habitat types (*Table 4.3*). Golf Courses and Urban Parks are classified as Grassland, and therefore have to be mapped using GIS data with reference to aerial photos and SPOT 5 images. The main data source for this class was the latest 1:20,000 urban facility GIS data provided by the Lands Department. This data, along with spectral feature and locations, helped to identify this habitat class with good confidence.

4.3.7 Mangrove

Approximately 0.45% of the land area of Hong Kong was classified as Mangrove. This habitat was mapped through See5 supervised classification. The 2007 habitat map, AFCD database and corresponding aerial photos were used to refine the See5 classified results. This process helped reduce the omission error in many areas. Final screen-editing was conducted to further improve the mapping of the Mangrove class.

4.3.8 Wetland (Freshwater/Brackish Wetland)

Approximately 0.49% of the land area of Hong Kong was classified as Wetland (*Table 4.3*). Wetlands class was mapped with a high user's accuracy (77%). The classification was also cross-checked against the aerial photos to identify areas of inconsistency. The areas that were found to be uncertain were mostly confused with dense and wet vegetation (trees) that were spectrally similar to that of Wetlands. In such cases, reference to the 2007 habitat map was made to determine if the area should be reclassified.

Because the SPOT 5 images used were acquired in November 2008, the relative dryness of the season at this time of the year may have limited the inclusion of all possible Wetlands in Hong Kong. Hence the Wetlands in the preliminary habitat map may have under-represented the actual area of Wetlands.

4.3.9 Forest (Montane Forest, Lowland Forest, Plantation or Plantation/Mixed Forest and Fung Shui Forest)

Around 21.68% of the land area of Hong Kong was classified as the captioned habitat types (*Table 4.3*). The quality of mapped Forest class from training data was good (70% – 93%). For consistency with previous studies (2005 and 2007 habitat mapping), the separation of Montane and Lowland Forest was made based on digital elevation data using 600 metres above sea level. After this separation, some Lowland Forest was still mixed with tree Plantation. Aerial photos, data provided by AFCD and the 2007 habitat map were used to identify tree Plantation areas and screen-edit those pixels. The Plantation was identified through visual interpretation of relatively unique patterns in tree planting. Finally, the Fung Shui Forest was mapped onto the habitat

map based on the information of the 2007 habitat maps and was differentiated from the Forest class.

Compared with the 2007 habitat map, new habitat types were found in some Urban areas (mainly obtained from recent reclamation works). The Project Team believes that Plantation works had been conducted on those vacant lands since 2007, and the Present Study reflects the latest changes of the habitat types on those Urban lands.

The Preliminary habitat map based on the analysis presented in *Sections 3* and *4* is shown in *Figure 4.2*.

Table 4.3 Account of Habitat Areas based on the Preliminary Habitat Map

Land Cover Class	Habitat Class	Area (km²)	% of Total Area
Bare Soil	Quarry	148.99	0.13
	Landfill	211.41	0.19
	Rocky Shore	1,485.03	1.31
	Artificial Rocky/ Hard Shoreline	353.12	0.31
	Intertidal Mudflat	696.49	0.61
	Sandy Shore	462.30	0.41
	Bare Rock/Soil	3,673.69	3.24
	Seagrass Bed	8.60	0.01
	Total	7,039.63	6.21
Others	Rural Industrial Storage/Containers	93.96	0.08
	Other	12,945.54	11.41
	Total	13,039.50	11.49
Water	Natural Watercourse	591.62	0.52
	Modified Watercourse	2,600.21	2.29
	Fishpond/Gei Wai	950.55	0.84
	Total	4,142.38	3.65
Grassland	Grassland	18,354.76	16.17
Shrubby Grassland	Shrubby Grassland	23,584.50	20.78
	Cultivation	2,145.10	1.89
	Total	25,729.60	22.67
Mixed Shrubland	Mixed Shrubland	18,118.89	15.96
	Golf Course/Urban Park	1,396.52	1.23
	Total	19,515.41	17.19
Mangrove	Mangrove	512.63	0.45
Wetland	Freshwater/Brackish Wetland	557.84	0.49
Forest	Montane Forest	135.56	0.12
	Lowland Forest	23,712.99	20.89
	Plantation or Plantation/ Mixed Forest	546.55	0.48
	Fung Shui Forest	211.21	0.19
	Total	24,606.31	21.68

* The preliminary habitat map was further reviewed against latest orthophotos and aerial photographs in detail, after the submission of Topic Report in March 2009. The size of the habitat classes presented above is different from the table in the *Topic Report* after the revision.

Key

Habitat

- Natural Watercourse
- Modified Watercourse
- Fung Shui Forest
- Montane Forest
- Lowland Forest
- Mixed Shrubland
- Freshwter/Brackish Wetland
- Mangrove
- Seagrass
- Intertidal Mudflat
- Shrubby Grassland
- Plantation or Plantation/Mixed Forest
- Fishpond/Gei Wai
- Sandy Shore
- Cultivation
- Bare Rock or Soil
- Grassland
- Golf Course/Urban Park
- Quarry
- Rural Industrial Storage/Containers
- Landfill
- Other (Urban or Highly Modified Area)
- Artificial Rocky/Hard Shoreline
- Rocky Shore

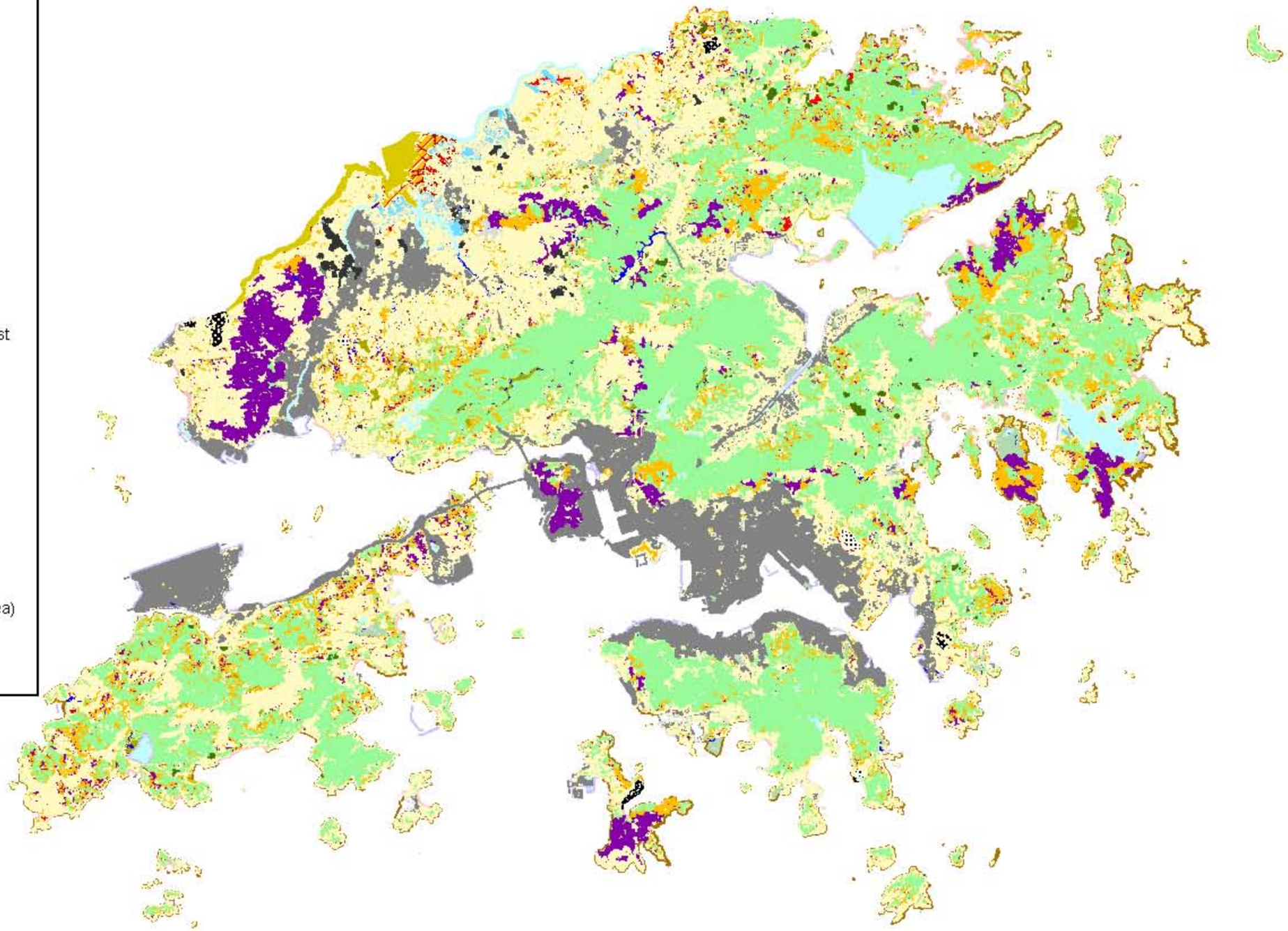


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Figure 4.2

Preliminary Habitat Map of Hong Kong

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5 SURVEY EFFORT ALLOCATION

5.1 SELECTION OF FIELD TRUTHING SURVEY LOCATIONS

The locations where field truthing surveys had been undertaken in the Previous Studies and the approach to select the survey sites are shown in *Figure 5.1*. A total of 2,345 sites were allocated for random sampling on habitat categories for the Present Study. The site locations were generated randomly by computer on the polygons of each habitat of the preliminary habitat map. Details of the randomly selected 2,345 sites, in terms of their site coordinates and the habitat category to which they belonged, are shown in *Table A3-a, A3-b* and *A3-c* of *Annex A*.

Clause 3(c) (iii) of Service Specification required that a total of 80 days of effort was allocated to field surveys. Based on the experience of the Previous Studies, it was considered that a total of 577 sites could be effectively surveyed over 80 survey days. The *Service Specification* for the Present Study also required that survey effort should be focused on those areas which have been shown to be more uncertain to distinguish, identify or classify in the remote sensing analysis and desktop truthing. The discrepancies, uncertainties and outstanding information gaps identified under the Present Study were also considered such as sites that were uncertain with regard to the habitat type and/or boundary and/or sites that had the potential to be upgraded/downgraded from the indicative ecological value assigned to that habitat type; and/or sites that lacked updated information on ecological status.

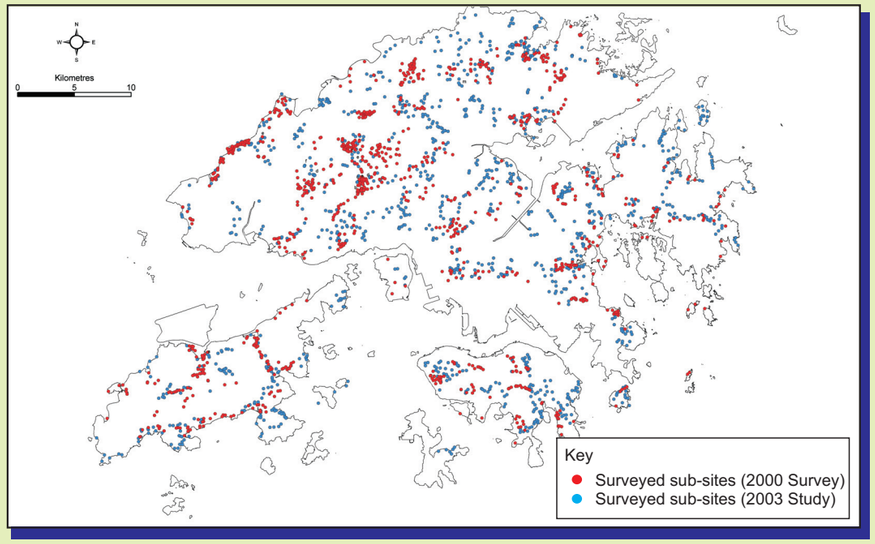
Following this procedure, the next step was to apply selection criteria so that the focus was on 577 sites. The following site selection criteria were used for the Present Study:

5.1.1 *Criteria of Site Selection for the Present Study*

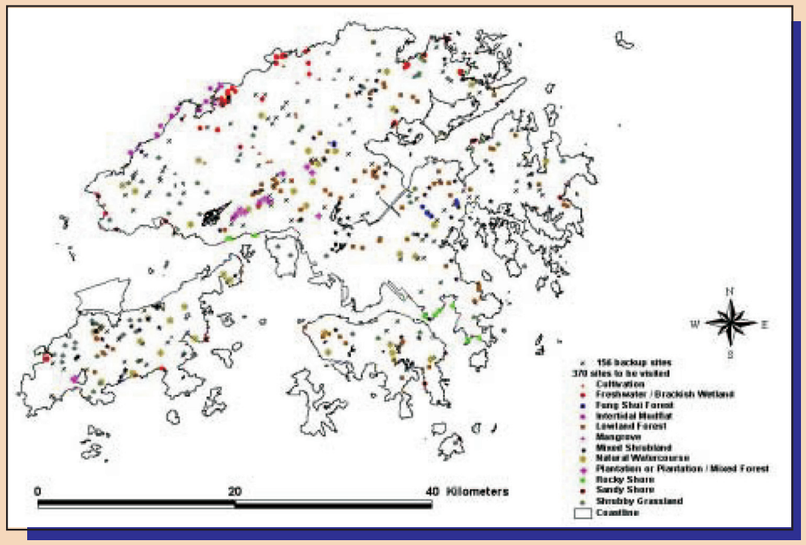
The strategy for site selection criteria adopted in the 2005 and 2007 Studies was reviewed and where appropriate, modifications to the approach were adopted to suit the purpose of the Present Study; these included:

- Only habitat classes of high and medium ecological value were considered for assessment,i.e.15 habitat categories including: Montane Forest, Lowland Forest, Fung Shui Forest, Mixed Shrubland, Freshwater/Brackish Wetland, Natural Watercourse, Mangrove, Intertidal Mudflat, Plantation or Plantation/Mixed Forest, Shrubby Grassland, Cultivation, Sandy Shore, Rocky Shore, Fishpond and Seagrass. No survey effort was allocated to low (i.e. Bare Rock or Soil, Grassland, Modified Watercourse, Artificial Rocky/Hard Shoreline, Golf Course/Urban Park and Quarry) and negligible value habitats (i.e. Rural Industrial Storage/Containers, Buildings, Landfill and Other (urban or other highly modified habitats);

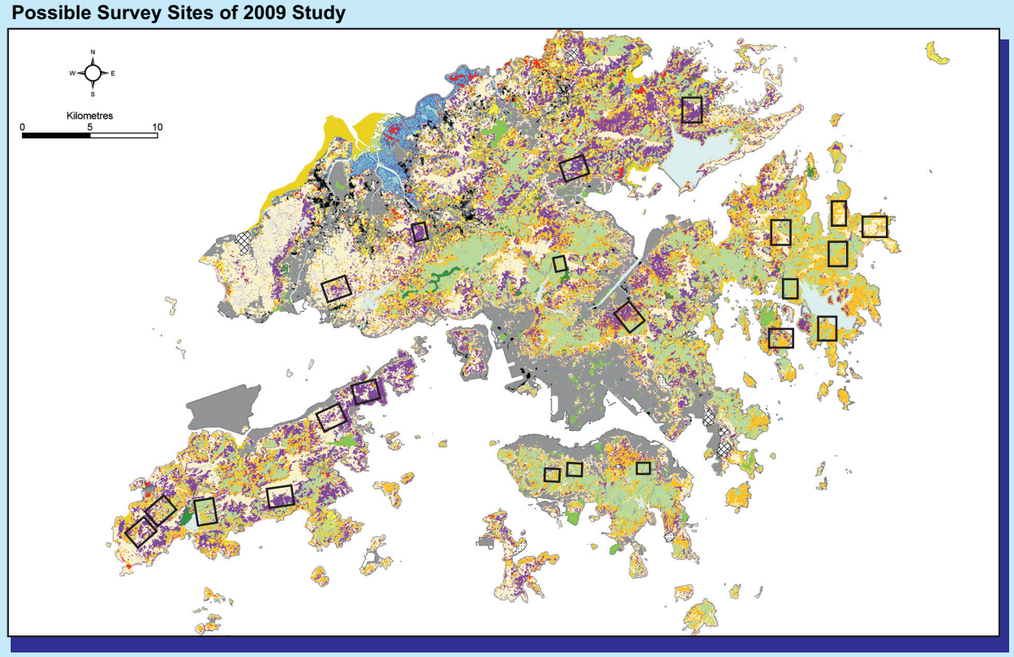
Surveyed Sub-sites of 2003 Survey



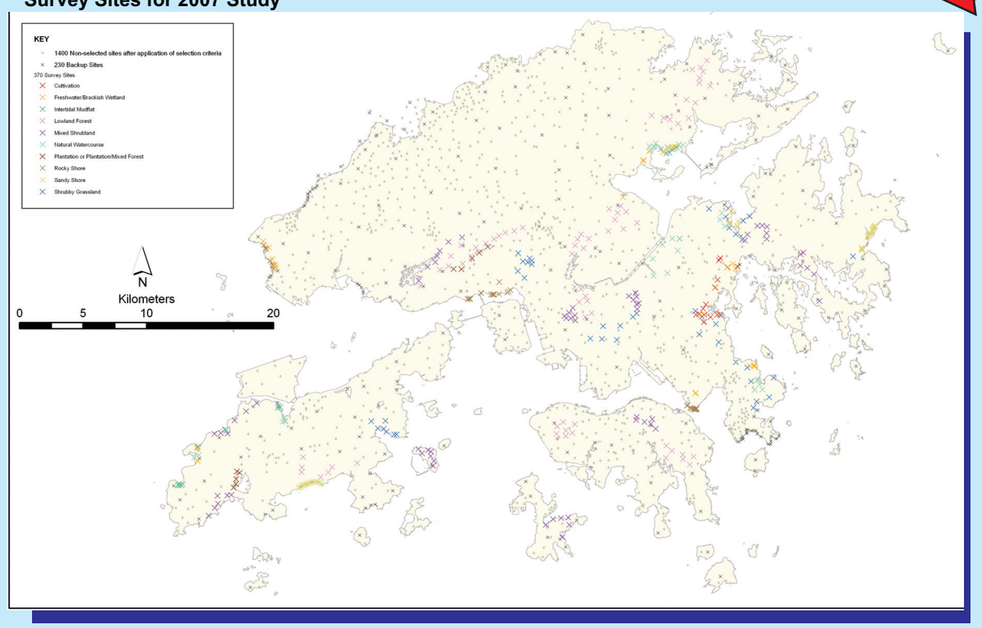
Surveyed Sites for 2005 Study



Possible Survey Sites of 2009 Study



Survey Sites for 2007 Study



Site Selection Criteria for 2009 Study

- sites that are uncertain with regard to the habitat type and/or boundary; and/or
- sites that have the potential to be upgraded/downgraded from the indicative ecological value assigned to that habitat type; and/or
- sites that lack updated information on ecological status;
- sites that fall within the boundary of Sites of Special Scientific Interest (SSSIs) and Country Parks;
- sites that have also been surveyed in the Previous Studies; and
- locations where known development projects (e.g. designated projects according to EPD's records on Environmental Permit application) are undertaking.
- the habitat categories that has less 75% mapping accuracy based on field survey results (2000, 2003, 2005 and 2007 Studies)
- Uncertainties, discrepancies and unidentified information gap from the preliminary Terrestrial Habitat Map (2000, 2003, 2005 and 2007 Studies)

Figure 5.1

The Site Selection Criteria and Approach for 2009 Study

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- Two of the 15 habitat categories (Fishpond and Fung Shui Forest) were excluded due to, as advised by the Government representatives, the limited size of the area and/or the fact that the relevant information was readily available from various Government departments.

- Montane Forest was also excluded from the 15 habitat categories because of its limited size and a contour line of 600m could also be used to define lands covered with natural forests 600m above sea level.

- A total of 12 habitat categories, i.e., Plantation (plantation services inside and outside country parks) or Plantation/Mixed Forest, Lowland Forest, Mixed Shrubland, Freshwater/Brackish Wetland, Natural Watercourse, Mangrove, Intertidal Mudflat, Shrubby Grassland, Cultivation, Seagrass, Sandy Shore and Rocky Shore, remained from which the 577 survey sites and 368 backup sites were selected;

- Sites that were remote and not reasonably accessible by transport and hiking routes were excluded so that the 945 (577 +368) sites were not overly inaccessible;

- 70 of 577 survey sites were allocated based on the desktop truthing on areas with error, uncertainty and low levels of confidence based on the desktop truthing results of the Present Study;

- The remaining 507 survey of 577 sites were selected based on selection strategies of general verification, supplemental verification, ecological value assessment, low mapping accuracy of the 2007 Study, high coverage of particular habitat categories and readjustment of survey days, which were detailed in the following *Section 5.1.2.* The location of the allocated sites was selected using the stratified random sampling method which has been adopted in the 2007 Study;

- The selected polygons of 12 habitat categories to be surveyed within the 80-day survey period avoided overlapping with the 370 surveyed sites in the 2007 Study as much as possible,i.e.select sites in areas that remained un-surveyed under the 2007 Study were selected; and

- The remaining 368 sites were selected as backup sites for the 577 sites if some of them were not accessible *in situ*.

The 12 selected habitat categories for the field truthing survey are summarised as follows:

High value ecological habitats:

- Lowland Forest

- Mixed Shrubland

- Freshwater/Brackish Wetland

- Natural Watercourse
- Intertidal Mudflat
- Mangrove
- Seagrass

Medium value ecological habitats:

- Plantation (plantation services inside and outside country parks) or Plantation/Mixed Forest
- Shrubby Grassland (including *Baeckea* Shrubland)
- Sandy Shore
- Rocky Shore
- Cultivation

5.1.2 Survey Effort Allocation

To effectively utilise the 80-day field truthing survey days, a strategy for effort allocation was devised to ensure maximum utilisation of survey days so that valuable and representative information could be collected from target sites of selected habitats by the Field Survey Team. Factors considered in the Previous Studies for devising the effort allocation strategy were also considered in the Present Study.

Prioritised Effort for Uncertain Areas Based on Remote Sensing and Desktop Truthing of the Present Study

As discussed in *Sections 2* and *3*, habitats which were identified as of higher uncertainty were allocated additional survey effort to verify their habitat type and boundary. **14 sites** for verification were allocated to each of those categorised as high indicative and medium ecological value which were also regarded as having a medium level of confidence (less than 75%) based on remote sensing and desktop truthing of the Present Study (*Table 4.2)*. These habitats included:

- Intertidal Mudflat (73%)
- Plantation or Plantation Mixed Forest (73%)
- Shrubby Grassland (70%)
- Sandy Shore (70%)
- Cultivation (57 %)

General Verification

In the Previous Studies, limited survey effort was allocated for General Verification which involved ground truthing of the habitat for the purpose of "spot-checking", even if the interpretation of the satellite imagery and aerial photographs (under the 2005 & 2007 Studies) was valid given the desktop information available. The purpose of these limited surveys was to confirm, through further ground truthing, the accuracy of the habitat type classification and the boundary of the habitat. **22 sites** were assigned to each of the habitat categories that had an indicative high ecological value, and **20 sites** to medium ecological value including the following:

High value ecological habitats:

- Lowland Forest
- Mixed Shrubland
- Freshwater/Brackish Wetland
- Natural Watercourse
- Mangrove
- Seagrass
- Intertidal Mudflat

Medium value ecological habitats:

- Shrubby Grassland
- Plantation or Plantation /Mixed Forest
- Sandy Shore
- Rocky Shore
- Cultivation

Supplemental Verification

The purpose of the supplemental verification survey allocation was to devote additional effort to ground truthing habitat types which the satellite imagery and orthophoto methodology could not easily distinguish. The desktop truthing mapping accuracy of each habitat category of the preliminary habitat map produced under the 2007 Study had been assessed with regard to the habitat type and boundary and a graded level of mapping confidence had been assigned to individual mapping categories. Habitats which had been mapped with less than a high level of mapping confidence, except for those which have a negligible indicative ecological value, were allocated additional

survey effort to verify their habitat type and boundary. **15 sites** were allocated to each category labelled as high and medium indicative ecological value habitat categories which had been regarded as having a medium level of mapping confidence. These habitats included:

- Freshwater/Brackish Wetland
- Shrubby Grassland
- Rocky Shore
- Cultivation

Ecological Value Assessment

Apart from basing the overall assessment of the category against a number of criteria (including biodiversity, support of rare species, ecological function, rarity, vulnerability, size and potential), it is desirable to validate the indicative ecological value for specific sites, especially when variability within a given habitat type is high.

Since habitats with an indicative low or negligible ecological value are, in general, less likely to be ultimately assigned the rating of high ecological value habitat, further efforts were not allocated to these habitats for ecological value assessment. The number of days to be allocated was assigned to each habitat category depending on that habitat's ecological importance and the variability of the habitat type and boundary. Four classes, namely "High Ecological Value with High Variability", "High Ecological Value with Low Variability", "Medium Ecological Value with High Variability" and "Medium Ecological Value with Low Variability " had been identified in the Previous Studies to assist in allocating the survey effort. For the Present Study an additional **15 sites** were allocated to each of the habitats that were classified as "high ecological value with high variability". These habitats included:

- Lowland Forest
- Mixed Shrubland
- Freshwater/Brackish Wetland
- Mangrove

Additional Effort Based on Field Truthing Survey Mapping Accuracy

The Previous Studies proposed to allocate additional survey effort to the habitat categories that had an overall mapping accuracy (based on field truthing survey results) of less than 70% and this was subsequently implemented in the Previous Studies. The habitats that had a <70% overall mapping accuracy as indicated in the 2007 Study included:

- Freshwater/Brackish Wetland (66.6%)

- Shrubby Grassland (56.2%)
- Cultivation (57.3%)

An additional **35 sites** of field truthing effort were allocated to these habitats.

Additional Effort Based on High Coverage

Based on the area coverage of habitats identified on the conservation ranking assessment map, high ecological value habitats were mainly composed of Shrubby Grassland and Mixed Shrubland with percentage coverage of 44% (2007 Study). It was therefore proposed to allocate **14 additional survey sites** to each of the two habitat categories.

- Mixed Shrubland
- Shrubby Grassland

The above field truthing effort allocation is summarised in *Table 5.1* below.

Allocation of Backup Survey Sites

The allocation of 368 backup sites of survey effort in proportion to the survey effort of the 577 survey sites and their allocations are shown in *Table 5.1*.

Table 5.1 Provisional Allocation of Field Truthing Survey Effort for the Present Study

Habitat Category	Prioritised Effort for Uncertain Areas Based on Remote Sensing and Desktop Truthing of the Present Study	General Verification	Supplemental Verification	Ecological Value Assessment	Low Mapping Accuracy based on Previous Field Truthing Survey Results	High Coverage	Total No. of Field Truthing Survey Sites	Total Number of Backup Site
High Ecological Value								
Lowland Forest		22		15			37	32
Mixed Shrubland		22		15		14	51	32
Freshwater/brackish Wetland		22	15	15	35		87	32
Natural Watercourse		22					22	32
Mangrove		22		15			37	30
Seagrass		22					22	30
Intertidal Mudflat	14	22					36	30
Medium Ecological Value								
Shrubby Grassland	14	20	15		35	14	98	30
Plantation or Plantation/ Mixed Forest	14	20					34	30
Sandy Shore	14	20					34	30
Rocky Shore		20	15				35	30
Cultivation	14	20	15		35		84	30
Total No. of Sites	70	254	60	60	105	28	577	368

6 SURVEY METHODOLOGY

The survey for the Present Study was executed in accordance with *Clause 3(c) (iii) of the Services Specifications*. The methodology employed was based on the review of the previously used environmental baseline survey in the Previous Studies. The scope of the survey encompassed all terrestrial habitats including all habitats above the low tide mark.

6.1 SURVEY METHODOLOGY

As described in the *Inception Report*, field truthing surveys were proposed to fulfil three objectives: field truthing, habitat verification (general and supplemental) and ecological value assessment. The general approach of the surveys adopted by the Present Study to achieve the above objectives included the following:

Field Truthing Surveys: The information collected in the field truthing surveys was used to improve the accuracy of multispectral classification of the satellite images through site data training / calibration / rectification.

Habitat Verification (HV) Surveys: To fulfil the purpose of habitat verification, the sites selected for each habitat category were ground truthed by a qualified ecologist assisted by a qualified land survey specialist. Ground truthing included verifying the habitat location, type and, wherever possible, boundary (some habitats, eg Forests, may cover a huge area or offer poor accessibility which may make boundary verification impossible). The methodology applied when visiting sites for ground truthing included recording the date and time, taking photographs, and checking the locations (and boundaries) against the base map (1:5,000 (1) scale wherever available) using Global Positioning System (GPS) with the assistance of a land survey specialist. Two types of GPS were employed in the field. One GPS (*Haicom-CF GPS*) connected to *Compaq iPaq* (where *ArcPad* and *Proforma* were installed). This GPS was employed as guidance to the location and enabled the ecologists to interface to *Proforma* and the maps setup in *ArcPad*. The accuracy of this GPS is around to 5-10 meters with the availability of 5-6 satellites. The degraded accuracy is corrected by Differential GPS (DGPS) which was used concurrently with the field truthing exercises. The DGPS (*Leica GPS1200*) could bring the accuracy up to 10-20 cm. Therefore, on average, the accuracy was resolved to 1-2 meters. In the Present Study, 360° panoramic digital photographs of surveyed habitat were taken to fulfil the requirements set forth in *Clause 3(c) (iii)* of the *Service Specification*. During the field truthing surveys, the survey team consisted of at least two people, one ecologist and one land survey specialist. In order to assist the surveyor

(1) It was advised by Lands Department that B5000 digital map was sufficient for field truthing survey. It could be provided to ERM from LandsD upon request. Since it required 4 working days to process the data under 200 numbers of tiles for an order, we would well plan for the area of interests for the field truthing trips ahead for LandsD to supply the required B5000 digital map.

to locate their position in the field, they were provided with a Pocket Computer (PC) linked to GPS units (although it was acknowledged that the GPS may be of limited use when surveying under canopy, the data would be post-processing and corrected by data obtained by DGPS) and installed with a reasonably high resolution base map with adequate locational indicators (eg footpaths, streams, buildings, police stations). However, even with these aids, mapping the boundary of a Shrubland/Forest habitat relied heavily on the judgment of the land surveyor who would map as accurately as possible given the conditions and the effort limitations (i.e. time available). Details of the Pocket PCs are discussed below.

Ecological Value Assessment (EVA) Surveys: Field truthing surveys using habitat-specific methodology were conducted, and were supplemented with information on dominant species and species of conservation importance observed during the field truthing survey, to validate the indicative ecological value of certain habitat categories. The information collected was used to provide an initial assessment of the suitability of the habitat for rare, endangered or otherwise special species and the likelihood that these species may be present. The data was also used to justify the validity of ecological value against the criteria delineated in the Previous Studies and upgrade or downgrade the indicative value, when necessary.

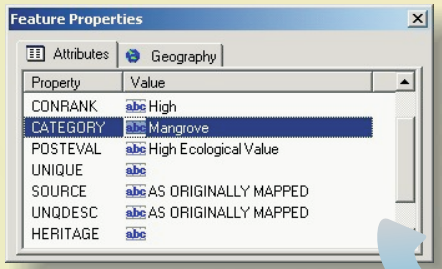
Use of Pocket Computer (PC) for Field Survey Work

It was important during the field survey phase of the project that information be collected in a consistent, comprehensive and accurate fashion. Paper based surveys were often inefficient for a variety of reasons including incomplete data capture, inconsistent nomenclature when many survey teams are involved and mistakes made while transcribing data during entry at base. Inputting the field data directly into a computer would eliminate these errors. Current technology would allow the loading of a digital *Proforma* for collection of ecological data, base maps of the existing Habitat Map and a "light" version of GIS software (such as ESRI's ArcPAD) onto hand held Windows CE PCs. This would ensure validation of the data at point of collection, eliminate double entry and ensure completeness. The other advantage of these units is that they could be linked to GPS units quite easily, which would greatly assist surveyors in locating where they were in the field. *Figure 6.1* shows an example of what such a system looks like.

It was therefore intended that pocket PCs were used to assist in field surveys. Topographic data, aerial photos and the existing habitat map could be "clipped" into manageable data packets for uploading onto the Pocket PCs and used by the field surveyors.

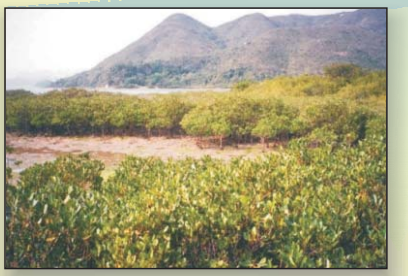
6.2 COORDINATION AND PLANNING OF FIELD SURVEYS

Once the proposal for field truthing surveys was approved by the Government, the Present Study Team mobilized the field truthing survey team



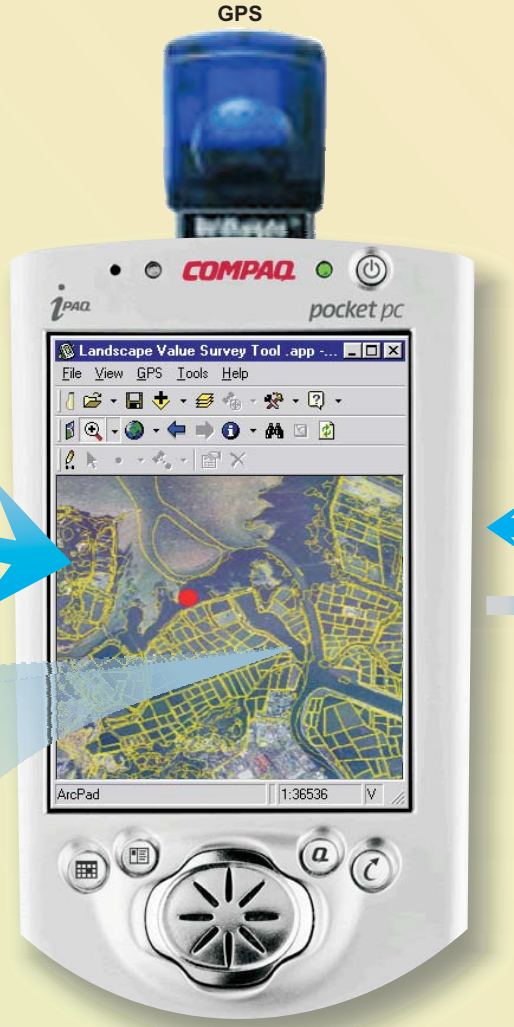
Attribute of Selected Ecologically Significant Feature

Can be edited by surveyors in the field



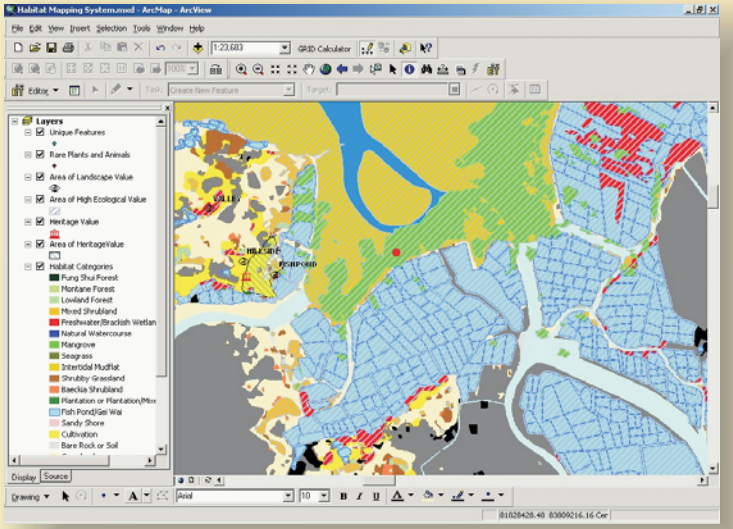
Field Photograph of Mangrove Habitat

Photographs taken in the field can be attached to a locating point stored in the GIS database



Pocket PC for Field Surveys

Surveyors can directly edit habitat boundaries, input information into forms for the areas, connect to GPS to aid with location in the field, and upload the data to the central GIS when back at base.



Central Habitat Mapping GIS

System provides information for use on Pocket PC. Data edited in the field is uploaded to the main GIS when the unit is returned to base.

FIGURE 6.1

Use of Pocket PC and GIS in Field Surveys

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within two days upon receipt of the approval to ensure that surveys on habitats could be completed according to schedule (refer to *Figure 6.2*).

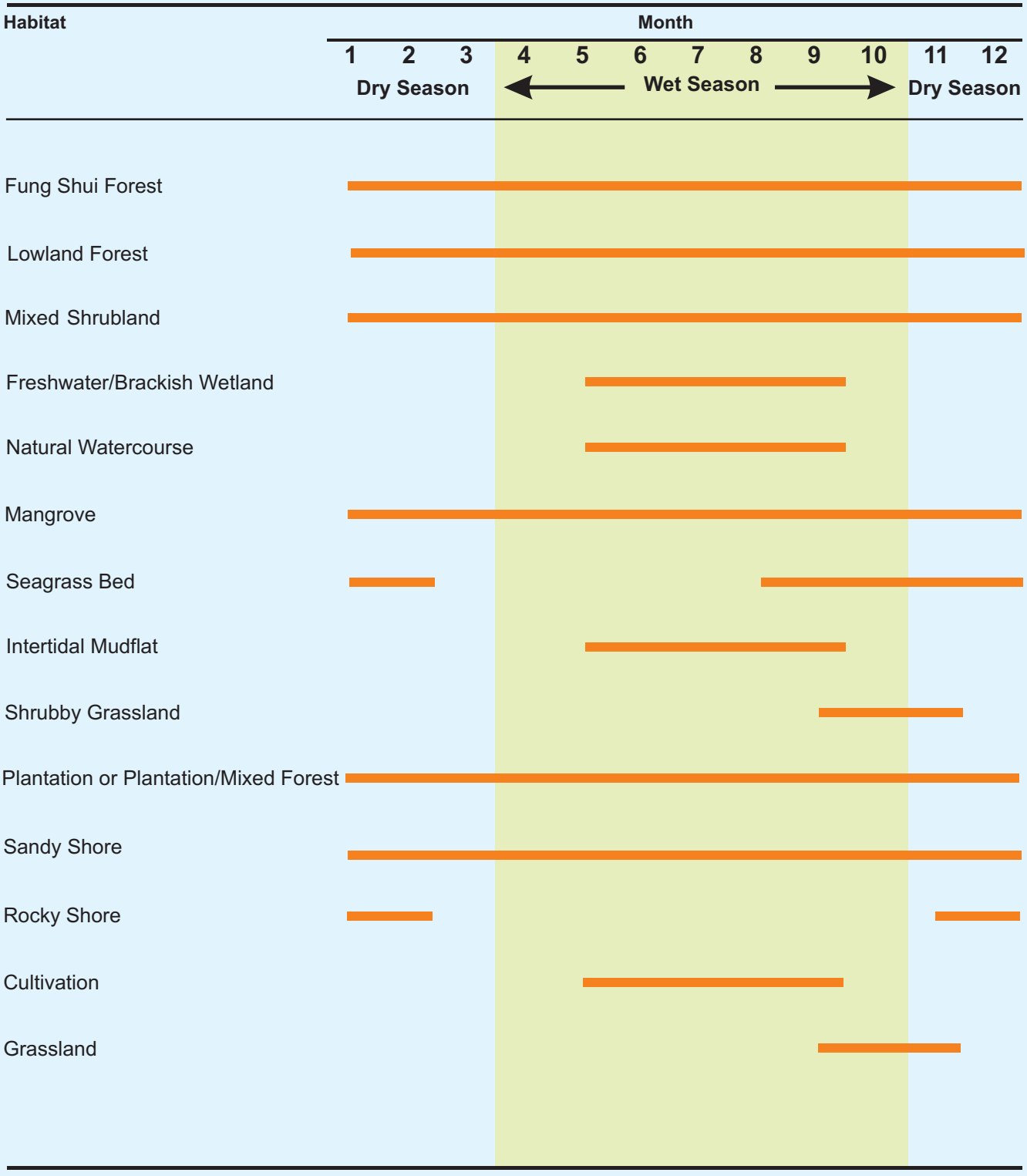
Prior to actual commencement of field *truthing* surveys, each surveyor familiarised himself/herself with the approved methodology and the equipment (eg field-computer for data entry, Differential GPS, Digital Camera) to be used for the survey. In order to ensure consistency of habitat judgment and conservation value assessment, it was one day pre-trip was conducted to the selected high value habitats types where the habitats were often intermingled with other habitats (eg Mixed Shrubland). This also to ensured that all Field Truthing Survey Team members had acquired thorough understanding of the habitats and would be consistent with their judgment of habitat categorization with reference to the definitions defined for each habitat, familiarised themselves with the usage of field equipment and the survey methodology adopted for the habitats.

6.3 FIELD SURVEYS

The 80 field survey days were planned to be undertaken during the period from March to May 2009. Due to poor weather conditions, surveys at the end of May, carefully scheduled to coincide with the tides, had to be postponed. These surveys were for Mangrove, Seagrass Bed, Intertidal Mudflat and Sandy Shore. These surveys were re-scheduled and all surveying was completed by the end of June 2009. Surveyors collected information on the survey sites in accordance to the *Proformas* (*Annex B*).

Surveys were conducted according to the approved methodology outlined in *Section 6.1*, which was very similar to the methodology used for the Previous Studies. Surveyors collected information on the survey sites in accordance with a *Proforma* devised for each habitat type. In order to maximise the number of species recorded and to minimise the time spent on each site (so as to visit more sites within a day), active search for the dominant species, including vegetation and wildlife (i.e. mammals, birds, butterflies, dragonflies, reptiles, stream fauna, intertidal fauna and macroalgae), in particular species of conservation importance were conducted during the field truthing surveys.

During the field truthing surveys, accuracy of habitat identifications and delineation of land cover boundaries were checked using GPS and the land survey specialist, and conservation assessment undertaken according to the approved methodology. For the habitat map to be useful to Government it was important that the data were accurate. ERM was confident that through the experience gathered from the Previous Studies, an accuracy of around 1-2 m was achieved (with the use of high-accuracy Differential GPs system,i.e.*Leica GPS1200+*). This statement was based on familiarity with the satellite imagery and information and a critical analysis of the survey work conducted in the aforementioned studies. In addition, each of the qualified ecologists was supported by a land surveyor to enhance the mapping accuracy during the field surveys. Field computers were used to assist in field truthing surveys.



("▬" represents optimal survey period)

Figure 6.2

Optimal Survey Periods for Specific Habitat Types

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6.3.1 Collection of Field Data

Two main types of data were collected in the filed:

- Point data – This included habitat type, weather, mapping accuracy, field photographs and some ecological value information, eg species information, etc; and

- Polygonal data – Polygons were drawn where areas of habitat had changed from that mapped in the previous habitat mapping exercise.

Point Data: *Proformas* was developed to assist surveyors in inputting the above data while in the field. These had validation mechanisms built in so that information was recorded systematically.

Polygonal Data: Changes in habitat areas previously mapped are mapped by surveyors as an "edit mask" polygons layer. The polygons were drawn directly over the habitat map base on the Pocket PC and indicated to what type the habitat category should be changed.

In addition to the field computer, surveyors also carried with them a hard copy site plan onto which they could mark the field observations, in case they might need to do so. Surveyors marked the field truthing survey points with raw GPS data tagged with time and date, and recorded one 360° panoramic digital photograph for each survey point and made the boundary of habitat during the ground truthing survey. Surveyors ensured that maximum utilization of survey effort could be achieved and duplication of effort avoided.

The specific methodology used for each of the proposed habitat types to be surveyed for the habitat verification (general and supplemental) and ecological value assessment are presented in the following sections.

6.3.2 Plantation

Objective: Habitat Verification (HV)

Ground truthing of the habitat was achieved by checking the habitat type, location and boundary against the preliminary habitat map using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the plantation in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during the field surveys. This information included the following components:

- naturalness of the habitat;
- size of the habitat;
- structural complexity (i.e. openness of the canopy, canopy stratification and status of the under-storey vegetation);
- number and abundance of faunal and floral species groups;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of recognised ecologically important habitats in close proximity to the survey area which contained like habitats within it were also noted as this increased the opportunity for the study area to support animals which were of ecological importance. Similar to other forest habitat types, Plantation has no evident seasonal trend in ecological resources and, therefore, this habitat could be surveyed at any time during the survey period. Surveys are undertaken in March, April and May 2009. The survey effort allocation for the Plantation habitat category, and the survey locations are presented in *Figure 6.3*.

6.3.3 Lowland Forest

Objective: Habitat Verification (HV)

Ground truthing of the habitat were achieved by checking the habitat type, location and boundary against the preliminary habitat map using a hand held Window's CE PC with GIS software linked to GPS unit. Field data was inputted directly into an electronic database during the survey, and the boundary of the Lowland Forest in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during the field surveys. This information included the following components:

- naturalness of the habitat;
- size of the habitat;
- structural complexity (i.e. openness of the canopy, canopy stratification

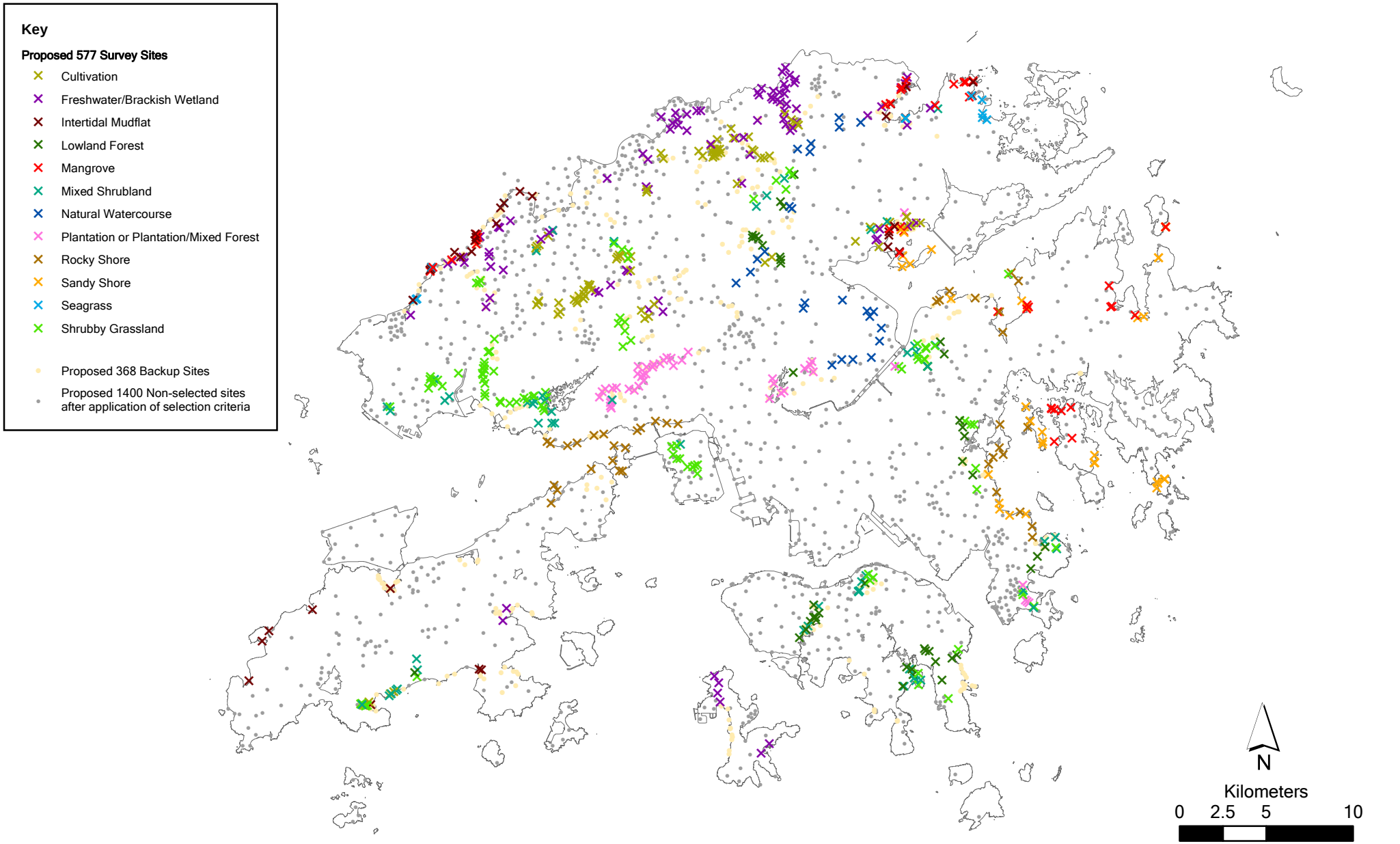

Figure 6.3

The Spatial Distribution of 2345 Sites (with 577 sites + 368 backup sites + 1400 non-selected sites) Selcted for Field Survey by Random Sampling Based on Desktop Truthing of 2009 Preliminary Map

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and status of the under-storey vegetation);

- number and abundance of faunal and floral species groups;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of recognised ecologically important habitats in close proximity to the survey area which contains like habitats within it were also noted, as this may increase the opportunity for the study area to support animals which are of ecological importance. Similar to other forest habitat types, Lowland Forest has no evident seasonal trend in ecological resources and, therefore, this habitat could be surveyed at any time during the survey period. Surveys were undertaken in March and April 2009. The survey effort allocation for the Lowland Forest habitat category, and the survey locations are presented in *Figure 6.3*.

6.3.4 Mixed Shrubland

Objective: Habitat Verification (HV)

The habitat type, location and boundary of an identified Mixed Shrubland habitat were checked against the preliminary habitat map and using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the Mixed Shrubland in the map were marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during the field surveys. The information included the following aspects:

- naturalness of the habitat;
- size of the habitat;
- structural complexity (i.e. openness of the habitat and habitat heterogeneity);
- number and abundance of faunal and floral species groups;

- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of recognised ecologically important habitats in close proximity to the survey area which contains like habitats within it were also noted as this may increase the opportunity for the study area to support animals which are of ecological importance. Since the habitat shows no optimal survey periods, Mixed Shrubland surveys could be conducted at any time during the survey period. Surveys were undertaken in March and April 2009. The survey effort allocation for the Mixed Shrubland habitat category, and the survey locations are presented in *Figure 6.3*.

6.3.5 Freshwater/Brackish Wetlands

Objective: Habitat Verification (HV)

The habitat type, location and boundary of the visited Wetlands were checked against the preliminary habitat map and using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the Freshwater/Brackish Wetlands in the map were marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat. The tidal cycle or water level was considered in planning of field truthing of the Freshwater/Brackish Wetlands to ensure they were assessable on the survey date.

Objective: Ecological Value Assessment (EVA)

The ecological value assessment of the Wetland was conducted based on compilation of information including:

- naturalness of the habitat;
- size of the habitat;
- type of wetland (eg, marsh, reedbed, pool and pond) (1);
- salinity of the habitat waters;
- number and abundance of faunal and floral species groups encountered;

(1) The types of wetlands are taken from Dudgeon and Chan (1996) which include marsh, reedbed, pool and pond. Additional categories would be defined in the field, if necessary.

- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

Salinity of the wetland waters was measured using an optical refractometer to distinguish the brackish (> 10 ppt) [1] habitats from the freshwater ones as this information could assist in characterising species assemblages and hence in determining the value of individual wetland sites. The number of animal and plant species groups encountered along a walking transect was recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of macroinvertebrates (eg dragonfly larvae), as well as vertebrates (eg fish and amphibian), were also noted. Disturbance to Wetland habitats and associated wildlife was minimised during the surveys. Two sampling methodologies were adopted for macroinvertebrates depending on the nature of the Wetland habitat under survey. For Wetlands which had been overgrown with vegetation and lacked extensive areas of open waters, surveyors would try to look for as many microhabitats as possible, including deep and shallow waters, shaded and unshaded areas, and in and around as many vegetation and substratum types as represented at the survey site. For Wetlands where there were extensive areas of open waters (eg ponds), surveyors paid more attention to areas close to the pond banks, in and around emergent and submerged vegetation, where animals tend to congregate. Wetland surveys are preferably carried out during the wet season when the habitat resources were more likely to be detected. Surveys were undertaken in April and May 2009. The survey effort allocation for the Wetland habitat category, and the survey locations are presented in *Figure 6.3*.

6.3.6 Natural Watercourse

Objective: Habitat Verification (HV)

The habitat type and extent/boundary of the watercourses selected for surveying were uploaded on a hand held Window's CE PC with GIS software linked to GPS unit and checked against the information on the preliminary habitat map. Field data were inputted directly into an electronic database during the survey, and the extent of the natural watercourse was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value assessment of the Natural Watercourse was conducted based on compilation of information including:

- naturalness of the habitat;

(1) Dudgeon D and Chan EWC (1996). Op cit.

- size of the habitat;
- water quality (i.e. turbidity, water flow rate);
- nature of the substratum (i.e. coarseness of particles);
- number and abundance of floral and faunal species groups observed;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

Since a highly turbid, stagnant watercourse tended to have a lower ecological value, turbidity and water flow condition of a habitat were also noted during field visits. The nature of the substratum,i.e.whether it was composed of large pebbles or fine mud, was also described as it could affect the habitat value through a variation in its ability to provide shelter for stream organisms. The number of animal species groups encountered along a walking transect of the habitat was recorded with particular attention devoted to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). Animals living under rocks (eg mayfly nymph) were recorded through active searching. Disturbance of watercourse habitats and wildlife were minimised during the surveys. Animals living in deep and shallow waters, and shaded and unshaded areas, as well as areas closed to the river banks, and in and around emergent and submerged vegetation where animals tend to congregate, were noted. In addition to the characteristics described above, the degree of shade and presence of notable amount of detritus were noted as they were regarded as important attributes of natural watercourse (1). Watercourse surveys are preferably conducted during the wet season when the habitat resources (eg insect larvae, fish) were more likely to be detected. Surveys were undertaken in May 2009. The survey effort allocation for the natural watercourse, and the survey locations are presented in *Figure 6.3*.

6.3.7 Intertidal Mudflat

Objective: Habitat Verification (HV)

Ground truthing of the habitat type and boundary of Intertidal Mudflat were achieved by checking the locations and boundaries of the habitats against the preliminary habitat map prepared for the Previous Studies wherever possible (i.e. some of the mudflats may be very soft in texture making surveying dangerous) by using a hand held Window's CE PC with GIS software linked to GPS unit. Field data was inputted directly into an electronic database during the survey, and the boundary of the intertidal mudflat in the map were marked and amended *in situ*. 360° panoramic digital photographs were

(1) David Dudgeon and Richard Corlett (2004). *The ecology and Biodiversity of Hong Kong*.

taken to show the general condition of the habitat. The tidal cycle or water level was considered in planning of field truthing of the Intertidal Mudflat to ensure they are assessable on the survey date.

Objective: Ecological Value Assessment (EVA)

The ecological value assessment of the Intertidal Mudflat was conducted based on compilation of information including:

- naturalness of the habitat;
- size of the habitat;
- number and abundance of macrofaunal species groups;
- presence of "rare" species (if any);
- presence of known ecologically important areas (eg Seagrass Beds) in its vicinity (if any); and,
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). Presence of other mobile fauna, such as crabs, fishes and mudskippers, were also recorded. Any signs of the presence of species of conservation importance (eg horseshoe crabs) were also noted. Any birds sighted as well as footmarks left by them (eg egrets) on the mudflat surface were also recorded. Any on-going construction activities nearby or other disturbances, such as the discharge of pollutants into the habitat, were also recorded as these may cause degradation to the ecological status of the survey habitat. Field surveys on Intertidal Mudflats were undertaken in May and June 2009. The survey effort allocation for the Intertidal Mudflat habitat category and the survey locations are presented in *Figure 6.3*.

6.3.8 Mangrove

Objective: Habitat Verification (HV)

"Spot-checking" of the habitat type and boundary of Mangrove stands was achieved by checking the locations and boundaries of the stands against the habitat map prepared for the Previous Studies using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the Mangrove in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value assessment of the Mangrove was conducted based on compilation of information including:

- naturalness of the Mangrove stand;
- size of the habitat;
- number and abundance of mangrove plant species groups;
- number and abundance of benthic macrofaunal species groups;
- presence of "rare" species (if any);
- presence of known ecologically important areas (eg fish spawning grounds) in its vicinity (if any); and
- degree of disturbance and damage (if any).

The distribution of the flora in each stand was measured by transect and quadrat analyses. Two transects were laid perpendicularly to the shoreline covering the extent of the Mangrove community from land to sea. Along each transect, three quadrats (3m x 3m) were laid to record the type and abundance of the floral and macrofaunal species groups present, as well as the presence of plant seedlings. Special attention was devoted to the presence of ecologically important floral and faunal species groups. Any on-going construction activities nearby or other disturbances, such as the discharge of pollutants into the habitat, were also recorded as these may cause degradation to the ecological status of the surveyed habitat.

As there was no seasonal restriction on the survey period for Mangroves, surveys were conducted at any time when the tide was low enough to expose the habitat. Surveys were undertaken during the period between May and June 2009. The allocation of survey effort for Mangrove habitats and the survey locations are presented in *Figure 6.3*.

6.3.9 Seagrass

Objective: Habitat Verification (HV)

Ground truthing of the habitat type and boundary of Seagrass was achieved by checking the locations and boundaries of the habitats against the preliminary habitat map prepared for the Previous Studies wherever possible by using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the boundary of the Seagrass in the map were marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat. The tidal cycle or water level was considered in planning of field truthing of the Seagrass to ensure the sites were accessible on the survey date.

Objective: Ecological Value Assessment (EVA)

The ecological value assessment of the Seagrass was conducted based on compilation of information including:

- naturalness of the habitat;
- size of the habitat;
- number and abundance of macrofaunal species groups;
- presence of "rare" species (if any);
- presence of known ecologically important areas (eg Mangrove) in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). Presence of other mobile fauna, such as crabs, fishes and mudskippers, were also recorded. Any signs of the presence of species of conservation importance (eg horseshoe crabs) were also noted. Any birds sighted as well as footmarks left by them (eg egrets) on the mudflat surface were also recorded. Any on-going construction activities nearby or other disturbances, such as the discharge of pollutants into the habitat, were also recorded as these may cause degradation in the ecological status of the survey habitat. Field surveys on Seagrass were undertaken in May and June 2009. The survey effort allocation for the Seagrass habitat category and the survey locations are presented in *Figure 6.3*.

6.3.10 Shrubby Grassland

Objective: Habitat Verification (HV)

The habitat type, location and boundary of identified Shrubby Grassland habitat were checked against the preliminary habitat map using a hand held Window's CE PC with GIS software linked to GPS unit. Field data was inputted directly into an electronic database during the survey, and the boundary of the Shrubby Grassland in the map were marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during the field surveys. The information compiled included the following aspects:

- naturalness of the habitat;

- size of the habitat;
- structural complexity (i.e. openness of the habitat and habitat heterogeneity);
- number and abundance of faunal and floral species groups encountered;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of recognised ecologically important habitats in close proximity to the survey area which contains like habitats within it were also noted as this may increase the opportunity for the study area to support animals which are of ecological importance. Surveys on Shrubby Grassland took place in March and April 2009. The allocation of survey effort for the habitat category and the survey locations are presented in *Figure 6.3*.

6.3.11 Sandy Shore

Objective: Habitat Verification (HV)

The habitat type and extent of a Sandy Shore were verified by checking against the preliminary habitat map and using a hand held Window's CE PC with GIS software linked to GPS unit. Field data was inputted directly into an electronic database during the survey, and the extent of the Sandy Shore in the map were marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat. The tidal cycle or water level was considered in planning of field truthing of the Sandy Shore to ensure the sites were accessible on the survey date.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during field surveys. A general description of the habitat included the following components:

- naturalness of the habitat;
- size of the habitat;
- water quality (i.e. turbidity);
- nature of substratum;

- number and abundance of faunal and floral species groups encountered;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

A walking transect method (similar to Intertidal Mudflat) was employed to record the areal extent of the area and epifaunal species information. Infaunal species were recorded by taking core samples (size: 50 x 50 x 50 cm [(1)]) (5 - 15 replicates per site depending on habitat size) randomly, covering high, mid and low shore regions. All the macrofaunal organisms within the core were recorded. Sandy shore surveys can be conducted at any time of the year. Surveys were undertaken in April, May and June 2009. The survey effort for the Sandy Shore habitat type and the survey locations are presented in *Figure 6.3*.

6.3.12 Rocky Shore

Objective: Habitat Verification (HV)

"Spot-checking" of the habitat type and extent of a Rocky Shore were achieved by checking the location and extent of the shore against the preliminary habitat map and using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the extent of the Rocky Shore in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat. The tidal cycle or water level was considered in planning of field truthing of the rocky shore to ensure the sites were accessible on the survey date.

Objective: Ecological Value Assessment (EVA)

The ecological value of the habitat was determined based on the information collected during field surveys. A general description of the habitat included the following components:

- naturalness of the habitat;
- size of the habitat;
- water quality (i.e. turbidity);
- nature of substratum;
- number and abundance of faunal and floral species groups encountered;

(1) As some sandy shores, particularly in the low shore region, are covered with numerous cobbles of various sizes, collecting a core sample with a depth of 50 cm would be difficult. However, our surveyor has tried to collect a sample with a reasonable depth in order to make the sample as representative as possible.

- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The selected rocky shores were surveyed using a standard transect method. The data collected provided information on the composition of the faunal and floral assemblages, and productivity of the habitats. At each site three 10 m wide horizontal (belt) transects were set up along the shore (no less than 50 m apart) and surveyed at three heights up the shore at 50 cm intervals perpendicular to the waterline starting at 1.0 m above Chart Datum. On each transect, 10 quadrats (0.5 x 0.5 m) were placed randomly to assess the distribution of flora and fauna. All animals found in each quadrat were recorded. The percentage cover of algae (including encrusting, foliose and filamentous algae) within each quadrat was also recorded.

The changes in physical conditions between seasons in Hong Kong cause marked changes in the species composition of Rocky Shore communities. Several surveys on local Rocky Shores (eg, Kennish *et al* (1996) and Kaehler and Williams (1996)) have demonstrated that algal and faunal diversity and abundance are highest during the dry season and lowest during the wet season. On the basis of this, field surveys for the Rocky Shores were preferably scheduled during the dry season in order to best establish and evaluate the ecological value of the survey shores. Surveys were undertaken from the end of March to April 2009. The survey effort for the Rocky Shore habitat type and the survey locations are presented in *Figure 6.3*.

6.3.13 Cultivation

Objective: Habitat Verification (HV)

Ground truthing of Cultivation habitat were achieved by checking the habitat type, location and boundary of the habitat against the preliminary habitat map and using a hand held Window's CE PC with GIS software linked to GPS unit. Field data were inputted directly into an electronic database during the survey, and the extent of the habitat in the map was marked and amended *in situ*. 360° panoramic digital photographs were taken to show the general condition of the habitat.

Objective: Ecological Value Assessment (EVA)

The ecological value of Cultivation was assessed based on the following information collected during the field surveys:

- management status of the cultivation (i.e. active, abandoned, fallow, etc);
- size of the habitat;
- structural complexity (i.e. openness of the habitat and habitat heterogeneity);

- number and abundance of faunal and floral species groups encountered;
- presence of "rare" species (if any);
- presence of known ecologically important areas in its vicinity (if any); and
- degree of disturbance and damage (if any).

The number of animal and plant species groups encountered along a walking transect were recorded, with particular attention being directed to the presence of "rare" species and dominant species (dominant being defined as occurring in > 80% of the defined area). The presence of recognised ecologically important habitats in close proximity to the survey area which contains like habitats within it was also noted as this may increase the opportunity for the study area to support animals which are of ecological importance. As it is desirable to conduct surveys on a habitat when its resources are more likely to be observed, surveys on Cultivation were scheduled during the wet season (i.e. April and May 2009) when organisms such as odonates and amphibians were most likely to be present, and were predominantly carried out in April 2009. The allocation of survey effort for Cultivation habitats and the survey locations are presented in *Figure 6.3*.

6.4 SURVEY PROGRAMME

Field truthing surveys were conducted by the Field Truthing Survey Team which was a team of qualified terrestrial and coastal ecologists for terrestrial and coastal habitats, respectively. Wherever possible, all surveys were conducted during the period (if known) when the ecological value of the habitat was most apparent thus most accurately recorded. In addition, all surveys of individual habitat types were scheduled during the same period and conducted, where possible, by the same ecology specialist in order to allow direct compatibility of results within a habitat type and individual consistency among surveyors.

6.4.1 Seasonal Constraints

The Present Study team was fully aware of the seasonal constraints for ecological field assessments and that some of the mapped habitats had an optimal survey period limited to certain months of the year (*Figure 6.2*).

6.4.2 Summary

This *Final Report* has presented the rationale for utilising 80 field survey days allocated under the Present Study to verify the habitat categories assigned through initial, desktop mapping exercises, and to investigate the ecological value of the habitats at individual sites. Survey effort was provisionally allocated to 12 selected habitat types that have either high or medium indicative ecological value as shown in *Table 6.1*

Table 6.1 Proposed Field Survey Sites allocated to each habitat

Habitat	Proposed No. of Field Survey Sites
Lowland Forest	37
Mixed Shrubland	51
Freshwater/Brackish Wetland	87
Natural Watercourse	22
Mangrove	37
Seagrass	22
Intertidal Mudflat	36
Shrubby Grassland	98
Plantation (plantation services inside and outside country parks)	34
Sandy Shore	34
Rocky Shore	35
Cultivation	84
TOTAL	**577**

More field survey sites were devoted to high ecological value that is of comparatively low mapping accuracy based on the results from the 2007 Study. Survey methodologies were proposed based on those that were adopted in the previous 2005 and 2007 Studies with minor modifications proposed for consideration and approval by the Director's representatives.

Individual survey sites were identified with rationale for selection. The results of the field surveys were used to adjust the mapped boundaries of habitats at particular sites and, if warranted, to upgrade or downgrade the indicative ecological value assigned on the basis of criteria agreed in the *Inception Report* prepared for the Present Study.

6.5 FIELD TRUTHING SURVEY TEAM

In order to provide a dedicated and focused service, the overall Present Study Team was divided into three individual teams. The **Study Management Team** had ultimate responsibility for the Present Study Programme and the quality of all deliverables, whereas, the **Field Truthing Survey Team** were responsible for the coordination and conduct of all necessary field truthing surveys, and finally the **Remote Sensing** and **Geographical Information System (GIS) Team** maintained the data integrity of satellite image, incorporated all field data and updated the interface GIS habitat map. Key staff members for each team are presented below with a short Curriculum Vitae.

6.6 TEAM MEMBERS

The **Field Truthing Survey Team**, was led by the *Study Manager* **Terence Fong**. He was responsible for the review and comparison of available information for habitats, collecting field data for habitat verification and conservation value assessment of habitats. Mr. Fong was supported by a highly experienced team of terrestrial ecology specialists, including **Karen Lui, Jasmine Ng, Jovy Tam, Francesca Zino, Elizabeth West, Yasmin Chir,**

Pang Chun Chui and **Sung Yi Hei** and land survey specialists including **Ng Kin Sun, Cheung Kam Fai**, **Fung Chun, Chan Chi Won** and **Law Tat Keung.**

Ecology Specialist: Ms Karen Lui *BSc (Hons), MPhil*

Ms Lui is an ecologist with ERM - Hong Kong's Marine Science and Ecology Team with experience in ecological assessments. Ms Lui has sound knowledge and experience in ecology and water science with a good understanding of the both the terrestrial and marine environment of Hong Kong. Her experience includes conducting baseline vegetation and marine surveys for various kinds of projects, conducting eco-tours for the communities and leading educational field survey workshops. Previously working in WWF Hong Kong, Ms Lui was the Project Co-coordinator of a wetland conservation project for two wetland nature reserves in South China. She was responsible of overseeing the implementation and administration of the project. The works include the development and implementation of a conservation plan to protect biodiversity and the habitats, and the co-management of local communities to achieve wise-use concepts. Ms Lui conducted surveys for the following habitat types: Freshwater/Brackish Wetland, Mangrove, Seagrass, Intertidal Mudflat, Sandy Shore, Rocky Shore and Cultivation.

Ecology Specialist: Dr Jasmine Ng *BSc (Hons), PhD*

Dr Ng is a marine scientist with ERM's Marine Science and Ecology Team with experience in ecological assessments. Dr Ng specializes in marine ecology with extensive experience in conducting ecological surveys in coastal habitats. She has undertaken various quantitative ecological baseline studies/surveys and led various intertidal baseline field surveys associated with local environmental impact assessment projects. During her postgraduate studies, she undertook demonstration duties for numerous undergraduate/ postgraduate courses at The University of Hong Kong, and was responsible for introducing survey techniques of coastal habitats (especially mangroves, rocky shores, sandy shores and subtidal habitats) and teaching basic knowledge of species diversity and coastal ecology. Dr Ng conducted surveys for the following habitat types: Rocky Shore.

Aquatic Ecology Specialist: Mr Jovy Tam *BSc (Hons), MPhil*

Mr Tam is an ecologist with ERM's Ecology and Marine Science Group with experience in conducting aquatic ecological field surveys. Mr Tam is an aquatic ecology specialist and he was working for the AFCD as ecology surveyor from January to August 2006. Mr Tam was responsible for the conservation work of freshwater fish and his major duty was to carry out assessment of freshwater fishes and the freshwater environment where those fishes were found. The scope of ecological survey covered a diverse range of freshwater habitats, which included highland streams, lowland steams, estuaries, marshes and reservoirs that distributed all over Hong Kong. Besides the survey of freshwater life, Mr Tam also performed water quality analysis for stream environment in Hong Kong. Mr Tam was also involved in the

Ecological Monitoring and Visitors' Impact Assessment in Hoi Ha Wan, Tung Ping Chau Marine Parks: 2005-2005. He conducted the field survey works for the previous study **2006 Update of Terrestrial Habitat Mapping and Ranking Based on Conservation Value (2007 Study)** for aquatic flora and fauna identification and ecological assessment of the surveyed habitats. Mr Tam conducted surveys for the following habitat types: Natural Watercourse.

Ecology Specialist: **Ms Francesca Zino** *BA (Hons), MSc*

Ms Zino is an ecologist with ERM's Ecology and Marine Science Group. She has experience in terrestrial ecological surveys and marine ecological surveys having been involved in habitat, bird and intertidal surveys. Miss Zino conducted surveys for the following habitat types: Lowland Forest, Mixed Shrubland, Shrubby Grassland, Plantation, Cultivation, Freshwater/Brackish Wetland, Sandy Shore, Rocky Shore, Intertidal Mudflat, Mangrove and Seagrass.

Ecology Specialist: **Dr Elizabeth West** *BSc (Hons), PhD*

Dr West is a marine scientist with ERM's Ecology and Marine Science Group. Elizabeth completed her Bachelor of Science and Honours degrees and her Doctor of Philosophy (PhD) degree in Australia. Dr West has extensive experience in experimental design and statistical analyses. She has also conducted extensive marine field research, including sampling intertidal invertebrates, plankton, sponges, jellyfish, algae, seagrasses, mangroves and fish. Further, she has had experience in sampling terrestrial habitats, including plant, bat, bird and insect surveys. Dr West conducted surveys for the following habitat types: Rocky Shore, Sandy Shore, Intertidal Mudflat, Mangrove and Seagrass.

Ecology Specialist: **Ms Yasmin Chir** *BSc (Hons), MSc*

Ms Chir is a Consultant with ERM's Ecology and Marine Sciences Group with over 5 years experience in terrestrial ecology, particularly in plant science. Ms Chir has extensive experience in environmental management, vegetation and tree surveys, and horticulture knowledge. She has performed monitoring and supervisory function for numerous projects in Hong Kong and Canada. Ms Chir conducted surveys for the following habitat types: Lowland Forest, Mixed Shrubland, Shrubby Grassland, Plantation, Cultivation, Freshwater/Brackish Wetland, Intertidal Mudflat, Mangrove and Seagrass.

Terrestrial Ecology Specialist: **Mr Pang Chun Chui** *BSc (Hons) MPhil*

Mr. Pang is an independent terrestrial ecologist with solid field experience in conducting biodiversity surveys. Mr. Pang is an experienced vegetation and habitat surveyor. He is familiar with the local flora and able to identify most native plant species including ferns, gymnosperms and angiosperms. He has worked for the Conservancy Association and the 10-year Extended LPM Project for vegetation and habitat surveys. He is able to identify at least 1,500

plant species in Hong Kong. Through a summer internship at AFCD, Mr Pang has been trained in bat survey techniques including mist netting and has field experience in these techniques. Mr. Pang has a great deal of experience as a birdwatcher. He is also an accredited bird surveyor for HKBWS with a lot of bird counting experience. Mr. Pang is conversant with the reptiles and amphibians of Hong Kong and has previously undertaken night surveys for recording amphibians and reptiles including during internship at AFCD. Mr Pang conducted surveys for the following habitat types: Lowland Forest, Mixed Shrubland, Shrubby Grassland, Plantation, Cultivation and Freshwater/Brackish Wetland.

Terrestrial Ecology Specialist: **Mr Sung Yi Hei** *BSc (Hons) MPhil*

Mr Sung is an independent terrestrial ecologist with strong field experience in conducting biodiversity surveys. He is an experienced biodiversity surveyor specializing in herpetofauna and birds. He has worked for the Herpetofauna surveys in Long Valleys Conservancy Association where he learned the identification of wetland herpetofauna. He is accredited to be a regular surveyor for Hong Kong Waterbirds Count and the Bird Monitoring Programme in Nature Conservation Management for Long Valley organized by Hong Kong Bird Watching Society and Conservancy Association. He is able to identify at least 500 plant species in Hong Kong. Mr Sung conducted surveys for the following habitat types: Lowland Forest, Mixed Shrubland, Shrubby Grassland, Plantation, Cultivation and Freshwater/Brackish Wetland.

Land Surveyors:

Mr Ng Kin Sun is a Chief Surveyor at Winson Engineering Survey Co. He has over 30 years experience on land survey and is member of "The Hong Kong Institution of Engineering Surveyors".

Mr Cheung Kam Fai is a Chief Surveyor at Winson Engineering Survey Co., with over 20 years experience on land survey.

Mr Fung Chun Wai is a Surveyor at Winson Engineering Survey Co., with over 12 years experience on land survey.

Mr Chan Chi Won is a Surveyor at Winson Engineering Survey Co., with over 16 years experience on land survey.

Mr. Law Tat Keung is a Surveyor at Winson Engineering Survey Co., with over 12 years experience on land survey.

7 RESULTS OF FIELD TRUTHING SURVEY

7.1 INTRODUCTION

The major findings on habitat mapping accuracy and ecological value ranking of individual habitat types that were selected for field surveys are discussed in the following sections. The total area surveyed for each habitat category in the Present Study is shown in *Table 7.1*. The field data collected have been analysed with reference to the results obtained in the Previous Studies. The number and percentage of partially or wholly mis-identified sites for each habitat category are provided in *Tables 7.3* to *7.13*.

For sites where habitat areas have been re-classified, the re-classified habitat categories and the rationale for the re-classification are presented in *Annex D*. The percentage value of mis-identified habitat area provided for each site in *Annex D* was calculated using GIS rather than the surveyor's *in situ* judgement in the field. For GIS, the total accurate area of habitat was given as a percentage of the total area of habitat surveyed.

The sites where ecological value was re-adjusted and the reason for the re-adjustment are summarised in *Annex E*. The unique features (i.e. whether the site fell within a country park or SSSI) that were identified for individual habitats during the field surveys are listed in *Annex F*.

The field data of each surveyed habitat collected from the field surveys are provided in *Annex G*. In addition, the outstanding information gaps filled by the Present Study and information gaps yet to be filled are also discussed in this Section.

Table 7.1 Total Area Surveyed for Each Habitat Category Selected for Field Surveys in Present Study

Habitat Type	Total Area Surveyed (ha)	% Area Surveyed
Indicative Ecological Value - High		
Lowland Forest	408.24	17.47
Mixed Shrubland	358.55	15.34
Freshwater/Brackish Wetland	246.44	10.55
Natural Watercourse	22.61	0.97
Mangrove	25.41	1.09
Seagrass Bed	6.01	0.26
Intertidal Mudflat	194.80	8.34
Indicative Ecological Value - Medium		
Shrubby Grassland	618.26	26.46
Plantation or Plantation/Mixed Forest	120.58	5.16
Sandy Shore	50.44	2.16
Rocky Shore	99.03	4.24
Cultivation	186.26	7.97

7.2 SURVEY DAYS AND SURVEY SITES

Although 80 survey days were allocated for field truthing to cover 577 survey sites, in reality a total of 84 field survey days were completed covering 610 sites. This was due to the following reasons:

- Weather conditions sometimes prevented enough sub-sites being completed in one field survey day meaning further time had to be allocated to that habitat type; and
- Some habitats were much less accessible, meaning a lot of the working day was taken up reaching the sub-sites for field truthing and hence less sub-sites were completed on that day.

The proposed and actual numbers of field survey sites are shown in *Table 7.2*

Table 7.2 Proposed and Actual Field Survey Sites allocated to each habitat

Habitat	Proposed No. of Field Survey Sites	Actual No. of Field Survey Sites
Lowland Forest	37	44
Mixed Shrubland	51	55
Freshwater/Brackish Wetland	87	92
Natural Watercourse	22	24
Mangrove	37	43
Seagrass	22	13[1]
Intertidal Mudflat	36	35
Shrubby Grassland	98	99
Plantation (plantation services inside and outside country parks)	34	43
Sandy Shore	34	38
Rocky Shore	35	39
Cultivation	84	85
TOTAL	**577**	**610**

7.3 MAPPING ACCURACY OF HABITAT IN PREVIOUS AND CURRENT STUDIES

7.3.1 Lowland Forest

Previous Studies

A total of 278 sub-sites (approximately 1,113 hectares) were surveyed in the 2003 Study. The mapping accuracy of most of the sub-sites was moderate. A number of the habitat areas being re-classified as Fung Shui Forest, Mixed Shrubland, Plantation or Plantation/Mixed Forest, Shrubby Grassland, Cultivation and Other. The field surveys conducted for the 2005 Study covered a total of 98 sites. 70 sites (71.43%) were mapped correctly as Lowland Forest. The other sub-sites were identified with varying degrees of

(1) Due to the scattered distribution of Seagrass Bed in Hong Kong, the small size of Seagrass Bed patches and the time constraints on tidal change, it was not possible to conduct 22 survey sites within 3 survey days.

accuracy and were re-classified either as mixed Shrubland, Natural Watercourse, Shrubby Grassland and Grassland. The 2007 Study surveyed 70 sites of Lowland Forest to verify the habitat's mapping accuracy and ecological value. The mapping accuracy of most of the sites was very high (98.57%) with only one site being re-classified as Plantation (Plantation services inside country parks).

Present Study

The Present Study surveyed 44 sites of Lowland Forest to verify the habitat's mapping accuracy and ecological value. Field surveys for this habitat category commenced on 10th March 2009 and were completed on 14th May 2009 (*Annex G, pages 2-5*).

Habitat Mapping: A total of 44 survey sites were surveyed within the survey period. The location of the sites is presented on *Figure 7.1*. The mapping accuracy of most of the sites is very high (43 out of 44, 97.73%) with only one site (LF44) being re-classified as Plantation (plantation services inside country parks) *(Annex D1).*

Site LF44 was re-identified as Plantation as it was dominated by the exotic tree species, *Acacia confusa* and *Acacia auriculiformis* (*Table 7.3*). Mis-identification of Plantation as Lowland Forest was likely due to the proximity of the spectral properties of these vegetation habitats and their tendency to intermingle with each other.

Table 7.3 Number and Percentage of Lowland Forest Mis-identified Sites (Total Number of Sites Surveyed = 44)

Habitat Type of Mis-identified Area	Number of Sites	Percentage (%) of Total Number of Surveyed Sites
Plantation	1	2.27

Ecological Value Assessment: The majority of the Lowland Forest surveyed showed high species diversity, and were predominantly open to moderately open with only a few sites having closed canopy. They were mostly moderately stratified. There was abundant to frequent under-storey vegetation and little human disturbance.

The re-classified Plantation habitat (LF44) was dominated by *Acacia* species. Plantation shows a relatively lower species diversity than Lowland Forest and so a lower ecological value of "Medium" was assigned to it (*Annex E1*).

The Lowland Forest habitat is natural (secondary) forest often dominated by native species with different colours and textures. Climax plant species such as *Machilus chekiangensis* and *Cinnamomum camphora* were commonly recorded in these habitat areas. In addition, these forests supported a wide range of wildlife (eg avifauna).

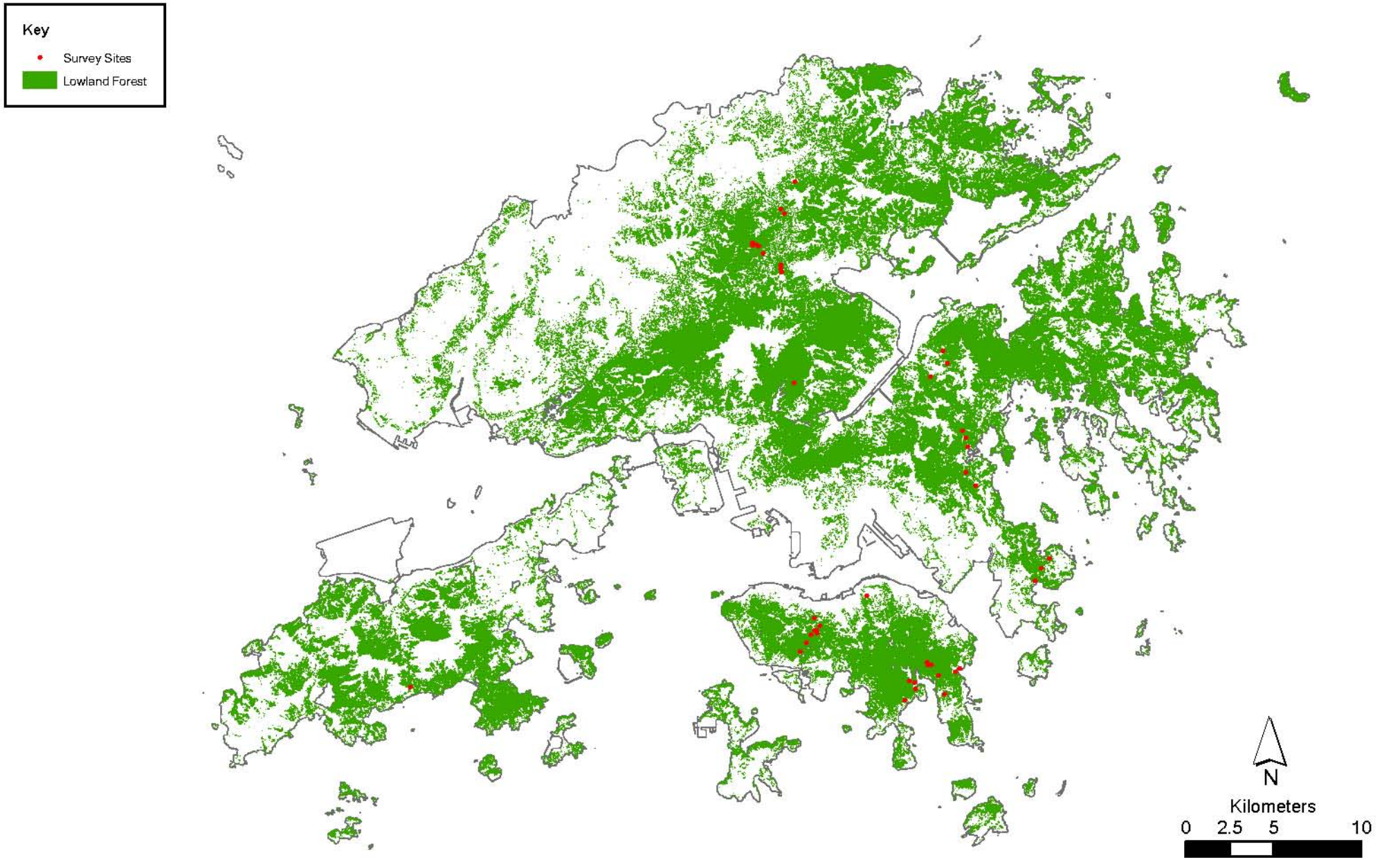

Figure 7.1

Location of Surveyed Sites of Lowland Forest Habitat

File: Surveyed_Sites\0090526_LF_SurveyedSites.mxd
Date: 11/08/2009

Environmental Resources Management

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Information Gaps

A total of about 408.24 ha (1.72%of Lowland Forest in Hong Kong) of Lowland Forest were surveyed in the Present Study. There is still Lowland Forest identified on the habitat map left unsurveyed and its habitat type and ecological value remain to be field verified.

7.3.2 Mixed Shrubland

Previous Study

A total of 309 sub-sites (approximately 867.00 hectares) were surveyed in the 2003 Study. The majority of the Mixed Shrubland surveyed out of 309 was correctly identified and no re-classification was required. The 2005 Study surveyed a total of 47 sites of Mixed Shrubland. Of the 47 Mixed Shrubland patches surveyed, 68.09% of sites (32 out of 47) were mapped accurately. Thirteen sites were mis-classified as Shrubby Grassland and two were mis-classified as Lowland Forest. The 2007 Study surveyed 65 sites of Mixed Shrubland. The majority of the Mixed Shrubland surveyed (63 out of 65, 96.92%) were correctly identified. A total of two Mixed Shrubland habitats (about 3.08% of total sites surveyed for Mixed Shrubland) were actually Lowland Forest and Shrubby Grassland.

Present Study

The Present Study surveyed 55 sites of Mixed Shrubland. The Field Survey Team commenced surveys on this habitat on 10th March 2009 and completed them on 12th May 2009 (*Annex G, pages 6-10*).

Habitat Mapping: A total of 55 Mixed Shrubland habitats were surveyed during the survey period and the locations of the sites are presented on *Figure 7.2*. The majority of the Mixed Shrubland sites surveyed (52 out of 55, 94.55%) were correctly identified.

A total of three Mixed Shrubland habitats, MSh20, MSh23 and MSh43 (about 5.45% of total sites surveyed for Mixed Shrubland) were actually Lowland Forest or Plantation (*Table 7.4*). Around 81.60% of the total area of Mixed Shrubland in polygon MSh20 and 64.10% in polygon MSh43 were re-classified as Plantation (*Annex D2*). The Mixed Shrubland near Tai Lam Country Park (Msh23) had 66.00% of its area which re-classified as Lowland Forest. The patch had medium heterogeneity with trees such as *Cinnamomum camphora* and *Sterculia lanceolata* dominating. The other patches, MSh20 and Msh43, had low habitat heterogeneity and were re-classified to Plantation. They were dominated by *Acacia, Eucalyptus* and *Ficus* species and *Syzygium jambos.*

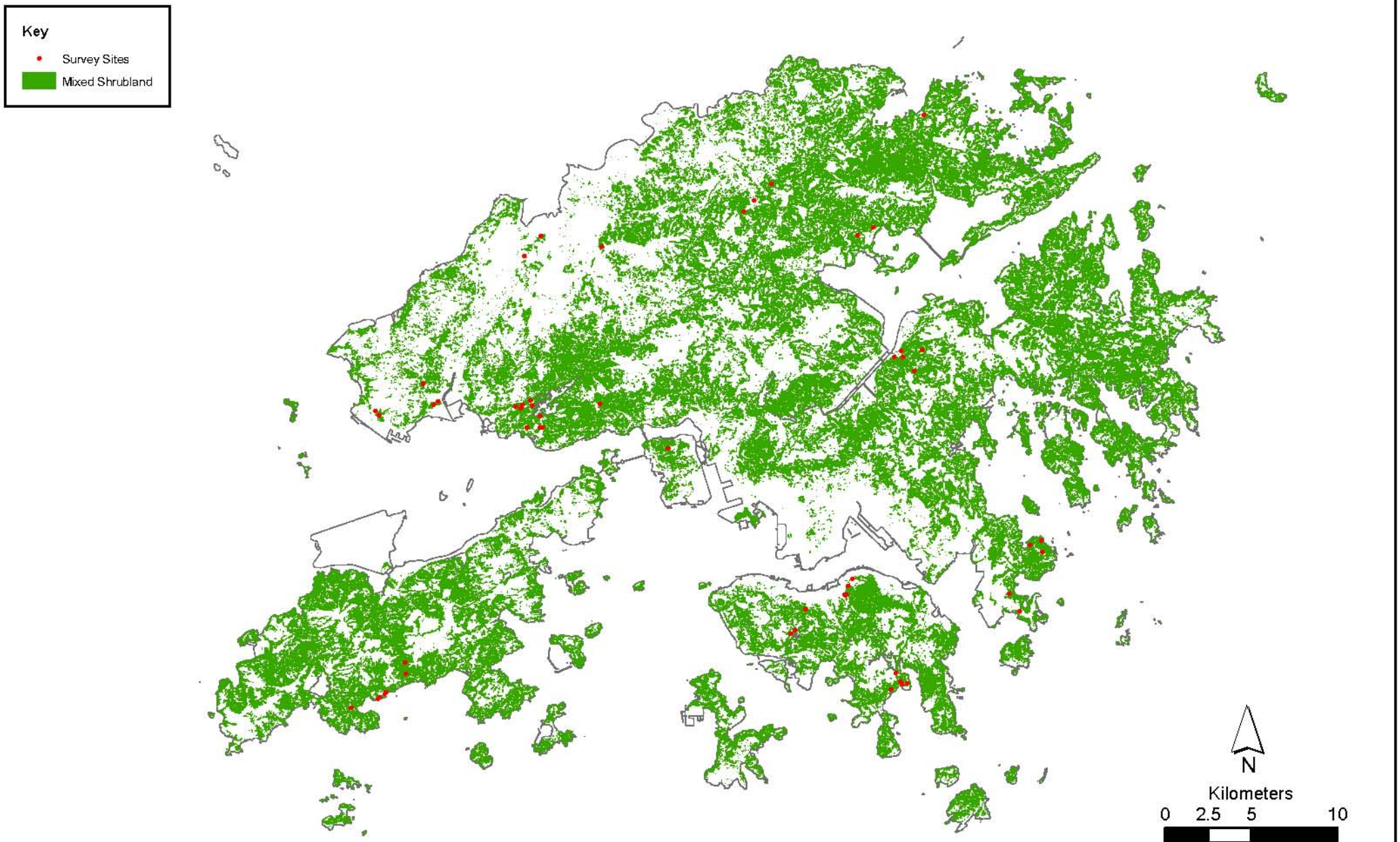

Figure 7.2

Location of Surveyed Sites of Mixed Shrubland Habitat

File: Surveyed_Sites\0090526_MSh_SurveyedSites.mxd
Date: 11/08/2009

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Table 7.4 Number and Percentage of Mixed Shrubland Mis-identified Sites (Total Number of Sites Surveyed = 55)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Lowland Forest	1	1.82
Plantation/Mixed Forest	2	3.64
	Total: 3	5.45

Ecological Value Assessment: Most of the Mixed Shrubland surveyed had slight or moderate disturbance. Only a few small patches were recorded as highly modified due to the pollution from the road or footpath nearby, or plantation habitat in the polygon. One patch was highly modified due to the presence of a pet owners club that had been built in the area. Two surveyed sites that were re-identified as Plantation were downgraded from high to medium ecological value after assessment (*Annex E2*).

Information Gaps

A total of 55 sites with a total of about 358.55 ha (1.97% of Mixed Shrubland in Hong Kong) were surveyed and verified in the Present Study. There is still Mixed Shrubland identified on the habitat map left unsurveyed and its habitat type and ecological value are yet to be confirmed.

7.3.3 Freshwater/Brackish Wetland

Previous Study

In the 2003 Study, the mapping accuracy of the Wetland habitats surveyed was considered to be moderate. About 31.73% (33 out of 104) of the total sub-sites surveyed for Wetland was found to be mapped 100% correct. The majority of the misidentified sub-sites (30 out of 71) were reclassified to Cultivation. In the 2005 Study, a total of 45 sites were visited and the mapping accuracy of Freshwater/Brackish Wetland was found to be moderate (64.44%). 29 out of 45 sites were misclassified either as Shrubby Grassland, Grassland, Cultivation or Mixed Shrubland. A total of 35 sites were visited in the 2007 Study. Most of them were located in villages in rural areas, like those in Sai Kung and Tai Mei Tuk. The mapping accuracy of the Wetland habitats surveyed was considered to be low. The majority of the misidentified sub-sites (17 out of 35) were re-classified into Other (i.e. construction site, road and car park), Cultivation, Mixed Shrubland, Mangrove, Natural Watercourse and Lowland Forest.

Present Study

The Present Study surveyed 92 sites of Freshwater/Brackish Wetland from 20th April 2009 to 12th May 2009 (*Annex G, pages 11-18*).

Habitat Mapping: A total of 92 sites of Freshwater/Brackish Wetland habitats were surveyed and the locations of the sites are presented in *Figure 7.3*. Most of them were located in villages in rural areas, like those in Nam

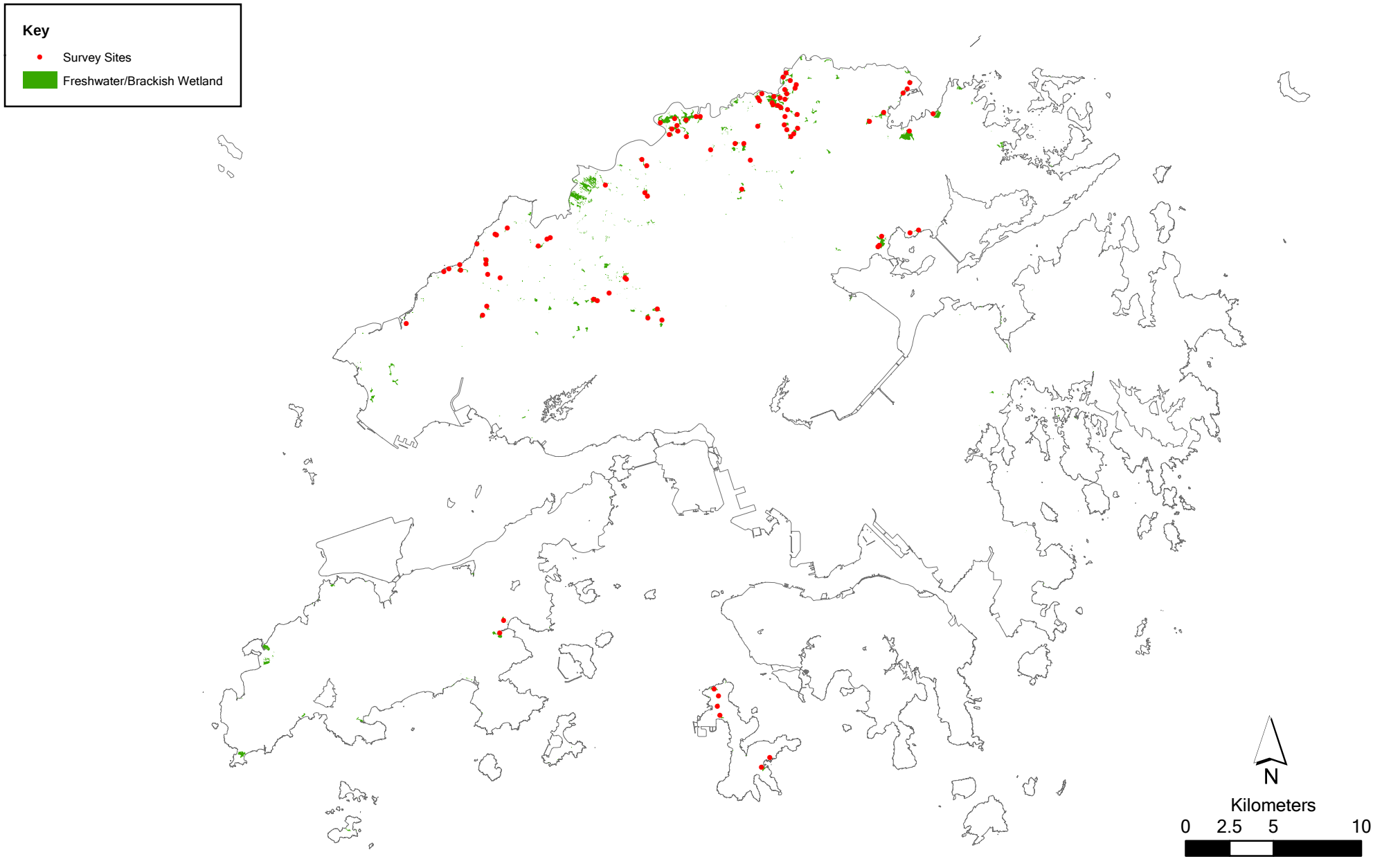

Figure 7.3

Location of Surveyed Sites of Freshwater/Brackish Wetland Habitat

File: Surveyed_Sites\0090526_FW_SurveyedSites.mxd
Date: 29/06/2009

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Sang Wai, Kam Tin and Sheung Shui. The mapping accuracy of the Wetland habitats surveyed was considered to be generally high. About 81.52% (75 out of 92) of the total sites surveyed for Wetland were found to be mapped correctly.

The majority of mis-identified sub-sites (17 out of 92) were re-classified as Grassland while there was some re-classification to Other, Fish Pond, Rural Container, Mangrove and Cultivation as well (*Table 7.5*). The sub- sites without wetland plants, water visible and filled with grass (FW01, FW09, FW18, FW47, FW82, FW83 and FW88) were re-classified as Grassland. FW27, FW41 and FW44 were actually rural container storage areas. FW08 was reclassified as Other, as it had been turned into a road and dumping area. Three sub-sites were changed to Fish Pond; FW07 and FW51 were wholly changed while FW30 was partly changed to Fish Pond and partly to Other. Two sub-sites (FW84 and FW86) had been developed into Cultivation. FW87 in Sha Tau Kok was identified as Mangrove with *Kandelia obovata* dominating this site (*Annex D3*).

Most of the surveyed sites were located in rural areas. Disturbance to the habitat due to human activities, development, dumping and change of land use to container storage was significant at these survey sites.

Table 7.5 Number and Percentage of Freshwater/Brackish Wetland Mis-identified Sub-sites (Total Number of Sites Surveyed = 92)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Cultivation	2	2.17
Other	1	1.09
Fishpond/Gei Wai	2	2.17
Fishpond/Gei Wai + Other	1	1.09
Mangrove	1	1.09
Grassland	7	7.61
Rural Industrial Storage/Container	3	3.26
Total:	17	18.48

Ecological Value Assessment: The ecological values of most Wetland sites (75 out of 92) remained unchanged. Of the 17 misclassified sites, only one remained as high ecological value; that re-classified to Mangrove (FW87). Cultivation and Fishpond/Gei Wai are deemed of medium ecological value and five of the Wetland sites (FW07, FW30, FW51, FW84 and FW86) had their ecological-value re-adjusted from high to medium. The seven sites that were re-classified to Grassland (FW01, FW09, FW18, FW47, FW82, FW83 and FW88) saw their ecological value fall from high to low. Rural Industrial Storage/Container has limited wildlife and hence a negligible ecological value, as does habitat classified as Other. Therefore four sites (FW08, FW27, FW41 and FW44) saw their ecological value drop from high to negligible (*Annex E3*).

Information Gaps

A total of 92 sites amounting to about 246.44 ha (49.53% of Freshwater/Brackish Wetland in Hong Kong) were verified in the Present Study. There remain Wetlands identified on the habitat map not surveyed in either the Previous Studies or the Present Study. The existing status and ecological value of those habitats remains to be confirmed.

7.3.4 Natural Watercourse

Previous Study

There were a total of 97 sub-sites including 34.10 hectares surveyed and verified in the 2003 Study. A total of 58 sub-sites surveyed were mapped correctly as Natural Watercourse. The mapping accuracy of the Natural Watercourse habitats after verification was moderate. The majority of the mis-mapped sub-sites (33 out of 39) were actually Modified Watercourses. A total of 34 sites of Natural Watercourse were visited in the 2005 Study. The results obtained from the previous field surveys showed that about 23.53% of the Natural Watercourse sites were mapped accurately. The low mapping accuracy of Natural Watercourse was due to difficulties in identifying small streams by remote sensing. The 2007 Study visited 35 sites to verify the habitat type and ecological ranking of Natural Watercourse. The mapping accuracy of the natural watercourse habitats after verification was high. A total of 29 sites (82.85%) were mapped correctly as Natural Watercourse. The majority of the mis-mapped sites (4 out of 6) were actually Modified Watercourses.

Present Study

The Present Study visited 24 sites to verify the habitat type and ecological ranking of Natural Watercourse. The locations of the surveyed sites are shown in *Figure 7.4*. Field surveys were conducted from 15th May 2009 to 19th May 2009 (*Annex G, pages 19-20*).

Habitat Mapping: The mapping accuracy of the natural watercourse habitats after verification was high. A total of 18 out of 24 sites (75.00%) were mapped correctly as Natural Watercourse.

All mis-mapped sites were actually Modified Watercourses. The modified watercourses (i.e., NW08, NW13, NW14, NW16, NW17 and NW24) were found to have been channelised or disturbed by construction work and thus supported low species diversity (*Table 7.6*). These channelised watercourses were therefore re-classified as Modified Watercourse (*Annex D4*) and were given a low to medium indicative ecological value.

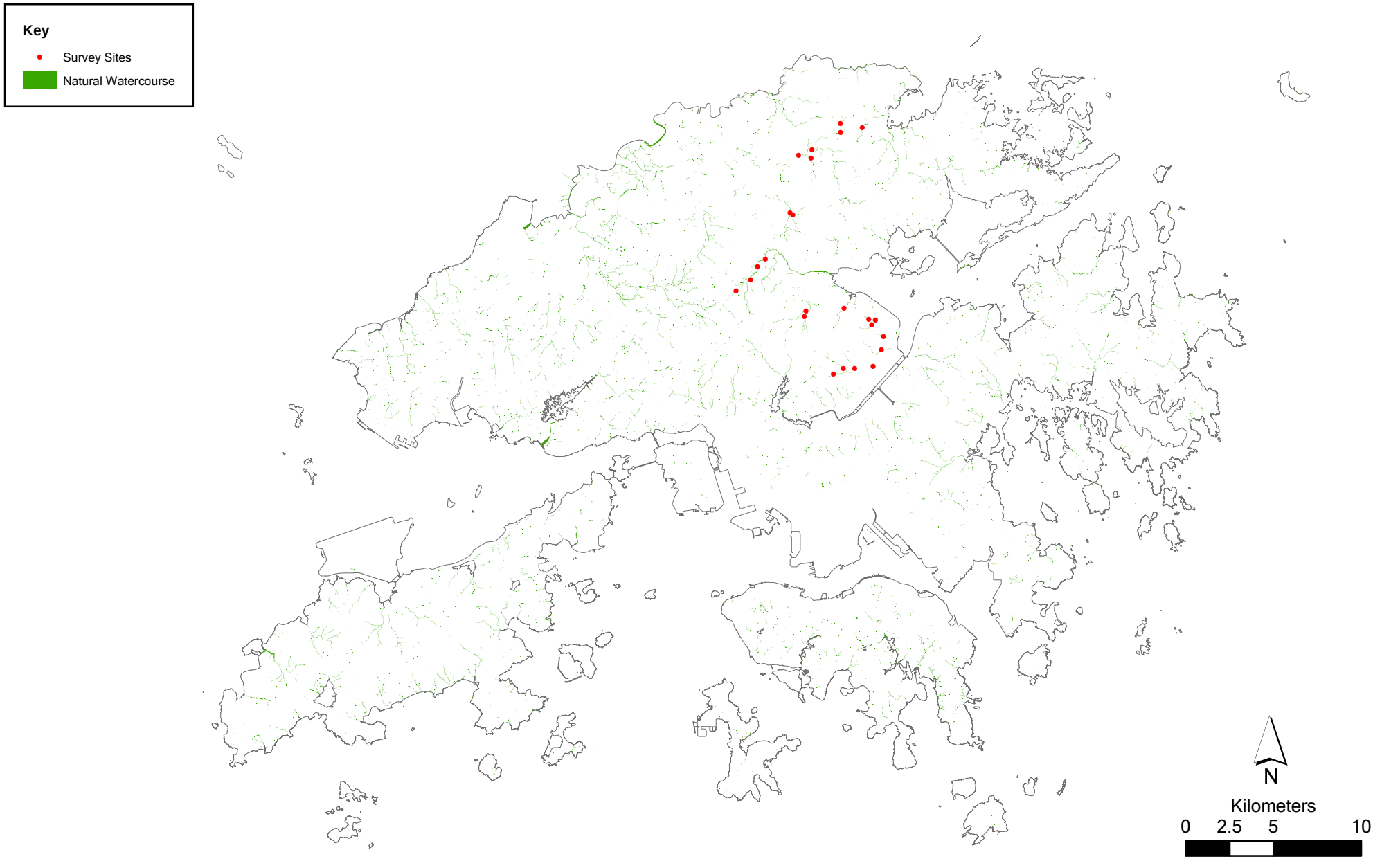

Figure 7.4

Location of Surveyed Sites of Natural Watercourse Habitat

File: Surveyed_Sites\0090526_NW_SurveyedSites.mxd
Date: 11/08/2009

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Table 7.6 ***Number and Percentage of Natural Watercourse Mis-identified Sub-sites (Total Number of Sites Surveyed = 24)***

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Modified Watercourse	6	25.00

Ecological Value Assessment: The ecological value of the correctly mapped natural watercourses remained high due to limited disturbance to the habitats. Six mis-identified sub-sites were downgraded to low ecological value since they were re-classified to Modified Watercourse (*Annex E4*).

Information Gaps

A total of 24 sub-sites of an approximate area of 22.61 ha (3.83% of Natural Watercourse in Hong Kong) were surveyed and verified in the Present Study. There are still some identified Natural Watercourse areas left unsurveyed under the Previous and Present Studies or those which lack sufficient existing information to substantiate their indicative high ecological ranking. Effort may be required in the future to verify the boundary and ecological value of these habitats.

7.3.5 Intertidal Mudflat

Previous Study

A total of 9 sub-sites (43.00 hectares) of Intertidal Mudflat were surveyed in the 2003 Study. The mapping accuracy of the Intertidal Mudflat in the 2003 Study was generally high. In the 2005 Study, a total of eight sites of Intertidal Mudflat were surveyed and all of them were mapped correctly. A total of 15 sites of Intertidal Mudflats were surveyed in the 2007 Study. The mapping accuracy of Intertidal Mudflats was 73.3% (11 out of 15 sites) and was generally high. Most of the surveyed Intertidal Mudflats were covered with fine sediments.

Present Study

A total of 35 sites of Intertidal Mudflats were surveyed in the Present Study and the surveys commenced on 8th May 2009 and were completed on 23rd June 2009 (*Annex G, pages 21-23*). The locations of the surveyed sites are presented in *Figure 7.5*. All of them were located in rural areas of Lantau Island and the New Territories

Habitat Mapping: The mapping accuracy of Intertidal Mudflats was 88.57% (31 out of 35 sites) and is generally high. Most of the surveyed Intertidal Mudflats were covered with fine sediments.

All mis-classified Intertidal Mudflats (IM02-05) were re-classified as Sandy Shore (*Table 7.7*) (*Annex D5*). The mis-identification was likely due to the fine sand and slightly turbid water in these sub-sites.

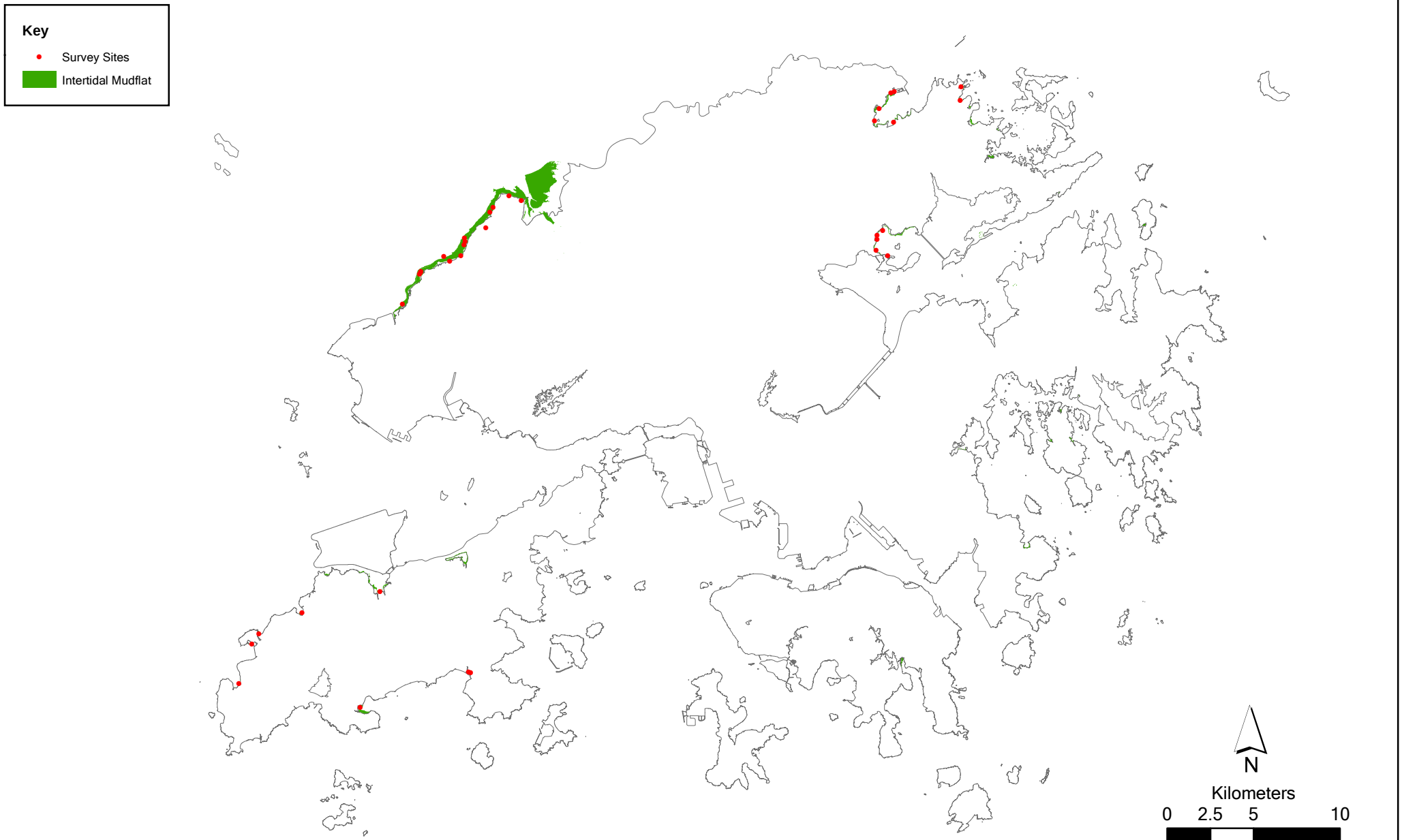

Figure 7.5

Location of Surveyed Sites of Intertidal Mudflat Habitat

File: Surveyed_Sites\0090526_P_SurveyedSites.mxd
Date: 11/08/2009

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Table 7.7 ***Number and Percentage of Intertidal Mudflat Mis-identified Sub-sites (Total Number of Sites Surveyed = 35)***

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Sandy Shore	4	11.43

Ecological Value Assessment: Most of the sites were only slightly modified or truly natural, had fine sand and mud and slightly turbid water. Only four sub-sites (IM02-05) were downgraded from high to medium ecological value due to re-classification into Sandy Shore (*Annex E5*).

Information Gaps

A total of 35 sub-sites with an approximate area of 194.80 ha (27.37% of Intertidal Mudflat in Hong Kong) were surveyed and verified in the Present Study. There are still some identified Intertidal Mudflat habitats left unsurveyed under the Previous and Present Studies or those which lack sufficient existing information to substantiate their indicative high ecological ranking. Effort may be required in the future to verify the boundary and ecological value of these habitats.

7.3.6 Plantation or Plantation/Mixed Forest

Previous Study

In the 2003 Study, the Agriculture, Fisheries and Conservation Department (AFCD) provided the Present Study Team with the most up-to-date information on Plantation (in GIS format) including location and size. The polygon data contained 179 Plantation patches of approximately 532.30 hectares. AFCD confirmed that the habitat areas represented by the Plantation polygons are actual Plantation sites that have been planted for less than 9 years and/or are currently subject to regular maintenance management of AFCD. All areas covered by the Plantation areas, except for the habitats Natural Watercourse and Freshwater/Brackish Wetland, were changed to the category "Plantation or Plantation/Mixed Forest" and an indicative ecological value of medium was assigned. In the 2005 Study, a total of 19 sites of Plantation (plantation services inside country parks) were surveyed. 12 of them were mapped accurately and the mapping accuracy was 63.16%. A total of 10 sites of Plantation (plantation services inside country parks) were surveyed in the 2007 Study and all of the 10 plantation sites were mapped correctly.

Present Study

A total of 43 sites of Plantation (plantation services inside country parks) were surveyed in the Present Study and field surveys for this habitat category commenced on 8th April 2009 and were completed by 14th May 2009 *(Annex G, pages 24-27)*.

Habitat Mapping: A total of 43 sites of Plantation/Mixed Forest were surveyed and the locations of the sites are shown in *Figure 7.6*. The mapping accuracy was considered to be generally high. About 81.40% (35 out of 43) of the total sites surveyed for plantation was found to be mapped correctly.

The mis-identified sub-sites (8 out of 43) were mostly re-classified into Grassland (P02-04), Shrubby Grassland (P07-08), Lowland Forest (P33 and P39) and Mixed Shrubland (P06) (*Table 7.8*) (*Annex D6*). The change of habitat type in sub-sites P06-08 in country park was due to hill fires. Some sparse vegetation, grasses and shrubs were found but the habitat had not fully recovered. On the other hand, P33 in Tai Lam Country Park was re-classified as Lowland Forest due to abundant under-story vegetation and the presence of trees such as *Machilus pauhoi, Schefflera heptaphylla* and *Schima* species. Sub-site P39 in the country park near Shing Mun Road was also re-classified as Lowland Forest; it had a moderately stratified canopy layer and native trees such as *Ficus variegata, Garcinia oblongifolia* and *Zanthoxylum avicennae*. Neither of the patches re-classified as Lowland Forest were dominated by a single exotic species.

Table 7.8 ***Number and Percentage of Plantation or Plantation/Mixed Forest Mis-identified Sub-sites (Total Number of Sites Surveyed = 43)***

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Grassland	3	6.98
Shrubby Grassland	2	4.65
Lowland Forest	2	4.65
Mixed Shrubland	1	2.33
	Total: 8	18.60

Ecological Value Assessment: Three small sub-sites (P02-04) were downgraded from medium to low ecological value due to re-classification from Plantation or Plantation/Mixed Forest to Grassland. Three sub-sites (P06, P33 and P39) were upgraded from medium to high ecological value due to their being re-classified as Mixed Shrubland and Lowland Forest (*Annex E6*).

Information Gaps

A total of 43 sites with an approximate area of 120.58 ha (19.61% of Plantation or Plantation/Mixed Forest in Hong Kong) were surveyed and verified in the Present Study. There are still Plantation sites (plantation services inside country parks) not covered by the previous and present field surveys and their existing boundary and ecological value remain to be field verified.

7.3.7 Shrubby Grassland

Previous Study

In the 2003 Study, among the 183 sub-sites surveyed for Shrubby Grassland, 62 of them were mapped correctly. About 51.91% (95 sub-sites) of the

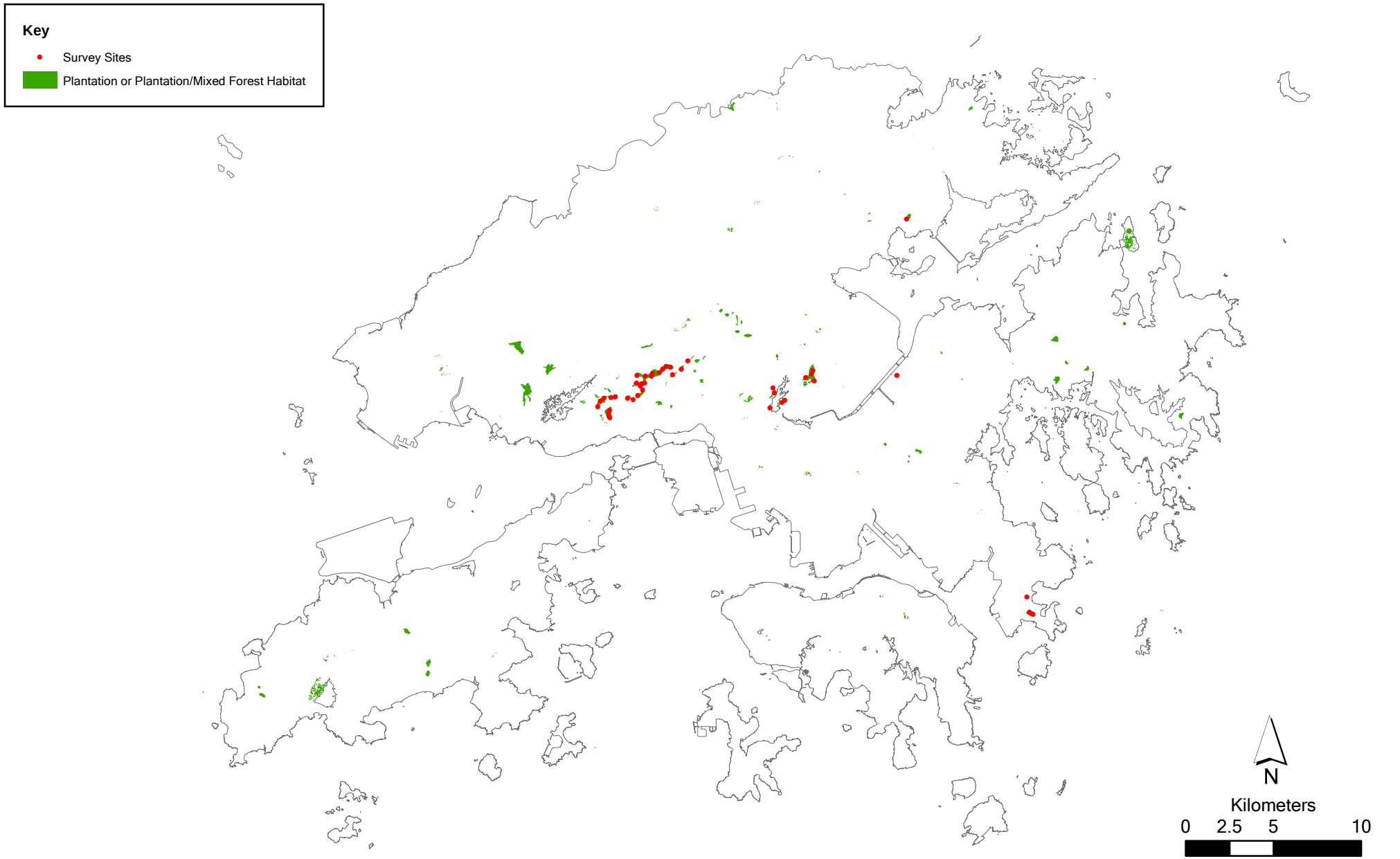

Figure 7.6

Location of Surveyed Sites of Plantation or Plantation/Mixed Forest Habitat

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Date: 11/08/2009

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Shrubby Grassland sub-sites had been re-classified as Mixed Shrubland after site verification as these sites were seen to be occupied by more than 50% of shrub species. In the previous 2005 Study, a total of 60 sites of Shrubby Grassland were surveyed. 40 of them were mapped accurately and the remaining 20 sites were found to be mis-classified either as Mixed Shrubland or Grassland, with one of them mis-classified as Cultivation. A total of 45 sites of Shrubby Grassland were surveyed in the 2007 Study. Among the 45 sites surveyed for Shrubby Grassland, 22 of them were mapped incorrectly. About 48.89% of the Shrubby Grassland sites (partially or wholly) were re-classified as Mixed Shrubland. The mis-classification could possibly be due to the spectral similarity of Mixed Shrubland to Shrubby Grassland, their tendency to intermingle with each other, and the gradual natural succession of Shrubby Grassland to Mixed Shrubland that might have occurred after the time when satellite imagery and aerial photographs were taken during the 2005 Study.

Present Study

A total of 99 sites of Shrubby Grassland were surveyed in the Present Study and field surveys for this habitat category were conducted between 10th March 2009 and 15th April 2009 *(Annex G, pages 28-36)*. Locations of the 99 sites surveyed are shown in *Figure 7.7*.

Habitat Mapping: Among the 99 sites surveyed for Shrubby Grassland, 6 of them were mapped incorrectly (*Table 7.9*). The mapping accuracy was considered to be high (93 out of 99 sites, 93.94%). Two sub-sites (SG02 and SG06) in Lantau Island were actually Cultivation. SG44 in Tsing Yi was re-classified as an immature patch of Plantation of medium size. SG64 in Tuen Mun was actually a small patch of Mixed Forest with medium heterogeneity and a moderately open canopy. Both SG44 and SG64 were re-classified as Plantation or Mixed Forest. One sub-site, (SG21) in Fanling, was classified as Lowland Forest and one, (SG61) in Tuen Mun, was classified as Mixed Shrubland (*Annex D7*). The mis-classification could possibly be due to the spectral similarity of Mixed Shrubland, Lowland Forest and Plantation to Shrubby Grassland, their tendency to intermingle with each other, and the gradual natural succession of Shrubby Grassland to Mixed Shrubland that might have occurred after the time when satellite imagery and aerial photographs were taken during the previous Study.

Table 7.9 Number and Percentage of Shrubby Grassland Mis-identified Sub-sites (Total Number of Sites Surveyed = 99)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Cultivation	2	2.02
Lowland Forest	1	1.01
Mixed Shrubland	1	1.01
Plantation/Mixed Forest	2	2.02
Total:	6	6.06

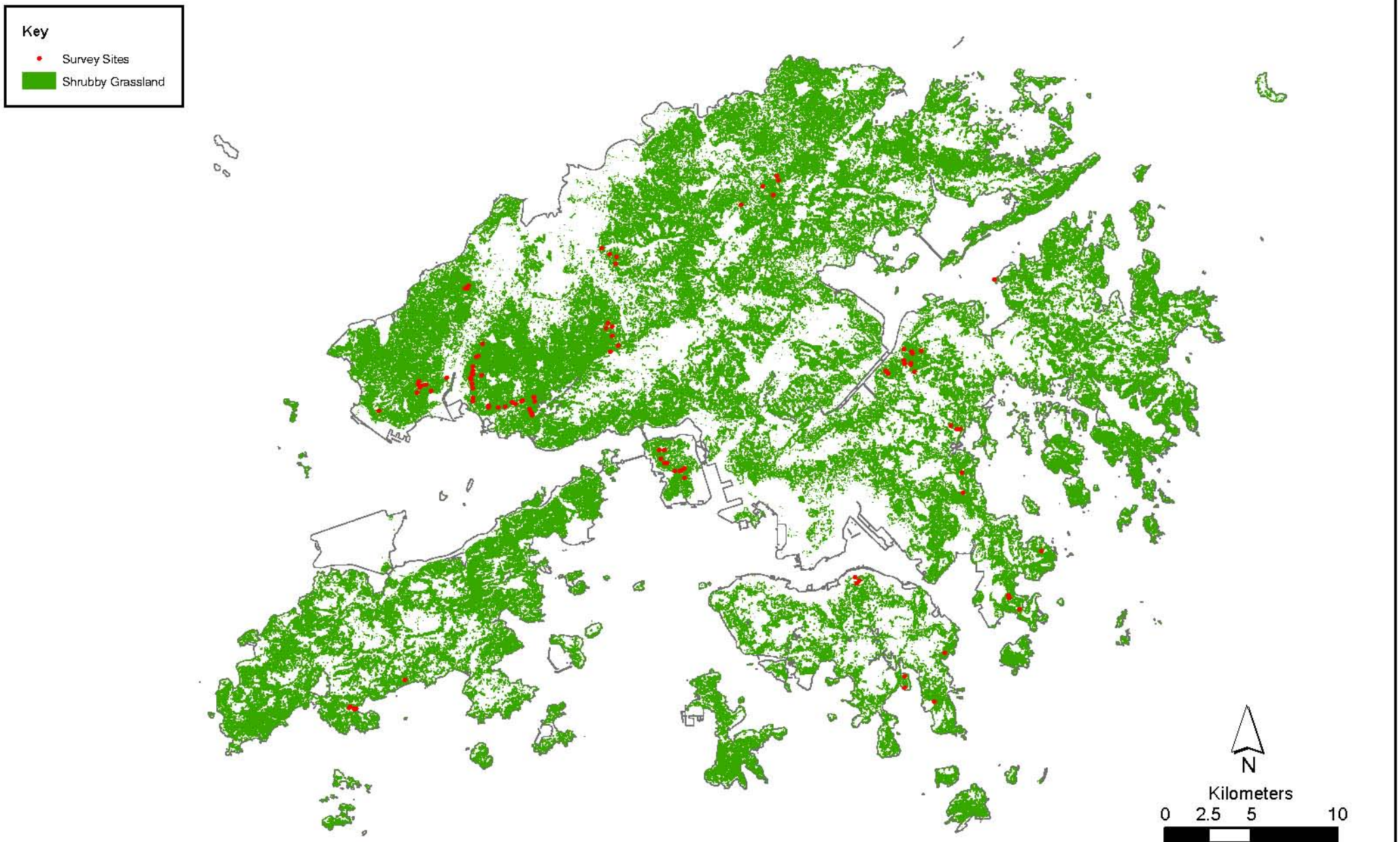

Figure 7.7

Location of Surveyed Sites of Shrubby Grassland Habitat

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Date: 11/08/2009

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Ecological Value Assessment: The majority of the identified Shrubby Grassland was regarded as of medium ecological value. The adjustment in ecological value was recorded mostly for sites with partially changed habitat types. No sub-site's ecological value was downgraded after the surveys. Two sub-sites were upgraded from medium to high ecological value due to re-adjustment to Lowland Forest (SG21) or Mixed Shrubland (SG61) (*Annex E7*). The other four sites, although they underwent re-classification, saw no change to their overall value as the newly classified habitat was of the same ecological value as Shrubby Grassland.

Information Gaps

A total of 99 sites covering approximately 618.26 ha (2.64% of Shrubby Grassland in Hong Kong) were surveyed and verified in the Present Study. There is still Shrubby Grassland not covered by the previous and present field surveys and their existing boundary and ecological value remain to be field verified.

7.3.8 Sandy Shore

Previous Study

In the 2003 Study, a total of 22 sub-sites (approximately 14,700.00 ha) were surveyed and the mapping accuracy of the Sandy Shore habitats after verification was generally high. Seven sites of Sandy Shore were visited in the 2005 Study and only two of them were mapped accurately. The mis-classified sites were either re-classified as Rocky Shore, Bare Rocks, Grassland or Urban Parks. A total of 45 sites of Sandy Shore were surveyed for the 2007 Study and all were mapped correctly, giving a mapping accuracy of 100%.

Present Study

A total of 38 sites of Sandy Shore were surveyed for the Present Study. Surveys commenced on 27th March 2009 and were completed on 23rd June 2009 (*Annex G, pages 37-40*).

Habitat Mapping: A total of 38 sites of Sandy Shore were surveyed and the location of the surveyed sites is presented in *Figure 7.8.* The mapping accuracy of the Sandy Shore was considered to be high. About 86.84% (33 out of 38) of the total sites surveyed for Sandy Shore were found to be mapped correctly.

All mis-classified Sandy Shore sub-sites were partially (SS02 and SS28) or wholly (SS09, SS15 and SS36) re-classified as Rocky Shore (*Table 7.10*) (*Annex D8*). Large boulders and medium-sized pebbles were found in these sub-sites.

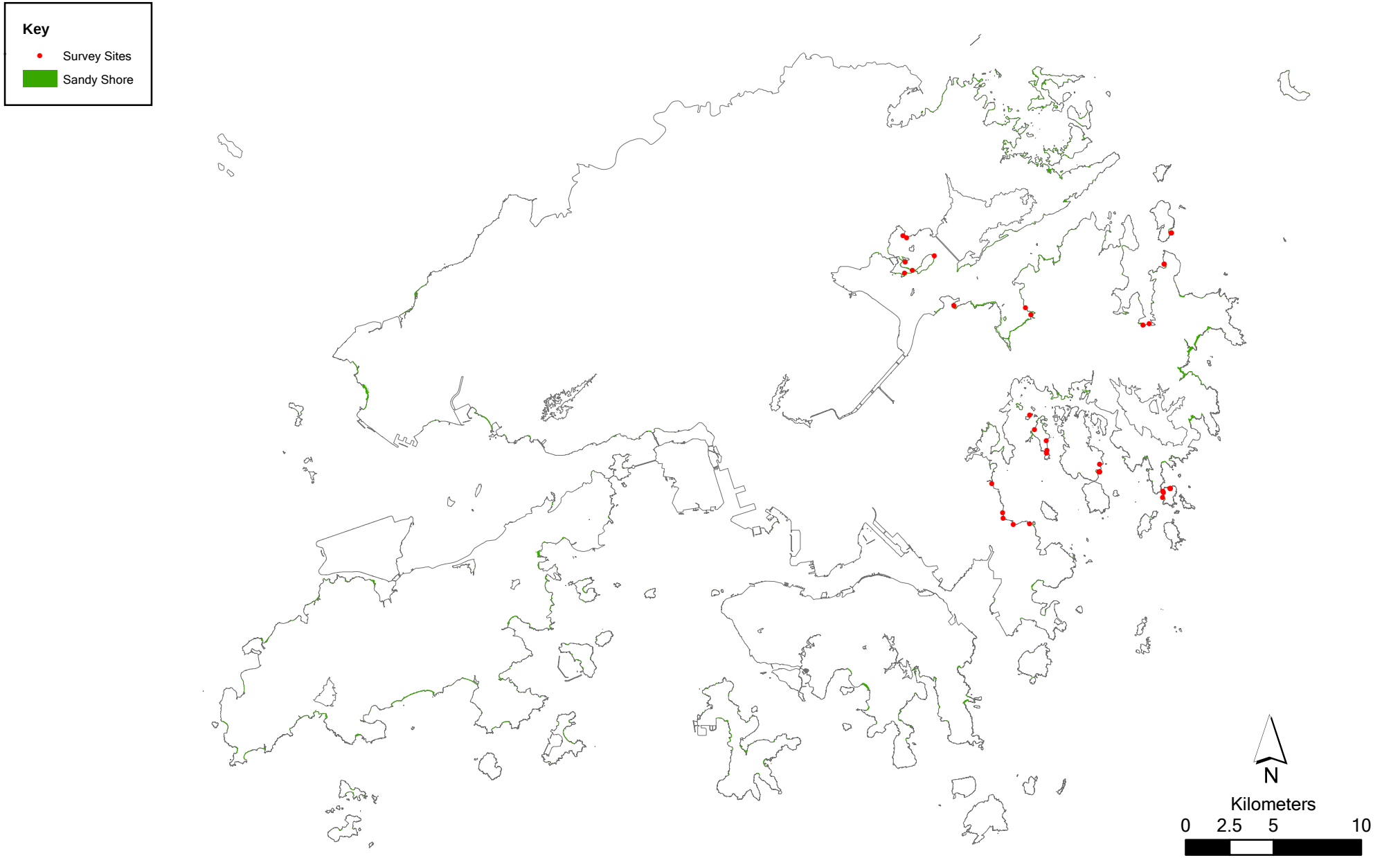

Figure 7.8

Location of Surveyed Sites of Sandy Shore Habitat

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Date: 11/08/2009

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Table 7.10 Number and Percentage of Sandy Shore Mis-identified Sub-sites (Total Number of Sites Surveyed = 38)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Rocky Shore	5	13.16

Ecological Value Assessment: Corals were recorded near the sub-site in Tai Tan Hoi (SS38) but the ecological value of the actual site remained the same, at medium. Although five sites were re-classified to Rocky Shore, as the ecological value of Rocky Shore is the same as Sandy Shore (medium), no site was downgraded or upgraded due to re-classification.

Information Gaps

A total of 38 sandy beaches comprising an approximately area of 50.44 ha (10.07% of Sandy Shore in Hong Kong) were surveyed during the Present Study. Taking account of the Sandy Shores reviewed and surveyed in the Previous Studies, some Sandy Shore habitats remain unsurveyed and no data are available to justify their ecological value. Further survey efforts may be devoted to those sheltered Sandy Shores which are located in very remote areas, eg, North-east New Territories, where upgrading of indicative ecological value may be necessary.

7.3.9 Rocky Shore

Previous Study

A total of 21 sub-sites (3,380.00 ha) of Rocky Shores were surveyed in the 2003 Study. The mapping accuracy of the Rocky Shore in the 2003 Study was generally high. Minor adjustments were made to Sites which was re-classified as Sandy Shore. In the 2005 Study, a total of 7 sites were surveyed to validate the habitat type and assess the conservation value of Rocky Shore. Two of them were re-classified as Grassland and Urban Park with total mapping accuracy of 71.43%. The 2007 Study surveyed 35 sites of Rocky Shore habitat. The mapping accuracy of the Rocky Shore after verification was medium (62.86%). A total of 14 out of 35 sites (40.00%) were re-classified as Sandy Shore and Other; 11 sites were mis-identified and re-classified as Sandy Shore and 3 sites in Tsuen Wan were developed into roads (Other).

Present Study

The Present Study surveyed 39 sites of Rocky Shore habitat. Field surveys commenced on 27th March 2009 and were completed on 24th April 2009 (*Annex G, pages 41-44*). The locations of the surveyed sites are shown in *Figure 7.9*.

Habitat Mapping: The mapping accuracy of the rocky shore after verification is generally high, 87.18% (34 out of 39).

The Rocky Shore sub-sites mis-mapped in Tai Lam were actually Artificial Rocky/Hard Shoreline (RS09, RS11 and RS13) and Other (RS10) (*Table 7.11*).

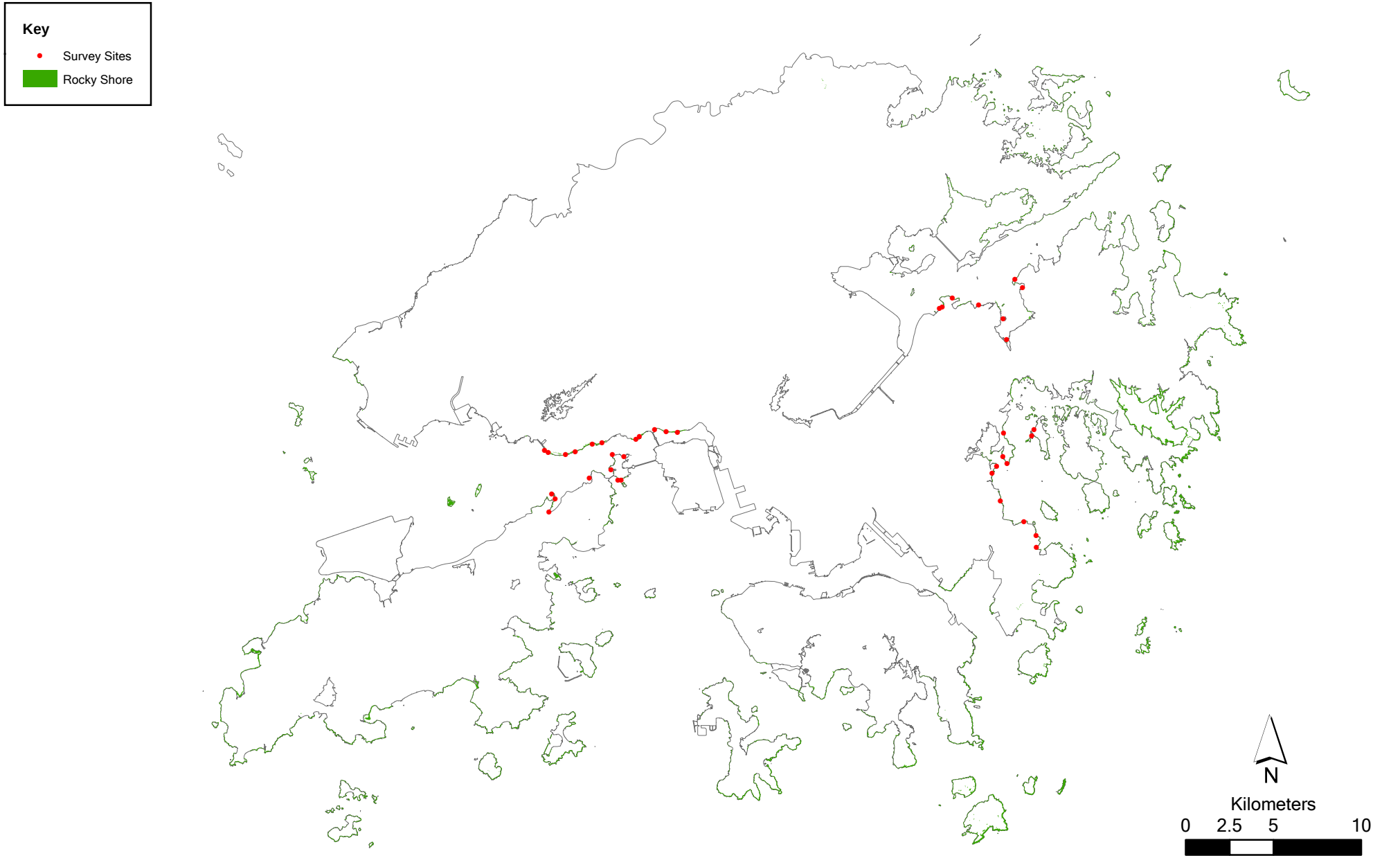

Figure 7.9

Location of Surveyed Sites of Rocky Shore Habitat

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Date: 29/06/2009

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They were developed areas without natural pebbles or boulders. One sub-site (RS02) in Wu Kai Sha was re-classified as Sandy Shore as fine sand and small pebbles were found there (*Annex D9*).

Table 7.11 Number and Percentage of Rocky Shore Mis-identified Sub-sites (Total Number of Sites Surveyed = 39)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Number of Surveyed Sites
Artificial Rocky/Hard Shoreline	3	7.69
Other	1	2.56
Sandy Shore	1	2.56
	Total: 5	12.82

Ecological Value Assessment: Slight to moderate disturbance was observed for most of the sites surveyed. Three sub-sites (RS09, RS11 and RS13) were downgraded from medium to low ecological value as they were Artificial Rocky/Hard shoreline and RS10 was changed to negligible value as it was a developed urban area (*Annex E8*). RS02 remained as medium ecological value as the ecological value for Sandy Shore is the same as Rocky Shore.

Information Gaps

A total of 39 sites were surveyed and verified in the Present Study with an approximate area of 99.03 ha (6.95% of Rocky Shore in Hong Kong). There are still Rocky Shores where surveys have yet to be undertaken and therefore data are not available to justify their ecological value. Further efforts may be required to survey those exposed Rocky Shores which are located in very remote areas, eg outlying islands, where upgrading of indicative ecological value may be necessary.

7.3.10 Cultivation

Previous Study

In the 2003 Study, a total of 81 sub-sites were surveyed for Cultivation and 38 of them showed 100% accuracy. Some of them were found to have been mis-identified and all these were re-classified as Other. The 2005 Study surveyed a total of 27 sites of Cultivation to assign the habitat category. Among the 27 sites, 21 were mapped accurately, and the remaining sites were mapped as Shrubby Grassland, Mixed Shrubland and disturbed by development. A total of 15 sites of Cultivation were surveyed in the 2007 Study. The majority of them (8 sites) were mis-classified. Among the mis-classified sites, 4 of them (i.e. 26.67% of total sites surveyed for Cultivation) were re-classified as Shrubby Grassland. The other 4 sites of Cultivation were modified due to urban development, for example conversion into developed land and garden.

Present Study

A total of 85 sites of Cultivation were surveyed in the Present Study. Field surveys were undertaken from 10th March 2009 to 28th April 2009 (*Annex G, pages 45-51*). The locations of surveyed sites are shown in *Figure 7.10*.

Habitat Mapping: A total of 85 sites were surveyed for Cultivation and 94.12% (80 out of 85) of them were mapped correctly (*Annex D10*). The change of habitat may be due to succession after cultivated land has been abandoned. Four sub-sites were re-adjusted to Shrubby Grassland (C24, C26, C69 and C72) predominantly for this reason (*Table 7.12*). C05 was re-classified as Freshwater/Brackish Wetland as *Ceratopteris thalictroides* and *Centella asiatica* were recorded there, species which are normally found in swampy wetland (*Table 7.11*).

Table 7.12 Number and Percentage of Cultivation Mis-identified Sub-sites (Total Number of Sites Surveyed = 85)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Surveyed Site
Shrubby Grassland	4	4.71
Freshwater/Brackish Wetland	1	1.18
	Total: 5	5.88

Ecological Value Assessment: Around 25% of the Cultivation sub-sites were totally abandoned land and three of them (C08-10) were disturbed by war games and archery activity. Only one sub-site (C05) was upgraded from medium to high ecological value as it was re-classified to Freshwater/Brackish Wetland (*Annex E9*). The rest of the sites remained as medium ecological value as Shrubby Grassland, like Cultivation, has medium ecological value.

Information Gaps

A total of 85 sites covering 186.26 ha (8.70% of Cultivation in Hong Kong) were surveyed and verified in the Present Study. There is still Cultivation mapped on the habitat map which has not been covered by the previous or present field surveys. Uncertainties remain in these unsurveyed areas with regard to their habitat type and ecological status. As the habitat is highly heterogeneous in nature, further efforts may be required to differentiate cultivated land from other habitat type(s) to justify the ecological rating.

7.3.11 Mangrove

Previous Study

A total of 52 sub-sites were surveyed in 2003 and the mapping accuracy was moderate. Some of the sub-sites were re-classified as Fishpond/Gei Wai, Lowland Forest, Intertidal Mudflat, Cultivation or Mixed Shrubland. A total of 9 sub-sites were surveyed in the 2005 Study. About 88.89% (8 out of 9) were classified accurately.

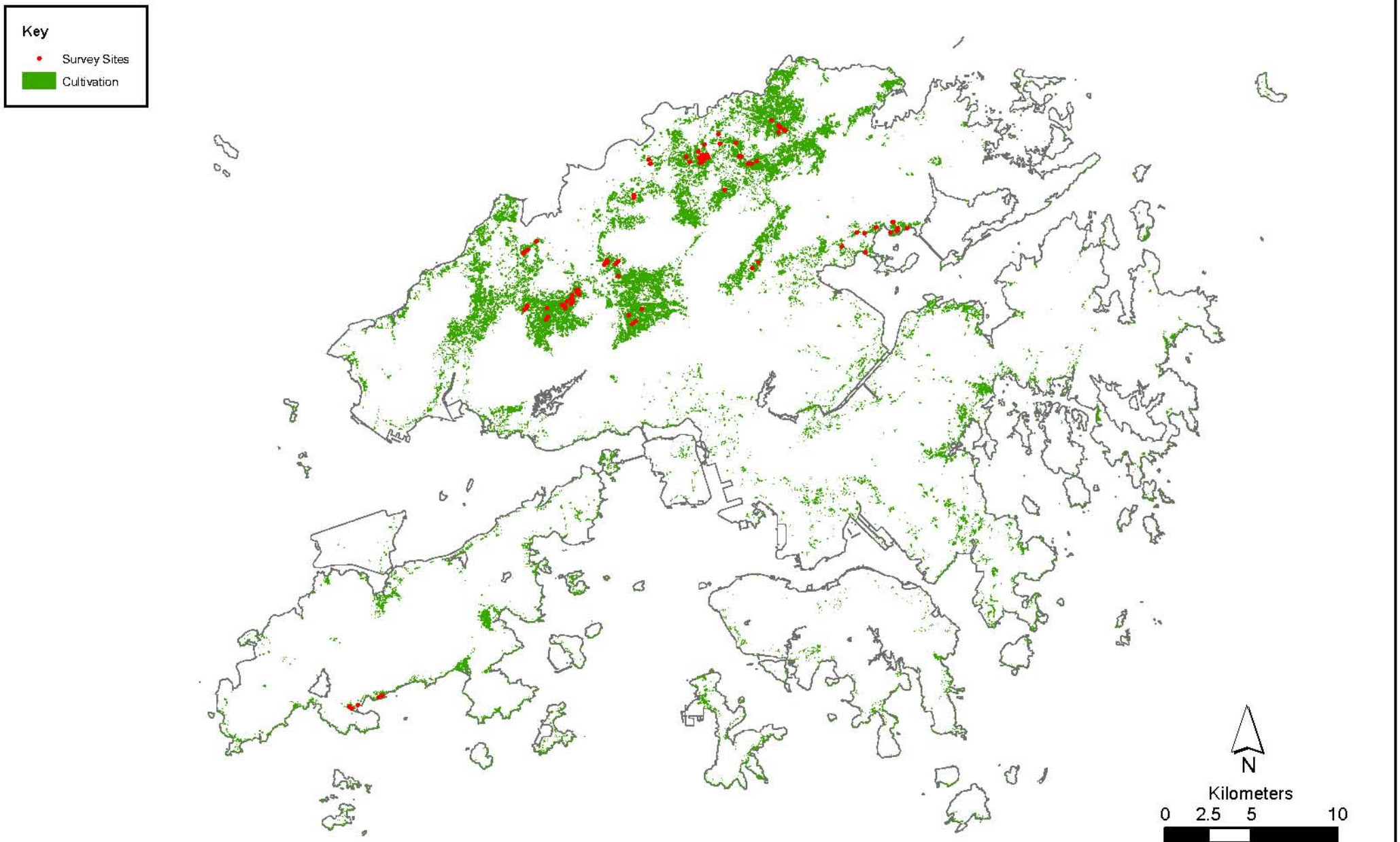

Figure 7.10

Location of Surveyed Sites of Cultivation Habitat

File: Surveyed_Sites\0090526_C_SurveyedSites.mxd
Date: 11/08/2009

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Present Study

A total of 43 sites were surveyed in the Present Study. Surveys started on 27th March 2009 and were completed on 23rd June 2009 (*Annex G, pages 52-55*). The locations of the sites are presented on *Figure 7.11*.

Habitat Mapping: All of the 43 Mangrove sites were mapped correctly. Out of these Mangrove sites, four of them were located inside country parks while eight of them inside SSSIs.

Ecological Value Assessment: Most sites (19) were slightly modified or truly natural (15) and of small to medium size with fine sand and small pebbles as their substratum. Most sites were disturbed by litter and often by being near human disturbances as well, such as shellfish harvesting or near a golf course or pier. *Kandelia* spp., mainly *Kandelia obovata,* was identified at all the sites. *Avicennia marina was* also identified at the majority of sites. Most of the mangroves were between 1 -2m high, with a record at one site of the mangroves being about 6m high. At one site, the seagrass *Halophila beccarii* was recorded in front of the mangroves, in small patches. *Boleophthalmus* spp. was recorded at about half the sites. Of the molluscs recorded, *Cerithidea* spp. was the most common, followed by *Saccostrea cucullata.* The crustacean *Uca* spp. was also recorded at most of the mangrove sites. All identified Mangrove was regarded as of high ecological value and none of their ecological value was adjusted.

Information Gaps

A total of 43 sites of an approximately area of 25.41 ha (4.90% of Mangrove in Hong Kong) were surveyed and verified in the Present Study. There are still Mangrove areas mapped on the habitat map left unsurveyed and uncertainties remain in these areas with regard to their habitat type and ecological status.

7.3.12 Seagrass

Previous Study

No seagrass surveys were conducted in 2003, 2005 and 2007 Studies.

Present Study

A total of 13 sites were visited in the survey period, from 11th May 2009 to 23rd June 2009 (*Annex G, page 56*). The locations of the surveyed sites are shown in *Figure 7.12.* Due to the scattered distribution of Seagrass Bed in Hong Kong, the small size of Seagrass Bed patches and the time constraints on tidal change, it was difficult to conduct 22 survey sites within three survey days. Therefore, the total number of surveyed sites was 13 instead of 22 as originally planned.

Habitat Mapping: The mapping accuracy of the Seagrass after verification is high. A total of 10 out of 13 sites (76.92%) were mapped correctly as Seagrass.

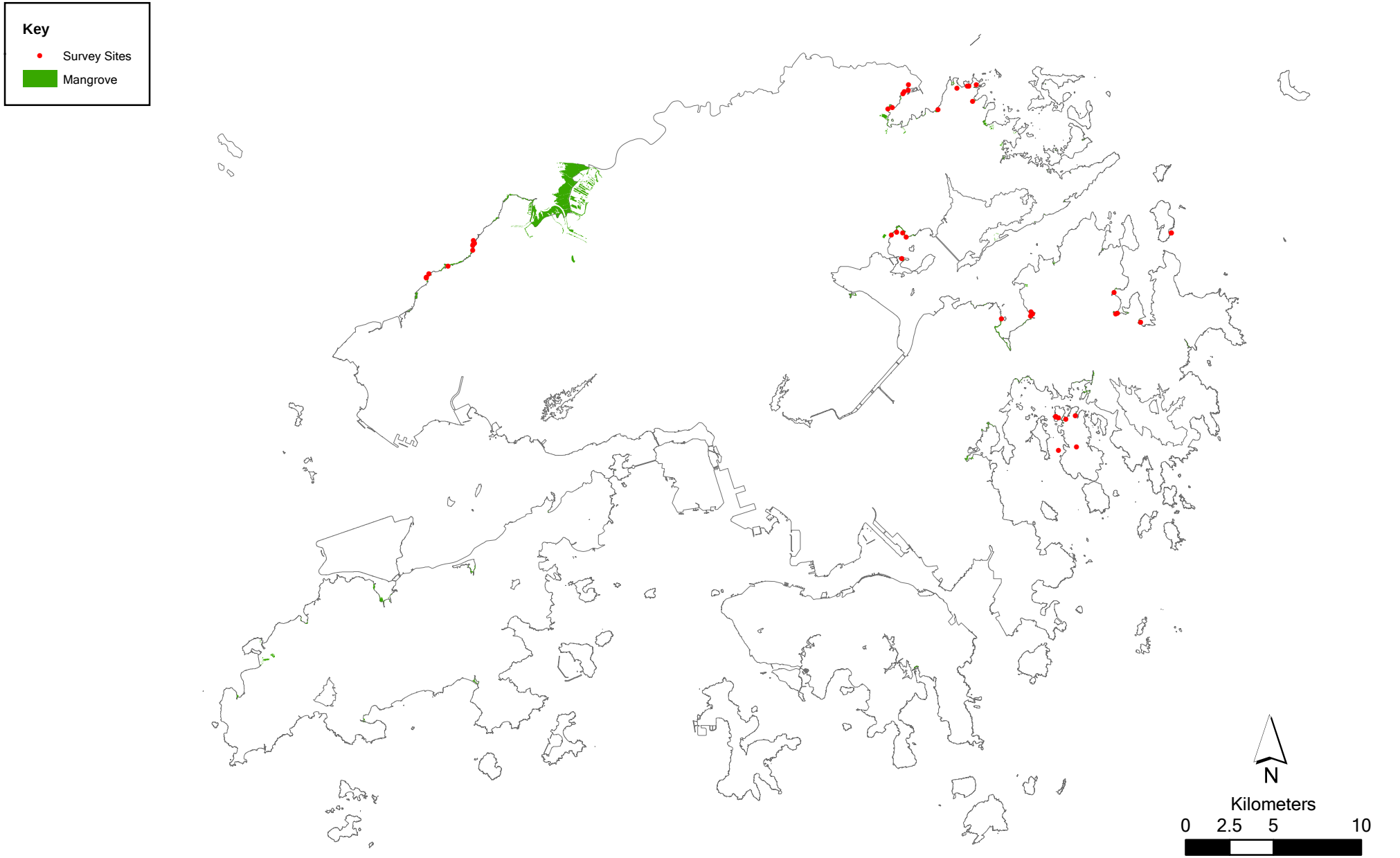

Figure 7.11

Location of Surveyed Sites of Mangrove Habitat

File: Surveyed_Sites\0090526_M_SurveyedSites.mxd
Date: 11/08/2009

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Figure 7.12

Location of Surveyed Sites of Seagrass Bed Habitat

File: Surveyed_Sites\0090526_SB_SurveyedSites.mxd
Date: 11/08/2009

Environmental Resources Management

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No Seagrass was found on the sites SB10-12 and these sites were re-classified as Intertidal Mudflat, same as the surrounding habitat (*Table 7.13*) (*Annex D11*).

Table 7.13 Number and Percentage of Seagrass Mis-identified Sub-sites (Total Number of Sites Surveyed = 13)

Habitat Type of Mis-identified Area	No. of Sites	Percentage (%) of Total Surveyed Site
Intertidal Mudflat	3	23.08

Ecological Value Assessment: Some rare species of seagrass were identified during the survey; *Halophila ovalis* (SB05-07 and SB10-12), *Zostera japonica* (SB08) and *Halophila beccarii* (SB13). All sub-sites remained as having high ecological value, even those re-classified as Intertidal Mudflat, because Intertidal Mudflat is categorised as having a high ecological value. The ecological value of the correctly mapped Seagrass remained high due to limited disturbance inside or near marine parks and country parks.

Information Gaps

A total of 13 sites with an approximately area of 6.01 ha (54.49% of Seagrass Bed in Hong Kong) were surveyed and verified in the Present Study. There is still Seagrass mapped on the habitat map left unsurveyed and uncertainties remain in these areas with regard to their habitat type and ecological status.

7.4 OTHER CONSERVATION COMPONENTS

The surveyors recorded opportunistic notes on the other two conservation components, i.e. landscape and recreational value, during their site visits and the data were incorporated into the conservation assessment map.

During ecological field surveys, landscape features including coastline, prominent watercourse, reservoir, oyster shell flats and forest were also identified.

Recreational features such as nature trails, bike trails, barbecue sites, parks and picnic areas, war game sites, archery sites, golf courses and swimming beaches, and recreational activities such as boating and shellfish collection were observed in some of the surveyed sites, in particular within country parks and coastal areas.

7.5 AREAL MAPPING ACCURACY OF SURVEYED HABITATS BASED ON FIELD SURVEYS

The level of accuracy associated with the mapping of each of the surveyed habitats was calculated using GIS, extrapolating figures from observations of surveyors when in the field. The total area of habitat correctly mapped was calculated by summing the accuracy for each surveyed site and then dividing the sum by the number of sites surveyed.

The mapping accuracies calculated for each surveyed habitat type in the Present Study are presented in *Table 7.14*.

Table 7.14 Areal Mapping Accuracy of Each Surveyed Habitat Category for the Present Study

Habitat Category	Overall Mapping Accuracy of the Surveyed Area (%)
Seagrass Bed	92.89
Mangrove	88.61
Lowland Forest	88.42
Intertidal Mudflat	79.73
Sandy Shore	79.36
Plantation or Plantation/Mixed Forest	72.90
Cultivation	67.14
Mixed Shrubland	64.17
Freshwater/Brackish Wetland	63.66
Natural Watercourse	56.43
Shrubby Grassland	55.05
Rocky Shore	38.37

The areal mapping accuracy of the surveyed habitats in the Present Study ranged from 38.37% for Rocky Shore to 92.89% for Seagrass Bed. Seagrass Bed obtained high mapping accuracy (>90%). Satisfactorily high mapping accuracy percentage (70% - 90%) was obtained for Mangrove (88.61%), Lowland Forest (88.42%), Intertidal Mudflat (79.73%), Sandy Shore (79.36%) and Plantation or Plantation/Mixed Forest (72.90%). Habitats having a moderate mapping accuracy of between 40 - 70% include Cultivation (67.14%), Freshwater/Brackish Wetland (63.66%), Mixed Shrubland (64.17%), Natural Watercourse (56.43%) and Shrubby Grassland (55.05%). Only 1 relatively low mapping accuracy (<40%) was recorded for Rocky Shore.

The mapping accuracy was generally higher in the remote and protected areas such as in the country parks. Lower mapping accuracy for Rocky Shore, Shrubby Grassland and Natural Watercourse was observed, particularly in the unprotected areas such as in or near villages where human disturbance was more evident. In addition, as discussed above, the lower mapping accuracy for Shrubby Grassland was likely due to the spectral similarity of Mixed Shrubland to Shrubby Grassland, their tendency to intermingle with each other, and the gradual natural succession of Shrubby Grassland to Mixed Shrubland that might have occurred after the time when satellite imagery and aerial photographs were taken during the Previous Studies. On the other hand, a number of Natural Watercourse sub-sites were partially re-identified as Modified Watercourse which were channelized or distributed by construction work. Therefore, the mapping accuracy for Nature Watercourse was low as it was difficult for remote sensing to classify between natural or modified habitat in this situation. The mapping accuracy for Rocky Shore was classified as 'relatively low', which was much lower than the 2007 Study. The accuracy was particularly low in the area with a mix of fine sand and medium pebbles. A number of sub-sites were partially re-classified as Sandy

Shore. Therefore, though the percentage of mis-identified sites was low in *Table 7.10*, the mapping accuracy in terms of surveyed area was much lower.

Precise mapping of the boundary of some of the natural vegetation habitats during field surveys was found to be difficult as many of the natural vegetation habitats (eg Shrubby Grassland, Mixed Shrubland and Lowland Forest) do not have a well defined boundary between habitat types. In fact, these habitats are often intermingled with each other and the boundary of the categorised habitats is actually represented by a gradual change in the vegetation species composition and the plant forms. The Field Survey Team made use of their expertise and professional judgment to define the boundary of each habitat area they surveyed, for example, by examining the change in species composition, vegetation structure and spatial complexity. Topographic information and other locational features such as houses, footpaths, streams, overhead electrical cables, changes in contour levels of nearby mountains and valleys, as well as the structural complexity of habitats were found useful in helping surveyors identify the habitat boundary. The colour of the habitat area was also found helpful in distinguishing the boundary of different habitats.

It is important to understand that the mapping accuracy presented in *Table 7.14* was calculated using GIS, based on the results obtained from the field surveys. Therefore it can only be used to indicate the mapping accuracy of the habitat area surveyed and does not reflect the mapping accuracy of the whole habitat map. In many cases, the sites for field surveying were chosen specifically because the accuracy for determining a particular habitat type during the initial mapping period of the existing habitat map in the Previous Studies was low. In this way the field surveys provided an opportunity to upgrade the accuracy of the habitat map. In addition, the surveys covered only a small percentage of area for most of the habitat types surveyed (see *Table 7.1*) so again it is not valid to extrapolate the field survey data to represent the mapping accuracy of individual habitat types.

8 REVISED HABITAT MAP AND CONSERVATION ASSESSMENT MAP

8.1 EDITING OF MAPPED AREAS BASED ON FIELD SURVEYS

The field surveying exercise made use of Pocket PC technology for the collection of data from the Survey Site locations and recording changes to the habitat type and the ecological value of sites being surveyed. These edits of each habitat, described in *Section 7,* include polygons identifying:

- additions to the habitat (where the habitat was under classified); or
- deletions (where the habitat was mis/over-classified).

These edits were thoroughly checked and then used to update the existing habitat map and conservation assessment map. A field was created in the final GIS database to indicate where changes had been made to the map as a result of the surveying process. All processing was carried out using the ArcGIS product. The updated habitat map is shown in *Figure 8.1* and the updated conservation assessment map in *Figure 8.2*. The updated habitat map and conservation assessment map in GIS format are shown in *Annex H*.

8.2 AREA AND PERCENTAGE COVER OF HABITAT CATEGORIES

8.2.1 *Previous 2007 Study*

In the previous 2007 Study, a total of 111,787.50 ha were mapped for the terrestrial area of Hong Kong (*Table 8.1*). Among the 24 habitat categories mapped on the revised habitat map, Mixed Shrubland was the most extensive habitat occupying 27,941.40 ha and constituted the highest percentage habitat cover (25.00%). Shrubby Grassland and Grassland remained the second and the third largest natural vegetation habitats identified on the habitat map and occupied 19.95% and 13.81% of the total habitat cover respectively.

The land areas identified as natural aquatic (i.e. Natural Watercourse and Freshwater/Brackish Wetland) and intertidal (i.e. Mangrove, Intertidal Mudflat, Sandy Shore and Seagrass Bed) habitats were, in general, small and individual habitats occupied < 1.00% of the total land area. Seagrass Beds showed a very limited distribution and occupied around 0.01 % (i.e. 6.60 ha) of the total land cover. Artificial or modified water habitats showed a comparatively higher land cover (2.52%) than the natural watercourse (0.77%). Fishpond/Gei Wai habitat occupied a map area of 895.50 ha which was 0.80% of the total land area. A total of 2819.90 ha (i.e. 2.52%) were mapped for Modified Watercourse.

Disturbed habitats with negligible ecological value, such as Landfill, Rural Industrial Storage/Containers and Others, showed a varied percentage of coverage. Landfill covered 0.27% of the survey area while Rural Industrial

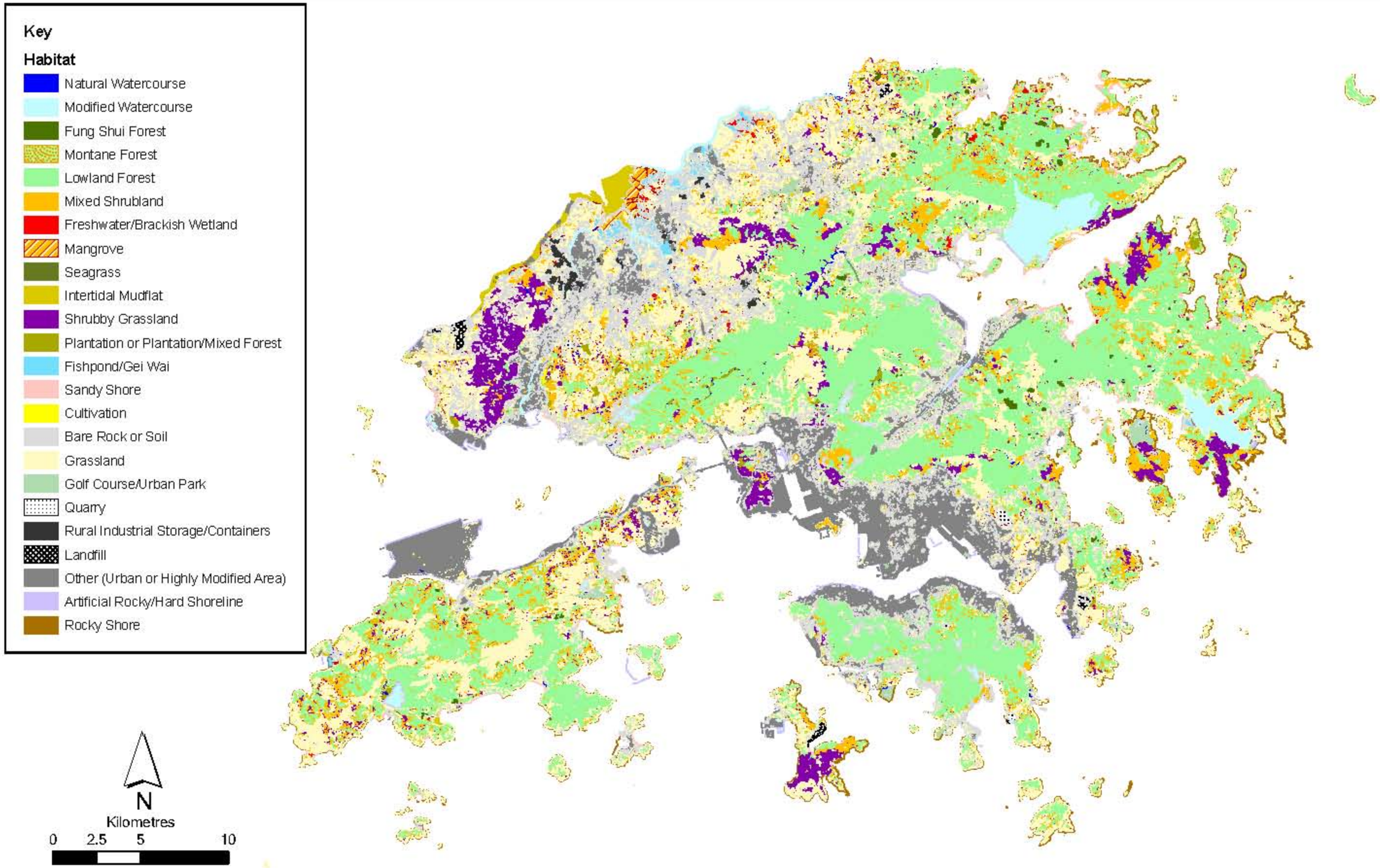

Figure 8.1

Final Habitat Map of Hong Kong in 2009

File: Final report\0090526_final habitat.mxd
Date: 15/01/2010

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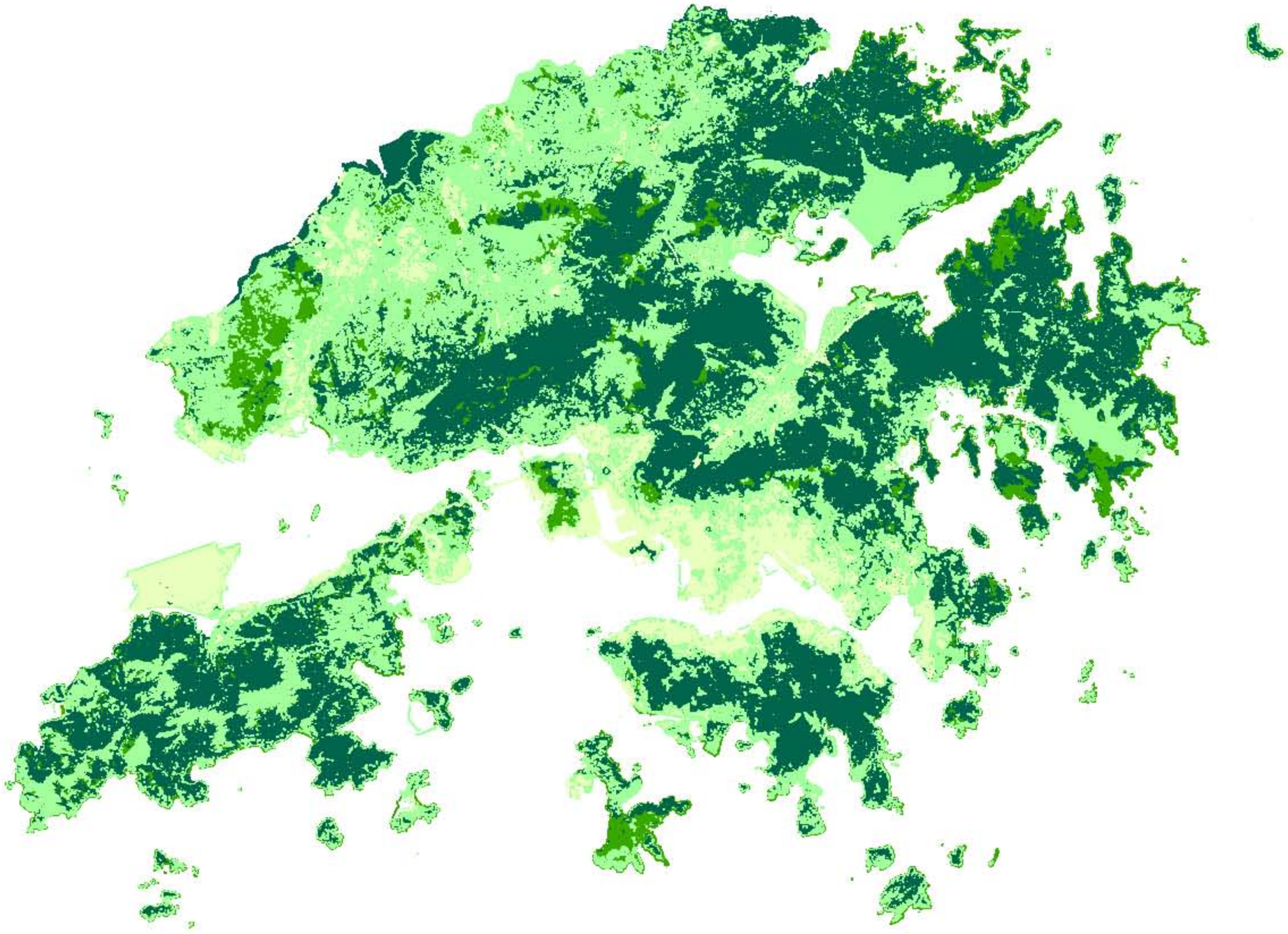
Key

Ecological Value

- High
- Medium
- Low
- Negligible



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0 2.5 5 10

Figure 8.2

Final Conservation Assessment Map of Hong Kong in 2009

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Date: 15/01/2010

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ERM

Storage/Containers covered 0.93%, both showing about a -24.33% cover value compared to the 2005 Study. Urban or highly modified area (including buildings), which was put into the Other habitat category, was found to be relatively extensive and occupied 12.47% (i.e. 13936.50 ha) of the total land area, up 10.12% compared to the 2005 Study.

Comparing the 2007 Study with the 2005 Study, the percentage change in habitat areas ranged from -31.10% (Lowland Forest) to 589.78% (Freshwater/Brackish Wetland) (*Table 8.1*). Coastal habitat change was slight: Rocky Shore decreased by 3.82% and Sandy Shore increased by 17.48%.

Table 8.1 Comparison of the Area Mapped for Each Habitat Type, their Percentage Change in the Previous Studies

Type	Area Mapped in year 2005 (ha)	Area Mapped in year 2007 (ha)	Percentage Change (%)	Post-survey % Cover
Grassland	21,572.70	15,439.90	-28.43	13.81
Other	12,656.30	13,936.50	10.12	12.47
Lowland Forest	18,318.30	12,621.70	-31.10	11.29
Mixed Shrubland	15,196.50	27,941.40	83.87	25.00
Shrubby Grassland	24,674.80	22,305.30	-9.60	19.95
Cultivation	3,838.30	6,300.70	64.15	5.64
Modified Watercourse	2,384.10	2,819.90	18.28	2.52
Fishpond/Gei Wai	1,031.70	895.50	-13.20	0.80
Intertidal Mudflat	656.10	745.70	13.66	0.67
Bare Rock or Soil	5,101.80	2,029.80	-60.21	1.82
Freshwater/Brackish Wetland	130.10	897.40	589.78	0.80
Rural Industrial Storage/Containers	1,379.20	1,043.70	-24.33	0.93
Golf Course/Urban Park	1,398.30	1,158.20	-17.17	1.04
Natural Watercourse	803.90	860.60	7.05	0.77
Landfill	404.30	303.10	-25.03	0.27
Mangrove	343.10	456.80	33.14	0.41
Quarry	168.60	245.60	45.67	0.22
Plantation or Plantation/ Mixed Forest	417.00	926.00	122.06	0.83
Fung Shui Forest	106.30	211.20	98.68	0.19
Montane Forest	123.40	109.50	-11.26	0.10
Seagrass Bed	5.40	6.60	22.22	0.01
Rocky Shore	94.20	90.60	-3.82	0.08
Artificial Rocky/ Hard Shoreline	315.40	230.90	-26.79	0.21
Sandy Shore	179.60	211.00	17.48	0.19

8.2.2 Present Study

Table 8.2 presents the land cover of each habitat type and the change in areal coverage of each before and after the field surveys conducted for the Present Study (see *Section 7.1*). The final percentage cover on the revised habitat map

is also provided in the *Table 8.2*. The total land area of Hong Kong in 2008 was 110,432.00 ha(1). The total study area was higher than the official land area because Sandy Shore, Rocky Shore, Seagrass Bed, Intertidal Mudflat and Mangrove are coastal features that were not included as part of the 110,432.00 ha. In addition, the satellite images were extracted during low tide and the resolution of the images provided was 5m and 10m, which might cause great differences for those marginal pixels.

Among the 24 habitat categories mapped on the revised habitat map, Lowland Forest (23,775.16 ha; 20.96%) was the most extensive habitat and constituted the highest percentage habitat cover. Shrubby Grassland (23,383.46 ha; 20.61%) remained the second largest natural vegetation habitat. Grassland (18,290.03 ha; 16.12%) was the third largest natural vegetation habitat. Mixed Shrubland (18,245.30 ha; 16.08%), which was the largest habitat in 2007, became the fourth largest, with a slightly lower percentage cover than Grassland. Habitat verification in the Present Study resulted in an addition of 62.16 ha (0.26%) to Lowland Forest, 126.41 ha (0.70%) to Mixed Shrubland, but a reduction of 64.45 ha (0.35%) to Grassland and 201.04 ha (0.85%) to Shrubby Grassland. The fifth biggest portion of habitat was Other (13,721.83 ha; 12.09%). 74.77 ha (0.55%) was added to Other after the field surveys.

The remaining habitat categories constituted a small proportion of cover and recorded only slight changes of post-survey area. A slight increase of area was recorded for Modified Watercourse (10.30ha; 0.39%), Fish Pond/Gei Wai (18.58 ha; 1.88%), Rural Industrial Storage/Containers (9.7 ha; 3.13%), Golf Course/Urban Park (4.84 ha; 0.35%), Mangrove (6.28ha; 1.23%), Montane Forest (1.00 ha; 0.74%) and Artificial Rocky/Hard Shoreline (4.41 ha; 1.14%). Habitats with large increases in area included, Seagrass Bed (2.44 ha; 28.37%), Plantation or Plantation/Mixed Forest (68.47 ha; 12.53%) and Sandy Shore (32.35 ha; 6.91%). A slight reduction of area was recorded for Grassland (64.45 ha; 0.35%), Shrubby Grassland (201.04 ha; 0.85%), Bare Rock/Soil (52.72 ha; 1%), Cultivation (3.62 ha; 0.17%), Intertidal Mudflat (3.63 ha; 0.51%), Natural Watercourse (1.83 ha; 0.31%), Fung Shui Forest (0.53 ha; 0.25%) and Rocky Shore (60.91 ha; 4.10%) respectively. Freshwater/Brackish Wetland (60.30 ha; 10.81%) had a significant reduction of area after field survey adjustments. No change was recorded between pre- and post-survey area for the Landfill and Quarry habitats.

The changes of area and number of habitat types between pre- and post-survey maps were more than the 2007 Study as the Field Survey Team drew larger survey boundaries for each sub-site,i.e.the survey area not only included the targeted sampling survey site, but also the habitat nearby. Therefore, more habitat types were identified and re-classified. The justification for the change of surveyed habitat area was stated in *Section 7.1*.

(1) Survey and Mapping Office (2009). Survey and Mapping Office – Circulars and Publications. Retrieved on January 8, 2010 from The Government of Hong Kong Special Administrative Region, Survey and Mapping Office/Lands Department Web site: http://www.landsd.gov.hk/mapping/en/publications/map.htm

Table 8.2 ***Area Mapped Before and After Field Surveys and Habitat Verification for Each Habitat Type, their Percentage Change and Final Percentage Cover (Present Study)***

Type	Pre-Survey Area (ha)	Post-Survey Area (ha)	Change in Area (ha)	Percentage Change (%)	Post-survey % Cover
Grassland	18,354.48	18,290.03	-64.45	-0.35	16.12
Other	13,647.07	13,721.83	74.76	0.55	12.09
Lowland forest	23,712.99	23,775.16	62.17	0.26	20.96
Mixed Shrubland	18,118.89	18,245.30	126.41	0.70	16.08
Shrubby Grassland	23,584.50	23,383.46	-201.04	-0.85	20.61
Cultivation	2,145.09	2,141.47	-3.62	-0.17	1.89
Modified Watercourse	2,648.00	2,658.31	10.31	0.39	2.34
Fishpond/GeiWai	989.02	1,007.60	18.58	1.88	0.89
Intertidal mudflat	715.48	711.84	-3.64	-0.51	0.63
Bare Rock/Soil	2,564.87	2,539.15	-25.72	-1.00	2.24
Freshwater/Brackish Wetland	557.84	497.54	-60.30	-10.81	0.44
Rural Industrial Storage/Containers	309.57	319.27	9.70	3.13	0.28
Golf course/Urban park	1,396.52	1,401.36	4.84	0.35	1.24
Natural Watercourse	591.62	589.79	-1.83	-0.31	0.52
Landfill	211.41	211.41	0.00	0.00	0.19
Mangrove	512.63	518.91	6.28	1.23	0.46
Quarry	148.99	148.99	0.00	0.00	0.13
Plantation or Plantation/ Mixed Forest	546.55	615.02	68.47	12.53	0.54
Fung Shui Forest	211.21	210.68	-0.53	-0.25	0.19
Montane forest	135.56	136.56	1.00	0.74	0.12
Seagrass bed	8.60	11.04	2.44	28.37	0.01
Rocky shore	1,485.03	1,424.12	-60.91	-4.10	1.26
Artificial Rocky/ Hard Shoreline	388.59	393.01	4.42	1.14	0.35
Sandy shore	468.42	500.77	32.35	6.91	0.44
TOTAL	113,452.93	113,452.62			

8.2.3 Comparison of Habitat Change between Previous 2007 Study and Present Study

In the previous 2007 Study, 111,787.50 ha of the Hong Kong area were mapped in 24 habitat categories. With the latest SPOT5 data and remote sensing classification technique, the boundary of land was defined and the total area mapped with the 24 habitat categories in the Present Study was 113,452.62 ha based on the final habitat map of 5-m resolution.

Increases of total area of habitat within Hong Kong for Grassland (2.55%), Lowland Forest (9.98%), Shrubby Grassland (0.96%), Fish Pond/Gei Wai (0.10%), Bare Rock/Soil (0.46%), Golf Course/Urban Park (0.22%), Mangrove (0.06%), Rocky Shore (1.19%), Artificial Rocky/Hard Shoreline (0.15%) and Sandy Shore (0.26%) were observed (*Table 8.3*). The significant increase for Lowland Forest was likely due to the succession from Mixed Shrubland. The increase in Grassland was partially due to the habitat change from abandoned cultivated land and partially due to the change from Plantation after hill fires.

There was a reduction of total area of habitat within Hong Kong for Other (0.19%), Mixed Shrubland (8.67%), Cultivation (3.72%), Intertidal Mudflat (0.03%), Modified Watercourse (0.14%), Freshwater/Brackish Wetland (0.36%), Rural Industrial Storage/Containers (0.65%), Natural Watercourse (0.24%), Landfill (0.08%), Quarry (0.09%) and Plantation or Plantation/Mixed Forest (0.28%). The significant reduction for Mixed Shrubland was likely due to the succession to Lowland Forest as mentioned above. The change of abandoned cultivated land to other natural habitat (such as Freshwater/Brackish Wetland, Grassland and Shrubby Grassland) or urban land use (such as Rural Industrial Storage/Container, Other and Urban Park) contributed to the significant decrease of Cultivation. During the field survey, the influence of hill fire on Plantation led to the change of plant species and stratification was observed.

No significant change in the percentage of total area within Hong Kong was observed among habitats of Intertidal Mudflat, Fung Shui Forest, Montane Forest and Seagrass Bed.

Table 8.3 Habitat Areas Mapped for the Previous 2007 Study and Present Study

Type	Area Mapped in year 2007 (ha)	Present Study Area (ha)	Change in Area (ha)	Change in % of Total Area of Hong Kong
Grassland	15,439.9	18,290.03	2850.13	2.55
Other	13,936.5	13,721.83	-214.67	-0.19
Lowland Forest	12,621.7	23,775.16	11153.46	9.98
Mixed Shrubland	27,941.4	18,245.30	-9696.10	-8.67
Shrubby Grassland	22,305.3	23,383.46	1078.16	0.96
Cultivation	6,300.7	2,141.47	-4159.23	-3.72
Modified Watercourse	2,819.9	2,658.31	-161.59	-0.14
Fishpond/Gei Wai	895.5	1,007.60	112.10	0.10
Intertidal Mudflat	745.7	711.84	-33.86	-0.03
Bare Rock or Soil	2,029.8	2,539.15	509.35	0.46
Freshwater/Brackish Wetland	897.4	497.54	-399.86	-0.36
Rural Industrial Storage/ Containers	1,043.7	319.27	-724.43	-0.65
Golf Course/Urban Park	1,158.2	1,401.36	243.16	0.22
Natural Watercourse	860.6	589.79	-270.81	-0.24
Landfill	303.1	211.41	-91.69	-0.08
Mangrove	456.8	518.91	62.11	0.06
Quarry	245.6	148.99	-96.61	-0.09
Plantation or Plantation/ Mixed Forest	926.0	615.02	-310.98	-0.28
Fung Shui Forest[k]	211.2	210.68	-0.52	0.00
Montane Forest	109.4	136.56	27.16	0.02

Type	Area Mapped in year 2007 (ha)	Present Study Area (ha)	Change in Area (ha)	Change in % of Total Area of Hong Kong
Seagrass Bed[k]	6.6	11.04	4.44	0.00
Rocky Shore	90.6	1,424.12	1333.52	1.19
Artificial Rocky/ Hard Shoreline	230.9	393.01	162.11	0.15
Sandy Shore	211.0	500.77	289.77	0.26

k: Some of the habitat areas were mapped as dot locations on the base map. Seagrass data is provided by SDD and generated by AFCD. The database has accumulated several years' survey data on the distribution of seagrass in the territory of Hong Kong. Since the size of each seagrass bed at different locations varies from time to time, in the Present Study, we extracted data that was collected in the most recent time representing the current size of the seagrass beds into our habitat map. The final estimation of the area size is 6.56 hectares.

8.3 CONSERVATION ASSESSMENT

8.3.1 Ecological Value of Spatial Habitats

Previous Study

In the previous 2007 Study, there were 43,849 ha of habitats classified as of high ecological value which represented 39.23% of the total mapped area (*Table 8.4*). Medium value habitats comprised 30,707 ha (i.e. 27.47%) of the total land area mapped for Hong Kong. Low and Negligible value habitats comprised 19.63% and 13.67% respectively of the total land cover (*Table 8.4*).

Table 8.4 Total Area of Spatial Habitats Assigned Ecological Value of High, Medium, Low and Negligible for the Previous 2007 and Present Studies

Ecological Value	Total Area (ha) (Previous 2007 Study)	Percentage Cover (%) (Previous 2007 Study)	Total Area (ha) (Present Study)	Percentage Cover (%) (Present Study)	Change between 2007-2009 (ha)
High	43,849.00	39.23	44,696.80	39.40	847.80
Medium	30,707.00	27.47	29,072.44	25.63	-1,634.56
Low	21,949.00	19.63	25,430.85	22.42	3,481.85
Negligible	15,283.00	13.67	14,252.52	12.56	-1,030.48

Present Study

After field assessment for the Present Study, the total habitat area that was classified as of high ecological value comprised 44,696.80 ha (i.e. 39.40%of total area) (*Table 8.4*).

A total of 29,072.44 ha (i.e. 25.63%) of the total habitat area was identified as of medium ecological value (*Table 8.4*). The areal coverage obtained for the low and negligible value habitats in the Present Study was 22.42% and 12.56% respectively (*Table 8.4*).

An increase of 1.93% was observed in high ecological value habitat area between the 2007 Study and Present Study (*Table 8.4*). Such an increase was likely due to an increase in the classification of Lowland Forest habitat. A decrease of 5.32% was observed in medium ecological value habitat area.

This was likely due to the loss of Cultivation. An additional 15.86% of Low ecological value habitat area was observed between the previous 2007 Study and Present Study (*Table 8.4*), and this was likely due to the increase in Grassland and Bare Rock/Soil. A decrease in habitat areas for negligible ecological value (6.74%) was observed between the previous 2007 Study and Present Study (*Table 8.4*). This was likely due to a decrease in Other and Rural Industrial Storage/Containers; however, this may also be the result of discrepancies in classification between Bare Rock/Soil and Other.

9 SUMMARY & CONCLUSIONS

9.1 SUMMARY

This *Final Report* presents the results of a review of the previous habitat mapping updating exercises conducted as part of the SUSDEV 21 Study with details on the discrepancies, uncertainties and outstanding information gaps identified. The *Final Report* also presents the key findings of the 84 days of ecological field surveys conducted during the period from 10 March 2009 to 23 June 2009 for the Present Study. Discussions on finalised definitions of habitat mapping categories, conservation ranking system, strategy of survey effort allocation, survey methodology and the information gaps filled by the Present Study are also included in this *Final Report*. The key findings of the Present Study are summarised below:

- The definitions of individual habitat mapping categories were reviewed and it was considered appropriate to maintain the same 24 habitat categories as the previous 2007 Study. Indicative ecological value (i.e. high, medium, low and negligible) of individual habitat types defined in the Previous Studies were unchanged and no modification was considered necessary.

- It was considered appropriate to retain the conservation ranking system devised in the Previous Studies to provide an acceptable and composite means by which the conservation values of different areas, representing different features, can be ascribed, mapped and compared.

- Eighty-four days of ecological field-truthing surveys for the Present Study commenced on 10 March 2009 and were completed on 23 June 2009. A total of 610 sites comprising approximately 2,336.6 hectares of spatial habitats were visited during the Present Study period. Field surveys were conducted in accordance with the approved methodology (*Sections 5* and *6* of this Report).

- The results of the 84 days of field surveys were used to adjust the mapped boundaries of habitats at particular sites and to upgrade or downgrade the indicative ecological value assigned on the basis of the criteria presented in *Section 4*. The data collected from the field surveys were analysed and used for editing the existing habitat map and refining the ecological value ranking.

- The updated habitat map comprised a total land mass (above low tide mark) of 113,452.61 hectares. Among the 24 habitat categories mapped on the habitat map, Lowland Forest (23,775.16 ha) and Shrubby Grassland (23,383.46 ha) were the most extensive habitat types, whilst Seagrass Bed occupied the smallest land cover (11.04 ha). This partially differed from

the 2007 Study, where Mixed Shrubland was the most extensive habitat type and Seagrass Bed the least extensive.

- The areal mapping accuracy of the habitats surveyed in the Present Study ranged from 38.37% for Rocky Shore to 92.89% for Seagrass Bed. Seagrass Bed obtained high mapping accuracy (>90%). Satisfactorily high mapping accuracy percentage (70% - 90%) was obtained for Mangrove (88.61%), Lowland Forest (88.42%), Intertidal Mudflat (79.73%), Sandy Shore (79.36%) and Plantation or Plantation/Mixed Forest (72.90%). Habitats having a moderate mapping accuracy of between 40 - 70% include Cultivation (67.14%), Freshwater/Brackish Wetland (63.66%), Mixed Shrubland (64.17%), Natural Watercourse (56.43%) and Shrubby Grassland (55.05%). Only one relatively low mapping accuracy (<40%) habitat was recorded and that was Rocky Shore (38.37%).

- A significant increase in the total area within Hong Kong for Lowland Forest was observed between the 2007 Study and Present Study (9.98%). This was probably due to the natural succession from Mixed Shrubland into Lowland Forest. Grassland also saw an increase of 2.55% and this was most likely due to the habitat change from abandoned cultivation and partially due to the change from Plantation after hill fires.

- There was a significant reduction in the total area within Hong Kong for Mixed Shrubland (8.67%) compared to the 2007 Study and this was most likely due to its succession to Lowland Forest as mentioned above. Cultivation also saw a decrease of 3.72% and this was probably due to the change of abandoned cultivated land to other natural habitat (such as Freshwater/Brackish Wetland, Grassland and Shrubby Grassland) or urban land use (such as Rural Industrial Storage/Container, Other and Urban Park).

- The total habitat area that was classified as of high ecological value comprised 44,696.80 ha (i.e. 39.40%). A total of 29,072.44 ha (i.e. 25.63%) of the total habitat area was identified as of medium ecological value. The areal coverage obtained for the low and negligible value habitats in the Present Study was 25,430.85 ha (22.42%) and 14,252.52 ha (12.56%) respectively.

- An increase of 1.93% was observed in high ecological value habitat area between the 2007 Study and the Present Study. This small increase was likely due to the significant increase of Lowland Forest, which was slightly more than the significant reduction in Mixed Shrubland habitat.

- There was a significant increase (15.86%) of low ecological value habitat area between the 2007 Study and Present Study. This was most likely due to the total area being relatively small, so any changes being more pronounced and the increase in Bare Rock/Soil habitat. In addition, there were significant area and percentage increase of Grassland (2850.13 ha; 18.46%) and Bare Rock or Soil (509.35 ha; 25.09%) between 2007 Study and Present Study.

9.2 RECOMMENDATIONS FOR FURTHER STUDIES

The Present Study provides the most up-to-date information on existing terrestrial habitats in Hong Kong and the results have been compared with the Previous Studies. This has allowed changes in different habitats that have occurred between 2007 and 2009 to be identified. Recommendations for further study are summarised as follows:

- More resources should be assigned to training site surveys to ensure sufficient high quality input for remote sensing analysis. The accuracy can be greatly increased.

- Training site and survey site results of Previous Studies can be used as one of the inputs for remote sensing analysis. However, desktop truthing and surveys should be conducted in advance to ensure the habitat type remains unchanged.

- Longer duration between remote sensing analysis results and the first report submission, to provide more time for desktop truthing. Desktop truthing is important to further enhance the mapping accuracy of habitat type classification in each land cover class generated by remote sensing technique, especially for Bare Rock or Soil, Sandy Shore, Rocky Shore and Natural Watercourse.

- Since the overall habitat boundary and ecological value of each habitat type are not expected to be changed frequently, it is recommended to be updated on a 3 to 5 year and as needed basis;

- Additional field truthing surveys are recommended to further enhance the accuracy of the habitat map and conservation map by random assessment of more polygons.

- A longer survey period covering both wet and dry seasons as much as possible, to allow the intertidal habitats and natural watercourses to be assessed within their optimal seasons.