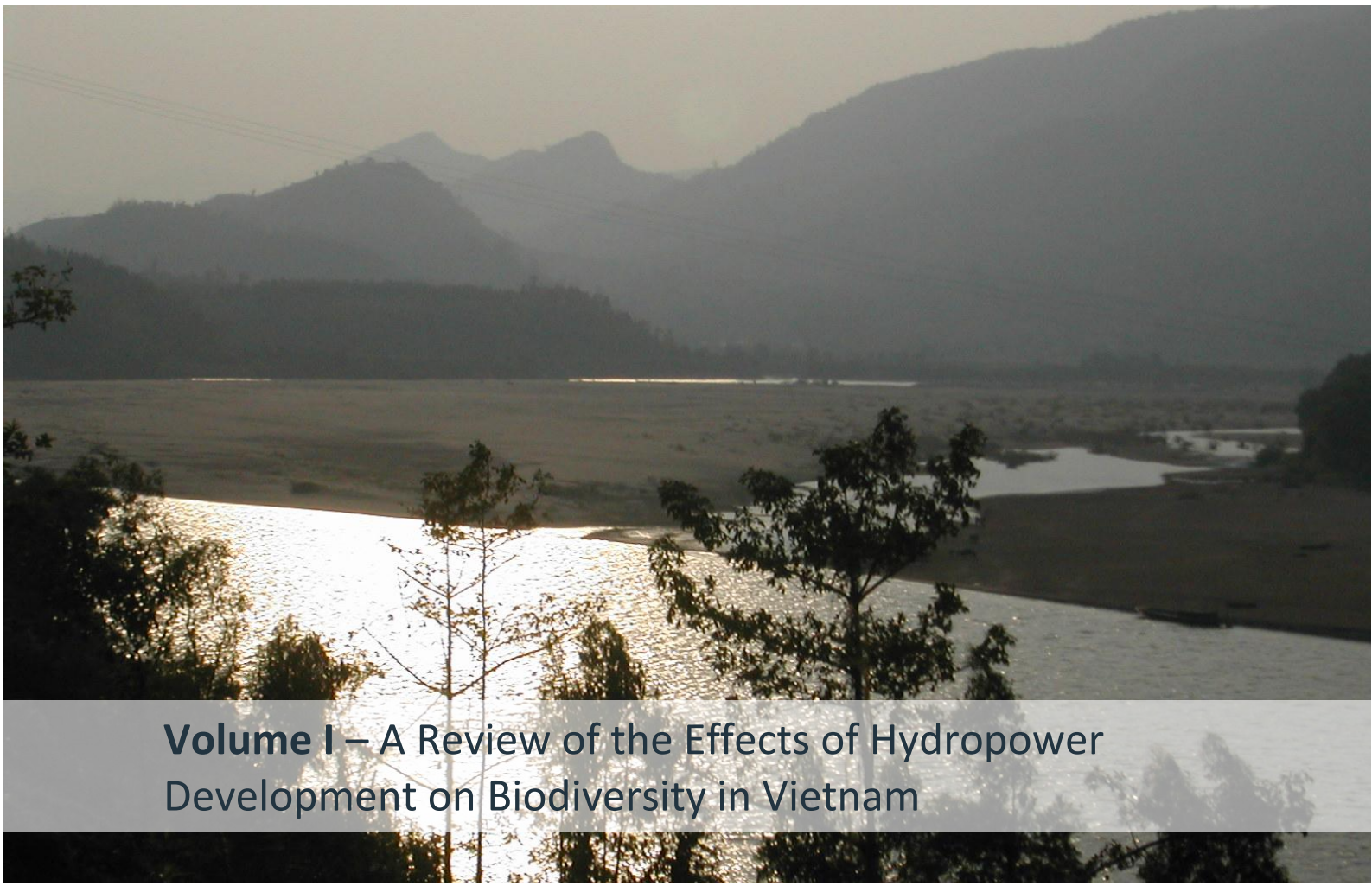
2010

Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnamese Experience



Volume I – A Review of the Effects of Hydropower Development on Biodiversity in Vietnam

Produced by: ICEM Asia

Sponsored by: Critical Ecosystem Partnership Fund

Citation: Carew-Reid, Jeremy, Josh Kempinski and Alison Clausen. 2010. *Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnamese Experience – Volume I: Review of the Effects of Hydropower Development on Biodiversity in Vietnam.* ICEM – International Centre for Environmental Management, Prepared for the Critical Ecosystem Partnership Fund, Hanoi, Viet Nam.

More information: www.icem.com.au | info@icem.com.au

ICEM Asia
International Center for Environmental Management
32 Xuan Dieu,
Tay Ho, HANOI,
Socialist Republic of Viet Nam

Cover Image: Song Bung River (Jay Roop, 2006)

Table of Contents

Acronyms

ADB	Asian Development Bank
CEPF	Critical Ecosystems Partnership Fund
EVN	Electricity of Vietnam
GHG	Greenhouse gas
IBA	Important bird area
ICEM	International Centre for Environmental Management
KBA	Key biodiversity area
MONRE	Ministry of Natural Resources and Environment
MPA	Marine protected area
NP	National park
NR	Nature reserve
PA	Protected area
PDP	Power Development Plan
SEI	Stockholm Environment Institute
SUF	Special use forest
ZOI	Zone of Influence

Preface

Vietnam is one of the most biologically diverse countries on Earth. It is a conservation hotspot supporting nearly 10 percent of the global total of mammal and bird species. Many species are found only in Vietnam or in few other places. It is recognised as having especially high rates of terrestrial endemism. For example, in the decade to 2002, 13 new genera, 222 new species and 30 new subspecies of plants were described in Vietnam – many endemic to the country. Its freshwater biodiversity is equally significant for its conservation values. Those assemblages of ecosystems, plants and animals play a critical role in national development and wellbeing, providing economic sectors and local communities with essential goods and services. Yet, human uses and consumption are placing stress on this natural systems foundation for development. Nearly 700 species are threatened with extinction nationally while over 300 species are threatened with global extinction. Forty-nine of Vietnam's globally threatened species are classified as 'critically endangered', meaning that they face a high risk of extinction in the wild in the immediate future.[1]

At the same time, Vietnam is undergoing a prolonged period of rapid and successful economic and social development. Significant advances in poverty alleviation – a reduction from 58% in 1993 to 15.9% in 2006[2] – urbanisation and industrialisation have been achieved. This growth has resulted in significant and continuing increases in electricity demand. In April 2010, the Ministry of Industry and Trade's Electricity Regulatory Authority raised its forecast increase in demand for the year from 15% to 17%. Demand for power in the first quarter of 2010 rose by 20.2%. In 2008, growth in electrical output increased by 13% and in 2009 by 14%[3].

To meet these growing demands, while also trying to minimise negative environmental effects planners and scientists are endeavouring to establish a balanced energy mix for the country. The Government's 6th Power Development Plan for 2006-2015 reflects that goal. Hydropower is projected as one of the main sources of electricity, with ambitious plans to dam most of the nation's river systems.

Despite its important role as a renewable resource replacing fossil fuel dependent power generation, hydropower comes with its own significant social and environmental costs. The challenge facing Vietnam is settling on the right scale and pace of hydropower development so that natural resources and their uses by other sectors are maintained along with biodiversity and social and cultural assets. Potential losses in development, social and environmental values of biodiversity need to be weighed against the economic and social benefits of hydropower. It is in this context that Strategic Environmental Assessment, or SEA, is valuable as a development planning tool.

This set of good practice manuals on "*Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnamese Experience*" is designed to increase our understanding of the relationship between hydropower and biodiversity, and provide guidance on the assessment tools that are available to help minimise negative and unwanted side effects of hydropower development.

[1] World Bank, 2007, Biodiversity, Vietnam Environment Monitor, Hanoi, Vietnam

[2] UNDP, Migration, Development and Poverty Reduction Workshop & UNDP HDR, Monday 5 October 2009

[3] Mr. Do Duc Quan , Deputy Director General of Energy Department, MOIT. Workshop on Power Development, 7 January 2010.

Acknowledgements

This set of good practice manuals has been prepared by an ICEM - International Centre for Environmental Management. This volume was prepared by Jeremy Carew-Reid, Josh Kempinski, and Alison Clausen drawing mainly on the work conducted by ICEM SEA teams especially Jack Tordoff, Marcus Sheaves, Andrew Grieser Johns and John Pilgrim. The team was assisted by Nguyen Thi Nga and Nguyen Kim Hai with inputs and advice on GIS from ICEM's Jasmine Muir and Lothar Linde from the ADB Environment Operations Centre.

Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnam Experience was sponsored by a grant from the Critical Ecosystem Partnership Fund (CEPF). CEPF is a joint program of *l'Agence Française de Développement*, Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. In Vietnam the CEPF is administered by the BirdLife International Indochina Programme. This project was overseen and facilitated by John Pilgrim and Nguyen Hoang Long of BirdLife International and Douglas Graham of the World Bank.

Production of these manuals was based mainly on three previous studies that used SEA to assess hydropower and in particular its impact on biodiversity: the World Bank, ICEM and BirdLife International SEA of the National Hydropower Plan with special reference to biodiversity (2006), the Asian Development Bank (ADB) and ICEM SEA of Hydropower Development in the Vu Gia – Thu Bon River Basin (2008) and the ADB and Stockholm Environment Institute (SEI) SEA of the National Power Development Plan (2009) all conducted with the Ministry of Natural Resources and Environment (MoNRE), the Ministry of Industry and Trade (MOIT) and Electricity of Vietnam (EVN). The Mekong River Commission and ICEM SEA of Hydropower on the mainstream Mekong River (2010), running parallel with this study was another important sources of guidance and innovation for these manuals.

1. Introduction

The Government of Vietnam has embarked on a major expansion of the hydropower sector which is transforming the aquatic systems of the country. All main river systems are or will be dammed by one or cascades of hydropower projects – each with road access and transmission lines and linked development shaping the terrestrial, aquatic and social environment. Recent strategic assessments of the relationship between hydropower and biodiversity in Vietnam have concluded the development envisaged would bring economic, social and even some environmental benefits. Yet, the pace and scale of that development is well beyond existing mechanisms and capacities for addressing social and environmental effects and the full economic consequences. Hydropower development is proceeding on a rapid and comprehensive scale for maximising power and profits but with only rudimentary or even misleading information and analysis on its sustainability and implications for other sectors and social and natural systems. The maintenance of ecosystem integrity, including the effects of multiple hydropower schemes within a river basin has been identified by governments of the region and their international partners as a key strategic concern for hydropower development in Vietnam and elsewhere in the Mekong Basin.[4]

There is a need for capacity development, research and information sharing on two fronts: first, in relation to **the potential effects of hydropower development on biodiversity** and second, in relation to the **tools and methods available to integrate consideration of biodiversity issues into hydropower planning and development**.

With funding from the CEPF Small Grants Program, ICEM –International Centre for Environmental Management has prepared an information kit that aims to assist in filling these gaps. This information kit, ***Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnamese Experience***, contains the following documents:

(i) Volume I – A Review of the Effects of Hydropower Development on Biodiversity in Vietnam

(ii) Volume II – Hydropower and Biodiversity: The Use of Strategic Environmental Assessment as a Development Planning Tool

(iii) Biodiversity and Hydropower Factsheet

(iv) Practice Note - Hydropower and Biodiversity: The Use of Strategic Environmental Assessment as a Development Planning Tool

(v) Hydropower and Biodiversity: Lessons Learnt from the Vietnamese Experience CD-ROM

This volume, ***Volume I – A Review of the Effects of Hydropower Development on Biodiversity in Vietnam***, targets civil society, Government and donors and aims to be an accessible, practical overview of current knowledge on the relationship between hydropower development and the potential effects on biodiversity. The document focuses on Vietnam, but includes reference to the results of current international knowledge. The report is a reference document for those carrying out investigations or studies related to hydropower development in Vietnam to guide comprehensive consideration of biodiversity issues.

Volume I is structured as follows:

[4] As reflected in the 2009/10 commitments of Mekong River Commission member countries to adopt sustainable hydropower guidelines and to conduct a SEA of hydropower proposals for the mainstream Mekong River.

- Section 1 introduces the information kit
- Section 2 discusses the current context of biodiversity and hydropower development in Vietnam
- Section 3 explores the relationship between hydropower and biodiversity
- Section 4 identifies data gaps and future research needs
- Section 5 introduces mitigation approaches and examples for reducing negative impacts of hydropower on biodiversity
- Section 6 identifies useful sources of further information

Box 1: Key definitions

Biodiversity: The variability among living organisms in an area and the ecological complexes of which they are part, including diversity within species, between species, and of ecosystems.

Ecosystem: A system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit.

Hydropower: refers to the generation of electricity from the movement of water, under the force of gravity, through a turbine. Hydropower includes very small-scale turbines (referred to as micro-hydropower) but is usually a term for large-scale operations associated with the damming of rivers. Dams create reservoirs which store vast quantities of water to ensure a constant and reliable flow of water (kinetic energy) to the turbines while also providing additional height (potential energy) to maximise the speed of the falling water, the spinning speed of the turbine and the thus the power output from the hydropower plant

Key Biodiversity Area (KBA): 102 KBAs have been identified in Vietnam. These areas, including those located outside the gazette protected area network, have been identified by Birdlife International as important for the conservation of globally endangered species.

Large Storage Dam: dams with spillway height greater than or equal to 15m, or dams with a spillway height between 5 and 15 m and a capacity of more than 3 x 103 m3.

Environmental Management Plan: A combination of activities that are implemented to ensure the environmental performance of a project is satisfactory and in line with legislation and agreed commitments. The Plan includes details on environmental mitigation and monitoring, together with institutional arrangements for implementation of activities, budgets, responsibilities, reporting, and feedback loops.

Environmental Mitigation: refers to activities that are implemented to reduce the severity of impacts. There exists a hierarchy of mitigation measures. First, measures are needed to avoid impacts (e.g. site selection to avoid impacts on key biodiversity areas). For negative impacts that can't be avoided, actions are needed to reduce their intensity. Also, actions are required to compensate for residual impacts (e.g. by providing compensatory protected areas). Finally, the benefits of the projects should be enhanced and equitably shared.

Environmental Monitoring: refers to a process of observation of the environmental performance and impacts of a project to validate impact predictions and inform the development of adaptive management measures.

Power Development Plan VI: the Vietnamese Government ten year plan from 2006 to 2015, with a vision to 2025, which outlines trends in Vietnam's consumption of electricity, projected consumption, and methods to meet present and future demand within the ten year period. The 6th PDP places particular emphasis on the central role of hydropower in meeting energy needs in this planning cycle. Dams have been built or are planned on all major rivers systems in the country.

Riparian ecosystem: the stream channel between the high and low water marks plus the terrestrial

landscape above the high water mark where vegetation may be influenced by elevated water tables, flooding patterns, or the ability of soils to hold water.

Run of the River Dam: generally a smaller dam located on a river that uses the river's natural flow to generate electricity. Such schemes are suitable for development on rivers with relatively consistent and steady flows and avoid the need for large impoundments.

Strategic Environmental Assessment (SEA): a method for systematically internalising sustainability principles within policies, plans and programs.

2. Biodiversity and hydropower in Vietnam: The context

Already hydropower development in Vietnam is transforming aquatic systems throughout the country and having significant effects on terrestrial biodiversity. Most catchments are targeted for development of large numbers of additional large to small hydropower projects over the next decade as set out in the national and provincial power plans.

The type and intensity of impact on biodiversity is influenced by the size of each project and cumulative effects as the number of projects on a single river, or within a river basin, increases. Hydropower projects include a dam, reservoir and the infrastructure linked to power transmission. Often, they involve resettlement of communities to new areas and other adjustments to surrounding land uses. Damming a river has the potential to impact on upper and downstream reaches of the river, the flow and function of the tributaries, the main stream aquatic habitats and biodiversity, forest habitats in the floodplain or basin, delta mangroves and coastal habitats, as well as the marine ecosystems such as sea grass, coral and the sediment and nutrient plume closely linked to fisheries productivity.

2.1 Biodiversity in Vietnam

Vietnam has biodiversity values of international importance - while covering less than one percent of the land area, it contains around ten percent of the world's species. Over 109 large mammals, 850 species of birds and over 15,986 plant species have been recorded in Vietnam. The country has been evaluated as one of the 16 most biologically diverse in the world,[5] and one of the top five Asian countries in terms of number of freshwater fish species.[6] Vietnam is a global conservation priority. It is part of the Indo-Burma 'Hyper-Hotspot' defined by Conservation International.[7] It contains all or part of six Global 200 Ecoregions identified by WWF.[8] It contains seven Centres of Plant Diversity identified by IUCN;[9] and it contains all or part of five Endemic Bird Areas identified by BirdLife

[5] WCMC (1992) *Development of a national biodiversity index.* A discussion paper prepared by the World Conservation Monitoring Centre, Cambridge, UK. Unpublished.

[6] Whitten, A. and Kottelat, M. (1996) *Freshwater biodiversity in Asia: with special reference to fish.* World Bank Technical Paper No. 343. Washington D.C.: The World Bank.

[7] van Dijk, P. P., Tordoff, A. W., Fellowes, J., Lau, M. and Jinshuang, M. (2004) Indo-Burma. Pp 323-330 in R. A., Mittermeier, Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreaux, J. and da Fonseca, G. A. B. eds. *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. Monterrey: CEMEX; Washington D.C.: Conservation International; and Mexico: Agrupación Sierra Madre.

[8] WWF (2005) *List of Global 200 Ecoregions*. Downloaded from http://www.panda.org on 6 April 2006.

[9] Davis, S. D., Heywood, V. H. and Hamilton, A. C. eds. (1995) *Centres of plant diversity: a guide and strategy for their conservation. Volume 2: Asia, Australasia and the Pacific*. Cambridge, U.K.: IUCN Publications Unit.

International.[10] Vietnam has several globally important conservation ecoregions identified by WWF including the Lower Mekong floodlands, Central Highlands / Annamite Mountains and the northern limestone forests,[11] (Map 1 & Map 3).

Vietnam's high significance for global biodiversity conservation is reflected in the wide diversity of natural ecosystems (Map 1 & Map 2), and the high levels of plant and animal endemism supported by them.

Vietnam's natural ecosystems support a large number of species with restricted global distributions, including many found nowhere else in the world. For many species Vietnam represents the only opportunity for their conservation. 10% of flora in Vietnam are endemic species.[12] Subsets of these species have extremely restricted global distributions, and are only known from one or a few individual sites.

One of the major centres of terrestrial biodiversity endemism in Vietnam is the Annamite (or Truong Son) Mountains. Since the early 1990s, a remarkable suite of new mammal and bird species have been discovered in these mountains, unparalleled elsewhere in the world. The newly discovered species include Saola *Pseudoryx nghetinhensis*, Large-antlered Muntjac *Muntiacus vuquangensis*, Annamite Striped Rabbit *Nesolagus timminsi* and Black-crowned Barwing *Actinodura sodangorum*. Other centres of endemism in Vietnam include limestone karst formations, which support many restricted-range plants and animals, notably in such groups as orchids, conifers,[13] land snails, cave invertebrates,[14] soil invertebrates and leaf monkeys,[15] and the Hoang Lien Mountains, which support high levels of endemism in plants, amphibians and several invertebrate groups.

Vietnam's remaining forest is of global biodiversity importance. The most extensive and widely distributed terrestrial ecosystems in the country are evergreen forests of various types. Lowland evergreen forests, which are distributed below 800-1,000 m asl in areas with high rainfall and a short dry season, support the highest diversity of tree species (Map 3). Deciduous forests are found in lowland areas with a prolonged dry season. They are dominated by a smaller number of tree species, in the *Dipterocarpaceae* family, and often have very open structures with grassy understoreys, supporting distinctive plant and animal communities. All lowland forests, extensively cleared for agriculture, are essential for the survival of many large mammals in Vietnam, among other rare species, including Javan rhinoceros *Rhinoceros sondaicus*, gaur *Bos gaurus*, elephant *Elephas maximus* and tiger *Panthera tigris*.

---

[10] Tordoff, A. W. ed. (2002) *Directory of* Important *Bird Areas in Vietnam: key sites for conservation*. Hanoi: BirdLife International *in Indochina* and the Institute of Ecology and Biological Resources.

[11] Baltzer et al (2001) *Towards a vision for biodiversity conservation in the Forests of the Lower Mekong Ecoregion Complex.* Hanoi: WWF Indochina Program.

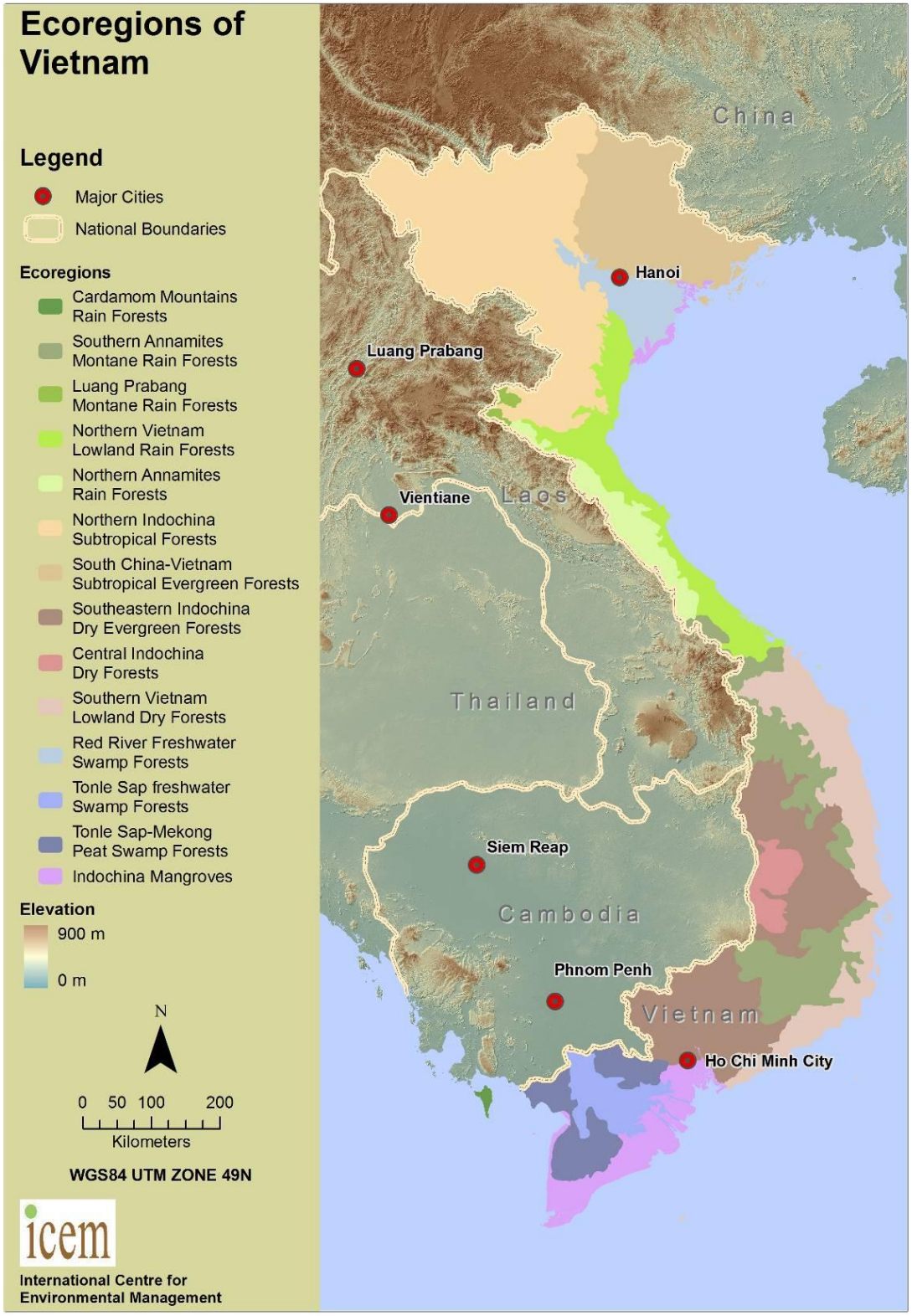
[12] Convention on Biological Diversity. Website accessed on April 20th 2010, http://www.cbd.int/countries/profile.shtml?country=vn

[13] Nguyen Tien Hiep, Phan Ke Loc, Nguyen Duc To Luu, Thomas, P.I., Farjon, A., Averyanov, L. and Regalado Jr., J. (2005) *Vietnam conifers: conservation status review 2004*. Hanoi: Fauna & Flora International Vietnam Programme.

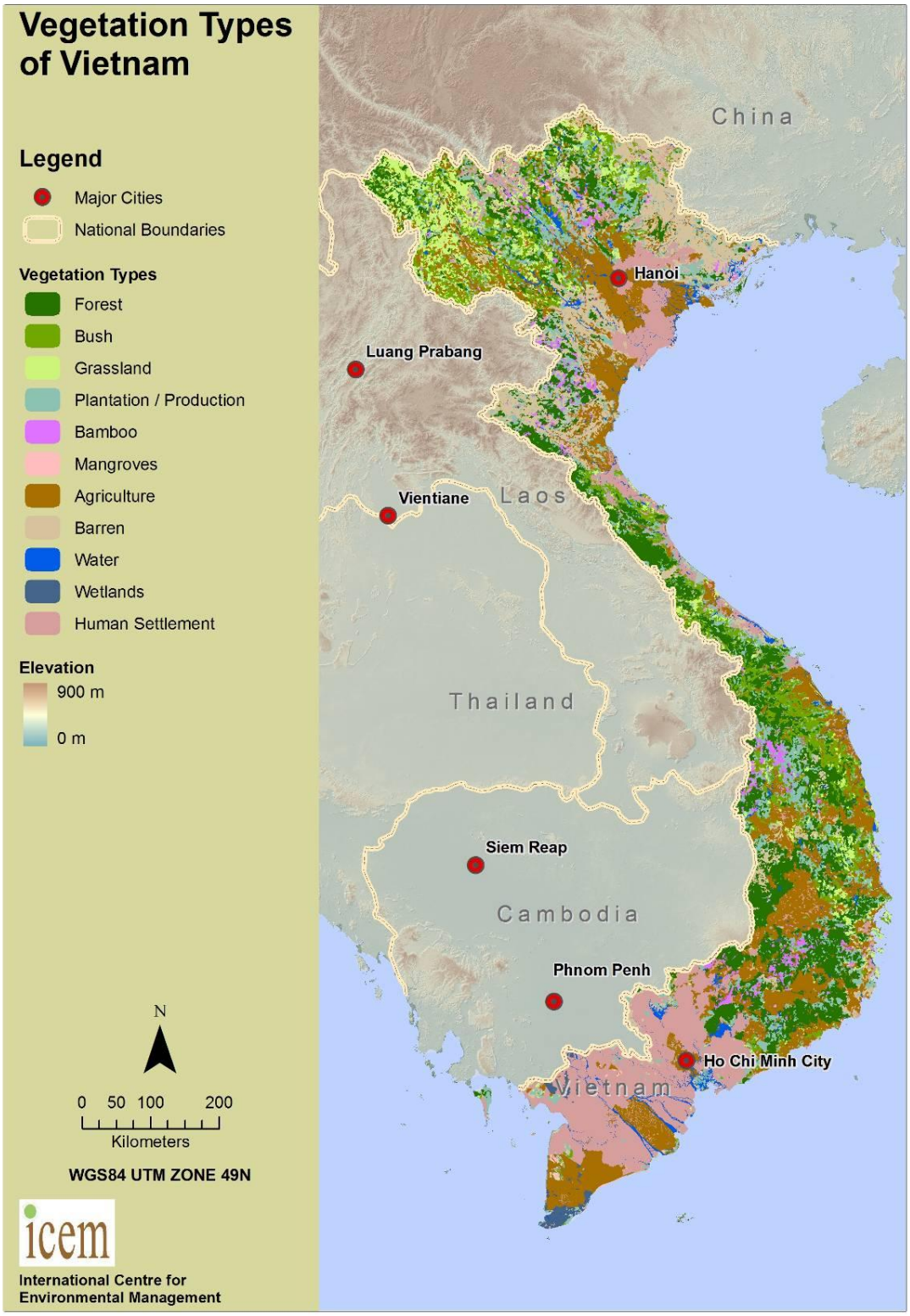
[14] Deharveng L., Le Cong Kiet and Bedos A. (2001) Vietnam. Pp. 2027-2037 in: Juberthie C. and V. Decu eds. *Encyclopaedia Biospeologica* tome III. (In French.)

[15] Nadler, T., Momberg, F., Nguyen Xuan Dang, and Lormee, N. (2003) *Vietnam primate conservation status review 2002. Part 2: leaf monkeys*. Hanoi: FFI Vietnam Programme and Frankfurt Zoological Society.

Map 1: Ecoregions in Vietnam



Map 2: Land use, land cover and vegetation types in Vietnam



Limestone forest is distributed on karst formations (see Map 3). These formations are concentrated in parts of north-eastern and central Vietnam, although smaller areas are distributed elsewhere in the country. Limestone forest ecosystems are characterised by high levels of localised plant and animal endemism and are considered to be a global priority for conservation.[16] Despite extensive clearing, they still harbour mammals and birds of conservation significance, including the Owston's civet *Chrotogale owstoni*, Delacours langur *Trachypithecus delacouri*, red-shanked douc langur *Pygathrix nemaeus*, Francois's langur *Semnopithecus francoisi* and three gibbon species. This 'ecoregion' is also noted for high bat diversity and endemism, as well as 300 bird species including three near-endemic and one endemic species.[17]

Montane evergreen forests, which are distributed at higher elevations, have less diverse tree communities, however, these forests are characterised by significant species richness and high rates of endemism among epiphytic and understorey floral species, notably orchids, as well as reptile and amphibian species.

Vietnam has a wide diversity of freshwater ecosystems. Viet Nam has 2,372 rivers over 10 km long and with a perennial flow. There are 13 rivers with basins over 10,000 km2. Although less studied than terrestrial areas, Vietnam's aquatic biodiversity includes many species of international importance. Fish diversity is high, with 2470 species, including at least 268 native freshwater fish and 7 species listed as nationally vulnerable *(Clupanodon punctatus, Onychostoma laticeps, Bangana lemassoni, Spinibarbus hollandi, Tor tambroides, Cranoglanis sinensis* and *Bagarius bagarius)* (Red Book of Viet Nam, 2000)[18]. Other aquatic taxa are also likely to be diverse, but are little studied, and as for fish, new species are still being identified[19].

Flowing wetlands can be grouped into high gradient waters and low gradient waters. High gradient waters, which include hill streams, rapids and waterfalls, tend to be distributed at elevations above 300 m asl. In Vietnam, these ecosystems tend to support high levels of endemism in fish, amphibians and insects. Low gradient waters, such as slow-flowing sections of streams and rivers, are concentrated at elevations below 300 m asl, and support lower levels of endemism in fish, amphibians and insects. Karst systems are particularly important for freshwater biodiversity. Limestone karst formations frequently contain extensive subterranean stream systems, which support very high levels of endemism; a large number of species are only known from a single cave or cave system.

Vietnam also supports a wide variety of non-or slow-flowing wetlands. The total area of natural lakes is estimated to be 20,000 ha[20]. Peat swamps are particularly important because they support specialised organisms with localised distributions and a high degree of endemism[21]. Natural peat swamps were once widely distributed in the Red River and Mekong Deltas but now are restricted to small areas in the Mekong Delta. Seasonally inundated grasslands are another important and increasingly fragmented habitat; they support populations of several threatened waterbirds, as well as Wild Rice *Oryza rufipogon*, the wild progenitor of cultivated rice.

---

[16] Brooks et al (2002) Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* 16: 909–923.

[17] WWF (2001) Ecoregion Profile – website accessed on 24th April 2010, http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0210_full.html

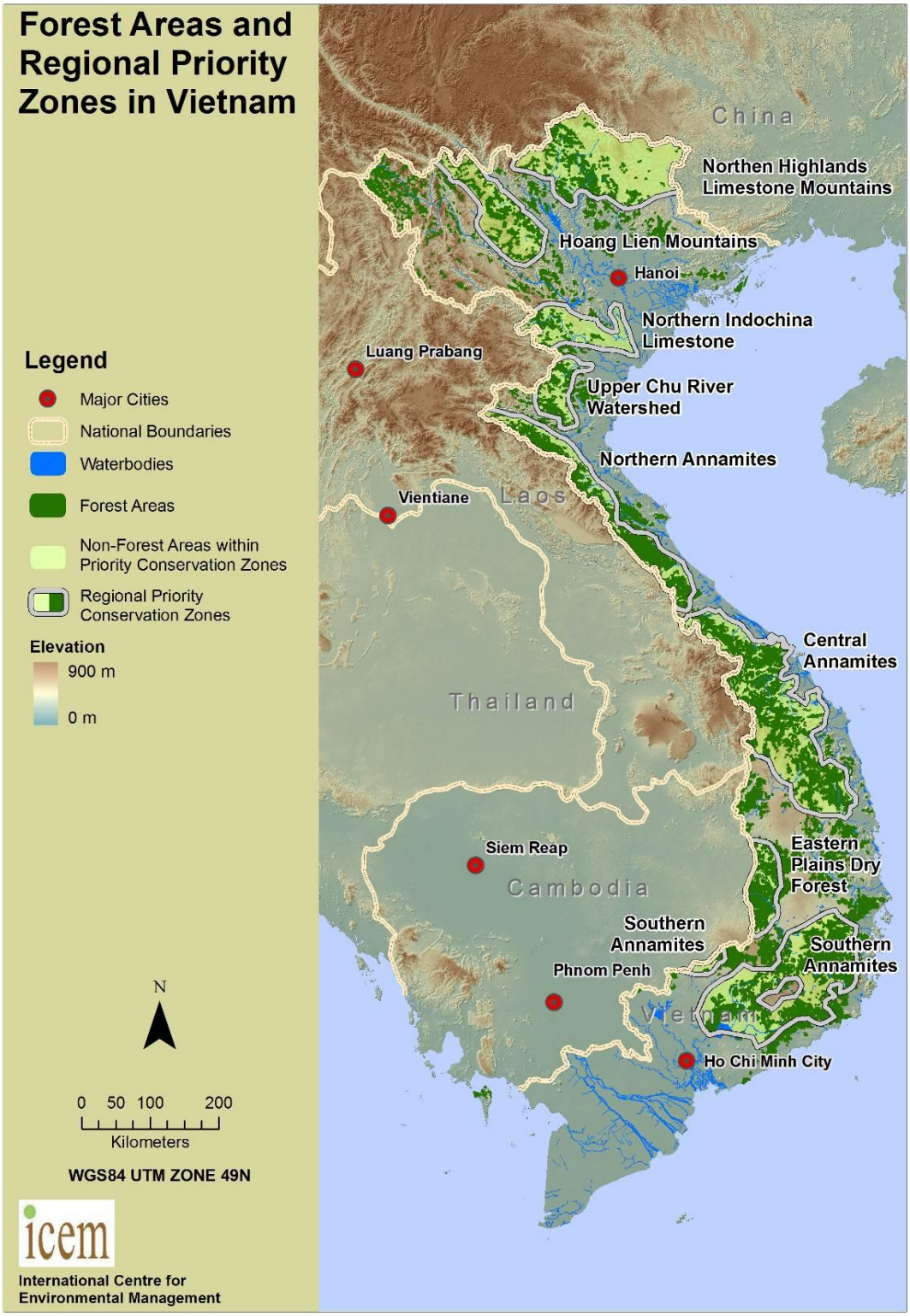
[18] MOSTE (1995) Biodiversity Action Plan for Viet Nam

[19] ICEM, 2008, Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Viet Nam.

[20] FISTENET (2006) *Vietnam fisheries overview*. Downloaded from http://www.fistenet.gov.vn on 8 November 2006.

[21] Whitten, A. and Kottelat, M. (1996) *Freshwater biodiversity in Asia: with special reference to fish.* World Bank Technical Paper No. 343. Washington D.C.: The World Bank.

Map 3: Forest cover and CEPF* Priority regions for conservation



***Critical Ecosystem Partnership Facility**

Extensive coastal ecosystems have multiple values. Viet Nam has more than 3,000 km of coastline dotted with numerous estuaries, lagoons, marshes, sand dunes and beaches, over 3,000 islands, and an extensive and shallow continental shelf. The coastal ecosystems include mangrove forests in the North and the South, sandy lands largely covered by Casuarina plantations in the central Viet Nam, and limited areas of *Melalauca* forests in the Mekong Delta region.

Mangroves were once widely distributed in the coastal Red River and Mekong Deltas but have been vastly reduced in recent decades. Where mangroves remain intact they provide many ecosystem services critical to the fisheries sector, tourism, waste treatment, navigation and for natural disaster management, defending coastal communities and infrastructure from storm surges and floods. These services are of growing importance in light of sea level rise and increased incidence and intensity of storms resulting from climate change[22]. Intertidal mudflats and sandflats develop at river mouths, as a result of deposition of sediment, and support important populations of migratory water-bird species, including a number of endangered species.

2.2 Managing biodiversity in Vietnam

Vietnam supports an extensive protected area network (Map 4) grouped into three categories: special use forests[23] (SUFs) (Table 1), marine protected areas (MPAs) and wetlands. To date, Vietnam has 164 SUFs (including 30 national parks), 15 proposed MPAs of which 6 are officially gazetted and 68 wetland sites[24].

Table 1: Numbers and types of special use forests in Vietnam

Categories	Number	Area
National Parks	30	1.08m ha
Nature Conservation Areas	69 including 58 Nature Reserves 11 Species/habitat conservation areas	1.10m ha
Landscape Conservation Area	45	0.078m ha
Scientific Experiment Areas	20	0.01m ha
TOTAL	164	2.3m ha (7% of Vietnam)

(Source: IUCN 2008 and ICEM 2007)

In addition to and overlaying the national protected area network, a number of sites (including existing protected areas) of international significance have been designated under the following international agreements: Ramsar sites (wetlands), World Heritage Sites and Man and Biosphere Reserves (MABs).

Table 2: Protected sites designated under international conventions

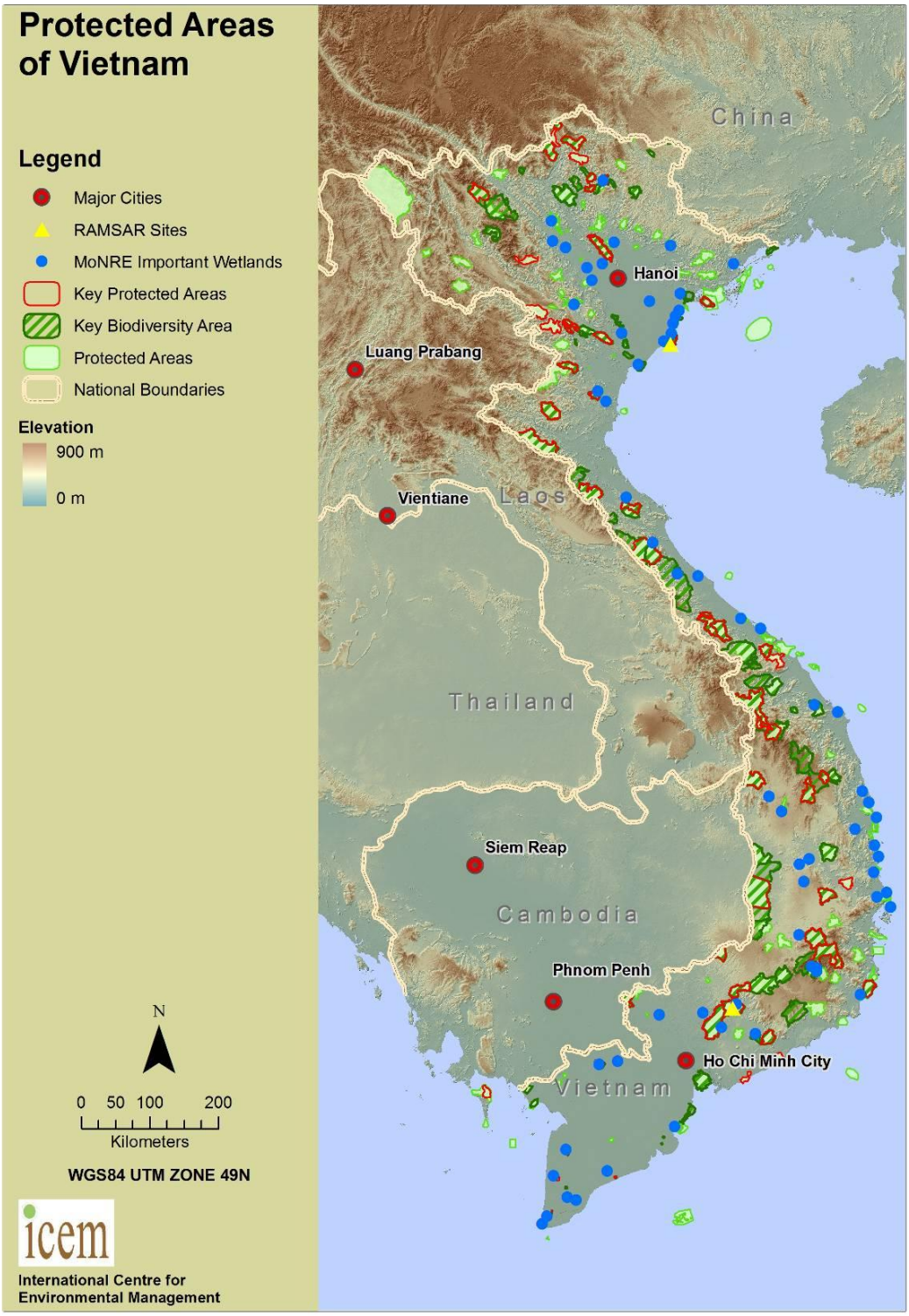
Type	Number	SUFs included in site
Ramsar Site	2	Xuan Thuy NR and Bau Sau (Cat Tien NP)
World Heritage Site	5	Phong Nha-Ke Bang NP
Biosphere Reserve	6	Cat Ba NP, Cat Tien NP and U Minh / Phu Quoc NPs

[22] ICEM (2009) An Evaluation of CARE's Community based mangrove rehabilitation and management project, Thanh Hoa, Vietnam

[23] Forested areas in Vietnam are classified as either Special Use Forest (SUFs), which include all terrestrial protected areas, Production Forests or Protection Forests.

[24] IUCN (2008) Protected Areas – A basis for Vietnam's Sustainable Development (presentation)

Map 4: Protected Areas, Key Biodiversity Areas and Important Wetlands



Following the adoption of the Government's Forest Development Strategy 2006 – 2020, in principle, no more national parks or nature reserves can be created in Vietnam. This moratorium on the gazettal of new PAs is active at the same time that an increasing number of parks and reserves are facing degradation and partial declassification to allow the construction of infrastructure including highways, resorts and hydropower dams.

Close to 65% of Vietnam's important biodiversity lies outside protected areas. Based on data for plants and vertebrates, a network of 102 'Key Biodiversity Areas' (KBAs) have been identified within Vietnam by Birdlife International[25]. KBAs are defined as zones of importance for biodiversity conservation of globally important species. KBAs are a useful additional tool in the consideration of biodiversity impacts as they often include important sites that are located outside the protected area system.

Within Vietnam, KBAs are concentrated in certain regions: wetland KBAs in the Mekong Delta and coastal zone of the Red River Delta; and terrestrial forest KBAs in the Annamite mountains, the Hoang Lien mountains, the dry deciduous forests of the Central Highlands and the limestone formations of northern and central Vietnam. 65% of the KBA network lies outside the gazetted protected area system and not subject to the same regulations and legal protection.

2.3 The socio-economic value of biodiversity

Vietnam's biodiversity provides goods and services to poor, rural communities and underpins national economic development. The Protected Areas and Development Review, conducted by ICEM through a partnership of government agencies, donor agencies and conservation NGOs in 2002-2003[26] concluded that the key socio-economic values of Vietnam's protected areas include:

1. Support to community development through regulating services and provision of ecosystem products (provision of clean water, medicine, food, fuel, etc.)
2. Management of water resources (flood control, storm protection, soil erosion control, etc.)
3. Support to energy development (particularly hydropower)
4. Support to agriculture development (conservation of wild relatives of crops)
5. Support to fisheries development (protection of spawning and stocking areas) and the aquaculture industry
6. Support to tourism development (provision of opportunities to develop nature-based tourism)
7. Support to industrial development (e.g. provision of raw materials and carbon sequestration)
8. Conservation of biodiversity (e.g. protection of wild gene stocks and medicinal plants)

2.4 Threats to biodiversity

Substantial and persistent threats to biodiversity in Vietnam. The national biodiversity estate in Vietnam continues to diminish with losses to habitat, species and genetic resources. The most significant threats are encroachment and forest and wetland clearing in areas of biodiversity value, increasing infrastructure development, and the wildlife trade (Table 3 and 4).

Table 3: Key threats and their relative importance to biodiversity in Vietnam

[25] Tordoff, A. W., Baltzer, M. C., Davidson, P., Fellowes, J., Ha Quy Quynh and Tran Thanh Tung (2007) *Ecosystem Profile: Indo-Burma Biodiversity Hotspot, Indochina Region*. Washington DC: Critical Ecosystem Partnership Fund.

[26] ICEM (2003) *Vietnam national report on protected areas and development*: Review of Protected Areas and Development (PAD) in the Lower Mekong River Region.

Rank / Threat	Drivers	Comments
(1) Hunting / illegal wildlife trade	Population pressure; economic development / trade liberalisation; high urban demand; low awareness; low management capacity and weak enforcement / disincentives	Interlinked issues. External market driven demand is increasingly replacing subsistence as the root cause
(1) Infrastructure development	Low coordination between agencies; lack of strategic planning and impact assessment across provinces and sectors; low awareness (lack of baseline data and monitoring)	Vietnam has an increasing number of dams / reservoirs, roads, power stations & linked facilities with direct impacts on biodiversity
(2) Deforestation/ Illegal timber trade	Agricultural expansion / population pressure; rural poverty / fuelwood; economic development / trade liberalisation; high urban (especially international) demand; low management capacity and weak enforcement / disincentives	Particular threat to small pockets of primary forest and core areas within and outside protected areas of high biodiversity value

Source: Adapted from WWF (2007) Implementing Landscape Conservation for Ecoregion Conservation in Vietnam, IUCN (2006) Protected Areas Policy Study & World Bank (2005) Vietnam Environment Monitor: Biodiversity

More than 80% of Vietnam's protected areas have people living within them and using their natural resources for subsistence and commercial purposes.[27] Socio-economic conditions fuel an illegal and widespread wildlife trade. Key drivers include widespread rural poverty, low environmental awareness, high demand for wildlife products from a growing middle class in urban areas domestically and internationally, weak governance and low capacity of forest managers and protection staff.

Table 4: Number of nationally and globally threatened species in Vietnam (2005)[27]

Taxonomic group	Nationally threatened*	Globally threatened†
Mammals	78	46
Birds	83	41
Reptiles	43	27
Amphibians	11	15
Fish	72	27
Invertebrates	72	0
Plants	309	148

***** Categories Endangered, Vulnerable, Rare and Threatened, following Anon. (1992, 1996).
† Categories Critical, Endangered and Vulnerable, following IUCN (2004).

Infrastructure projects are planned and underway within or close to many protected areas and KBAs. With the exception of Chu Yang Sin NP (CYSNP) in Dak Lak, the five largest national parks in Vietnam all contain surfaced highways forming part of the national road network – and there are plans to build a national road through CYSNP. Hydropower development within or affecting PAs is also increasing. The construction of dams in remote, mountainous and often forested locations reflects the need to site the development in areas of abundant water, low population density and with steep topography – this places many important biodiversity areas in the path of current and proposed

[27] IUCN (2006) *Protected Areas Policy Study: Technical Report.* Forest Protection Department (MARD), UNDP and IUCN, Hanoi, Vietnam

developments. Tourism facilities, irrigation reservoirs and artisanal and larger scale mining are also threats to biodiversity within PAs.

Since the 1998-2010 Five Million Hectare Reforestation Programme (Programme 661), forest cover in Vietnam has increased. Yet, the expansion of plantations – usually mono-crop exotic timbers – masks an ongoing decline in primary / closed canopy forest. Between 1990 and 2000, the area of natural (high biodiversity) forest reduced by over 50%[28]. Rural poverty, growing population pressures and greater demand and higher prices from abroad, notably from China and developed nations, provide incentives for continued deforestation (Table 5).

Table 5: Percentage loss of ecosystems in Vietnam

Type	% loss
Forest	75
Wetland	99
Mangroves	37
Coral reefs (under threat)	96

Source: ICEM 2003[29]

Despite the national PA system covering some 7% of the country and relatively high staffing levels, weakness in the enforcement and management frameworks, leave biodiversity vulnerable to continuing degradation (Table 5)[30].

The effects of climate change on biodiversity. Climate change is a relatively new and little understood threat, but the negative consequences of a significant rise in temperature, accompanying increases in sea level, changes in precipitation and intensity of extreme weather events have the potential to directly and indirectly impact biodiversity. The Intergovernmental Panel on Climate Change (IPCC) estimates that, with a 2 to 3°C increase in temperature, 20 – 30% of the world's species could be lost[31]. Tropical zones may be especially affected due to: (i) the presence of the majority of the worlds biodiversity, (ii) the presence of large, growing and poor populations whose dependence on natural resources is already strong and whose adaptive capacity for climate change is low, and (iii) poor governance and the significant levels of exposure to increased climate variability and extreme events that are predicted in these zones[32]. For example, it is projected[33] that a 1m rise

[28] World Bank (2004) *Going, Going, Gone... The Illegal Trade in Wildlife in East and Southeast Asia.* World Bank

[29] ICEM (2003) *Regional Report on Protected Areas and Development.* Review of protected areas and development in the lower Mekong river region. Indooroopilly, Queensland, Australia. *197pp*

[30] Pedrono M., Ha Minh Tuan, Chouteau P., and Vallejo F. (2009). *Status and distribution of the endangered Banteng Bos javanicus birmanicus : A conservation tragedy.* Oryx, 43 (4) : 618-625.

[31] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.

[32] Secretariat of the Convention on Biological Diversity (2009). *Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*. Montreal, Technical Series No. 41, 126 pp.

[33] Carew-Reid, J. (2007) *Rapid Assessment of the Extent and Impact of Sea Level Rise in Viet Nam, Climate Change Discussion Paper 1*, ICEM, Brisbane, Australia.

in sea level would have the following impacts on natural systems and biodiversity conservation:

- ***Forests*:** 8% of SLR inundation is forest cover or other natural vegetation (including shrub and grassland), 67.5% of which falls in the Mekong. Most are mangrove and melaleuca forests. 27% of existing mangroves and 20% of swamp forest would be permanently inundated, although the affected area is likely to be much higher with estimates using topographical maps.
- ***Water bodies:*** 82.5% of the affected water bodies are located in the southern lowlands of which 71.7% are in the Mekong Delta. The inundation would lead to changed salinity patterns, changed habitat conditions and productivity and changed species composition
- ***Protected areas and KBAs:*** 36 of Viet Nam's approved protected areas would be affected by sea level rise inundation in whole or in part. Eight of the nation's 27 national parks, 16 nature reserves and 11 cultural, historical and environmental sites are within the inundated or very high risk zone. Two in the Mekong Delta – U Minh Thuong National Park and Bac Lieu Nature Reserve – would be completely inundated. Of the 68 wetlands of national importance identified by MONRE, close to 50% are in the very high risk zone with 19 permanently inundated in part or in whole (excluding MPAs) A further 16 coastal KBAs would be inundated[34].

Monitoring of past climate changes shows that as temperature increases, biomes tend to shift. Modelling of future climate suggests that forests will react by "migrating" to more favourable environmental conditions[35]. Under natural conditions, this adaptation is possible, but where biodiversity is hemmed into small, isolated patches or 'islands' of habitat, as is the case with most PAs and KBAs in Vietnam, opportunities for migration will be limited. In some areas, climate change will also have negative impacts on food security increasing indirect impacts on natural systems as people are forced to exploit natural resources (as the yields of food crops decline). Crucially, the development of human settlements and associated infrastructure prevents coastal ecosystems from migrating inland. A climate change impact study for HCMC showed that SLR (predicted to be 26cm by 2050) would impact on mangrove systems - with impacts increasing significantly as the sea rises toward 1m - where ecosystem shift is impossible due to coastal developments[36].

3. Hydropower development in Vietnam

Vietnam's strategy for hydropower development is described in the 6th Power Development Plan (PDPVI) prepared by Electricity of Vietnam (EVN) and approved by the Prime Minister in 2007. PDPVI covers the period from 2006 to 2015 with a long term vision to 2025 and contains information on electricity demand forecasts as well as identification of infrastructure that will be required to meet that demand.

PDPVI states that to 2025[37] hydropower will play an important role in the nation's energy mix making up 23% of total installed capacity by 2025. It is now 36% (Table 6).

[34] Pilgrim J. (2007). *Effects of Sea Level Rise on Critical Natural Habitats in Vietnam.* International Symposium on Biodiversity and Climate Change – Links with Poverty and Sustainable Development Hanoi, 22-23 May 2007

[35] Gitay H., Suarez A., and Watson R. (2002). *Climate Change and Biodiversity: IPCC Technical Paper V*. 45pp.

[36] ICEM (2008) *Ho Chi Minh City Adaptation to Climate Change.* ADB / ICEM, Brisbane, Australia

[37] ICEM. (2007). *Pilot Strategic Environmental Assessment in the Hydropower Sub-sector, Vietnam. Final Report: Biodiversity Impacts of the hydropower components of the 6th Power Development Plan*. Prepared for The World Bank, MONRE, MOI & EVN, Hanoi, Vietnam.

Table 6: Generation Types in PDP VI

Generation Type	2010 Installed Capacity (MW)	Proportion of Total Installed Capacity	2025 Installed Capacity (MW)	Proportion of Total Installed Capacity
Hydropower	9412	36%	20,306	23%
Coal fired	6595	25%	36,290	41%
Gas fired	9072	35%	17,224	19%
Diesel / oil fired	472	2%	2,400	3%
Nuclear	0	-	8,000	9%
Imported hydropower	658	2%	4,628	5%
TOTAL	**26,209**	**100%**	**88,848**	**100%**

Despite a proportional reduction in its contribution to overall generation capacity by 2025, the absolute generation capacity of hydropower is expected to increase from 9,412MW in 2010 to 20,306 MW. Large and medium size plants (i.e. > 30MW) will account for 4738 MW of installed capacity, and small hydropower and pumped storage plants will account for 3,860 MW[38] (Table 7).

PDPVI refers to 73 existing and proposed hydropower projects (Map 5). However, most of the numerous small and medium dams proposed for each basin (e.g. some 60 in Quang Nam's Vu Gia – Thu Bong basin in addition to the 8 large projects listed in the PDPVI, and 92 in the Se San Basin in addition to the 7 listed in PDPVI) are not included in the PDP VI.

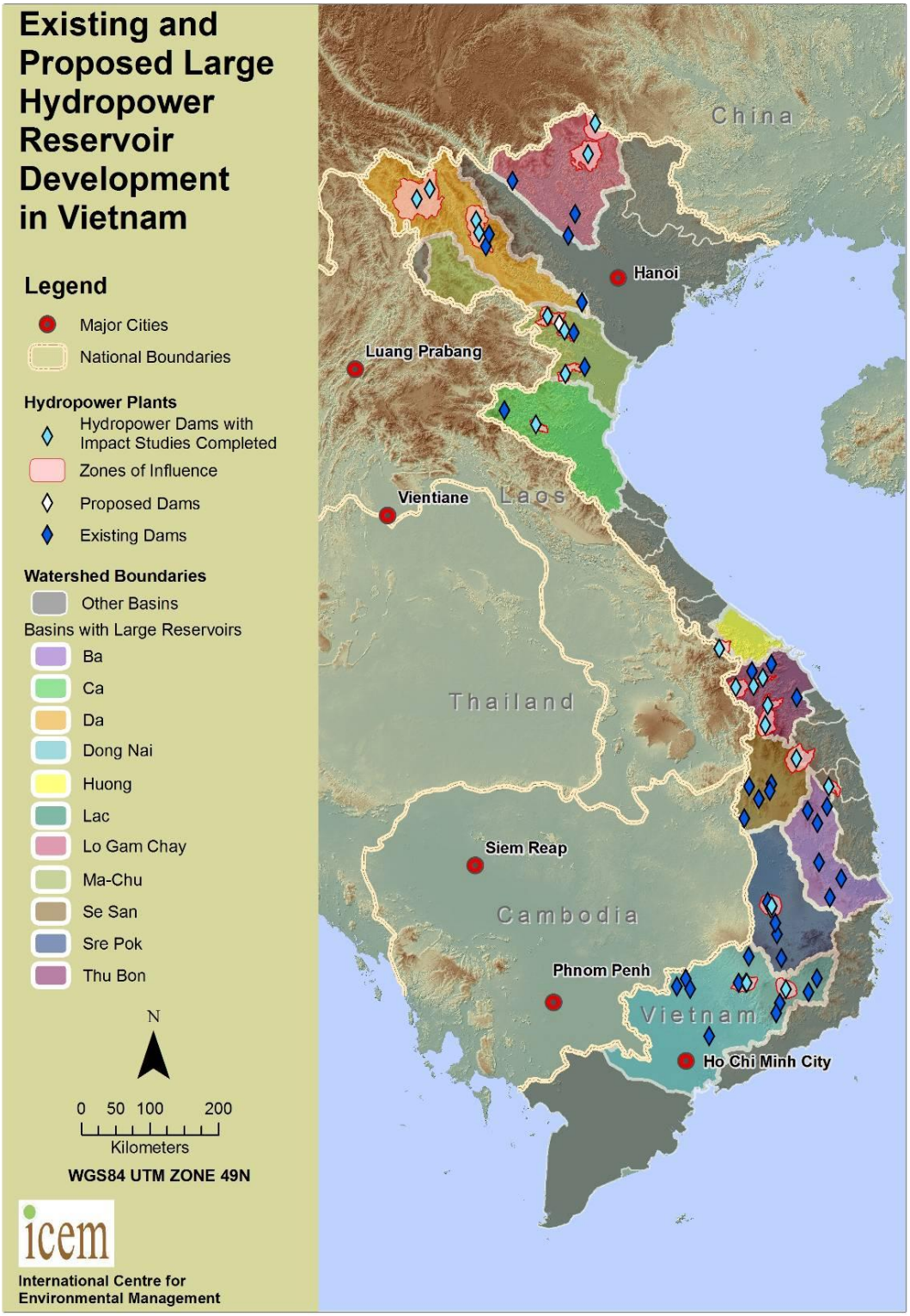
Table 7: Hydropower Development Status in PDPVI

Type	Installed Capacity MW
In operation 2010	9,412
Under construction	2,296
Large planned	4,738
Other hydro (small and PS*)	3,860
TOTAL HYDRO 2025	**20,306**

*PS = Pumped storage plant

[38] In addition a number of hydropower plants are under construction accounting for 2296 MW of installed capacity.

Map 5 Existing and proposed large dams in Vietnam identified in the 6th PDP



NOTE: The Huong and Lac are shown as separate basins, but have been assessed as single basin due to the significance of hydropower project impacts and interconnected river systems / basins

4. The relationship between hydropower and biodiversity

Globally the effects of hydropower development on biodiversity are significant and increasing.
There are an estimated 45,000 large dams on the world's rivers, which in total retain more than 6,500km3 of water, or 15% of total natural runoff. Over half of the world's major river systems are affected by dams, including the 8 most biogeographically diverse river systems[39].

The biological effects of hydropower are often difficult to disaggregate from those of other environmental impacts, particularly in highly developed catchments. Nonetheless, in the most comprehensive study to date on the effects of dams on environmental and social systems, the World Commission on Dams concluded that the effects of hydropower development have had extensive impacts on rivers, watersheds and aquatic ecosystems[40] (Table 8).

Table 8: Contributing impacts of hydropower development to loss of biodiversity resources

Contributing Impact	Description
Direct Impacts	
Habitat loss	Loss of terrestrial habitat can occur due to flooding of reservoir site, and through the development of roads, transmission lines and ancillary infrastructure. Loss of aquatic and riparian habitat occurs upstream due to increased water levels and downstream because of altered flow regimes.
Habitat fragmentation	Access roads and transmission lines and inundation of reservoir sites can fragment terrestrial habitat. Aquatic and riparian habitats can be fragmented by on-river dams.
Direct loss of species	Loss of entire populations or even species has occurred when endemic species with narrow ranges are located in the reservoir area. Drowning of wildlife during reservoir filling is a common effect. Small populations that rely on genetic transfer with surrounding populations and that become isolated because of habitat fragmentation or impediments to migration are also at risk of expiration or extinction.
Impediments to species migration	Migration of aquatic and riparian species can be impeded by dam construction; effects can be especially severe for diadromous species and benthic organisms, the latter because of their limited mobility. Terrestrial species migrations can be impeded by the inundation area as well as access roads or power line easements.
Genetic isolation of populations	Genetic isolation of ecosystems and populations as a result of habitat fragmentation or impediments to migration can threaten viability of species.
Invasive species propagation	Aquatic and riparian ecosystems are vulnerable to invasive species due to their dynamic nature and the availability of a natural network for dispersal. Changes to water quality and availability of nutrients can enhance invasive species growth resulting in reduced water movement, water oxygenation and light penetration. Inter-basin transfers of water can facilitate movements of exotic species. Terrestrial invasive species can be transmitted via access roads, or power transmission lines.
Indirect Impacts	
Water quality deterioration	Water quality deteriorates as a result of changes in temperature of released flows, salinisation caused by reduced freshwater flows or changes to groundwater recharge, or the release of large amounts of nutrients from decomposing vegetation or soils. Aquatic and riparian habitats and species are vulnerable to changes in water quality.
Hydrological flow	Hydropower operation replaces natural flow regimes with artificial downstream

[39] Nilsson C., Reidy A., Dynesius M., and Revenga C. (2005). *Fragmentation and Flow Regulation of the World's Large River Systems*. Science, vol. 308, pp. 405-408.

[40] World Commission on Dams (WCD) (2000) *Dams and Development – A New Framework for Decision Making*. 404pp

Contributing Impact	Description
regime changes	hydrological conditions. Flow regime is often considered to be the key driver of riverine and wetland ecosystem health. Dewatering of streams, changes in peak or low flows, or pulsing of flows can have significant effects on aquatic and riparian ecosystems that have evolved in conjunction with natural hydrological flow regimes. Physical habitat and biotic composition are changed, reducing longitudinal and lateral connectivity, increasing homogeneity of habitats or facilitating the success of invasive species.
Changes to sediment patterns	Dams retain sediment, which can lead to reduced sediment availability for downstream mangrove and coastal ecosystems. Irregular releases of large amounts of sediments from dams can cause erosion and result in loss of aquatic habitat through channel simplification.
Changes to flooding regimes	Altered flow patterns can affect downstream floodplains by changing the level and frequency of flooding on floodplains and overbank topping; this can have effects on species that rely on some part of the flood cycle for reproduction, seed dispersal, and availability of food sources.
Changes to natural shorelines in riparian ecosystems	The density of plant species adjacent to new storage dams and downstream river reaches has been found to rebound to near pre-dam levels for the first 20 – 30 years after dam construction but then to degenerate as a result of substrate erosion and lack of species pools. Diversity of plant species adjacent to run of the river dams generally recovers to a higher degree but the absolute number of species is lower because of the narrower regulated shoreline.
Increased pressure on natural resources	Temporary impacts can arise due to exploitation of natural resources by construction workers. Resettlement of communities to make way for hydropower development can result in longer term increases pressure on natural resources in newly settled areas, particularly when those areas are located near to important biodiversity resources and adequate livelihood support measures are not provided for resettled communities. Access roads and transmission line easements can open up undisturbed areas for resource exploitation.
Induced development	A reliable and large supply of water and electricity can lead to increased development across numerous sectors including agriculture, industry, or urban expansion. Such development can have a range of adverse impacts on biodiversity.

Source: Compiled by the ICEM review team

Hydropower development has species and ecosystem level effects. Hydropower development affects terrestrial, riparian and aquatic species and ecosystems to varying degrees[29]. Species level effects include changes in species persistence, richness and distribution, while ecosystem level effects include changes to ecosystem composition and function[41]. In temperate zones, riparian ecosystem diversity adjacent to hydropower reservoirs and in the downstream reaches of reservoirs is less when compared to riparian ecosystems on un-impounded rivers[42],[43]. Despite an initial rebounding of species diversity within reservoirs following completion in some locations, the long term negative effects on aquatic ecosystems can be severe[44]. In tropical environments, hydropower

[41] Jansson R (2002) *The Biological Cost of Hydropower.* Prepared for Coalition Clean Baltic.
[42] Bunn S and Arthington A. (2002). *Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity.* Environmental Management, vol. 30, pp. 492-502.
[43] Andersson E, Nilsson C and Johansson ME (2000) *Effects of river fragmentation on plant dispersal and riparian flora.* Regulated Rivers: Research and Management, vol. 16, pp. 83-89.
[44] Bernez I, Haury J, and Ferreira MT (2002) *Downstream effects of a hydroelectric reservoir on aquatic plant assemblages.* Proceedings of the 2nd Symposium on European Freshwater Systems.

development has led to irreversible loss of both aquatic and terrestrial species and ecosystems[45] (Box 2).

Box 2: Impacts of hydropower development on biodiversity in South East Asia

The following is a summary of three case studies on the effects of hydropower development on biodiversity in South East Asia:

- **Extinction of endemic species –** Three Gorges Dam (PRC) reduced the endangered baiji or Yangtze River dolphin's habitat and facilitated an increase in ship traffic, finally driving the species to functional extinction – the first extinction of cetacean species in 20 million years and one directly attributable to human actions[46]
- **Reductions in aquatic diversity and habitat -** Theun-Hinboun Hydropower Project in Lao PDR which become operational in 1998 resulted in the loss of riparian habitat, forest, fish and other aquatic species[47]
- **Loss of subsistence and commercial fisheries -** Impacts on aquatic resources in the Nang River since establishment of the Tuyen Quang Hydropower Dam, Vietnam, lead to significant population declines downstream in 32 freshwater species and some fish spawning grounds[48]
- **Increased ecosystem vulnerability -** Research undertaken on the Lancang River region and Yuanjiang River-Red River region of southern China (PRC) has shown that dams there increase ecological vulnerability by 2-3 times the baseline level[49]

Impacts are caused during construction and operation. Species and ecosystem effects are caused by a range of direct (e.g. clearing forest for roads or flooding by reservoirs) and indirect (e.g. the impact of itinerant workers in areas of high biodiversity) impacts during project construction and operation.[50] The construction period can results, for example, in major disruption to flow patterns and increases in sediment, in addition to degradation to the watershed affected by road and transmission construction activities. The large spike in the number of workers can create problems of illegal hunting and extraction of timber and NTFPs. The hydroelectric dam construction adjacent to Na Hang Nature Reserve, for example, attracted around 10,000 workers at peak time and supporting services into the area, with all of their housing, food, and other subsistence demands.[51]

---

[45] Rosenberg DM, McCully P, and Pringle C. (2000). *Global scale environmental effects of hydrological alterations: An introduction.* Bioscience, vol. 50, pp. 746-751.

[46] NOAA National Marine Fisheries Service (2007, September 13). Rare Dolphin Driven To Extinction By Human Activities, Scientists Fear. *ScienceDaily*. Retrieved January 15, 2010, from http://www.sciencedaily.com /releases/2007/09/070911114747.htm

[47] FIVAS (2007) *Ruined river, Damaged lives*: Impacts of the Theun-Hinboun Hydropower Project on Downstream Communities in Lao PDR. The Association for International Water Studies.

[48] Birdlife / WARECOD (2009) *Communities voice concerns about aquatic resources.* Accessed at http://birdlifeindochina.org/content/local-communities-voice-concerns-about-aquatic-resources-tuyen-quang-vietnam on March 30th 2010

[49] Zhai Hong Juan et at (2007) *Regional ecosystem changes under different cascade hydropower dam construction scenarios in the LRGR* State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University.

[50] Dudgeon D. 2000. *Large scale hydrological changes in tropical Asia: Prospects for biodiversity*. Bioscience, vol. 50, pp. 793-806.

[51] IUCN (2006) *Protected Areas Policy Study: Technical Report.* Forest Protection Department (MARD), UNDP and IUCN, Hanoi, Vietnam

The incidence of illegal hunting and wildlife trade increased. Table 8 summarises the direct and indirect effects of hydropower development on biodiversity[52].

Once operational, hydropower projects can prevent fish migration, lead to loss of species and cause major productivity losses – even taking reservoir fisheries into account. This is especially so for cascades of dams on one river. Fish ladders and passes have been found to be ineffective in Vietnam. Reductions in sediment and nutrients through reservoir trapping also effect species dependent on a natural flooding and deposition regime, as it does coastal fisheries which depend on the nutrient plume offshore from deltas. For example, hydropower projects constructed in the Central Highlands of Vietnam and in Yunnan Province of China are having a significant impact on the Mekong Delta fresh and coastal water systems through reduction in river sediment and nutrient load.[53]

Cumulative effects of multiple hydropower developments require special consideration.

A number of hydropower projects are often developed on a single river system. The cumulative impacts of such cascades require particular attention. One dam controls the water up to the next dam so that the downstream and upstream effects overlap[54]. Several small run of the river dams may exceed the effects of a single large scale dam.

4.1 Hydropower development, biodiversity and climate change

The relationship between hydropower, biodiversity and climate change is a complex yet important subject that is receiving increasing attention. There are 2 major elements of the relationship that need to be considered: first, greenhouse gas emissions and second, cumulative effects of hydropower and climate change on biodiversity (Annex 1).

Hydropower and greenhouse gas emissions. Hydropower is a renewable energy source that reduces the greenhouse gas intensity of power production. However, the situation is not clear cut for tropical environments where reservoirs can create significant GHG emissions. Greenhouse gases are released if the forest is cut and burned before reservoir filling and from reservoirs as flooded forests and other organic matter decomposes. Some projects, which flood extensive forest areas, have the potential to emit greenhouse gases in greater amounts than would be produced by burning fossil fuels for many years of comparable electricity generation[55]. Many hydroelectric reservoirs flood relatively little forest or other biomass and/or generate sufficient electricity to more than offset the greenhouse gases which would otherwise have been produced.

Cumulative effects of hydropower and climate change on biodiversity. Climate change is likely to have significant synergistic relationships with existing threats to biodiversity (Section 2.4). Biodiversity that is already stressed by non-climatic, anthropogenic pressure, including hydropower development, will generally have an increased vulnerability and lower capacity to adapt to negative effects of climate change[56]. Increased social pressures on natural resources as a result of climate

---

[52] Refer Section 6 for references used in the development of this summary table

[53] ICEM, 2010, Strategic Environmental Assessment of Hydropower Development on mainstream Mekong River, MRC, www.icem.com.au

[54] Anderson EP, Pringle C and Rojas M. 2006. *Transforming tropical rivers: an environmental perspective on hydropower development in Costa Rica.* Aquatic Conservation: Marine and Freshwater Ecosystems, vol. 16, pp. 679-693.

[55] Ledec G and Quintero JD. 2003. *Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects.* Prepared for The World Bank.

[56] Daufresne M and Boet P. 2007. *Climate change impacts on diversity of fish communities in rivers.* Global Change Biology, vol. 13, pp. 2467-2748.

change could exacerbate such effects, although some areas may experience certain benefits such as increased rainfall and agricultural production. Species with narrow climatic tolerance envelopes, restricted ranges, or where impediments to migration exist (i.e. anthropogenic barriers or habitat fragmentation) will be most affected[57]. Headwaters of river systems are likely to act as climate refuges for certain species and the maintenance of riverine corridors are important in species adaptation to climate changes through migration. It is those ecosystems that are amongst the most affected by hydropower development.

4.2 Hydropower development and biodiversity in Vietnam

This section provides information on the potential effects of Vietnam's proposed hydropower development strategy on the country's biodiversity resources. Information presented in this section has been sourced from two recent SEAs that investigated the effects on biodiversity of hydropower development, as outlined in the PDPVI,.[58,59,60] No new primary research has been carried out for this review. Instead it provides planners and decision makers with a synthesis of the known biodiversity implications of developing hydropower in Vietnam gathered from previous strategic impact assessments.

4.2.1 SEA of national biodiversity risks in the 6th Power Development Plan – ICEM

The first SEA on hydropower in Vietnam was carried out in 2007 by ICEM for the World Bank. It was the first to investigate the strategic implications and mitigation measures relating to hydropower planning and biodiversity conservation. The SEA covered 60 of the 73 large dams planned in nine basins highlighted for development in the 6th PDP. The 60 projects included 54 not under construction and a further 6 approved dams, where construction had begun, but were dams considered too important to not evaluate. The remaining 13 large projects were already under construction and so less open to influence of the SEA – although recommendations on operations and management of (all) hydropower projects were provided.

The PDP VI, in covering only 73 existing and planned large dams, did not include the growing number of existing and planned small–medium dams which now feature in all the basins described in the SEA. Therefore, the SEA was also unable to include them in the national assessment owing to the lack of reliable and accurate data, and sheer number of smaller dams which were progressively being added to power plans on an ad hoc basis – even to provincial plans already approve. No overall listing of existing and planned large, medium and small hydropower projects in Vietnam is available from EVN or MOIT.

Zone of influence assessment approach: This SEA pioneered a new approach to assessing the socio-economic and environmental impacts, at the basin and national level, of multiple dams, through a

---

[57] Gitay H., Suarez A., and Watson R. (2002). *Climate Change and Biodiversity: IPCC Technical Paper V*. 45pp.

[58] ICEM. (2007). *Pilot Strategic Environmental Assessment in the Hydropower Sub-sector, Vietnam. Final Report: Biodiversity Impacts of the hydropower components of the 6th Power Development Plan.* Prepared for The World Bank, MONRE, MOI & EVN, Hanoi, Vietnam.

[59] Soussan J. et al (2009) *Harnessing Hydropower for Development: A Strategic Environmental Assessment for Sustainable Hydropower Development in Vietnam*, Stockholm Environment Institute (SEI), Stockholm, Sweden

[60] At the time of preparation of this Volume, development of the next cycle of national hydropower planning was underway through PDPVII. Discussions with EVN staff involved in the preparation of PDPVII indicated that the river basins to be affected by hydropower development were unlikely to change significantly from those identified in PDPVI; however, no details of the content of PDPVII were available for use in the analyses contained in this Volume.

Zones of Influence (ZOI) methodology[61]. 23 projects, in two basins – Vu Gia-Tu Bong and Dong Nai – where detailed data on the dams was available, were assessed using that approach. The impacts on river basins in Vietnam from hydropower projects were analysed through a consideration of the effects in the area inundated by the reservoir and within a wider ZOI that took into account the construction of ancillary infrastructure, changes in resource use by local communities, and the associated upstream and downstream effects of dam operation. For the remainder of the projects, where reliable, detailed data sets were unavailable an over-view, risk-based assessment was carried out. The SEA used a two-tier method to provide detailed assessment were possible but also to included an indicative assessment of basins which lacked sufficient or accurate data.

River basin assessment approach: The 6th PDP groups the 73 large scale projects by three geographic zones: North, Central and South. The ICEM/World Bank SEA studied assemblages of dams at the basin level – an essential method for indentifying cumulative impacts on natural systems.

The overall categorization of biodiversity risk was calculated through consideration of the biodiversity values of the basin (terrestrial, freshwater and socio-economic) and the biodiversity impact. One (1) represents the highest concern (high level impacts to high biodiversity values) while four (4) represents the least concern (low impacts to low biodiversity values). All basins were assessed as being of very high, high or moderate concern. No basin was found to be of low or no concern.

The SEA concluded that river basins where biodiversity is at highest relative risk from hydropower development are the Ba, Da, Dong Nai and Se San. The Ca, Lo-Cam Chay, Ma-Chu, Srepok, Tra Khuc-Huong and Vu Gia-Thu Bon river basins are subject to slightly lesser risk but include specific zones or hot spots where potential cumulative and project specific impacts on terrestrial and aquatic biodiversity may be significant (Tables 9, 10 and 11).

Table 9: Results of assessment of basin-Level hydropower impacts

Basin	Terrestrial biodiversity value	Freshwater biodiversity value	Socio-economic value of biodiversity	Biodiversity impact	Overall classification of concern
Ba	Very High	Very High	High	Very High	1
Dong Nai	Very High	Moderate	Very High	Very High	1
Se San	Very High	High	Moderate	Very High	1
Da	Very High	High	Very High	High	1
Huong-Lac*	Very High	Moderate	Low	Moderate – High	2
Ca	Very High	Very High	Low	Moderate - High	1-2
Lo - Cam-Chay	Very High	Moderate	High	Moderate	2
Ma - Chu	Very High	High	High	Moderate	2
Srepok	High	High	High	Moderate	2

[61] Volume V of these SEA synthesis and training manuals contains the full ICEM / World Bank SEA including detailed explanation of the assessment methodology

Vu Gia-Thu Bon	Very High	High	High	Very High[62]	1

Source: ICEM 2007 *Huong - Lac basin is not in the original ICEM SEA, but is included here following assessment of projects in the SEI SEA (Section 3.2.2)

Table 10: Number of KBAs in each of the major basins targeted for hydropower development in the 6th Power Development Plan

Basin	Number of KBAs*
Lo-Gam-Chay	11
Da	3
Ma	6
Ca	2
Vu Gia-Thu Bon	7
Ba	4
Se San	5
Srepok	9
Dong Nai	12
Huong - Lac[63]	No data from the SEA

Source: ICEM 2007 Note: * = figures include KBAs that partly overlap within a basin.

Table 11: Relative levels of endemism among the major basins targeted for hydropower development in the 6th Power Development Plan

High endemism (i.e. flowing directly into the South China Sea)	Moderate endemism (i.e. flowing into the Nanpangjiang, Red or Mekong River)
Ma	Lo-Gam-Chay
Ca	Da
Vu Gia-Thu Bon	Se San
Ba	Srepok
	Dong Nai

Source: ICEM 2007

[62] The level of risk for the Vu Gia-Thu Bon River Basin was increased with subsequent more focussed SEAs: Starting as Moderate under the original ICEM SEA, then changed to Very High following the cumulative analysis of the ICEM SEA of hydropower in the VGTB basin and the SEI SEA

[63] No figures available from the SEA on this basin

4.2.2 SEA for sustainable hydropower development in Vietnam – SEI

The methodology used in the 2009 SEA conducted by SEI for ADB built upon that which was developed by ICEM, focussing on the socio-environmental impacts of direct, reservoir inundation and indirect impacts associated with the ZOI. The replication of the ZOI methodology by SEI demonstrates that one SEA can influence subsequent SEAs. The SEI study focused its ZOI assessment on 21 projects, giving the SEA less coverage than the previous study but at slightly higher resolution, by refining the ZOI analysis process. The 21 projects were chosen (using the same criteria as in the ICEM SEA) through an analysis of which dams were 'open to influence', i.e. planned, but not approved or under construction.

It is important to note here that in the space of 2-3 years between the two SEAs the number of "open to influence dams" dropped from over 54 to 21 – demonstrating the scale and speed of development in this sector (Table 12). This trend and the continually expanding nature of hydropower plans in Vietnam (even once approved) highlights the importance of conducting regular SEAs which look back on the effects of implementation and forward with a sharper capacity to project future trends.

This section will focus on the 21 large hydropower projects addressed in the SEI SEA, but still through the basin level approach developed in the 2007 ICEM SEA (Map 5 and Table 12)[64]. Projects already operational or under construction were excluded from consideration in the analyses. The results of those two strategic assessments are indicative only showing broad trends and ranges of impact because of the many other existing and planned hydropower developments not considered. Inevitably, were all hydropower projects planned for each basin taken into account, the full cumulative impacts would be greater.

Table 12: Target hydropower projects

Basin	Number of 'open to influence' Projects in PDPVI	Target Projects in the SEI SEA
Vu Gia - Thu Bon	8	5: Song Bong 2, 4, 5 and Dak Mi 1 and 4
Dong Nai	12-14	2: Dong Nai 2 and Dong Nai 5
Ba	5	1: Vinh Son 2
Ca	2	1: Khe Bo
Da	7	4: Lai Chau, Ban Chat, Huoi Quang and Nam Na
Srepok	4	1: Srepok 4
Huong (& Lac)	1+	1: A Luoi-Not
Se San	6	1: Se San 3
Ma Chu	4	3: Hua Na, Trung Son and Hoi Xuan
Lo - Gam-Chay	4	2: Bac Me and Nho Que
TOTAL	**54+**	**21**

[64] ICEM. (2007). *Pilot Strategic Environmental Assessment in the Hydropower Sub-sector, Vietnam. Final Report: Biodiversity Impacts of the hydropower components of the 6th Power Development Plan.* Prepared for The World Bank, MONRE, MOI & EVN, Hanoi, Vietnam.

The direct effects of hydropower development on biodiversity are significant: Consistent with the ICEM SEA, the SEI assessment found that the impact of hydropower development on the natural resource base and integrity of biodiversity in the ZOIs is considerable. The assessment of these risks is presented here through the analysis of potential impacts on forest and aquatic resources and risks associated with the degradation of biodiversity in the Zones of Influence. It is possible to identify options to mitigate some of these risks. Other risks would have irreversible consequences.

8,083 ha of PAs and KBAs would be inundated by the 21 large hydropower projects targeted in the SEI SEA. An additional 413,435 ha of PAs and KBAs would be indirectly affected through the construction of ancillary infrastructure, changes in resource use by local communities, and the associated upstream and downstream effects of dam operation (Map 5 and Tables 13 and 14).

These target projects represent a small part of the total planned hydropower development throughout the country – i.e. less than half the proposed hydropower capacity contained in the PDPVI, and an unknown number of additional medium and small hydropower projects proposed in provincial power development plans each with its access roads and transmission infrastructure. The overall effects on biodiversity of this massive hydropower development effort will be significant – involving a total transformation of the nation's aquatic systems and a reshaping of large segments of its terrestrial systems.

The Zones of Influence contain substantial areas of forest, with a total of 681,576ha that includes 534,995 ha of mature natural forest, 109,197 ha of immature or regenerating forest and 37,384 ha of plantations. Forests represent an important land use category in all of the Z0Is included in the scenarios analysis. They are the dominant productive land resource category in most projects, representing over 75% of the Z0I area in 17 of 21 projects once the category of grasslands, shrublands and rocky mountains are excluded.

Table 13: Area of zone of influence and reservoir created by each target project

Name	Area ZOI (ha)	Area Reservoir (ha)
A Luoi-Not	32,061	2,585
Bac Me	139,425	13,673
Ban Chat & Huoi Quang	166,735	7,129
Dak Mi 1 & Dak Mi 4	119,226	1,934
Dong Nai 2	67,164	1,972
Dong Nai 5	58,249	375
Hua Na	44,742	1,712
Khe Bo	27,320	1,531
Lai Chau & Nam Na	351,995	13,887
Nho Que 3	84,078	132
Song Bung 2 & Song Bung 4 & Song Bung 5	90,713	5,888
Srepok 4	77,030	1,027
Trung Son & Hoi Xuan	106,826	1,464
Upper Kon Tum	111,364	1,542
Vinh Son II	35,082	55
Total	**1,512,010**	**54,906**

Source: New GIS-based analysis carried out for this review manual based on ICEM and SEI maps / data. Where two or more dams are grouped together and given a single score it is because the ZOI and / or reservoirs overlap

Table 14: Sum of area of reservoirs and ZOIs in each basin

Basin	Reservoir Area (ha)	ZOIs Area (ha)
1. Ba / Kone	55	35,051
2. Ca	1,531	27,895
3. Da	21,017	518,730
4. Dong Nai	2,346	125,414
5. Huong (Lac)	949	32,031
6. Lo - Gam Chay	13,805	223,406
7. Ma – Chu	3,176	150,993
8. Se San	1,542	87,087
9. Srepok	1,027	77,030
10. Vu Gia-Thu Bon	7,822	195,553
Other	?	26,069
Total	**52,265**	**1,499,259**

Source: As for Table 13

Cascades of dams on one basin or a project flooding / degrading final refuges can threaten the survival of species that are endemic and / or range restricted (i.e. being found in single mountain range, protected area or river basin) – mainly fish, but also some reptiles, amphibians, birds and mammals (Table 15).

Table 15: Hydropower and distribution of selected highly range restricted endangered species

Species	Range / basin	Number	Status (IUCN)	Range restricted	Endemic	Minimum No. of large Projects Planned in Basin
Javan rhinoceros *Rhinoceros sondaicus*	Cat Tien NP / Dong Nai basin	<10	CR*	Yes	No	14
Tonkin snub-nosed monkey *Rhinopithecus avunculus*	Ha Giang & Tuyen Quang / Lo – Cam Chay basin	150-200	CR	Yes	Yes	4
Delacour's langur *Trachypithecus delacouri*	Ninh Binh, Hoa Binh and Thanh Hoa / Ma-Chu basin	<300	CR	Yes	Yes	4
Cuc Phuong Catfish *Parasilurus cucphuongensis*	Cuc Phuong NP / Ma-Chu basin	DD	DD	Yes	Yes	4

*CR = Critically endangered & DD = Data Deficient (IUCN Red List 2009)
Source: ICEM: 2007; World Bank Environment Monitor 2005; and IUCN 2009

4.3 Overall conclusion of findings from the ICEM and SEI SEAs

Underestimating the national cumulative impacts of hydropower. The SEAs upon which this review is based provide the first comprehensive analysis of impacts of hydropower on biodiversity in Vietnam. However, it is important that decision makers understand that these SEAs represent a significant underestimation of the impact because:

1. The SEAs looked only at projects which were "open to influence" at the time the assessments were conducted, not those already approved, under construction, or operational. For the SEI SEA this meant analysis of only 21 of 73 large projects in the PDP VI. Further, the majority of those project are now under construction or operational;
2. When the SEAs were written the extent of the additional small and medium dams was not appreciated. Today it is known that there are numerous (as many as 100 in some basins) small and medium dams per basin although a full analysis of provincial PDPs has not been conducted.

The full impact of hydropower on biodiversity in Vietnam will be significantly greater than estimated in the pilot SEAs or summarised in this synthesis report. Taxonomic diversity and ecosystem integrity, at the basin level and nationally, are in constant state of degradation resulting from the impacts of multiple dams – an issue not fully understood or appreciated among all stakeholders because of the absence of overall strategic analysis of all projects in the pipeline for all basins in the country. This knowledge gap highlights the need for SEAs, for regular SEAs, including monitoring and need for decision makers to use SEA tools in their planning. The pace, scope and scale of the hydropower development in Vietnam post publication of the two SEA implies that these pilots, and the information they present, has not been fully assimilated by those responsible for the planning and approval of hydropower dams at the national level and that their influence has been minimal.

4.3.1 Basin-level assessments of hydropower impacts on biodiversity

The following section provides four examples of basin level impact assessments. These basins were first assessed in the ICEM SEA in 2007 and 2 years later the remaining 'open to influence' projects were assessed again by the SEI SEA. The highlighted basins bring together the findings of both SEAs and one other - the ICEM SEA of the Vu Gia-Tu Bong River Basin.

Due to the extent and speed of dam development in Vietnam, the current level of impacts of hydropower in these basins on biodiversity is likely to be greater than those three assessment found and if all projects were considered rather than just some of the large ones in the pipeline. A synthesis of assessments for the six other basins indentified in the SEAs (Table 9) is available as an annex in Volume V of this review.

(i) Ba River and Kone River Basin(s) – Very high biodiversity risk

The Ba Basin forms part of the Central Annamites, a mountainous area of central Vietnam that is recognised internationally as an area of outstanding biodiversity. To the north of the basin is one of Vietnam's most important PA complexes: The contiguous Kon Ka Kinh – Kong Cha Rang (KKK-KCR) system contains one national park, one nature reserve and two KBAs (Map 6). The basin also contains Ea So Nature Reserve, Krong Trai Nature Reserve and A Yan Pa Nature Reserve, which are also important for biodiversity and each has a nearby hydropower project approved or under construction.

The Ba Basin has many rare mammals including three which are endemic: Yellow-cheeked Crested Gibbon *Nomascus gabriellae,* Gaur *Bos gaurus,* Grey-shanked Douc *Pygathrix cinerea* and Large-antlered Muntjac *Muntiacus vuquangensis* and forms the Kon Tum Plateau Endemic Bird Area, and supports six restricted-range bird species.[26]

Freshwater values in Ba Basin are amongst the highest in Vietnam. The basin is globally important site for the conservation of amphibian diversity as well containing endemic fish species. The KKK-KCR complex supports a number of amphibian species endemic to the Annamite Mountains.[65]

Natural resources in the basin are important to local communities, including river fisheries and local forests for the collection of forest products and firewood.

Of the five projects proposed for this basin in the PDPVI, four are located in or near PAs. The Vinh Son II project is located in close proximity to the KKK-KCR landscape. There is potential for extensive cumulative impacts of many projects within the Ba Basin.

Table 12: Impacts of assessed hydropower in the Ba River Basin

No. of hydropower projects proposed in PDP VI for the basin	5
No. of hydropower projects considered in most recent analysis	1 (Vinh Son II)
No. and area (ha) of KBA(s) affected by ZOI	1 / 2,165
No. and area (ha) of PA(s) affected by ZOI	2 / 1,298
No. and area of KBAs/PAs inundated by reservoirs	0 / 0

Source: Based on data from the ICEM and SEA SEAs

The reservoir of the Vinh Son II target project will not affect any PAs or KBA directly via inundation. However, this project has a ZOI of 35,226ha that will impact on three important areas for biodiversity. The ZOI will impact 410ha of Kon Cha Rang Nature Reserve, 888ha of An Toan Nature Reserve and 2,165 Tram Lap - Dakrong KBA (Table 12). It is important to highlight that Vinh Son II is on the border of the Kone Basin, adjacent to the Ba Basin, with the PAs and KBAs being partially in the Ba and partially in the Kone Basins (Map 7):

[65] Tordoff J. et al (2002) Sourcebook of Existing and Proposed Protected Areas in Vietnam: Second Edition BirdLife / MARD / World Bank & The Royal Netherlands Government

Map 6: Hydropower development and biodiversity Ba river basin

Map 7: Hydropower development and biodiversity in the Kone river basin

(ii) Dong Nai River Basin – Very high biodiversity risk

The Dong Nai basin is located in Lam Dong, Dong Nai, Binh Thuan and Binh Phuc Provinces. Together with Vu Gia – Thu Bong, Dong Nai is the only other basin in Vietnam to have been the focus of a detailed SEA of hydropower, being on of the two basins for which all 'open to influence' projects where assessed in the 2007 ICEM SEA. From a strategic perspective the Dong Nai Basin is important because it contains 14 large-scale hydropower projects with the potential to produce 2,353 MW (the second highest basin capacity in Vietnam). The basin wide hydropower system will have fundamental impacts on biodiversity, with the two SEI SEA target projects having particularly significant effects because of their location on the river.

From a biodiversity perspective, the Dong Nai basin is a hotspot in Vietnam. The Southern Annamites, recognised as an Important Bird Area (IBA) and KBA, have high endemism, harbour some of the last remaining populations of globally rare large mammals (including tigers, Asian elephants, Javan rhino and yellow-cheeked gibbons) and retains some of the largest blocks of intact and contiguous lowland forest in the country. Within the basin are two of Vietnam's largest and most important protected area complexes: Cat Tien – Vinh Cuu in the south of the basin area and Chu Yang Sing – Bi Doup - Nui Ba to the north. These PAs and surrounding forests, which protect the basin watershed, are of the highest value and concern for biodiversity protection, nationally and internationally. Cat Tien, for example, protects one of only two global populations of the Javan rhino.

South West Lam Dong Nature Reserve is also of key importance to biodiversity protection in this landscape. The NR serves as a corridor, linking Cat Tien NP with Ta Dung NR and on through to the Chu Yang Sin – Bi Doup - Nui Ba PA complex. This connectivity and maintenance of large forest blocks is essential for the conservation of large mammals (Map 8).

Lam Dong contains some of the largest tracts of riverine forest found in Vietnam – a habitat that is increasingly rare, of critical importance to numerous species and the most at risk from changes in water levels due to up or downstream damming.[66] The river system is also noted for its fish diversity.

The rivers in the basin are of great importance for fisheries, agriculture, industry, households and environmental function and services. However, deforesting, pollution from fish-breeding/aquaculture farms, agriculture and waste from households and industries are some of the main contributors to the deteriorating water quality in Dong Nai basin. Besides loss of biodiversity and nature resources the deteriorating water quality has significant implications for the economic growth in the area.

[66] Tordoff J. et al (2002) Sourcebook of Existing and Proposed Protected Areas in Vietnam: Second Edition BirdLife / MARD / World Bank & The Royal Netherlands Government

Map 8: Hydropower development and biodiversity in the Dong Nai river basin

Fourteen large scale projects are described in the PDPVI, of which two target projects have been assessed in detail. No data is available for the scope and quantity of medium sized and small scale hydropower projects with the basin. However, initial investigation and examples from other basins suggest that these too will be numerous. With 12 of the 14 large scale projects already approved and numerous other large, medium and small scale projects operational or pending, the cumulative impacts of these the projects are very significant. Cat Tien – Vinh Cuu National Park faces the prospect of the large Tri An project that will create a large reservoir that will flood part of the protected area. South West Lam Dong NR faces the additional cumulative impacts of Dam Bri, Dong Nai 4 and Dong Nai 3 (Table 13).

Table 13: Summary of assessed hydropower in the Dong Nai River Basin

No. of hydropower projects proposed in PDP VI	14
No. of hydropower projects covered in this analysis	2 (Dong Nai 2 & 5)
No. and area (ha) of KBA affected by ZOI(s)	0 / 0*
No. and area (ha) of PAs affected by ZOI(s)	4 / 22,777
No. and area of KBAs/PAs inundated by reservoirs	2 / 196

Source: Based on data from the ICEM and SEA SEAs

Dong Nai 2, will inundate, and radically alter the ecology of the river for approximately 22.5 km upstream of the dam. The ZOI of Dong Nai 2 will cover 6,601ha of Ta Dung Nature Reserve and 1,168ha of South West Lam Dong Nature Reserve. The reservoir created by Dong Nai 5 will inundate 94 ha of Cat Tien National Park and 102 ha of South West Lam Dong Nature Reserve – two critical sites for conservation in Vietnam. The ZOI will cover a further 5,298ha of Cat Tien National Park (the entire eastern half of the parks northern sub-section) and 9,710ha of South West Lam Dong Nature Reserve. The ZOI of Dong Nai 2 extends to within approximately 4km of Deo Nui San KBA. The KBA is separated from South West Lam Dong Nature Reserve by Highway 20 and it possible that road construction (to link with the dam site) will lead to disturbance inside the KBA, from construction activities and pollution thus extending the ZOI.

(iii) Se San River Basin – Very high biodiversity risk

The Se San basin borders two PAs, Ngoc Linh NR and Kon Ka Kinh NP and to the east, encompasses all of Chu Mom Ray NP (which is contiguous to forests in Lao PDR). Chu Mom Ray NP contains high levels of biodiversity, including several large mammal species and is one of the key locations for the conservation of tiger in Vietnam. The occurrence of Asian Elephant *Elephas maximus* has been confirmed at Chu Mom Ray, although the population has declined in size significantly since 1980. Also, there is evidence for the continued occurrence of Gaur *Bos gaurus* at the site (Map 9).

There is no data on freshwater or socio-economic biodiversity values in the Basin.

There are six planned hydropower projects in the basin according to the PDPVI, and an additional 92 medium and small projects in provincial plans which have not been assessed for their cumulative effects. Of the six large projects, only one project, at Se San 3A, on the border with Chu Mom Ray NP threatens an important PA, although no assessment has been carried out on its impact. The assessed project, Upper Kon Tum, will definitely impact Kon Plong KBA. Compared to other basins the cumulative impacts appear to be lower, with only one KBA impacted and no PA impacts identified. However, Mom Ray is a key site for biodiversity and could be affected by Se San 3A – and any additional pressures on biodiversity (in the form of Upper Kon Tum and the other dams for which there are no assessments) on important KBAs could have a significant impact. Aquatic biodiversity also faces high risks with extensive up and down stream impacts expected.

Map 9: Hydropower development and biodiversity in the Se San river basin

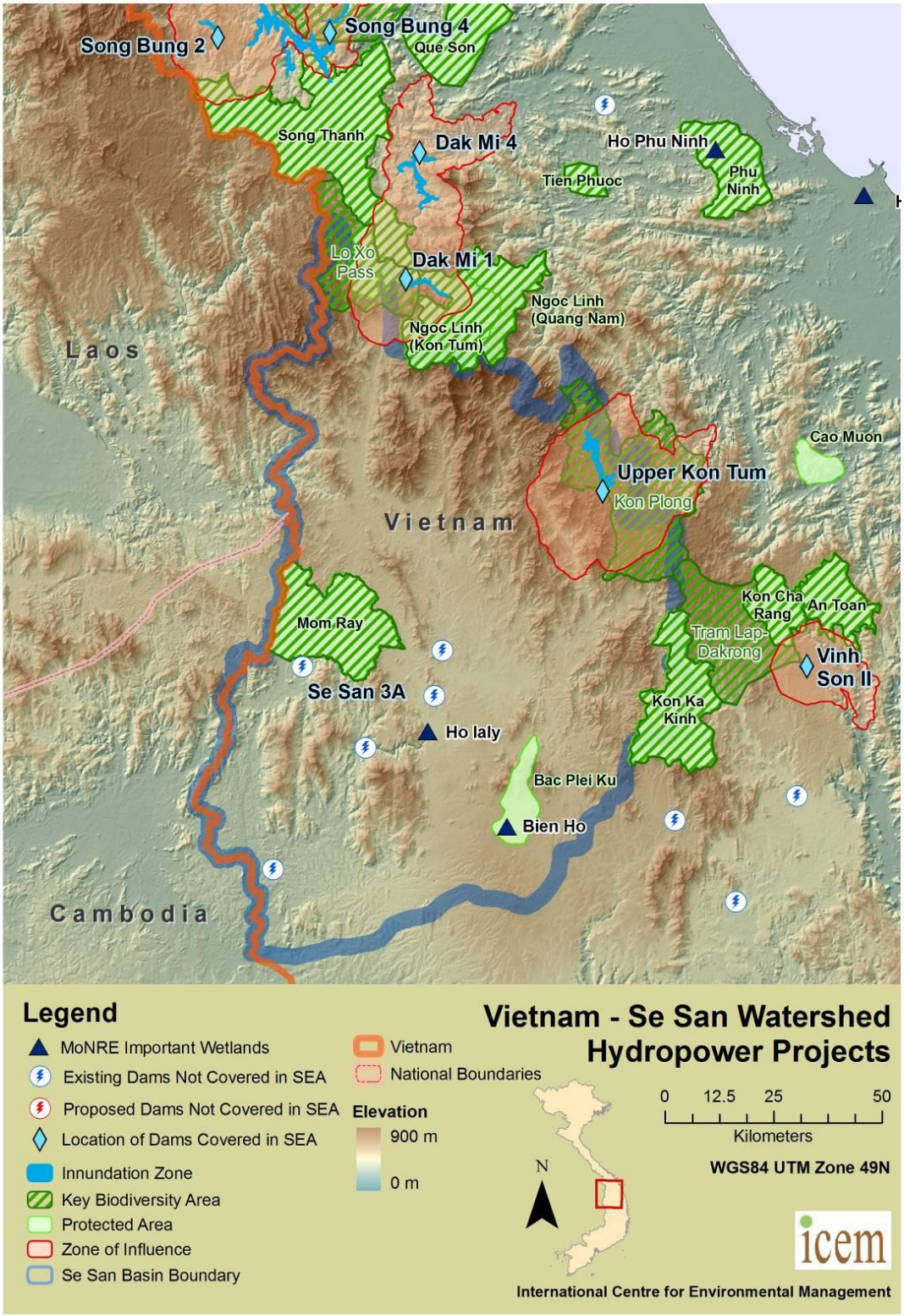


Table 14: Impact of assessed hydropower in the Se San River Basin

No. of hydropower projects proposed in PDP VI	6
No. of hydropower projects covered in the most recent SEA	1 (Upper Kon Tum)
No. and area (ha) of KBA affected by ZOI	1 / 62,446
No. and area (ha) of PAs affected by ZOI	0 / 0*
No. and area of KBAs/PAs inundated by reservoirs	1 / 1,539

Source: Based on data from the ICEM and SEI SEAs

The Upper Kon Tum project will impact on Kon Plong KBA where biodiversity values are not well studied. 1,539 ha of the KBA will be inundated by the project's reservoir and the ZOI will affect a further 62,446 ha. However, it is evident that if one well assessed dam shows such notable impacts, the affects of 6 large and around 90 small-medium dams, within the basin, are potentially very significant.

(iv) Vu Gia - Thu Bon River Basin - High biodiversity risk

The Vu Gia – Thu Bon Basin is located in central Vietnam and forms part of the central Truong Son landscape, which has been ranked as globally "critically important" for biodiversity conservation[67]. There has been general recognition of the importance of the central Truong Son (central Annamites) as an eco-region of international significance, considered one of the 200 most importance eco-regions globally[68] and rated as globally critically important in a more focused analysis. Aside from recent discoveries of new orchids, butterflies, and two new species of snake, several new mammal species have been discovered such as the antelope-like saola, the large antlered muntjac and doucs, or 5-coloured monkeys. It contains unique assemblages of species of birds, amphibian and butterflies, with a high degree of range restriction and endemism. Two Endemic Bird Areas are recognized, the Annamese lowlands extending into the northern part of Quang Nam (and characterized by the presence of the Annam Partridge *Arborophila merlini* and Edwards pheasant *Lophura edwardsi*), and the high Kon Tum plateau centred on Ngoc Linh and its two endemic bird species[69]. It also supports a number of endemic mammal species of limited distribution through the Annamites, especially the grey-shanked douc *Pygathrix cinerea* which is wholly restricted to this landscape and the saola *Pseudoryx nghetinhensis* and Annamite muntjac *Muntiacus troungsonensis* which extends into the northern Annamites.

Until recently, the Vu Gia – Thu Bon River System was a continuous water body without barriers to fish migration and comprising a diversity of aquatic habitats and species.[70] The fish survey conducted as part of the 2008 SEA found 119 species comprising 38 families, including 7 species listed as vulnerable in Vietnam's Red Book[71],[72]. The intense clustering of hydro developments on the Vu Gia –

---

[67] Baltzer et al (2001) *Towards a vision for biodiversity conservation in the Forests of the Lower Mekong Ecoregion Complex.* Hanoi: WWF Indochina Program.

[68] Olson D. (2002) *Terrestrial Ecoregions of the World: A New Map of Life on Earth. November 2001 / Vol. 51 No. 11* BioScience

[69] Todoff J. et al (2002) Sourcebook of Existing and Proposed Protected Areas in Vietnam: Second Edition BirdLife in Indochina, Vietnam Programme / MARD / World Bank & The Royal Netherlands Government

[70] Sheaves M. et all (2008) *Ecological attributes of a tropical river basin vulnerable to the impacts of clustered hydropower developments* Marine and Freshwater Research 59(11) 971–986

[71] ICEM (2008) *Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin*, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Viet Nam.

Thu Bon system has the potential for extensive impacts on aquatic fauna and ecosystems.

PDPVI identifies 8 major projects (60 – 225 MW) and there are close to 60 additional medium or small (<30 MW) hydro installations planned for completion over the next 10 years. Building on the ICEM SEA analysis, five target projects are included here, with details from the SEI SEA. The analysis of impacts summarised here also encapsulate the findings of an ICEM study that subjected the basin to a focused SEA (Box 4).[73]

Of the 8 major developments the A Vuong 1 and Song Tranh 2 projects were already under construction as of 2009, with the further six projects, Song Bung 2, Song Bung 4, Song Bung 5, Dac Mi 1, Dac Mi 4, and Song Con 2 identified for implementation over the next 5 years.

If all planned hydropower in the basin proceeds there is a very high probability of substantial loss of area and quality of forest, and disconnection of forest habitats, reducing the integrity of the landscape and its value for conservation. There is also a high probability of loss of aquatic habitats important or critical to some species such as frogs, turtles, riverine butterfly species and aquatic birds and a near certainty of local extinction of much of the remaining terrestrial biodiversity, particularly all types of large mammals, larger birds, larger snakes and lizards, and turtles. These changes will be permanent and irreversible.

Table 15: Impacts of assessed hydropower in the Vu Gia – Tu Bong Basin

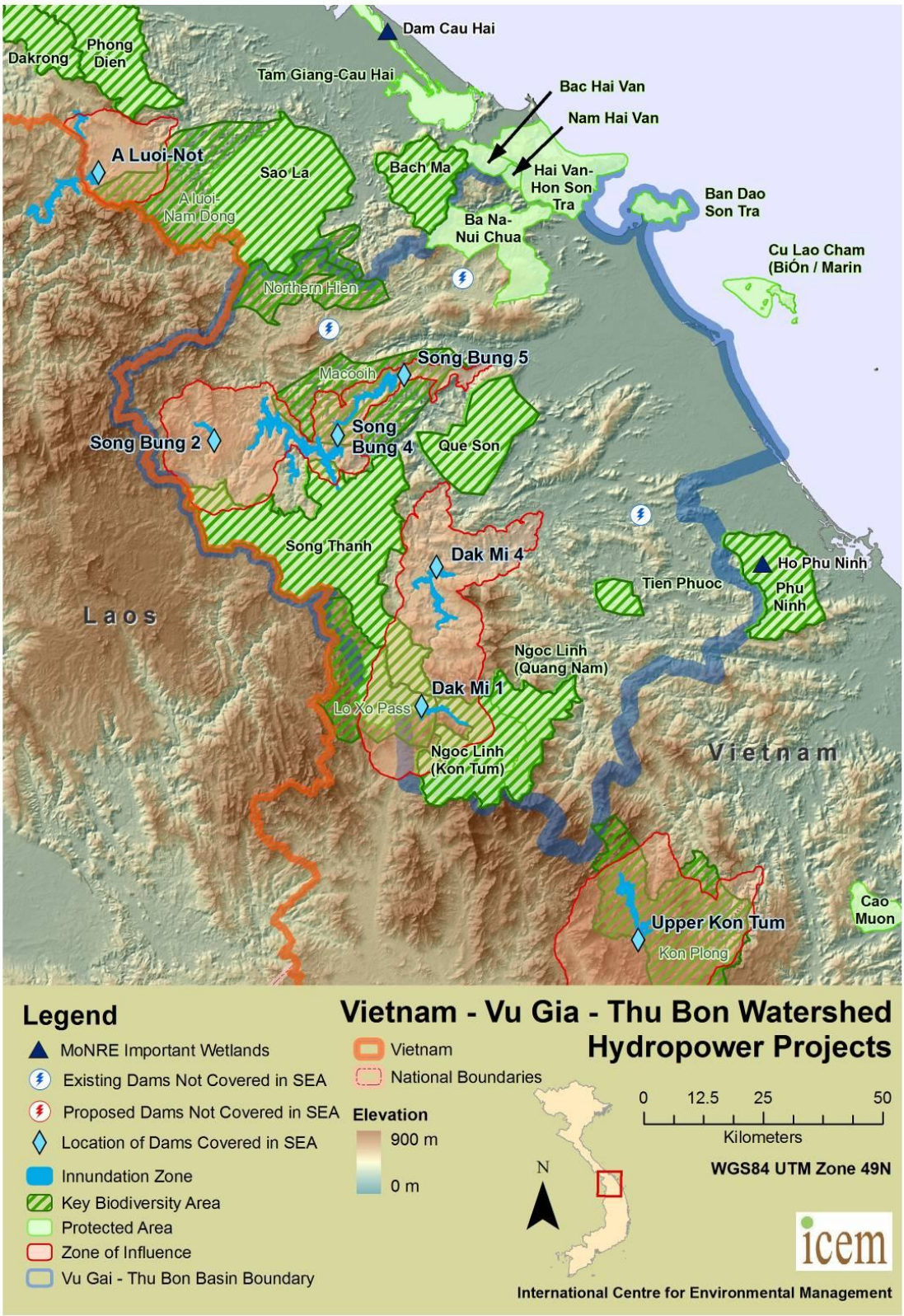
No. of hydropower projects proposed in PDP VI	8
No. of hydropower projects covered in this analysis	5 (Song Bung 2, 4 & 5 and Dac Mi 1 & 4)
No. and area (ha) of KBA affected by ZOI(s)	2 / 27,053
No. and area (ha) of PAs affected by ZOI(s)	2 / 57,536
No. and area of KBAs/PAs inundated by reservoirs	4 / 2,656

Source: Based on data from the ICEM and SEA SEAs

Song Bung 4 will inundate 411ha of Song Thanh Nature Reserve and 219ha of Macooih KBA. Song Bung 5 will inundate 1,387ha of Macooih KBA and Dak Mi 1 413 ha of Ngoc Linh Nature Reserve and 226ha of Lo Xo Pass KBA. The dams will affect a further 84,598 ha of PAs and KBAs through the cumulative ZOIs of the target projects.

[72] Whitten, A. and Kottelat, M. (1996) *Freshwater biodiversity in Asia: with special reference to fish.* World Bank Technical Paper No. 343. Washington D.C.: The World Bank.

Map 10: Hydropower development and biodiversity in the Vu Gia-Thu Bon basin



Box 4: Case Study: SEA of hydropower development on the Vu Gia-Tu Bong River Basin

An SEA was conducted of planned hydropower for the Vu Gia-Thu Bong river system. The detailed assessment was carried out as part of analyses of the PDPVI allowing for comprehensive investigation into specific **impacts and potential mitigation** measures for this basin, as a detailed case study. This SEA / basin-wide case study provides a benchmark for SEAs of hydropower (and other major infrastructure developments) required at the basin level, for all basins where dams are planned, under constriction or operational in Vietnam, and the wider region.

Impacts on Aquatic Systems: Eight major and at least 60 minor hydropower developments are planned for the Vu Gia – Thu Bon River Basin, Quang Nam Province, central Vietnam. The concentration of so many hydropower developments on one river system raises a series of major concerns from the integrity of aquatic ecosystems throughout the system.

1. Migration of aquatic organisms prevented

The 8 large developments and some 40% of the smaller hydropower developments involve blockage of streams with dam, weirs etc., most of which will prevent the passage of migratory organisms. Migration is crucial to the lives of many and probably most fishes and other aquatic organisms. Aquatic life, especially fish, need to migrate for reproduction, feeding, to enter nursery habitats, and to access dry season refuges. While even a single blockage is enough to severely impact life-history functions, the imposition of series of blockages has the potential for serious, irreversible and permanent damage to aquatic ecosystems, with many species unable to maintain viable populations without necessary migrations. Not only will migration be prevented but populations will be fragmented. Even those species able to maintain populations in the fragmented riverscape will be at risk because the potential for recolonisation following local extinctions will be severely curtailed. This impact will directly affect all rivers where dams are constructed, and have cumulative impacts throughout the whole river basin because those aquatic species that rely on access to many sections of the river will be denied continuity of access.

The primary mitigation measure for this issue is the establishment of an Intact Rivers Policy and Program, supported by Fish Passages, Comprehensive Environmental Flows Plans, Ecological Capacity Building and Control of Additional Ecological Stressor Activities.

2. Permanent change to riverine ecosystems

Within the reservoirs created by the hydropower dams current riverine habitats will be converted to lacusterine environments, representing complete and irreversible ecosystem changes that will be permanent while the reservoirs remain in place. Because hydropower requires sufficient head for power generation, the reservoirs will be situated in high flow areas. Few organisms adapted to those conditions will be suited to the altered conditions, and most will fail to thrive.

No mitigation measures can compensate for these complete habitat alterations.

3. Summary of specific alterations to aquatic systems and associated impacts

Diversion of water will leave large stretches of river between major dam walls and tailraces with little water for substantial periods, leading to loss of aquatic habitat due to drying

- Regulation of releases from reservoirs is likely to change the pattern of flows downstream of power stations, further altering the nature of aquatic habitats and reducing local migration.
- Inter-basin diversions (i.e. Dak Mi 4) will greatly increase flows in receiving streams (e.g. Ngon Thu Bon) leading to substantial destruction of aquatic habitats downstream
- The prevention of migrations will substantially alter the translocation of aquatic biomass around the system. This, together with altered nutrient flows due to changed patterns of lateral flooding

and physical nutrient transport, will lead to fundamental modification of aquatic trophic systems.

- Reservoirs will trap nutrients, reducing the supply of nutrients to aquatic habitats immediately downstream of dams.

These changes will be permanent. Where mitigation is possible mitigation measure for these issues include the development of Comprehensive Environmental Flows Plans, Water supply mitigation measures and an Intact Rivers Program, supported by Fish Passages

- Any aquaculture ventures in the new reservoirs provide the potential for invasive species to enter the river system, leading to competition for feeding and breeding space with native species, and in many cases predation on and extinction of native species
- The exact extent of reduction in sediment delivery downstream and coastal areas as a result of hydropower is uncertain (see Water Supply Story-Line), however any substantial reduction has the potential for serious impacts, particularly to estuarine coastal habitats and ecosystems, including the eventual loss of entire estuaries.

These changes will be permanent and there are no mitigation measures for them

Impacts on terrestrial systems

The concentration of so many hydropower developments in an area of national and international importance for terrestrial biodiversity raises a set of further major concerns:

- **Forest area will be lost due to inundation** by lakes, destruction by roads, transport corridors and transmission lines, causing extensive loss or damage to protected forests of high biodiversity value. Access roads, workers camps and other infrastructure, and as a result of forest land allocation to new settlements arising from relocations from the affected dam areas, will place additional pressure on land / forest resources.

These changes are not easily mitigated as the local effects are irreversible.

- **Forest quality will be degraded** throughout the river basin as improved infrastructure leads to increased ease of access for illegal logging activities, etc.

These changes can be mitigated and reversed by careful protection and rehabilitation and protection of the resources, but this is a very long-term, complex and expensive process.

- Increased infrastructure development, particularly reservoir, road and transmission line construction leads to **increased habitat fragmentation** which may isolate fauna and flora populations and render them unviable in the long term.

The primary mitigation measure for this issue is forest corridor development, but the corridors need to be effectively protected to allow species dispersal along them.

- It is likely that there will be **severe declines in species populations**, particularly in economic wildlife and timber species. Increased ease of access will lead to increased illegal logging and wildlife trade, the presence of large numbers of workers will create a local demand for wildlife and other forest and aquatic products, and in the longer term increased economic affluence in the province will increase the urban market for expensive wildlife products.

These changes are irreversible and very difficult to mitigate – to begin with there must be strict compliance requirements on the developers and sub-contractors.

Summary of effects relating to ecosystem integrity

Hydropower will have serious, and largely irreversible, impacts on aquatic ecosystems, their component habitats, species and community assemblages, and overall ecosystem functioning. In turn these changes will further alter wild fisheries, are expected to substantially reduce the yield of native

fisheries populations, and will probably lead to the collapse of wild fisheries. Wild fisheries stocks that are already heavily impacted [particularly due to current high levels of destructive fishing practices] are likely to be pushed further towards total collapse; due to loss of the small number of large breeding fish that remain, and due to the inability to carry out migrations necessary for feeding, nursery ground use, and successful breeding.

Similarly for the terrestrial ecosystem, these impacts will lead to a loss of economically valuable forests and timber resources and a permanent and irreversible loss of biodiversity values of international importance.

Ultimately, these changes will lead to depletion of the natural resources base for provincial development, the loss of species and ecosystems that could provide the basis for future ecotourism development, and prevent the province achieving its biodiversity conservation objectives.[73]

Source: ICEM SEA of Hydropower in the Vu Gia-Tu Bong Basin, 2008

[73] ICEM (2008) *Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin*, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Viet Nam.

Table 16: Summary of effects of assessed hydropower development on biodiversity by river basin

River Basin	Terrestrial Ecosystems			Terrestrial Species			Riparian / Aquatic Ecosystems			Riparian / Aquatic Species		
	PA / KBA inun-dated	Increase in access / threats to KBA / PA	Increase in fragment-ation of KBA / PA	Loss of habitat for key species	Increase in threats to key species	Decrease in mobility of key species	Inundation of KBA / PA riparian habitat	Threat to river system of high biodiver-sity value	Threat of invasive species from other dams	Loss of habitat for key species	Threat to comer-cial species	Threat to key / endemic species
HIGHER IMPACT RIVER BASINS												
Ba	No	Yes	Yes	No	Yes	No	No	Yes	No	Yes	?	**?***
Da	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	?	?
Dong Nai	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	?	?	?
Se San	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	?	?
MODERATE IMPACT RIVER BASINS												
Ca	No	No	No	No	Yes	No	No	Yes	No	Yes	?	**?***
Tra Khuc – Huong	No	Yes	No	Yes	Yes	Yes	No	?	No	No	?	?
Lo – Cam Chay	No	Yes	Yes	No	?	No	No	No	No	No	?	?
Ma – Chu	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	?	?	?
Srepok	Yes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	?	?
Vu Gia – Thu Bon	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes?	Yes

* = Unknown but pressured / likely

Source: Complied from data in the ICEM and SEI SEAs

5. Mitigation measures

This section on avoidance, mitigation and enhancement is adapted from the two ICEM SEAs and divided into three parts. First, the sustainability principles which need to guide implementation of the hydropower plan and the main mitigation measures associated with them are summarized. The second section focuses on mitigation policies and approaches related to the biodiversity concerns - assessed in the pilot SEAs upon which this review is based - as being of highest priority for mitigation. Finally, a wide range of mitigation and avoidance measures are discussed in detail for each stage of the hydropower development process – planning, construction and operation.

5.1 Policy principles guiding mitigation and enhancement

A general conclusion of SEAs conducted in this sector is that hydropower development proposed in the 6th Power Development Plan needs to move forward at a pace and scale which is more cautious and which includes more rigorous safeguards policies, arrangements and practices to mitigate biodiversity impacts. A more cautious approach will lead to better overall development outcomes with fewer opportunity costs and negative effects on biodiversity which undermine sustainability in the sector.

Significant investment will be required to institute and implement the policies and measures necessary for effective mitigation and management of hydropower development according to internationally accepted standards. A commensurate and complementary effort will be needed to improve the capacity of government and private sector institutions in applying these policies and measures. Technical assistance and capacity building should give high priority to national, policy-based and basin-wide strategies to mitigate the biodiversity impacts of hydropower development in Vietnam.

Key policy options and opportunities include:

- reappraisal of the risk premium and mitigation and opportunity costs associated with projects pending in the 6th PDP; and
- establishing a suite of mitigation instruments to address the cumulative risks of the plan, including provision for equivalent or reasonably comparable offsets for all critical habitat loss or deterioration, for optimum downstream flows to maintain freshwater biodiversity values and for payments for ecosystem services involving financial flows from hydropower projects to forest and water managers or affected local communities.[74]

At the sectoral and regional or river basin level, MOI and EVN needs to employ some or all of the following design and location measures to mitigate the cumulative impact of hydropower projects:

- concentrate dams in areas that have been significantly altered already as a result of the cumulative impact of hydropower development;
- limit the aggregate number or spatial concentration of projects in basins at the highest risk of cumulative impacts;
- review alternative locations for projects, such as lower impact dam sites on the same river system;

[74] In that context, the Vietnam Conservation Fund could serve as a potential conduit for system-level PES, although this option requires further study

- reduce or realigning the ecological footprint of related infrastructure and resettlement to avoid or minimise habitat loss or fragmentation;
- introduce environmental regulations for camp location, construction and workforce practices; and
- monitor and report on impacts over the project lifespan as the key to better implementation of mitigation/control measures, adaptive management and learning from experience regarding suitability and effectiveness.

Those prescriptions can be expressed as a number of policy principles which need to underpin and drive implementation of Vietnam's hydropower development. These took shape as intensive consultation with government experts progressed during the two ICEM SEAs – the World Bank SEA of Risks to Biodiversity in the 6th PDP (2007) and the SEA of Hydropower in the Vu Gia-Tu Bong River Basin (2008) (Box 4). They are principles, which if followed, would enhance the sustainability and equity of the hydropower sector. The seven principles are[75]:

1. ***Net provincial economic gain:*** Provincial economies should not be left worse off by national and provincial hydropower development plans
2. ***User pays:*** HP developers should contribute substantially to meeting all direct and indirect environmental and socio-economic costs of the plan implementation
3. ***Multiple use:*** HP projects with reservoirs should be designed and managed for multiple uses of water resources
4. ***Safe operations:*** Implement operational regimes and institutional arrangements to reduce droughts and floods and prepare for disasters
5. ***Net biodiversity gain:*** Avoid and minimize harm to biodiversity and introduce conservation offsets to extend and enhance biodiversity conservation.
6. ***Net gain in minority well being:*** Reduce poverty and increase food security and the quality of life in affected minorities
7. ***The precautionary principle:*** Take care to avoid permanent loss of provincial assets

Those seven principles need to be expressed in practical ways at site, provincial, river basin and national levels. They provide a useful framework for the recommendations for mitigation and enhancement set out in the pilot SEAs. In this section each principle of special relevance for biodiversity is discussed in more detail below. Full description of each principle can be found in the ICEM SEA of Hydropower in Vu Gia-Tu Bong River Basin, 2008.

Net biodiversity gain principle: In practice, every hydropower project will lead to losses in biodiversity. The intent of this principle is that those losses must be kept to a minimum and for substantial investments to be made in better managing, enhancing or rehabilitating biodiversity values on site and elsewhere in the basin. The principles should be expressed through the following policies and practices:

(i) ***Avoid and minimize harm*** to biodiversity directly affected by each HP project and take actions to maintain and enhance what remains.

(ii) ***Conservation offsets*** – in cases of unavoidable harm to biodiversity, each project or groups of projects should take conservation actions to compensate (e.g. compensatory forestry and construction of wetlands)

[75] ICEM (2008) *Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin*, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Viet Nam.

(iii) ***Environmental flows policy*** (on a basin wide basis) to maintain the natural features and functioning of the river system.

(iv) ***Intact rivers policy*** – to concentrate HP on the same rivers and preserve others in their natural state for optimal (rather than maximum economic) development benefits

Net gain in minority well being principle: The plan should not lead to increased poverty and food insecurity in minority communities or reduce their quality of life. To avoid negative effects, the following programs are required:

(i) ***Long term and well budgeted adjustment program*** for the sectors and communities negatively affected.

(ii) ***Integrated government service delivery to affected communities***

(iii) ***Investors and developers pay over life of HP projects***

Precautionary principle: The precautionary principle underpins the application of the other principles. The SEAs have concluded that hydropower development in Vietnam is moving forward at too rapid a pace and too large a scale – i.e. it is too much too quickly. This haste is unmanageable given current capacities, and brings with it many risks of serious irreversible environmental, social and economic harm. Most important, it is proceeding without government leaders having adequate information and knowledge of its consequences.

Applying the precautionary principle means:

(i) ***A more cautious and gradual approach*** to hydro development given the many uncertainties which remain concerning the risks to natural, social and economic systems. A more gradual approach implies that lessons can be learned and fed back to improve sustainability and conservation performance in future and existing hydropower projects.

(ii) ***The plan should be phased and projects postponed*** when there is good reason to believe that harmful effects may occur, and when the risk cannot be assessed with sufficient confidence to adequately inform decision-making.

5.2 Mitigating impacts during planning, construction and operations

Consideration of effective management of hydropower projects to protect biodiversity resources needs to be integrated into all stages of project development. Commencing with project design and site selection it must extend through project construction, and be an ongoing activity in project operation and decommissioning.

The following section provides guidance on this question drawing on examples of work carried out in Vietnam.

5.2.1 Planning phase

The planning phase is the most important phase in terms of identifying and implementing measures to avoid, reduce and offset adverse impacts. Measures identified at this stage are generally more environmentally effective and more cost effective than measures identified or implemented at later stages of the project development process. For example, the most effective measure to avoid biodiversity loss is sensitive site selection which uses a reliable and comprehensive baseline dataset. If a suitable site is found for a project which minimising conflict with biodiversity assets, development of mitigation and management measures, and implementation of an effective and adaptive monitoring program becomes simpler. Site selection and project design are usually determined before the commencement of environmental investigations, and comprehensive baseline

biodiversity datasets are incomplete in most cases

Table 16 summarizes the mitigation measures that should be considered during the planning phase.

Table 16: Planning phase mitigation measures

Mitigation measure	Comment
Location of project to avoid direct impacts on sensitive biodiversity resources or fragmentation of sensitive habitats	This is the priority mitigation measure to avoid impacts on biodiversity resources and relies on the availability of a robust data set and a participatory site selection process involving numerous stakeholders.
Selection of project concept – i.e. small run of the river project or large storage dam concept	Run of the river dams are sometimes advocated as a means of managing impacts because large storage dams are generally recognized as having more complex, permanent or wide-ranging effects. Options need to be considered which do not obstruct an entire river – partial obstruction or diversion canals and off-takes may have significantly less impact on biodiversity.
Selection of project design parameters – dam height, minimum operating level, location of power station	Dam height is a key factor in the determining the scale of upstream and downstream impacts; locating the power station close to the dam can reduce or eliminate lengths of dry river stretches
Location of ancillary infrastructure including access roads and transmission lines	To minimize habitat fragmentation and loss and avoid opening of sensitive areas for exploitation. Designs which require transfer of water from one river to another can be particularly disruptive for natural systems.
Development of operational protocols for downstream flows and sediment releases	To avoid periods of no-flow and to mimic as far as possible natural daily and seasonal variations in flows and sediment/nutrient loads.
Design of dam shoreline	To replicate natural shoreline conditions and create opportunities for riparian ecosystem establishment and persistence
Suitable siting of resettlement areas and development of livelihood support schemes in conjunction with local authorities	Given the lead-time required to plan and implement resettlement areas and support schemes, these measures require early attention in the project planning phase. Community forestry management schemes have the potential to provide livelihoods for local people and while simultaneously protecting natural resources.
Identification of suitable areas of compensatory protected areas to offset unavoidable losses and enhance biodiversity.	Given the lead time to identify and establish new protected areas, this process requires early attention in the project planning phase. The form of protected area to be established (i.e. Special Use Forest, community managed protected area, project buffer zone protected area) should be considered on a case by case basis.

5.2.2 Construction phase

Impacts that occur during the construction phase can be avoided or reduced to an acceptable spatial or temporal level through proper project planning. The following specific measures should be considered for implementation during the construction phase of the project.

Table 17: Construction phase mitigation measures

Mitigation measure	Comment
Minimization of construction activity footprint	By ensuring construction activities are confined as far as possible in areas of future disturbance, the impact footprint of the project is minimized.
Control of erosion, sediment generation, water pollution and downstream runoff	Protection of aquatic ecosystems during construction will aid in maintaining their resilience in the phase of operation stage impacts.
Implementation of reservoir filling protocols that avoid periods of no-flow downstream of the dam.	A longer reservoir filling period that allows for regular releases of flows that mimic natural conditions will aid to reduce impacts on downstream ecosystems
Measures to minimize wildlife drowning during reservoir filling	These measures need to be assessed and evaluated on a case by case basis. Wildlife rescue prior to flooding can be an ineffective mitigation measure because of complexities in the design and implementation of relocation programs, limited successes achieved to date and the high costs. Suitable site location followed by establishment of compensatory protected areas may be a more effective strategy.
Establishment / restoration of shoreline habitats	Dam and downstream shorelines should be restored or enhanced to a near natural state to enhance viability of riparian ecosystems
Implementation of resettlement strategies with integrated livelihood support programs	Livelihood support programs are essential to avoid overexploitation of natural resources by resettled communities.
Management of construction workforce	Proper siting of construction camps, provision of adequate food to avoid need for subsistence hunting, education, hygiene and safety measures, and restrictions on hunting and exploitation of natural resources are required.

5.2.3 Operation phase

During the operation phase mitigation measures should focus on operational processes to replicate natural processes and ongoing support to resettled communities. Adaptive management (Box 3) will form an important component of the operation phase mitigation activities.

Table 18: Operation Phase Mitigation Measures

Mitigation measure	Comment
Implementation and ongoing refinement of operational protocols for downstream flows and sediment releases	Adaptive management of downstream flow regimes and sediment releases should be implemented in response to monitoring needs
Management of biomass / invasive species in reservoir	To minimize risk of invasive species transfer downstream

Mitigation measure	Comment
area	
Management of dam and downstream shorelines	To replicate as far as possible natural riparian ecosystem conditions
Ongoing support for resettled communities	To ensure long term sustainability of alternative livelihoods and reduce dependence on natural resources
Ongoing support for established compensatory protected areas	To ensure long term sustainability of protected areas through development of management plans, biodiversity action plans, enforcement, financial contributions.

Greenhouse gas releases from reservoirs can be reduced by a thorough salvage of commercial timber and fuelwood, although frequently this does not happen because of (a) high extraction and transportation costs, (b) marketing constraints, or (c) political and economic pressures not to delay reservoir filling. The surest way to minimize greenhouse gas releases from reservoirs is to choose dam sites that minimize the flooding of land in general, and of forests in particular.

5.3 Key mitigation policies and programs

Substantial and innovative mitigation measures will be required to offset the major impacts on ecosystem integrity that will stem from such a concentration of projects in each river basin in Vietnam. The mitigation policies and programs proposed here are not seen as either-or propositions but as essential complimentary measures that together can help to alleviate some of the more severe biodiversity losses. These mitigation policies and program apply to the entire life span of hydropower projects and to the overall integrated management of the river basin they affect:

5.3.1 A moratorium on hydro projects inside SUFs of known biodiversity importance

Many of projects highlighted in this review show direct impact of dams on protected areas of recognised biodiversity value. Already under national forestry policy, infrastructure development is not permitted in core conservation zones of protected areas. But that policy is heavily qualified in cases of national projects and security. Often major developments proceed within protected areas causing irreversible losses to biodiversity of international importance. The commitment to no major infrastructure development within protected areas should be reinforced through the imposition of a government moratorium.

5.3.2 Intact rivers policy and program[76]

An Intact Rivers Program would mirror the approach taken in Marine Protected Areas programs that have been so successful around the world. In such as scheme at least one continuous river waterway in all rivers would be kept free of barriers to migration from its headwaters to the ocean, and environmentally destructive practices strictly controlled within and adjacent to the intact rivers to maximize habitat quality. Such a scheme would secure complete river continuums that could maintain aquatic biodiversity and the wild fisheries of the river system, despite severe disruption to migratory pathways and loss and fragmentation of habitats in other parts of the basin. Not only

[76] ICEM (2008) *Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin*, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Viet Nam.

would the intact river provide an area that would preserve critical fauna by providing for their life history requirements, but it would serve as an "aquatic faunal repository" from which other parts of the system could be repopulated in the future.

There is no precedent in Vietnam for such a system and no legal basis for protection and management of a river as a whole ecosystem. This would need to be approved as a pilot, perhaps under the classification of 'Protected Landscape' defined under Decision 186, with the River Basin Committee forming the Management Board for this Protected Landscape.

Detailed regulations could:

1. Prohibit the imposition of barriers (hydropower dams and other structures) from the headwaters to the ocean of at least one river within each system to ensure that a full sequence of habitats and migratory routes is protected in each river. Any human imposed barriers already in place should be removed or bypassed with fish passage devices.
2. Define ***Zones of Influence*** adjacent to the Intact Rivers in which activities that might impact the aquatic environments of the Intact Rivers are strictly controlled.
3. Prohibit mining in the river channel and river banks for the length of the intact river and its side branches and feeder streams within the Zones of Influence.
4. Impose strict controls on terrestrial mining in of the Zones of Influence to prevent pollutants (e.g. cyanide & mercury) and sediments entering the intact river.
5. Prohibit the construction of roads and road infrastructure within the Zones of Influence except where it can be demonstrated to be necessary and demonstrated to have no effect on aquatic ecosystems of the Intact Rivers.
6. Prohibit the establishment of new settlements, industrial areas and other new human activities within the Zones of Influence.
7. Strictly control human activities and industries already occurring in the Zones of Influence to reduce any current impacts on the Intact Rivers and prevent any new impacts.
8. Strengthen bans on destructive fishing practices (electro-fishing, explosive fishing, gill net fishing) within the Intact Rivers and Zones of Influence, and police the bans vigorously.

5.3.3 Compensatory forestry

Compensatory Forestry, in the form of replacing lost or forests with new forests, should take the form of establishing forest corridors to re-connect isolated forests or rehabilitating degraded forests to improve biological values of the landscape as a whole. Compensatory forestry, in the form of household based farm forestry fragmented through the landscape, is a commendable approach as a livelihoods improvement initiative, but has limited value as conservation (biodiversity) offset. Communities need to be involved in the allocation and management of these compensatory forest areas, but the areas should be selected to add incremental value to existing forest patches or to recreate connections between forest patches that may be lost by development projects. The Government should consider introducing regulations to enable hydropower developers to finance rehabilitation of forest connectivity to enhance their biodiversity values.

5.3.4 Fish passages

Fish passages, fish ladders, fish elevators or similar devices that are usable by key local species should be installed where possible) to overcome the cumulative impacts of series of barriers. Although this is probably only possible on smaller projects, where dam walls are low enough to allow this mitigation, it is crucial to reduce the cumulative impacts of clusters and series of barriers. In general,

tropical fish do not adapt well to fish passages and related devises. Therefore, careful design would be required to ensure that devices installed were suitable for the use of native fishes.

5.3.5 Environmental flows plan for hydropower operation

Multi-purpose and coordinated management of water releases could minimize excessive flooding and improve minimum flows to help maintain critical habitats and help to alleviate adverse impacts of altered flows in areas downstream of dams. Environmental flow releases need to be carefully timed and coordinated if they are to be effective, and need to be developed within an integrated framework to optimize the benefits to all sectors. For instance, environmental flow releases to reduce habitat loss during droughts are likely to coincide with compensatory flows for agricultural and water supply needs, but additional releases may also be required to support migration needs.

A comprehensive environmental flows policy and plan should be developed. The policy should provide requirements for environmental flows and regulatory guidance to the operators of hydropower infrastructure. The plan should be based on a location-specific understanding (i.e. understanding of the needs for species inhabiting the actual system under development).

5.3.6 Ecological monitoring and data systems for river basins

The definition of a specific policy to protect and manage aquatic biological resources is constrained by an absence of appropriate data. An extensive, carefully targeted data collection scheme should be implemented to collect basic ecological data, in particular detailed information on ***habitat relationships, spawning sites and migratory patterns***, particularly related to life cycle requirements of aquatic fauna. At the same time extensive monitoring of the health of Intact Rivers ecosystems should be conducted to ensure the benefits of that initiative are maximized. This data collection is a high priority because now rational management is hampered by a lack of fundamental understanding of aquatic ecosystems.

5.3.7 Control and enforcement

Strict controls on activities likely to exacerbate the impacts of hydropower development are needed to support other mitigation measures:

(i) The use of exotic species in any aquaculture developments in the reservoirs should be prevented, because accidental releases of exotic species can displace and destroy native fish species.

(ii) Current regulations on destructive fishing practices (eg. electro-fishing, explosive fishing) needs to be enforced vigorously throughout the river system, to reduce exploitive pressures on fish stocks.

(iii) Mining activities in all areas of the river basin need to be strictly controlled to reduce damage from dredging, bank excavation, pollution from toxic chemicals (eg. cyanide and mercury), and the creation of contaminated sites. These activities are likely to lead to further aquatic habitat loss and degradation.

(iv) Specific regulations are needed for the control of contractors and for the management of workers, ensuring that they do not engage in ecologically harmful practices either during their duties or during their free time. Responsibility for this must rest with the contractors during construction and the hydro project operators during operation.

Access into forests along new roads constructed to the dams and powerhouses, should be strictly controlled by establishing road barriers, the manning of which should be the responsibility of the hydropower project operators. This will help to prevent hunting and illegal logging and settlement in forests that are suddenly made more accessible.

5.3.8 Coordination of hydropower and forest planning

Forests of high conservation value are classified as Special Use Forests and consolidated into protected areas. Much of the protected areas are further zoned as Special Protection Zone, within which any form of development is prohibited according to Decision 186/2006. It is recommended that a moratorium be placed on planned hydro projects located inside the Special Use Zone of protected areas. Hydropower projects planned to be located within protected areas such as Dac Mi 1 in Kon Tum Province should be subject to immediate and comprehensive environmental assessment and strict conditions placed on its continued construction and operation.

Furthermore, hydro projects adjacent to and/or likely to impact heavily on protected areas should conduct detailed EIA with re-planning if necessary. This applies, for example, to Khe Dien hydropower project recently completed within the new Elephant Species and Habitat Conservation Area in Quang Nam Province.

5.3.9 Restrict ribbon development along roads crossing forested areas

Already existing provincial regulations restricting ribbon development along the transport corridor and HCM Highway, particularly, should be enacted, especially where these roads cross forests of high biodiversity value. To enable this, provinces need to approve provincial Forest Protection Department staff increases, plus capacity building and equipment for control of the road corridors.

5.3.10 Clarify responsibilities for mitigation

To achieve effective mitigation, responsibilities for paying for the required measures needs to be clearly placed within the contracts awarded to hydro operators (according to the user pays principle). Hydropower project operators also need to be assigned specific responsibilities in regard to limiting environmental damage during construction, controlling workers, and introducing ecologically friendly water release operations, etc. (all points covered in detail above). FPD, commune authorities and river basin authorities will be responsible for compliance monitoring. Capacity building will be needed of many authorities made responsible for overseeing mitigation and monitoring compliance: provincial authorities need to ensure that allocations of funds are made available for this such that the authorities can conduct their assigned tasks effectively.

5.3.11 Carry environmental management plan conditions into contracts

All environmental management plan conditions associated with a project need to be transferred to the tender documents to form part of the bid proposals. During construction the contractor must implement the plan and report regularly on progress in compliance.

6. Critical information gaps and research needs

Compared to studies in temperate zones, relatively little research has been undertaken on tropical ecosystem responses to hydropower development.[77] In addition there are significant gaps in biodiversity baseline information in Vietnam that limit the accuracy and robustness of impact predictions. This section highlights those gaps and research needs:

- Data on the distribution, ecology, endemism, and conservation status of freshwater biodiversity are seriously lacking in Vietnam. Most data provided in published studies are only lists of species, genera, and families, and these are sometimes of questionable reliability

[77] Dudgeon D. 2000. *Large scale hydrological changes in tropical Asia: Prospects for biodiversity*. Bioscience, vol. 50, pp. 793-806.

and relate to commercial catch in lower reaches of rivers. In most cases, there are no explicit data on ecology, specific habitat, distribution, migration and other key aspects of freshwater biodiversity.

- There is a strong need for more accurate and extensive biodiversity assessments in PAs and KBAs in Vietnam. Such studies perform two key functions: i) to identify and prioritise rivers and basins that should be maintained with biodiversity undiminished; and ii) to provide the baseline for ongoing monitoring and evaluation of hydropower impacts on biodiversity at a site, basin and national level.
- Assessments of dam impacts should include development in other sectors. Other types of development and current baseline threats will have impacts that interact with hydropower development, often in a cumulative fashion, so an assessment of hydropower in isolation from other developments would tend to underestimate some of its biodiversity impacts.
- A number of studies in temperate zones show that species impacts in terms of diversity and density around storage areas and downstream of impounded rivers can undergo initial rebounding but then taper off in the long term (> 30 years). Monitoring and research in tropical zones are required to determine the long term effects of hydropower development.
- Studies carried out to date only cover large hydropower dams, not small or medium hydropower dams or dams for other purposes, such as irrigation or water supply. This coverage further restricts consideration of cumulative impacts on biodiversity. In some cases the cumulative impacts of small and medium hydropower projects can be very significant especially when concentrated with large projects on the one river system. For example, in Giang District of Quang Nam Province, nine small and medium hydropower projects are planned along with four large projects under the 6th PDP.
- There is need to gain accurate and reliable location data for dam sites to allow accurate geo-referenced assessment of impacts. Without this data, biodiversity risks associated with hydropower projects may have been / be overestimated or underestimated. With current limitations, it is not always possible to determine whether or not projects are sited within, or close to, sites of high biodiversity value.
- There are no data available for Vietnam at the scale of individual basins that explicitly quantify full socio-economic values of either terrestrial or freshwater biodiversity. In the absence of national or regional level quantitative data on full socio-economic values of biodiversity, and impacts upon them, analysis must be based on the number of people living in close proximity to affected natural (freshwater and terrestrial) resources and poverty levels.
- There needs to be more comprehensive dialogue and sharing of information on the planning and implementation of hydropower projects. In undertaking assessments of hydropower effects on biodiversity, the ultimate aim is to be able to influence the parameters of projects to avoid or minimize adverse effects. However, it is crucial that information on which projects are still “open to influence” is shared by Government partners in a transparent and cooperative way.

7. Conclusions

The scale of hydropower development in Vietnam is extensive, with multiple small, medium and large projects planned, under construction or operating in every river basin in the country and on all the medium to large rivers. More than 73 large hydropower projects proposed in PDP VI, together with existing large dams are fundamentally reshaping Vietnam’s aquatic and significant terrestrial

systems in ways that will lead to irreversible losses of biodiversity of international, national and local importance. . The major dam projects are being developed within a context of hundreds of smaller dams, both existing and proposed that are approved at the local level and go largely unnoticed in terms of their cumulative and degrading effects on biodiversity.

Much of the planning for both the large and provincial level projects is done by the same national level agencies associated with EVN and its Institute of Energy. Yet, there is a serious failure in the development planning process within the sector. The effects on Vietnam's biodiversity are not being captured and adequately considered. Major losses in the national biodiversity estate are taking place throughout the country due to hydropower development without registering at national level – and without adequate attention to avoidance and mitigation – in planning, operations and enforcement.

Comprehensive information for species and ecosystems that will be impacted or degraded in some way by one or several dam projects is not available and generally has not been gathered prior to hydropower projects going ahead. Biodiversity survey coverage is inconsistent and where information exists, it is often either out of date or unreliable. A major upgrading of investment and effort is needed in recording and making accessible ecosystems, habitat and species information for each river basin.

The scale and pace of hydropower development envisaged in PDPVI and linked provincial power development plans will transform the hydrology and biodiversity of the country. A more cautious approach to hydropower development is needed with projects moving forward on a staged basis. . That way lessons can be learned and studies conducted to be fed back to influence and shape the next phase of projects that have already begun and projects not yet approved or even planned. Given the many uncertainties which remain concerning the risks to natural, social and economic systems, a concerted effort is needed to conduct thorough assessments and to establish biodiversity surveys for each river basin to guide future hydropower planning and operation decisions.

Hydropower is playing a very important role in the country's power development strategy. However, as has been repeatedly shown in EIAs and SEAs the cost of too many projects in environmentally sensitive locations will have long-term costs which are not being adequately considered in development decisions. Vietnam's development depends on intact natural systems. Environmental services from terrestrial and aquatic biodiversity are crucial to the lives of many poor, rural communities and the population as a whole relies on river water for industry, water supply, sanitation, irrigation, alluvial sediments and for fisheries, inland and marine. Future integrated planning of hydropower development must take into account the multiple values of biodiversity and the natural systems of river basins – resulting in a strategically planned and assessed energy mix for Vietnam that is ecologically sustainable.

References and further information

Anderson EP, Pringle C & Rojas M. 2006. *Transforming tropical rivers: an environmental perspective on hydropower development in Costa Rica.* Aquatic Conservation: Marine and Freshwater Ecosystems, vol. 16, pp. 679-693

Andersson E, Nilsson C & Johansson ME. 2000. *Effects of river fragmentation on plant dispersal and riparian flora.* Regulated Rivers: Research and Management, vol. 16, pp. 83-89.

Baird I. 2009. *The Don Sahong Dam: Potential Impacts on Regional Fish Migrations, Livelihoods and Human Health.* POLIS Project on Ecological Governance.

Baltzer et al. 2001. *Towards a vision for biodiversity conservation in the Forests of the Lower Mekong Ecoregion Complex.* Hanoi: WWF Indochina Program.

Bernez I, Haury J, & Ferreira MT. 2002. *Downstream effects of a hydroelectric reservoir on aquatic plant assemblages.* Proceedings of the 2nd Symposium on European Freshwater Systems.

Biodiversity and Climate Change. Montreal, Technical Series No. 41, 126 pp.

Birdlife (2009) Operational Management Plan for Chu Yang Sin National Park, Dak Lak Province, Period: 2010-2015, Birdlife in Indochina, Vietnam Programme

Birdlife / WARECOD (2009) *Communities voice concerns about aquatic resources.* Accessed at http://birdlifeindochina.org/content/local-communities-voice-concerns-about-aquatic-resources-tuyen-quang-vietnam on March 30th 2010

Brooks et al (2002) Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* 16: 909–923.

Bunn S and Arthington A. (2002). *Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity.* Environmental Management, vol. 30, pp. 492-502.

Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on

Daufresne M and Boet P. 2007. *Climate change impacts on diversity of fish communities in rivers.* Global Change Biology, vol. 13, pp. 2467-2748.

Davis, S. D., Heywood, V. H. and Hamilton, A. C. eds. (1995) *Centres of plant diversity: a guide and strategy for their conservation. Volume 2: Asia, Australasia and the Pacific*. Cambridge, U.K.: IUCN Publications Unit.

Deharveng L., Le Cong Kiet and Bedos A. (2001) Vietnam. Pp. 2027-2037 in: Juberthie C. and V. Decu eds. *Encyclopaedia Biospeologica* tome III. (In French.)

Do Duc Quan, Deputy Director General of Energy (Power) Department, MOIT. Workshop on Power Development, 7th January 2010

Dudgeon D. 2000. *Large scale hydrological changes in tropical Asia: Prospects for biodiversity*. Bioscience, vol. 50, pp. 793-806.

FISTENET (2006) *Vietnam fisheries overview*. Downloaded from http://www.fistenet.gov.vn on 8 November 2006.

FIVAS (2007) *Ruined river, Damaged lives*: Impacts of the Theun-Hinboun Hydropower Project on Downstream Communities in Lao PDR. The Association for International Water Studies.

Gitay H., Suarez A., and Watson R. (2002). *Climate Change and Biodiversity: IPCC Technical Paper V*. 45pp.

ICEM (2003) *Vietnam national report on protected areas and development.* Indooroopilly: Review of Protected Areas and Development in the Lower Mekong River Region.

ICEM (2007) Pilot Strategic Environmental Assessment in the Hydropower Sub-sector, Vietnam. Final Report: Biodiversity Impacts of the hydropower components of the 6th Power Development Plan. Prepare for The World Bank, MONRE, MOI & EVN, Hanoi, Vietnam.

ICEM (2008) Strategic Environmental Assessment of the Quang Nam Province Hydropower Plan for the Vu Gia-Thu Bon River Basin, Prepared for the ADB, MONRE, MOITT & EVN, Hanoi, Vietnam.

ICEM (2009) An Evaluation of CARE's Community based mangrove rehabilitation and management project, Thanh Hoa, Vietnam

International Energy Agency Implementing Agreement for Hydropower Technologies and Programs Annex III: Hydropower and the Environment: Present Context and Guidelines for Future Action. Volume I: May 2000. Pg. 9-12 [In "Continental Energy Sector Issues" the Canadian Energy Research Institute 2004]

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.

IUCN (2006) *2006 IUCN red list of threatened species*. Downloaded from http://www.redlist.org on 7 November 2006.

IUCN (2008) Protected Areas – A basis for Vietnam's Sustainable Development (presentation)

Jansson R, Nilsson C, and Renöfält B (2000) Fragmentation of Riparian Floras in Rivers with Multiple Dams. Ecology: Vol. 81, No. 4, pp. 899-903.

Jansson R. 2002. *The Biological Cost of Hydropower.* Prepared for Coalition Clean Baltic.

Ledec G and Quintero JD. 2003. *Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects.* Prepared for The World Bank.

MOSTE (1995) Biodiversity Action Plan for Viet Nam, Ministry of Science, Technology and Environment, Government of Vietnam

Nadler, T., Momberg, F. et al (2003) *Vietnam primate conservation status review 2002. Part 2: leaf monkeys*. Hanoi: FFI Vietnam Programme & Frankfurt Zoological Society.

Nguyen Tien Hiep, et al (2005) *Vietnam conifers: conservation status review 2004*. Hanoi: Fauna & Flora International Vietnam Programme.

Nilsson C and Berggren K. 2000. *Alterations of riparian ecosystems caused by river regulation.* Bioscience, vol.50, pp. 783-792.

Nilsson C., Reidy A., Dynesius M., and Revenga C. (2005). *Fragmentation and Flow Regulation of the World's Large River Systems*. Science, vol. 308, pp. 405-408.

NOAA National Marine Fisheries Service (2007, September 13). Rare Dolphin Driven To Extinction By Human Activities, Scientists Fear. *ScienceDaily*. Retrieved January 15, 2010, from http://www.sciencedaily.com /releases/2007/09/070911114747.htm

Olson D. (2002) *Terrestrial Ecoregions of the World: A New Map of Life on Earth. November 2001 / Vol. 51 No. 11* BioScience

Pedrono M., Ha Minh Tuan, Chouteau P., and Vallejo F. (2009). *Status and distribution of the endangered Banteng Bos javanicus birmanicus : A conservation tragedy.* Oryx, 43 (4) : 618-625.

Pilgrim J. (2007). *Effects of Sea Level Rise on Critical Natural Habitats in Vietnam.* International Symposium on Biodiversity and Climate Change – Links with Poverty and Sustainable Development Hanoi, 22-23 May 2007

Rosenberg DM, McCully P, and Pringle C. (2000). *Global scale environmental effects of hydrological alterations: An introduction.* Bioscience, vol. 50, pp. 746-751.

Secretariat of the Convention on Biological Diversity (2009). *Connecting Biodiversity and Climate*

Sheaves M. et all (2008) *Ecological attributes of a tropical river basin vulnerable to the impacts of clustered hydropower developments* Marine and Freshwater Research 59(11) 971–986

Soussan J. et al (2009) *Harnessing Hydropower for Development: A Strategic Environmental Assessment for Sustainable Hydropower Development in Vietnam*, Stockholm Environment Institute (SEI), Stockholm, Sweden

Tordoff A. et al (2002) *Sourcebook of Existing and Proposed Protected Areas in Vietnam: Second Edition BirdLife in Indochina*, Vietnam Programme / MARD / World Bank / Royal Netherlands Gov.

Tordoff, A. W. ed. (2002) *Directory of* Important *Bird Areas in Vietnam: key sites for conservation*. Hanoi: BirdLife International *in Indochina* and the Institute of Ecology and Biological Resources.

Tordoff, A. W., Baltzer, M. C., Davidson, P., Fellowes, J., Ha Quy Quynh and Tran Thanh Tung (2007) *Ecosystem Profile: Indo-Burma Biodiversity Hotspot, Indochina Region*. Washington DC: Critical Ecosystem Partnership Fund.

UNDP, Migration, Development and Poverty Reduction Workshop & UNDP HDR, 5th October 2009

van Dijk, P. P., Tordoff, A. W., Fellowes, J., Lau, M. and Jinshuang, M. (2004) Indo-Burma. Pp 323-330 in R. A., Mittermeier, Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreaux, J. and da Fonseca, G. A. B. eds. *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. Monterrey: CEMEX; Washington D.C.: Conservation International; and Mexico: Agrupación Sierra Madre.

WCMC (1992) *Development of a national biodiversity index.* A discussion paper prepared by the World Conservation Monitoring Centre, Cambridge, UK. Unpublished.

Whitten, A. and Kottelat, M. (1996) *Freshwater biodiversity in Asia: with special reference to fish.* World Bank Technical Paper No. 343. Washington D.C.: The World Bank.

World Bank (2004) Going, Going, Gone... The Illegal Trade in Wildlife in East and Southeast Asia

World Commission on Dams (WCD). 2000. *Dams and Development – A New Framework for Decision Making*. 404pp

WWF (2005) *List of Global 200 Ecoregions*. Downloaded from http://www.panda.org on 6 April 2006.

WWF (2007) Implementing Landscape conservation – Ecoregional conservation in a priority landscape in Vietnam: An assessment of the WWF MOSAIC project in Quang Nam Province, Vietnam

Zhai Hong Juan et at (2007) *Regional ecosystem changes under different cascade hydropower dam*

construction scenarios in the LRGR State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University.

Useful websites

Sustainable hydropower:

http://www.sustainablehydropower.org/index.html

IUCN information on hydropower:

http://www.iucn.org/about/work/initiatives/energy_welcome/energy_impacts/hydropower/

The International Hydropower Association:

http://www.hydropower.org/

The threats facing biodiversity – CEPF:

http://www.cepf.net/WHERE_WE_WORK/REGIONS/ASIA_PACIFIC/INDO_BURMA/ECOSYSTEM_PROFILE/Pages/synopsis_of_threats.aspx

International Rivers

www.internationalrivers.org