Chapter 7. The conservation of aquatic and wetland plants in the Indo-Burma region

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7.1 Species selection

The aim of this study was to assess the conservation status of freshwater plants occurring in the Indo-Burma region and which are dependent upon standing or flowing fresh, or at most slightly salty water for their survival. There were two main difficulties with this process: the adoption of a definition of what constitutes an "aquatic plant" which would both include the target species and be unambiguous, and; selection of the species to assess. With regard to the notion of aquatic plants, one of the most important issues is that of obligation or tolerance. A large number of vascular plants, such as water naiads (*Najas* species) cannot survive out of water and may be considered obligate aquatics. Conversely many species including some trees and ferns can tolerate even quite long submersion but are not dependent upon wetlands and may be considered facultative aquatics or not aquatic at all. Clearly it was critical to include the former but exclude the latter from this assessment. However the situation is further complicated by taxa which germinate and initially grow under water but flower and fruit in the air (termed "emergent") and those which are dependent upon temporary or ephemeral water bodies, often remaining dormant beneath standing water and germinating as water levels drop. The following definition was considered the most clear and unambiguous available: "Vascular aquatic plants are interpreted as all Pteridophytina and Spermatophytina whose photosynthetically active parts are permanently or, at least, for several months each year submerged in water or float on the surface of water" (Cook 1996). The only ambiguous element of this definition is the duration of inundation, details of which are unknown for the majority of plants and any attempt to be more precise would require guesswork.

The growth forms of aquatic vascular plants include taxa which are:

- Always completely submerged (obligate submerged aquatics) such as the naiads (Najadaceae).
- Submerged with sexually reproductive parts emergent (held above the water or at the surface), such as *Hydrilla verticillata*.
- Emergent, the roots and base of the plant are submerged, but some photosynthetic parts and sexually reproductive parts are emergent, such as many species of the Scrophulariaceae, including *Limnophila* and *Lindernia* species.
- Floating, without roots or with roots hanging in the water column, such as rigid hornwort (*Ceratophyllum demersum*), floating fern (*Salvinia natans*) and duckweeds (Lemnaceae).
- Amphibious, growing from the land over the water or adopting a variety of the above forms, such as some *Persicaria* species.

The following taxa were excluded from the assessment:

- Taxa known or suspected to not be native to the region; although this distinction is not always straightforward, particularly when considering long-established cultivated plants.
- Hybrids and taxa below species level.

A fundamental principle of these assessments was not to pre-

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judge the conservation condition, such as by selecting species known or believed to be of conservation concern, as this approach is likely to support existing areas of concern but overlook taxa which are not already known to be at risk. The approach adopted for a similar study in Africa (Darwall *et al*. 2011) was to select and assess all species in a suite of families considered likely to serve as representative of wetland plants in the region; the same approach and families were selected for this project, with the addition of the Podostemaceae, for which an expert was available to provide input. The families included, as well as number of genera and total number of species assessed in each of these families are shown in Table 7.1, the number of species assessed in each genus is shown in Table 7.2.

Table 7.1 The selected families included in the assessment, showing the number of genera and aquatic plant species occurring in the region.

FAMILY	Number of genera	Number of species	FAMILY	Number of genera	Number of species
Acanthaceae	3	8	Hydroleaceae	1	1
Acoraceae	3	2	Isoetaceae	1	1
Alismataceae	6	11	Juncaceae	1	5
Amaranthaceae	2	2	Lamiaceae	1	3
Apiaceae	3	3	Linderniaceae	1	15
Aponogetonaceae	1	4	Nymphaeaceae	3	9
Araceae	10	24	Orchidaceae	1	1
Arecaceae	1	4	Phrymaceae	1	1
Asteraceae	12	14	Plantaginaceae	6	24
Ceratophyllaceae	1	2	Podostemaceae	10	55
Commelinaceae	2	3	Polypodiaceae	1	1
Droseraceae	1	3	Potamogetonaceae	3	14
Elatinaceae	1	1	Rubiaceae	2	2
Fabaceae	3	4	Salviniaceae	2	3
Hanguanaceae	1	1	Typhaceae	2	8
Hydrocharitaceae	7	18	Xyridaceae	1	3

Table 7.2 The number of aquatic plant species occurring in the region in each genus assessed.

Genus	Number of species	Genus	Number of species	Genus	Number of species
Acanthus	1	*Eclipta*	3	*Nymphaea*	6
Acorus	2	*Enydra*	1	*Oenanthe*	1
Adenosma	1	*Ethulia*	1	*Oldenlandia*	1
Aeschynomene	2	*Euryale*	1	*Ottelia*	3
Alisma	1	*Grangea*	1	*Oxystelma*	1
Alocasia	1	*Hanguana*	1	*Paracladopus*	2
Alternanthera	1	*Hanseniella*	2	*Pistia*	1
Aponogeton	4	*Hemisteptia*	1	*Pogostemon*	3
Azolla	1	*Hippuris*	1	*Polypleurum*	12
Bacopa	1	*Hydrilla*	1	*Potamogeton*	12
Barclaya	2	*Hydrobryum*	20	*Ranalisma*	1
Bergia	1	*Hydrocharis*	1	*Sagittaria*	5
Blyxa	6	*Hydrodyssodia*	1	*Salvinia*	2
Butomopsis	1	*Hydrolea*	1	*Sesbania*	1
Caesulia	1	*Hygrophila*	6	*Sparganium*	3
Calamus	4	*Inula*	1	*Sphaeranthus*	1
Caldesia	2	*Isoetes*	1	*Spirodela*	1
Centella	1	*Juncus*	5	*Stuckenia*	1
Centrostachys	1	*Landoltia*	1	*Terniopsis*	6
Ceratophyllum	2	*Lapsanastrum*	1	*Thawatchaia*	1
Cladopus	5	*Lasia*	1	*Typha*	5
Colocasia	2	*Lemna*	3	*Typhonium*	1
Commelina	2	*Limnophila*	19	*Vallisneria*	2
Cryptocoryne	11	*Limnophyton*	1	*Wedelia*	1
Curanga	1	*Lindernia*	15	*Wolffia*	2
Cussetia	2	*Microcarpaea*	1	*Xanthium*	1
Cyanotis	1	*Microsorum*	1	*Xyris*	3
Dalzellia	4	*Mimulus*	1	*Zannichellia*	1
Dentella	1	*Najas*	4	*Zeuxine*	1
Dopatrium	1	*Nechamandra*	1	*Zeylanidium*	1
Drosera	3	*Neptunia*	1		

Eriocaulon species in a species-rich flush, Doi Suthep, Thailand.

Whilst this approach does enable assessment of a range of taxa, it is extremely selective and may present a distorted picture of the conservation status and requirements of freshwater plants in the region. Of particular concern is that adopting this approach precluded assessment of two of the most important wetland plant families, the sedges and allies (Cyperaceae) and grasses (Poaceae) as well as a number of other families, the inclusion of which could have given a completely different picture, such as the Eriocaulaceae. In addition, no trees were assessed and yet, particularly in this region, trees are a fundamental element of the wetland vegetation. It is likely that a comprehensive assessment covering all the wetland-dependent plants in the region could present a different perspective and show that there is a real need for concern regarding aquatic and wetland plant conservation in the region which is not the case with the taxa selected for this study.

There are many areas of taxonomic uncertainty affecting aquatic plants, for example, the taxonomy of the water-chestnuts (*Trapa* species) is very complex with at least 20 named taxa only one of which is widely recognised. Where the information was available, the taxonomic treatment by The Plant List (www.theplantlist.com) was followed. In cases where names had not yet been treated by this checklist, appropriate authorities, such as The Flora of Thailand (Hansen 1987, Hedge and Lamond 1992, Larsen 1972, Tagawa and Iwatsuki 1989 and Yamazaki 1990) were followed.

7.2 Conservation status

A total of 252 species had their conservation status assessed. The number of species assigned to each Red List category was calculated (Table 7.3, Figure 7.1) and the species assigned to each class presented in Table 7.4. The most notable points arising from this are the very small number of taxa assigned to a threatened category and the large number of species assessed as Data Deficient (DD). Of the species for which sufficient data are available, 2.4% (five species) are threatened (one CR species, two EN, and two VU). In many Data Deficient cases, such as for several species of Podostemaceae, as well as *Cryptocoryne*

Table 7.3 The number of aquatic plant species assessed in each Red List Category in the region.

	IUCN Global Red List Category	Number of species
	Extinct	0
	Extinct in the Wild	0
Threatened Categories	Critically Endangered	1
	Endangered	2
	Vulnerable	2
	Near Threatened	5
	Least Concern	197
	Data Deficient	45
	Total	**252**

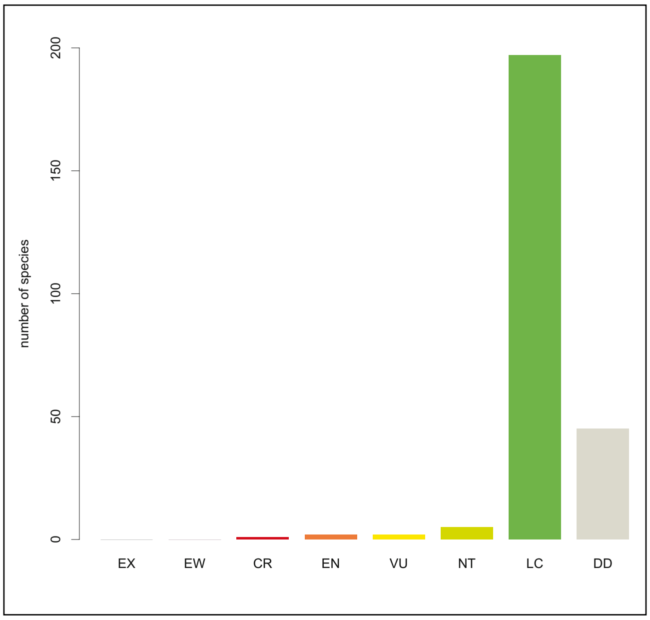


Figure 7.1 The number of assessed aquatic plant species in each Red List Category in the region.

annamica and *C. vietnamensis*, the species are currently known from single sites and may be extremely vulnerable to local stochastic events. Equally, some species may not have been recorded for more than a hundred years, often not since they were described, and it is not unlikely that they are extinct. Because of this lack of information on threats or distribution, they have been assessed as Data Deficient.

The only species considered Critically Endangered is *Terniopsis ubonensis*, a member of the Podostemaceae (Box 7.1). *Crinum thaianum* and *Terniopsis chanthburiensis* are both assessed as Endangered. *C. thaianum*, the Water Onion, was historically widespread in low-lying areas below 150 m altitude on the coastal plains of southern Thailand but a combination of habitat degradation and over-exploitation have resulted in the loss of a number of populations. It grows in clear, fresh, flowing water typically in broad, unshaded streams and rivers which vary from a few centimetres depth in the dry season to two or more metres depth in the wet season. Much of the habitat degradation was caused by dredging of rivers and streams to improve drainage and to derive aggregate for construction, leading to increased scour which has uprooted whole populations. This has been combined with landuse changes in the catchments of rivers and streams which formerly supported this species, resulting in a decline in water quality and loss of a number of populations. Two species of Podostemaceae are assessed as Vulnerable and are discussed in Box 7.1.

Over half of the species assessed as Data Deficient are members of the Podostemaceae (see Box 7.1), others include members of the Araceae, Hydrocharitaceae and the Scrophulariaceae (including *Limnophila* and *Lindernia* species). Many of these species, such as *Pogostemon* species, *Ottelia balansae* and *Ranalisma rostrata* occur in marshy places and seasonally damp depressions and probably in flushes and seepages over bedrock, although some species such as *Limnophila polyantha* and *Lindernia rivularis* are more strictly aquatic, the former occurring in ponds or lakes and the latter in shallow streams. For most of these species, there is simply not enough information to assess whether or not they are threatened, and they are considered Data Deficient. Some, such as *Limnophila helferi*, are only known from the type locality (i.e. the specimen collected and then used to describe the species new to science), while other species such as *Limnophila siamensis*, *L. verticillata*, and *Lindernia rivularis* are considered Data Deficient as, although they are known to persist at one or more sites, we have no information on their ecology, threats or conservation needs. Another example of a DD species is *Lindernia khaoyaiensis*, which is known from a restricted area of eastern Thailand and an adjacent part of Lao PDR; the only recent population has now been lost as the site where it occurred in Khao Yai National Park is now a radar installation (J.F. Maxwell *pers. comm.* 2011), however it has been recorded from a number of other sites where it may persist.

The Water Onion *Crinum thaianum* (EN), is now restricted to a few locations in the coastal plains of the Malay Peninsula in Thailand. © Somsak Soonthornnawapha

Table 7.4 Species assigned to threatened and Data Deficient Red List categories.

Critically Endangered	
Terniopsis ubonensis	
Endangered	
Crinum thaianum	*Terniopsis chanthaburiensis*
Vulnerable	
Dalzellia ranongensis	*Hanseniella heterophylla*
Near Threatened	
Cryptocoryne cruddasiana	*Polypleurum erectum*
Paracladopus chantaburiensis	*Polypleurum longicaule*
Polypleurum longifolium	
Data Deficient	
Barclaya motleyi	*Hydrobryum takakioides*
Blyxa quadricostata	*Hydrobryum tardhuangense*
Blyxa vietii	*Limnophila diffusa*
Cladopus fallax	*Limnophila hayatae*
Cryptocoryne annamica	*Limnophila helferi*
Cryptocoryne loeiensis	*Limnophila polyantha*
Cryptocoryne mekongensis	*Limnophila pulcherrima*
Cryptocoryne vietnamensis	*Limnophila siamensis*
Cussetia carinata	*Limnophila verticillata*
Cussetia diversifolia	*Lindernia khaoyaiensis*
Dalzellia angustissima	*Lindernia rivularis*
Dalzellia kailarsenii	*Lindernia succosa*
Dalzellia ubonensis	*Ottelia balansae*
Hanseniella smitinandii	*Pogostemon crassicaulis*
Hydrobryum kaengsophense	*Pogostemon quadrifolius*
Hydrobryum khaoyaiense	*Polypleurum longistylosum*
Hydrobryum minutale	*Polypleurum phuwuaense*
Hydrobryum phetchabunense	*Polypleurum pluricostatum*
Hydrobryum ramosum	*Polypleurum prachinburiense*
Hydrobryum somranii	*Polypleurum sisaketense*
Hydrobryum subcrustaceum	*Ranalisma rostrata*
Hydrobryum subcylindricum	*Terniopsis ramosa*
Hydrobryum taeniatum	

In contrast, Data Deficient species such as *Barclaya motleyi*, *Blyxa quadricostata* and *B. vietii* grow in flowing water. *B. motleyi* grows in forest streams and has been recorded from a wide area from southern Peninsula Thailand in the north, south through Malaysia and Indonesia to Irian Jaya. However, it has apparently

A species-rich flush including *Drosera*, *Utricularia* and *Eriocaulon* species, Doi Suthep, northern Thailand. © R.V. Lansdown

been recorded from single sites very widely spread through Southeast Asia with no obvious population centres and few recent records.

In most of the cases of Data Deficient species, there is a need to survey and document populations to establish whether they are, in fact, widespread or demonstrably threatened. In some cases, such as *Limnophila helferi*, there is a need to return to the area from which it was collected and establish whether it still occurs. However, there are two main conclusions from the assessments carried out:

1. The taxa assessed do not necessarily represent a sample which can be taken to indicate the overall conservation status of freshwater plants in the region. The inclusion of different or additional families may have presented a very different picture, however the families selected for inclusion were done so to allow comparison with other regional aquatic plant assessments (for example, Allen *et al*. 2010, Darwall *et al*. 2011) and to reduce potential bias towards species of families perceived to be more threatened and thereby present an alternative biased perspective.
2. The definitions employed and the limit on the number of species that could be assessed under the present study have excluded many of the taxa which are most vulnerable, such as those which are dependent upon flushes and shallow flow over bedrock, as well as many taxa dependent upon seasonal wetlands.
3. There is an urgent need to further document freshwater plants in the region to enable informed assessment of their conservation status.

Species richness maps (as presented for other taxonomic groups in this report) are not presented for aquatic plants as significant numbers of species were mapped at the country (or in some cases, sub-country units or provinces) level, due to a lack of information on detailed distributions or ecological preferences. For this reason aquatic plants are also not included in the richness maps shown in Chapter 8.

7.3 The freshwater vegetation of the region

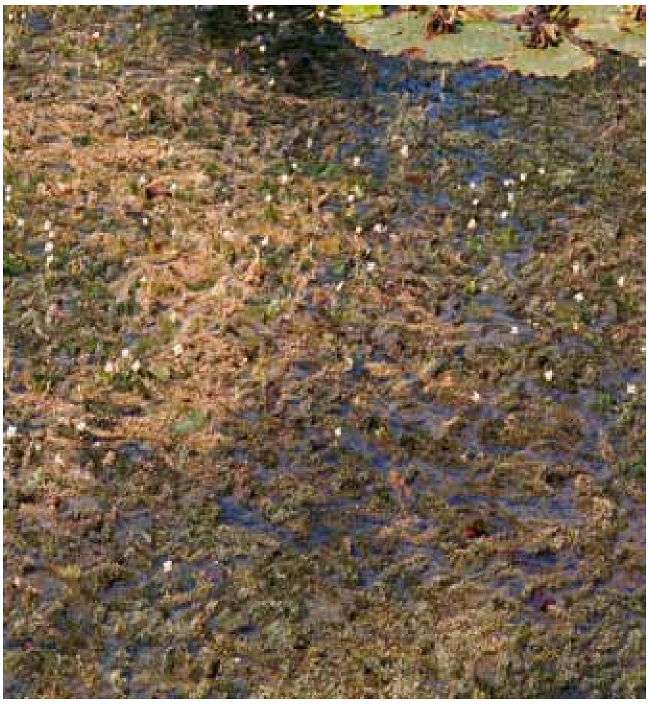
The area treated in this report covers only a small proportion of mainland Asia, but includes huge climatic and landscape diversity. It ranges from some of the highest mountains in the world at the eastern end of the Himalaya to the humid tropics in Narathiwat Province in southern Thailand. Habitats for plants vary in a similar way, from more or less bare ground above the tree line in high mountains, through coniferous forests, deciduous and mixed forests throughout northern Thailand, Lao PDR, Cambodia and Viet Nam to rainforest in southern Peninsula Thailand; the habitats for wetland and aquatic plants lie within these and vary from montane flushes, seepages and high altitude bogs, through forested rivers and streams to lowland marshes, peat swamp forest and rice fields.

The most important wetlands in the region are the rivers, particularly the Lower Mekong River (Box 7.2), which touches on all the countries covered by this report, but also other large river systems such as the Salween River in Myanmar and the Mun / Chu river wetlands and the Khwae Yai River system in Thailand. Not only do these rivers support a wide range of aquatic and wetland plant species both in their channels and on the margins, which in some places spread over many kilometres, but in the wetlands formed by fluvial processes within their active floodplains. These rivers start as flushes and seepages in the mountains, often arising in small wetland systems characterised by a high diversity of bryophytes, including *Sphagnum* mosses, as well as vascular plants such as sundews (*Drosera* species), pipeworts (*Eriocaulon* species) and bladderworts (*Utricularia* species). They then flow down through forest, often very shaded and with very high humidity, dominated by species of fern and bryophytes, gradually slowing down and meandering, at which point aquatic plants specialised for shaded rivers such as *Cryptocoryne* (Box 7.3) and *Barclaya* species start to occur. Wherever these rivers cross harder rocks, torrents, rapids and waterfalls occur which support plants such as humidity demanding ferns, rattans of the genus *Calamus* and species of the Podostemaceae (Box 7.1), many of which are endemic to single rapids or short reaches of a single river.

In the larger river systems the high scour and turbidity of spate flows leads to opening of the canopy, braiding of channels and the consequent creation of mosaics of seasonal channels, *kai kum* areas (sensu Maxwell 2001), oxbow lakes, ephemeral pools and backwaters associated with rocky outcrops. It is these reaches of the river which create and maintain the widest range of wetland habitats and which probably support the greatest diversity of aquatic and wetland plants. Many of the ferns, *Cryptocoryne* and *Barclaya* species and rattans which occur upstream will also occur in these areas, as well as a wide variety of taxa typically found in lowland marshes and ponds. However, many of the species which occur in these wetland complexes are generalists, rather than the highly specialised species that often show a high degree of local endemicity and occur in torrents or in shaded forest streams.

Eventually, the rivers start to break up to form complex series of channels in deltas, in places flowing through extensive marshlands dominated by large monocots such as *Typha*, *Actinoscirpus grossus* and grasses, before reaching their tidal limits which are often indicated by the presence of *Nypah* palms and ferns of the genus *Acrostichum*. Where they reach the sea, deltaic systems may flow through a fringe of mangrove. The major deltas in the region, such as the Ayeyarwaddy and Mekong, which show a gradation from freshwater to brackish or saline conditions, probably once supported a wide range of aquatic and wetland plants, but much of this richness has been lost through drainage of marshes and their conversion to agriculture; mainly rice production.

Hydrilla verticillata, a species capable of forming extensive mono-specific stands covering the surface of the water. © R.V. Lansdown



The region also includes a number of very large lakes and associated habitats, including Inlé Lake (Box 7.4) in Myanmar, Beung Khong Long, Kwan Phrayao, Nong Han, Songkhla Lake and Thale Noi in Thailand, Tam Giang Lagoon in Viet Nam, and the Great Lake, Tonlé Sap (Box B7.5) in Cambodia. The number of medium-sized to large open bodies of water in the region has been significantly augmented by impoundment, mainly for the purposes of providing drinking water, agricultural irrigation water, or hydropower. However, only very few of these artificial impoundments, such as Bung Nam Ngum in Lao PDR, have any real conservation value and most support only the more adaptable and widespread aquatic and wetland plant species. Along with the upper reaches of estuaries and coastal deltas, natural lakes often originally provided the only extensive wet, non-forested areas which supported species now most often found in rice fields and seasonally inundated pasture.

Historically, large lake systems and extensive open water in freshwater marshes supported most of the true aquatics; species which grow in standing water and cannot tolerate extended exundation, particularly *Aponogeton* species, *Hydrilla verticillata*, *Monochoria hastata*, *Najas* species, water lilies such as *Nymphaea nouchali*, *N. pubescens*, *N. rubra* and *N. tetragona*, *Pistia stratiotes*, pondweeds (*Potamogeton* species) and *Vallisneria* species. The margins of these lakes; associated wetlands such as pools; seasonally inundated habitats and freshwater marshes will have supported most of the aquatic and wetland plants of the region not dependent upon forest streams, seepages and flushes or torrents. Extensive freshwater marshes once dominated the Fang and Chiang Mai basins in northern Thailand and spread across much of the Central Plains south from Phitsanulok and Itteradit to the vicinity of Bangkok. In the drier northeast, the swamps were more limited in extent and were chiefly confined to the valleys of the rivers Songkhram, Chi and Mun, meandering across the plateau toward the Mekong. By the turn of the twentieth century, virtually this entire habitat had been canalised, drained and converted to agriculture and urbanised areas. Today, no untouched freshwater wetland habitats remain in Thailand. What was not converted to agriculture was, like the swamps of Beung Boraphet north of Nakhon Sawan, dammed and turned unto lakes in order to enhance fisheries (Round and Graham 1994).

Extensive freshwater marshes in the region were originally mainly associated either with the upstream extremes of estuaries and deltas or with large lake systems. Most of these have been

Seasonally inundated marshland around the Tonlé Sap in Cambodia, showing the extent of land converted to agriculture. © Adrian Whelan

replaced by agriculture, often extensive areas of rice fields, which retain many of the former marshland species, but lack the great natural species diversity that once occurred. In many ways the vegetation of rice fields with sump ponds, canals and drainage ditches mimics that of former marshland systems, supporting many species formerly typical of freshwater marshes, including *Adenosma indianum*, *Alisma plantago-aquatica*, *Blyxa echinosperma*, *Caesulia axillaris*, *Curanga amara*, *Cyanotis axillaris*, *Dentella repens*, *Eclipta angustata*, species of *Limnophila*, *Lindernia* and *Marsilea*, *Microcarpaea minima*, *Mimulus orbicularis*, *Monochoria* species, *Oldenlandia diffusa*, *Ottelia alismoides*, *Sagittaria pygmaea*, *Salvinia auriculata*, *Spirodela polyrhiza*, *Typhonium flagelliforme* and *Zeuxine strateumatica*. These are mainly emergent or marginal species, with most of their bulk held above the water and so they are particularly well adapted to temporary water bodies, such as rice fields. Many of these species will also occur in small, low-lying wet areas outside active agriculture or other land-use, as well as in damp areas on waste ground and between fields. Weeds, that is more ephemeral herbs, include some species which are typically found in rice fields and can be seen when these places are wet. These include: *Dopatrium acutifolium*, *Utricularia bifida* var. *bifida* and *U. minutissima*, *Eriocaulon quinquangulare* and *Burmannia coelestis*. *Grangea maderaspatana*, *Sphaeranthus indicus* and *Ammannia baccifera* are species which flower and fruit when the fields are dry. Species found in sandy, often seasonally inundated areas, include *Spilanthes paniculata*, *Glinus lotoides*, *Polycarpon prostratum*, *Polygonum plebeium*, *Cyperus pygmaeus*; *Digitaria bicornis*, *Eragrostis amabilis* and *Eleusine indica*.

There are a number of different types of forested wetland in the region including swamp forests, *Melaleuca* forest and seasonally inundated forests. Swamp forests are permanently inundated and often grow over deep peat, often with a high proportion of palms in the taller vegetation and are restricted to southern Peninsula Thailand within the region. They often support a range of aquatic plants in channels, including species of *Cryptocoryne* and *Barclaya*. *Melaleuca* forest is typically seasonally inundated and forms a patchwork among more open swampy habitats which may support highly diverse wetland vegetation. There is only one *Melaleuca* species native to the region; *M. cajuputi*, with most species native to Australasia (WCSP 2012). Most of the forested wetlands in the region are seasonally inundated and occur along large river systems such as the Mekong (Theliade *et al*. 2011). Seasonally inundated swamp forest ecosystems also surround the Tonlé Sap Lake in Cambodia. Formerly these ecosystems were also extensive in the deltas and lower floodplains of the Mekong and Chao Phraya rivers but are now restricted to isolated fragments.

Wet grassland ecosystems range from small, seasonally wet meadows within dry forest landscapes, to the extensive, seasonally inundated grasslands that characterize the inundation zone of the Tonlé Sap Lake. Seasonally inundated grasslands, which support distinctive assemblages of species, including several globally threatened species, are one of the most threatened ecosystems in the region. They were formerly widely distributed in central Thailand and the Mekong Delta, and a few remain, some of which such as Tram Chim National Park, Lang Sen Nature Reserve, Tra Su, Hon Dat, Phu My and a few smaller areas in Viet Nam and Boung Prek Lapouv and Anlung Pring in the Cambodian part of the Mekong Delta. However, the majority have almost completely disappeared through conversion to agriculture, aquaculture and forestry.

One remnant grassland is Takeo grassland in Cambodia. In the wet season, the whole of this area is a floating mat of vegetation, supporting more than 30 aquatic plant species dominated

Eichhornia crassipes, an invasive aquatic originating in the New World and now a problem throughout the tropics. © R.V. Lansdown

A navigable channel through reed swamp in Tonlé Sap, where the only floating vegetation is the alien Water Hyacinth *Eichhornia crassipes*. © Charles Pieters

by *Echinochloa stagnina*, *Polygonum tomentosum*, *Ipomoea aquatica*, *Hymenachne acutigluma*, *Leersia hexandra* and *Pseudoraphis brunoniana*, with smaller populations of *Oryza rufipogon*, *Ischaemum rugosum*, *Salvinia cucullata*, *Cyperus iria*, *Monochoria hastata*, *Nymphoides indica*, *Sacciolepis interrupta* and *Paspalum scrobiculatum*. When floodwaters recede, the floating mats come to rest on the ground. In dry and hot conditions, biomass from the previous year quickly decomposes and provides nutrients for new shoots that re-sprout from old stems. The new shoots mainly root in the loose semi-decomposed mats and not in the soil, the whole mat then floats again when the site is next flooded (Tran 2003).

7.4 Major threats

Wetlands in the region and the plants which depend upon them are under threat from a wide range of direct and indirect anthropogenic actions. The biggest single threat worldwide and no less so in the region, is drainage, simply the removal of standing or flowing water to enable the land to be used for other purposes. One of the first actions usually undertaken by people when they settle to exploit an area is to modify the drainage. This may simply involve relatively minor tinkering by redirecting and locally damming small streams to manage the availability of water for stock but more often involves drainage of any low-lying depressions, pools and ponds together with canalisation of larger flowing water-bodies. Thus, the first thing that typically happens when an area is opened up for exploitation is the loss of marginal habitats and seasonal wetlands which support the greatest diversity of freshwater plants.

Most river systems in the region are threatened by plans for dam construction. Construction of dams on rivers modifies the hydrological regime, divorcing floodplains from the river so that floodplain wetlands loose connectivity and are often more vulnerable to drainage and conversion to other land-uses; inundation regimes and the erosion-deposition balance change such that taxa dependent on particular niches are lost and some taxa cannot survive under the modified regime. This applies both to small scale dams, which often destroy diverse and sensitive springhead and flush communities and to the large dams which inundate kilometres of river with previously wide amplitude of inundation variation, leading to sediment deposition upstream, but often starving downstream areas of the sediment needed to support species-rich wetlands. Disruption of the erosion-deposition balance can also mean that plants such as some of the more vulnerable *Cryptocoryne* species may be buried beneath sediments deposits. There is a significant increase in the number of dams in the area, varying in scale from large international or national projects on rivers such as the Mekong, to the installation of bunds on small streams to provide water during the dry season.

Even in the upstream reaches of rivers, where most catchments are still forested, uncontrolled or poorly controlled conversion to agriculture, as well as slash and burn forest clearance, usually results in increased erosion and sediment loading in upland rivers, whilst increasing the flashiness of the river leading to increased scour, simultaneously reducing the water retention capacity of the catchment and increasing the risk of flooding. Similar issues result from the blasting of bars and rapids, which result in greatly increased flow and reduced water retention, increasing the risk of flash-flooding downstream. The destruction of rapids and torrents also destroys the habitat of plants such as members of the Podostemaceae, which, because most are endemic to a single torrent, are immediately extinct.

All wetlands in the region are threatened by pollution, from small-scale untreated sewage and waste water to large-scale industrial effluent and poorly buffered run-off from agriculture. Increased nutrient-loading, often derived from a combination of sediment inflow and poorly buffered agriculture within the catchment, can lead to hyper-eutrophication in backwaters and pools during low flows with consequent algal blooms followed by die-back and eventually dissolved oxygen depletion, at which point most submerged vegetation will die. Other forms of pollution include untreated sewage and household and industrial waste which can build up in the sediment and lead to similar conditions. Even small streams are under threat from casual modification and untreated sewage.

Small floodplain wetlands, such as pools, as well as the seasonal wetlands associated with larger wetland complexes are extremely vulnerable to drainage and conversion to agriculture. This has happened throughout much of Thailand and it is difficult to quantify the effect on some of the wetland plants such as *Lindernia* species. Lakes and ponds are becoming shallower due to a combination of build-up of decayed vegetation and litter, sedimentation, abstraction and diversion of inflow streams (La-ongsri *et al.* 2009). Many small floodplain pools and pools in marshland complexes have been modified for lotus cultivation, which typically involves bunding to make seasonal waterbodies permanent, accompanied by eradication of competitive natural vegetation. Intensification of traditional agricultural practices reduces the potential for non-crop species to survive in the habitat further reducing habitat availability, at the same time agricultural intensification brings an increase in the use of fertilisers and pesticide which enter the system and disrupt the functioning of ecosystems. These and larger wetlands are also threatened by burning during the dry season which is intended to promote growth of grasses for livestock.

All wetlands are also affected, to some extent, by small-scale and largely uncontrolled modification, including embankment to protect roads, houses or crops from flooding, diversion of small streams for irrigation, local drainage of seasonal wetlands and low-lying depressions around settlements. This is exacerbated by the spread of industrial and urban areas, which have a knock-on effect on wetlands. A recent study found that wetlands close to villages, grazed by cattle or which were seasonally burned were the most likely to become badly degraded (Seng Kim Hout *et al*. 2002). This is a particular problem for seasonal wetlands which can be grazed and burnt during the dry season without the need for expensive or labour-intensive drainage. Equally, the vegetation of the channel of the Mekong is dramatically over-grazed during the dry season by water-buffalo and other livestock, and cleared for river bank vegetable cultivation.

Invasive species are an increasing problem in the area, including the well-known and obvious species such as Common Water Hyacinth *Eichhornia crassipes* and *Mimosa pigra*, but also grasses introduced as fodder and even ornamental species. All of these species displace native vegetation and in some cases rendering large areas unsuitable for native plants.

7.5 Conservation

There is little conservation action undertaken in the region that is specifically targeted at wetland plants. Most wetland conservation initiatives are directed at vertebrates and such actions rarely benefit plants. Sites protected for vertebrates often either support the simplified and low-diversity communities that are associated with rice fields or reservoirs, or they gradually loose specialist plant species. This is because protection and management focus on factors which directly affect the target organisms rather than bottom-up conservation which looks to safeguard diverse vegetation associations on the basis that these will support animals.

It is clear that the main priority arising from this limited suite of assessments is the need for critical identification of freshwater plants, determination of species distributions through survey, and a better understanding of threats, enabling accurate documentation of their ecology and distributions. For example, Maxwell (2009) found 23 taxa new to the country during a single survey along a 55 km stretch of the Mekong and associated habitats in Kratie and Stung Treng provinces in Cambodia. It is very likely that such detailed survey will recognise new freshwater taxa to science, as well as new regional records, many of which will be shown to be rare or conservation dependent. Such documentation would also almost certainly show that some taxa currently considered Data Deficient are sufficiently abundant not to need active conservation. However, it is equally likely that some taxa would be shown to be threatened and in need of conservation action. For example, from available data, it is not possible to show that *Barclaya motleyi* still occurs throughout its range and recent records suggest that it has been lost from large areas of its former range. In all likelihood, data exist that are more up to date than that available for these assessments, but this information is either unpublished, available only in "grey" literature or published to provide context for different taxa. For example much of the information published on aquatic plants is in descriptions of habitat for birds or fishes.

Due to the limited number of specialist wetland botanists in the region, it has been very difficult to be certain that no wetland-dependent taxa have been omitted from the families covered by these assessments.

The following actions would make a significant contribution to the conservation of aquatic and freshwater plants of the region:

1. Compile and publish information from the "grey" literature, anecdotal evidence, and studies targeting other taxa.
2. Document the occurrence of aquatic and wetland plants, particularly their representation in protected areas.
3. Assess the wetland-dependent plants not covered by this assessment and re-assess Data Deficient taxa as information becomes available.
4. Identify areas where data are lacking and plan surveys.
3. Develop and publish identification guidance, for example guidance on the identification of *Cryptocoryne*, *Limnophila* and *Lindernia* species could improve recording and thereby enable more informed conservation assessment.
4. Where taxa are genuinely threatened, there is a need to better document their ecology, so that work toward their conservation is effective.

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Box 7.1 The Podostemaceae – riverweeds

Masahiro Kato and Richard V. Lansdown

The Podostemaceae are an unusual aquatic flowering plant family of alga- or moss-like plants of approximately 300–320 species in 54 genera. They occur in the tropics and subtropics of the world, with the greatest species diversity in the Americas. Approximately 135–155 species belonging to 21 genera occur in South and Central America, one of which also occurs in eastern North America and is scarce. Approximately 80 species belonging to about 16 genera occur in tropical and southern Africa and Madagascar and approximately 80 species of 18 genera occur in southern and southeastern Asia, some of which occur in temperate eastern Asia and northern Australia where they are scarce. All the Asian-Australian genera, like almost all African-Madagascan and American genera are endemic to the superregion, which suggests that each genus underwent diversification in its own region. They are absent from regions outside the tropics and areas which lack rivers with torrents.

Hydrobryum species. © Masahiro Kato

Molecular phylogeny shows that the Podostemaceae are close to the Hypericaceae. Taxonomically, the family comprises three subfamilies; Podostemoideae is the largest subfamily (c. 300 species in 47 genera), the Tristichoideae (six genera with 18 mostly Asian species) and the Weddellinoideae (a single South American species). Twenty-two or two-fifths of genera are monotypic, while the remaining genera are mainly small, comprising fewer than ten species, indicating that morphological variation is discontinuous and unique. Associated with this, species endemism is high. For example, in the well-documented Podostemaceae of Thailand, three-quarters of the 42 species (and three genera) are endemic to Thailand and most are known from very few sites, often a single population on one rapid complex or waterfall. Of the 56 species recorded from Southeast Asia (of which ten have yet to be formally described), only six species are known from more than ten sites and 21 are known from single sites. Many rivers and torrents or waterfalls support only a single species, although a few or occasionally several species may occur together in a river system or even in single torrents.

Description

Members of the Podostemaceae are structurally reduced, they lack the cuticular layer and vascular tissue typical of terrestrial vascular plants which may be an adaptation to growth in highly oxygenated rocky torrents and which make them unable to survive if permanently exposed. The morphology of the Podostemaceae is markedly diverse in contrast to their apparently uniform environment. The vegetative parts of *Hydrodiscus koyamae* comprise only a leafy branched shoot, lacking the apical meristem which is essential for vascular plants. In the genera *Hanseniella* and *Thawatchaia* and most species of *Hydrobryum*, the plant comprises a foliose root with usually reduced shoots or tufts of leaves on the dorsal surface, a body plan common in other Podostemaceae. In a few other species of *Hydrobryum*, the root is subcylindrical or ribbon-like and repeatedly branched. The vegetative parts of *Dalzellia* comprise a rootless foliose shoot with scaly leaves on the dorsal surface, while those of *Indotristicha* comprise a branched subcylindrical root with elongate branched leafy shoots on the flank and those of *Indodalzellia* comprise a foliose shoot adventitious to, and borne on the flank of the branched subcylindrical root. A few species are monocotyledonous even though the family is a member of the dicotyledons.

Hydrodiscus koyamae. © Diego Juffe-Bignoli

Habitat and ecology

The vegetative parts of plants grow exclusively submerged in torrents during the rainy season, tightly attached to water-worn rock surfaces by creeping organs, either the root or stem, with sticky rhizoids on the ventral surface. They tend to grow on granitic or volcanic rocks such as basalt and lava, or exceptionally limestone and sandstone and only occur in open, sunlit areas. In rivers with suitable rocky riverbeds or torrents along a considerable length, Podostemaceae grow in long interrupted populations. Thus, they may occur in single or multiple torrents on one river.

In the dry season when water levels drop, the plants are exposed to the air and set flowers and fruits for a short time. The seeds have a sticky coat; they are dispersed and settle at appropriate sites and then germinate and grow under water. Thus, Podostemaceae are amphibious in the sense of submerged growth in the rainy season and aerial propagation and dispersal in the dry season. The small seeds (usually 0.2–0.5 mm long) are dispersible to long distances, but nonetheless actual long-distance dispersal is rare. This is probably partly because suitable torrents and waterfalls are rare and sparse, and partly because the exalbuminous seeds have low establishment capability. The seeds may be dispersed by wind, but dispersal by birds, to whose feet seeds adhere, is also a possibility.

Box 7.1 The Podostemaceae – riverweeds, cont'd

Threats

The extremely restricted distribution of Podostemaceae populations means that most species are extremely vulnerable to local, small-scale and even temporary changes in their environment. It is reported that approximately one third of South American species are threatened by human activities, especially large dams. The greatest threat to all species is the modification of river hydrology, particularly construction of dams. This assessment has shown that more than half of the species in the region are similarly threatened or simply too poorly known to be assessed. Rocky torrents are often used to construct dams for hydropower, water storage and flood control. Dam construction mainly affects them:

- When the rock on which they grow is damaged or destroyed by blasting to enable construction of dam infrastructure.
- When construction covers the surface of rocks supporting populations.
- When impounded water precludes flowering leading to the gradual decline and eventual extinction of populations because they become permanently submerged and unable to flower.

Typical Podostemaceae habitat. Tad Xai Falls, Phou Khao Khouay National Park, Lao PDR. © Diego Juffe-Bignoli

Deforestation of watersheds and the slopes of headwater streams will often lead to increased deposition of sediment onto rocks, making it inhospitable to Podostemaceae. Similarly, water pollution and consequent eutrophication can compromise Podostemaceae populations by allowing other plants and algae to out-compete them. Populations of Podostemaceae are also extremely vulnerable to agricultural encroachment into areas adjacent to or upstream of populations, where factors such as increased turbidity, herbicide run-off and water abstraction can impact populations. Tourist pressure can also lead to loss or degradation of habitat through the effects of walking or climbing on the rocks which support populations, as well as pollution.

Conservation

There are currently no conservation actions being undertaken in the region specifically to protect Podostemaceae populations. Only one species occurring in the region, *Terniopsis ubonensis*, is assessed as Critically Endangered. It is known from a single locality in a small area of the Mun River in eastern Thailand. The river passes through the city of Ubon Ratchathani (capital of the province with the same name) upstream of the population and pollution, probably derived from this city, has been observed to affect the known population. There is an urgent need to assess the nature of the threat to this species and identify practical action for its conservation.

A single species; *Terniopsis chanthaburiensis* is assessed as Endangered, the only known population covers an area of less than 500 m^2 in the Klong Yai, Pong Nam Ron District, Chanthaburi Province in eastern Thailand. There is a small dam located downstream of half of the known population which is causing water to back up beyond the population, such that only half of it is able to flower, the remainder being permanently submerged. The site supporting the species is not protected, but there is a need to assess whether the dam can be relocated or removed before this species becomes extinct.

Two species are assessed as VU. *Dalzellia ranongensis* is known from a single location near Haew Long waterfalls in Chumphon Province, peninsula Thailand. The site is a popular site visited by tourists and local people and consequently it is threatened by habitat degradation and water pollution. *Hanseniella heterophylla* is known from three sites in Thailand. Despite all known populations being within protected areas, one is close enough to agricultural land to be vulnerable to pesticide spraying or water pollution, whilst the other population is threatened by tourism. Four species (*Paracladopus chantaburiensis*, *Polypleurum erectum*, *P. longicaule* and *P. longifolium*) are assessed as NT; they are all known from single localities and all are potentially threatened by habitat degradation resulting from local and international tourism. Available information is inadequate for a further 17 species and they are considered DD.

In situ conservation is essential for the preservation of these ecologically unique plants as they are difficult to cultivate without special equipment and controlled environments. However, in a few cases some small dams or artificial barriers, which control soil erosion have been colonized by Podostemaceae suggesting both that *ex situ* conservation may be possible and that management could be carried out to protect populations in the wild using artificial or imported substrate.

Many species no doubt will be discovered from torrents and waterfalls in the rainy and dry seasons in subtropical and tropical Asia by future exploration. This discovery is very likely given the results of recent field studies that revealed the remarkable diversity of Podostemaceae in Thailand and very recent detailed local field exploration that is uncovering a number of unrecorded species from a single province of Thailand. Prior to actions for conservation, taxonomic information on Podostemaceae, in particular badly underexplored Asian species should be increased by field research.

Box 7.2 The vegetation of the Lower Mekong

Richard V. Lansdown

At nearly 5,000 km long with a catchment of 795,000 km^2, the Mekong is the world's tenth longest river and the seventh longest in Asia. It rises on the Tibetan Plateau together with the Yangtze and Salween Rivers and then flows through Yunnan province in China, Myanmar, Lao People's Democratic Republic, Thailand, Cambodia and Viet Nam, where it divides into nine channels of the Mekong Delta and discharges into the South China Sea. The Mekong Basin can be divided into two parts: the Upper Basin in Tibet and China and the Lower Basin from Yunnan downstream to the South China Sea. The Upper Basin is mainly characterised by narrow gorges among high mountains and over this length the river drops 4,500 metres before it enters the Lower Basin where the borders of Thailand, Lao PDR, China and Myanmar come together in the Golden Triangle.

For much of its length the Mekong flows through bedrock and the features normally associated with the alluvial stretches of mature rivers, such as meanders, oxbow lakes and extensive floodplains are restricted to a short stretch of the mainstream around Vientiane and downstream of Kratie. The Mekong basin is one of the richest areas of biodiversity in the world; estimates suggest that it supports 20,000 plant, 430 mammal, 1,200 bird, 800 reptile and amphibian and an estimated 850 fish species. In 2009, 145 new species were described from the Mekong Region, comprising 29 fish, two new birds, ten reptiles, five mammals, 96 plants and six new amphibians (www.mekongriver.info/biodiversity).

Landuse

Throughout the region, forest cover has been steadily reduced by shifting and permanent agriculture, and loss of forest cover in the Thai areas of the Lower Basin has been the highest in all the Mekong countries in the last 60 years. More than half of Cambodia is still under mixed evergreen and deciduous broadleaf forest, although forest cover declined from 73 to 63% between 1973 and 1993. Shifting cultivation is common in northern Lao PDR where it is reported to account for as much as 27% of the total land under rice cultivation. Most of Lao PDR lies within the Lower Mekong Basin, while Cambodia is entirely dependent upon the river for food and much of its economy. The annual floods provide much needed water for wet rice which is the main crop and is grown in the inundation zone of Tonlé Sap.

Covering an area of roughly five million hectares, the Mekong River Delta is a vast wetland complex, consisting of many different types of wetland ecosystems, from coastal salt and brackish to inland freshwater wetlands. Of the total area of land and water surface, approximately four million are in Viet Nam and one million in Cambodia. Wetlands of the Mekong Delta have long been used and altered by people. Most of the seasonally inundated grasslands of the Viet Nam part of the Mekong Delta have been turned into farmland, mostly rice paddies. The Mekong Delta in Viet Nam is farmed intensively and has little natural vegetation left.

Riverine vegetation of the Lower Mekong Basin

The greatest diversity of channel vegetation occurs in the Siphandone wetlands (Daconto 2001). In this area, Maxwell (2000) divided the vegetation into six major zones; sand-bars, *boong* areas, *Kai Kum* zone, the Acacia-Anogeissus zone, seasonal and perennial channels and aquatic habitats. Sand bars generally support amphibious trees, shrubs and large grasses such as *Saccharum spontaneum* and *Phragmites vallatoria* and parts are also cultivated during the dry season. The term *boong* refers to rocky places with permanent river flow with dense tufts or small islands of rheophytic vegetation on sandstone bedrock where there is a general absence of sand. *Kai Kum* refers to *Phyllanthus jullienii*, a shrub, which is the dominant species in the region below the *boong* area and above the falls. This area involves flat, rugged sandstone bedrock which is completely exposed from December to May. There are channels through the bedrock and patches of sand in some places. Amphibious herbs such as *Hygrophila incana* and *Cryptocoryne* species are also present. The Acacia-Anogeissus zone is a unique area below the falls which is the deepest zone of submergence in the wetlands and supports current-bent, deciduous trees up to 10 m tall.

Seasonal and perennial channels support a range of emergents and aquatics, including the free-floating alien *Eichhornia crassipes* which is uncommon in the Mekong River since it is washed away each year during the rainy season, *Ipomoea aquatica* which is cultivated for food, *Nymphaea nouchali* and *Nymphoides indica*, *Hydrilla verticillata*, *Ottelia alismoides*, *Marsilea quadrifolia*, *Potamogeton crispus* and *Ceratophyllum demersum*. *Utricularia aurea*, *Lemna perpusila* and several species rooting in the bottom of ponds and wet ditches, such as *Cyanotis axillaris*, *Monochoria vaginalis* and *Typhonium flagelliforme* are found in mostly seasonally dry areas away from the Mekong River. *Hydrocera triflora* and *Hydrolea zeylanica* are found in scattered wetlands in Dry Lowland Dipterocarp forest. There is also a filamentous green alga which is very dense in the Mekong River during February-March, but is absent by April-May.

Lotus (*Nelumbo nucifera*) and water lily (*Nymphaea* spp.) swamps occur commonly in seasonally inundated habitats in the delta region of the basin, or along the floodplain of the lower basin, mostly in Southern Lao PDR and in Cambodia. These are low-lying areas that hold water in the dry season. Many are connected by small streams that form a network of dry season water bodies. Seasonally inundated grasslands mainly support emergent vegetation including acid-tolerant plants such as *Eleocharis dulcis*, *E. ochrostachys*, *Lepironia articulata* and *Xyris indica*. Due to the connection with the sea, the downstream areas also have plants that are saltwater-tolerant such as *Paspalum vaginatum* and *Scirpus littoralis*.

The channel of the Mekong at Don Khone, Lao PDR. © T. Idei

Box 7.2 The vegetation of the Lower Mekong, cont'd

Threats

The most significant threats to wetland plants along the Mekong are habitat loss and degradation, especially from the construction of dams and habitat clearance. A number of dams have already been built on tributaries of the Mekong, notably the Pak Mun dam in Thailand, while China is engaged in an extensive program of dam building with three already completed and another 12 under consideration and the Lower Mekong basin countries are planning the construction of 12 more dams on the main channel (Tran Triet pers. comm.). Dams disrupt the natural hydrological cycle of the river, leading to an overall lowering of water levels, for example since the first Chinese dam was completed water levels have dropped causing problems for ferries and ports downstream. In addition there will be a reduction in the amplitude of variation in water levels, with consequent changes to the extent and nature of the active floodplain, the sediment erosion-deposition balance and scour. It is very likely that changes in the nature and extent of the active floodplain of the Mekong will not only result in loss of floodplain wetlands, but it will change the pattern of inundation enough to enable expansion of agriculture into areas which currently include wetlands. It is also very likely that they will have knock-on effects on Tonlé Sap (Box 7.5). Changes in the flow and water levels will have consequential effects both on threatened taxa instream, such as *Cryptocoryne loeiensis* and *C. mekongensis* and on taxa more typically associated with floodplain wetlands, such as *Limnophila* and *Lindernia* species. It is also extremely likely that the scale of impacts will increase with every dam constructed.Another significant threat to wetland plants on the Mekong system is the blasting of sand bars, rocks, gorges and rapids to facilitate navigation, which is causing increased flashiness and scour in the rivers, as well as the loss of habitat for species such as *Podostemaceae* (Box 7.1) and *Cryptocoryne* (Box 7.3).

The channel of the Mekong at Don Det, north of Don Khone, Lao PDR. © T. Idei

Invasive alien plants now pose a severe threat to the native wetland vegetation. *Eichhornia crassipes* is a particular problem as it is free-floating and can rapidly spread to cover large areas of the water surface, blocking out sunlight and precluding growth by other species. *Pistia stratiotes* and *Salvinia* species have a similar free-floating growth form but do not appear to have such a significant effect. Among emergent vegetation, grasses such as *Brachiaria mutica* and *Echinochloa stagnina* can dominate to the exclusion of more specialised native taxa (Tran 1999). On land, *Mimosa pigra* is a particular problem as it quickly becomes established in areas of disturbed ground, precluding re-colonisation by native species.

The floating mats of wetland plants which are such a peculiar feature of seasonally inundated wetlands in the area are unable to survive in the face of hydrological modifications. When canal systems are constructed to facilitate movement of water, this results in water-level changes that are too rapid to allow the establishment of these floating mats and they are quickly lost.

The Mekong Delta has been badly affected by the rate of development in the area. Governmental support for the production of rice led to a massive surplus, which became a financial burden when the international price plummeted. Much new development within the delta has been carried out with little or no regard to potential impacts on the natural wetlands of the delta and few intact areas now remain.

Conservation

There are as yet no direct actions for the conservation of aquatic and wetland plants in the Mekong system, in fact there is very little widely available information on the vegetation of the Mekong. The main conservation work needed for plants on the Mekong and associated water bodies involves:

- Documenting the vegetation of the main channels and associate wetlands in the way that has been applied by Maxwell (2009).
- There is a need to document the distribution and ecology of all taxa, but particularly rare or Data Deficient wetland-dependent taxa such as *Cryptocoryne loeiensis* and *C. mekongensis*.
- There is a need to establish the distribution and conservation status of Podostemaceae on the river.
- There is a need to document the distribution and vegetation of seasonal wetlands, to establish critical areas for the conservation of plants dependent upon these habitats.

Box 7.3 The *Cryptocoryne* genus

Richard V. Lansdown

The genus *Cryptocoryne* belongs in the large and diverse family Araceae and it is one of the larger genera of aquatic plants in the region. Globally, *Cryptocoryne* is a genus of about 60 known species and several naturally occurring interspecific hybrid combinations. Within *C. cordata* five, *C. crispatula* seven, and *C. spiralis* two varieties have been recognized (WCSP 2012).

The genus is restricted to Asia and Australasia, from Sri Lanka through India and Bangladesh to southern China, then south through Mainland Asia, the Philippines, Sumatera and Borneo to Papua New Guinea, with *C. beckettii* and *C. wendtii* established as non-native in the USA. All except around a dozen species have a rather restricted distribution and only four can be described as widespread, of which *C. albida* and *C. crispatula* occur from eastern India eastwards to southern China and south into mainland Asia, *C. cordata* occurs in southern Thailand, Peninsula Malaysia, Sumatra and Borneo, while *C. ciliata* occurs from India through Bangladesh, Thailand and Viet Nam south through Indonesia to Papua New Guinea. Three islands support nearly half the world's species; nine species are endemic to Sri Lanka, 13 species are endemic to Borneo, and five species are endemic to the island of Sumatera, in Indonesia. Ten species occur in the Indo-Burma region, including six varieties of *C. crispatula* and two varieties of *C. cordata* (Table C1).

Table C1. Distribution of the *Cryptocoryne* species and varieties occurring in the region.

Species	Distribution
C. albida	Myanmar and southern Thailand
C. annamica	Central Viet Nam
C. ciliata	India to New Guinea, including Thailand and Viet Nam
C. cordata	Thailand to Malesia
var. *cordata*	South-eastern peninsular Thailand, eastern and southern Peninsular Malaysia
var. *siamensis*	South-western peninsular Thailand to north-western Peninsular Malaysia
C. crispatula	India to southern China, Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam
var. *crispatula*	North-eastern India to south-eastern China, Cambodia, Lao PDR, Thailand and Viet Nam
var. *balansae*	China (Guangxi), Lao PDR, Myanmar, Thailand and Viet Nam
var. *yunnanensis*	China (Yunnan), Lao PDR, Thailand and Viet Nam
var. *tonkinensis*	Thailand and Viet Nam
var. *flaccidifolia*	China (Guangxi) and southern Thailand
var. *decus-mekongensis*	Lao PDR
C. cruddasiana	Myanmar
C. loeiensis	Thailand (the Mekong), and Lao PDR
C. mekongensis	Lao PDR and Thailand
C. retrospiralis	SW and S. India to Myanmar
C. Viet Namensis	Central Viet Nam

Description

Cryptocoryne species form tufts or swards of leaves arising from irregularly thickened creeping rhizomes which spread through the substrate and often develop runners. The leaves are extremely variable, with the variation at least partly influenced by whether they are submerged, emergent or entirely exposed and more than one form may occur on the same plant.

The leaves may have no defined petiole and blade and be more or less linear, or even terete or they may have a clear distinction between a petiole and blade. When petiolate, the leaves generally have a narrow, almost linear to broadly ovate more or less elongate, cordate or cuneate blade on a long petiole with entire or slightly toothed margins that may be flat or undulate; the leaves are usually green or brownish often with some red or purple coloration. They are generally flaccid when growing submerged but may be erect or drooping in emerged plants, in most species they are usually flat but they may be strongly undulate or bullate with entire or irregularly denticulate margins.

The flower is a typical Aroid spathe with a basal tube that opens upward with a flap extending to a limb. The limb may be ciliate,

Cryptocoryne loeiensis on the Mekong at Chiang Khan, Loei Province, northern Thailand. © T. Idei

Box 7.3 The *Cryptocoryne* genus, cont'd

smooth or warty, short or long to very long and attenuate, it may be more or less straight, curved or spirally coiled. The spathe often has a white background with pink or yellow parts and may have dark purple, brownish or black spots.

Habitats and ecology

All the *Cryptocoryne* species that occur in the region will grow in rivers; some such as *C. cordata* will also grow in peat swamp forests and in forest pools with some flowing water. *Cryptocoryne loeiensis* is only known from the margins and bars in the Mekong River, where it grows in the lea of boulders and bedrock outcrops; other species growing in similar habitats are *C. crispatula*, *C. retrospiralis,* and *C. mekongensis*. These last three will also grow in small forest streams, often where sunlight is able to reach the channel, although some species will tolerate shade. *C. annamica* and *C. vietnamensis* are both known from a few sites apparently on small rivers in central Viet Nam, while *C. cruddasiana* is known from forest streams and rivers in north-eastern Myanmar and *C. ciliata* is a species occurring in the inner parts of the mangroves.

Most species appear to require shade, possibly as few other aquatic plants will grow in such habitats and there is therefore less competition. However, some species, such as *C. cruddasiana*, have been shown to grow where openings in the canopy allow sunlight to reach the river (N. Tanaka pers. comm. 2011) and a few, such as *C. griffithii*, *C. longicauda* and *C. striolata* can cope with opening of the canopy and have re-colonised rubber plantations (Jacobsen 1986).

Most species typically grow in sand or gravel, although some will grow on mud or silt. Some species, such as *C. crispatula* will grow in firm substrates including travertine. Particularly in large rivers, they usually grow in sites where they are deep-submerged throughout much of the year, becoming exposed as water levels drop, when they flower. Plants or populations are often found largely buried in the substrate with only the upper parts of the leaves and flowering spathes exposed.

Threats

The habitats of *Cryptocoryne* species in the region can be split into large or very large rivers systems such as the Mekong, small forest rivers or swamp forest; the nature of the threats affecting these is very different. The threats affecting the Mekong are discussed in Box 7.2, however those which are most significant for *Cryptocoryne* species are the disruption of the erosion-sedimentation balance as a consequence of dam construction and the blasting of rapids and torrents to facilitate navigation. These are likely to lead to the loss of habitat suitable for the species particularly in the *boong* zone (*sensu* Maxwell 2001). Another particular problem affecting *Cryptocoryne* populations on the Mekong is dry-season over-grazing. During the dry season, large numbers of water-buffalo are left to graze more or less uncontrolled on the channel and floodplain of the river (J.F. Maxwell pers. comm. 2011). This is the period when *Cryptocoryne* species flower and this overgrazing will not only denude, break up and kill vegetative parts, but will compromise sexual reproduction.

The small forest streams on which most populations of most species in the region depend are extremely vulnerable to human activity. The most severe impacts arise from clear felling and subsequent conversion to other habitats, which normally results in the loss of all natural aquatic and wetland plant species and their replacement by taxa tolerant of high nutrient levels and disturbance. However other actions, such as logging or slash and burn agriculture in the catchments can lead to a massive increase in sediment, burying populations or conversely can lead to increased scour with the loss of sand banks and silt deposits in which these species normally grow. Another common cause of loss of aquatic plants in small forest streams is the construction of small dams for irrigation or domestic water, which reduce seasonal variation in flow, permanently submerge populations in turbid water and are often accompanied by pollution.

Species of *Cryptocoryne* are very popular aquarium plants; in general this involves only a few species, such as *C. crispatula*. However there are a large number of people with a particular interest in the genus who could place the rarer species at risk. For example, *C. annamica* is known from two occasions, the original collection from which the species was named and a photograph taken by an anonymous aquarist with an interest in the genus. All that it would take is for one irresponsible individual to over-harvest a population to bring it into trade and the known population could become extinct. Thankfully there appears to be a well-developed awareness of conservation among enthusiasts and this seems unlikely.

Conservation

Whilst there is currently no active in-situ conservation for *Cryptocoryne* species, some taxa will occur in protected areas and gain some protection. There is an urgent need to document the distribution and extent of all taxa, including information on ecology, to facilitate or enable conservation where needed. Some species have very restricted ranges and this, combined with the few known populations, means that some species are possibly vulnerable to local or stochastic events. For this reason *C. annamica*, *C. cruddasiana, C. loeiensis*, *C. mekongensis* and *C. vietnamensis* are assessed as Data Deficient.

Although many *Cryptocoryne* species are popular aquarium plants there is no formal collection of members of the genus as a living resource. The only known significant collection is a private one maintained by Niels Jacobsen at the Royal Veterinary and Agricultural University, Copenhagen. Conservation of the genus would be greatly enhanced by the development of a collection including all currently recognised taxa, particularly those at sub-specific level, to representation of genetic variation.

Box 7.4 Inlé Lake, Myanmar

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Description

Inlé Lake is the second largest lake in Myanmar, it lies about 420 km northeast of Yangon in the southern Shan State. It is tertiary rather than glacial in its origin and occupies the deepest part of the Yawnghwe basin, which has an average length of 65 km and at its widest is about 13 km wide. The region is characterized by a large, flat valley running north to south at an average elevation of 1,000 m above sea level, which is surrounded by mountain ranges averaging 1,300 m in elevation (Butkus and Su 2001). The whole basin was once occupied by a very large lake with an area of nearly 500 km^2. The present Inlé Lake is the remnant of this lake, with an average length of 14 km from north to south and at its widest, only 6 km from east to west (Nath 1960). In 1935 it was estimated to have a net open water area of 69 km^2, however this had declined by 2000 to 47 km^2, a loss of 32% during this 65-year period (Sidle *et al*. 2007). The depth of the lake fluctuates with the seasons; the average depth in the dry season is four meters and in the rainy season is around seven meters (Butkus and Su 2001), although there are extensive shallow margins (Sidle *et al*. 2007). The lake bed is comprised of fine silt deposited by approximately 30 streams entering the lake from the surrounding hills and flowing through the limestone plateau (Butkus and Su 2001), increasing carbon levels in the lake, it has one outlet which flows to the south entering the Thanlwin River (Butkus and Su 2001); it is eutrophic, with high concentrations of phosphate, nitrites and nitrates probably originating from domestic and agricultural inflows.

Land use

Land use in the area is dominated by agriculture with over 200 villages around the lake and within the watershed (Butkus and Su 2001). While there is some forest in the hills, this is being lost through slash and burn to shifting agriculture. In the valley the main crop is rice, but other crops such as wheat, grams and maize are also grown, while tomatoes which are the primary cash crop comprise two-thirds of the region's agriculture, the remaining one-third consists of flowers, vegetables, and sugarcane. However, a great variety of fruits, vegetables, ornamental flowering plants, especially for cut flowers, as well as the staple and cash crops, such as potatoes, sugarcane, tobacco, squash, pumpkins, melons, eggplants, peppers, spinach and other greens, beets, turnips, tomatoes, peas, beans, maize, okra, peanut, onions, strawberries, mangoes, custard apples, pineapples and cabbages as well as oranges, bananas and papayas are grown and sold at the various markets in the Southern Shan States (Nath 1960). The Inlé region is also well-known for its textile products; in eight villages, major textile industries use chemical dyes as well as natural dyes.

The lake itself supports two major sources of food; the native Inlé Carp (*Cyprinus carpio*) is a staple of the people who live around the lake, as well as being a cultural symbol of the ethnic Intha people. The carp breed year-round in clean and clear water; however, because of poor water quality, the population has become increasingly scarce (Butkus and Su 2001). In addition to fishing, the people of Inlé Lake construct floating vegetable gardens which they establish in the margins of the lake by constructing mattresses of *Typha* or other tall aquatic monocots. Submerged aquatic plants are spread over these and black silt from the eastern shores of the lake spread on the top, weighing them down without sinking them. When there is enough soil for a seed bed, the gardens are anchored by bamboo poles. On these vegetable gardens, people raise millet, peas, beans, lentil and sesame; bamboo sticks or reeds are also tied to them parallel to the ground, making trellises to support beans, peas or cucurbits, thus adding to the effective area of the garden (Nath 1960). Inlé Lake is a major tourist attraction and the government became aware of the problems caused by pollution when it began to promote tourism in 1996 (Butkus and 2001).

Natural vegetation

Much of the surface of the lake is covered by floating vegetation, both as the floating gardens, but also extensive stands of native plants, including *Azolla pinnata*, a *Lemna* species recorded as *L. minor* but probably *L. tenerum*, *Ottelia alismoides*, *Nymphaea nouchallii*, *Nymphoides indica* and *Salvinia cucullata*, as well as *Eichhornia crassipes* and *Nelumbo nucifera* which have been introduced. The submerged vegetation is diverse, including *Ceratophyllum demersum*, *Elodea canadensis*, *Hippuris vulgaris*, *Hydrilla verticillata*, *Myriophyllum verticillatum*, *Najas graminea*, *Potamogeton alpinus*, *P. crispus*, *P. lucens*, *P. nodosus*, *P. obtusifolius*, *P. perfoliatus*, *Ruppia maritima*, *Stuckenia pectinata*, *Utricularia aurea* and *Vallisneria spiralis*. In areas without floating gardens, the margins support extensive stands of tall monocots, dominated by *Phragmites karka* and *Typha angustifolia*, with species such as *Arundinella decempedalis*, *Cyperus cyperoides* subsp. *cyperoides*, *C. digitatus*, *Echinochloa crus-pavonis* and *Schoenoplectus lacustris*. Marshy areas support a diverse range of plants, among which there may be a range of smaller marginal plants including *Ammannia baccifera*, *Colocasia esculenta*, *Dichrocephala integrifolia*, *Fimbristylis aestivalis*, *Gahnia javanica*, *Lasia spinosa*, *Lythrum salicaria*, *Monochoria vaginalis*,

Establishing floating gardens on Inlé Lake. © Jonas Merian

Established floating gardens with young crops. © fabulousfabs

Box 7.4 Inlé Lake, Myanmar, cont'd

Rotala rotundifolia, *Schoenoplectiella supina*, *Sagittaria sagittifolia* and *Salix tetrasperma*. Marginal areas, shallow water, seasonal pools and occasionally the water gardens support a range of aquatic and marginal plants such as *Eclipta alba*, *Elephantopus spicatus*, *Eryngium foetidum*, *Hygrophila auriculata*, *Ludwigia octovalvis*, *Phyla nodiflora*, *Plantago major*, *Polygonum aviculare*, *Polygonum plebejum*, *Veronica anagallis-aquatica* and *Xanthium strumarium*.

Aquatic and marginal plants which occur in rice fields in the area include *Alisma plantago-aquatica*, *Cyperus difformis*, *Eriocaulon quinquangulare*. *Fimbristylis dichotoma*, *Hypericum japonicum*, *Ipomoea aquatica*, *Ludwigia repens*, *Monochoria hastata*, *Ottelia alismoides*, *Sagittaria sagittifolia* and *Utricularia flexuosa*. Common vegetation of the floating islands includes *Cyperus digitatus*, *Cladium jamaicensis*, *Cephalanthus occidentalis* and the ferns *Adiantum edgeworthii* and *Thelypteris interrupta*.

Threats
The main threats to Inlé Lake are siltation, leading to succession from open water to marsh or dry land, eutrophication and pollution of various sorts. Many factors, such as timber removal and slash and burn agriculture in the watershed have been blamed for the increased rate of siltation. However, in an intensive study, Sidle *et al*. (2007) found that the main cause of the decline in surface area of the lake was the on-going development of floating gardens which they considered to be responsible for 93% (i.e. 21 km^2) of the recent loss of open water. They also concluded that other impacts due to the floating gardens and agriculture in the margins of the lake include sedimentation, eutrophication, and pollution from pesticides which are routinely used on the floating gardens. Waste and garbage from households, lack of proper sanitation, and livestock breeding contribute to poor water quality. *Eichhornia crassipes* was introduced to the lake about 60 years ago as an ornamental plant and has become so abundant that it obstructs many waterways along the lake. Other threats to the lake include: extensive use of fresh water for agriculture, over-fishing, over-extraction of timber and fuel woods, overgrazing, development of dams and unsustainable agricultural practices in wetlands, hunting, trapping and poisoning of birds, panning for gold, illegal settlement and deforestation in catchments.

Conservation
In 1985, just under 65,000 ha of the lake was notified as the Inlé Wetland Sanctuary. In 1997, the government of Myanmar initiated the Inlé Lake Preservation Project, of which the executive committee includes members from Shan State Peace and Development Council, Nyaungshwe Township local authorities, and government staff from the Irrigation, Agriculture, and Forestry Departments. This project enables national, regional and local interests to influence management of the lake (Butkus and Su 2001).

There is currently no comprehensive account of the vegetation of the lake, taking into account the national and international conservation status of species present. Without this, effective conservation of wetland plants will be impossible. The conservation of the wetland plants of the lake system requires documentation of the existing vegetation, with particular reference to national and international conservation status, and the integration of wetland plant communities into management throughout the lake system.

Dense growth of aquatic plants in Inlé Lake, with *Stuckenia pectinata* in the foreground. © Marina & Enrique

Box 7.5 The Tonlé Sap Great Lake

Richard V. Lansdown

The Tonlé Sap (the Great Lake) is the largest permanent freshwater lake in Southeast Asia (Scott 1989) lying over silts and clays in the centre of the Cambodian plain. It is connected to the Mekong River by the Tonlé Sap River at Phnom Penh, some 120 km to the southeast. Shortly after the onset of the rainy season, the strength of the Mekong discharge begins to act as a dam on the Tonlé Sap River. Initially, this causes the river to spread laterally but subsequently its current reverses and carries the Mekong floodwaters into the Tonlé Sap basin. At low water level the Tonlé Sap floodplain is about 120 by 35 km, covering an area of 250,000–300,000 ha and less than one metre deep, however under peak flood conditions it expands to over a million hectares with a mean depth of 8–10 m. Water levels fall rapidly between January and March and the lowest levels occur in April and May (Scott 1989).

Inundated forest, Tonlé Sap © Petre

The principal economic activities of the communities living on the lake and surrounding the floodplain are rice cultivation, collection of wood for fuel and aquaculture (chiefly fish), as well as subsistence and commercial fishing. Fishing is the mainstay of communities situated closer to open water and major waterways, while rice cultivation and other agriculture are economically more significant to communities in the outer floodplain. Rice cultivation traditionally involved deepwater (floating) rice and historically about 200,000 ha was grown in the Tonlé Sap inundation zone, but by 2000 only c.70,000 ha remained. The most recent and accurate estimate is of approximately 470,000 people living within the 10 m inundation zone and approximately 1.19 million in all zones including urban centres. A small out-migration of people from all provinces surrounding the lake (except for Kompong Chhnang) has recently been reported, due to decreasing fish catches, droughts and unpredictable flooding which is affecting rice yields, and reduction in river water quality due to increased sediment loads (Davidson 2006).

Episodic cultivation of deepwater rice created a mosaic landscape of great biodiversity importance in parts of the floodplain, and has probably been instrumental in the creation and maintenance of grasslands in the floodplain. The Tonlé Sap Biosphere Reserve supports the largest remnant tract in the region of a unique seasonally inundated freshwater swamp forest formation, which although relatively species poor is highly distinctive and rich in both regional and narrow endemics. This swamp or gallery forest has an understory of lianas, made up of a group of species that form their own distinctive formation, in the absence of the larger species in the middle floodplain. It also supports what may be the largest remaining area of seasonally inundated grasslands of diverse structure and community composition in Southeast Asia (Davidson 2006).

Vegetation

The vegetation of Tonlé Sap is defined by centuries of exploitation by man but fundamentally is dictated by the peculiar hydrology of the lake. Its floodplain supports a low overall diversity of plant species, but is rich in species that are unique to the Indochinese floristic region (Rundel 2000), some of which are entirely restricted to the Tonlé Sap floodplain (McDonald *et al*. 1997). The floodplain vegetation can be crudely differentiated into irregular concentric bands radiating out from the dry season low water mark of Tonlé Sap. At the centre is the area which is inundated each year, this is surrounded by a band of swamp forest generally some 20–30 km wide but extending for 65 km west from the west end of the lake, containing numerous small rivers and streams and innumerable lakes and ponds. The belt of swamp forest is in turn surrounded by a broad belt of rice paddies up to 25 km wide which borders on extensive forested areas.

The open water of Tonlé Sap does not support rooted aquatics possibly because they are unable to tolerate the massive seasonal change in water level of the lake and its strong turbidity. The shallow shoreline of Tonlé Sap and patches within the gallery/swamp forests support dense mats of herbaceous vegetation, 1-3 m tall, that may be emergent from shallow water but are more typically floating. These large, often clonal assemblages float freely over the lake, colonising large openings and gaps within the swamp forest. The wet-season floating rice field agro-ecosystem near Roluos in Kompong Thom supports vegetation very similar to the floating aquatic vegetation mats of the open lake and gallery/swamp forest clearings. Grassland areas within and around the Tonlé Sap floodplain may cover more than 2,000 km^2 (Davidson 2006). Wild rice *Oryza rufigpogon* is the dominant grassland type within the inundated forest-scrub of the inner and middle floodplain, occurring in homogeneous dense mats mixed with *Leersia hexandra*. Burning promotes species diversity in these grasslands: *Oryza* dominated swards burnt during the

Extensive irrigated rice field, Tonlé Sap. © David Allen

Box 7.5 The Tonlé Sap Great Lake, cont'd

previous dry season often support a wider range of species. Further from the lakeshore, these species become less common, merging into *Paspalum*-type grasslands. A distinctive aquatic community occurs in isolated ponds in the outer floodplain, in which grasses and sedges are important, while *Phragmites karka* is a local dominant at the mouth of Tonlé Sap and at other river inlets and exits (Davidson 2006).

Houses on the Tonlé Sap among extensive carpets of *Eichhornia crassipes*. © David Allen

Threats

The two main direct threats to aquatic and freshwater plants in Tonlé Sap are the direct destruction of wetland habitats, mainly due to changes in agricultural practices and clearance of seasonally inundated forest for agriculture and settlements. Endorsement by the Cambodian Government of commercial production of dry season paddy in the inundation zone has led to an increase in the extent a rate of loss of seasonally inundated grasslands around Tonlé Sap. Similarly, the area of forested habitat in the Tonlé Sap Biosphere Reserve has declined over the past five decades. Significant areas of inundated forest-scrub have also been destroyed through clearance and conversion to rice cultivation, burning, harvesting of wood for fuel and construction materials and collection for firing brick kilns (Davidson 2006).

Agricultural intensification is a major cause of biodiversity loss in the area, particularly conversion to irrigated rice production with associated high levels of chemical inputs and the loss of dry season stubble and fallow habitats. Rapid expansion of dry-season irrigated rice now presents a serious and immediate threat to landscapes of the outer Tonlé Sap floodplain and at the same time, abandonment of deep water rice cultivation and reversion to tall scrub due to low economic returns from deep water rice harvests represents a substantial concern. In 2004–05, at least 15 dams were constructed to irrigate over 60 km^2 for intensive rice production within and surrounding two sites in Kompong Thom. This is expected to greatly reduce habitat suitability for grassland dependent species due to reduced structural diversity, high pesticide inputs and greatly reduced opportunities for non-crop species to survive, as well as reducing access to natural resource such as grazing and fishing by local communities (Davidson 2006).

There is also an increasing risk of effects due to pollution; untreated urban and domestic solid and liquid waste especially from floating villages, are discharged directly into water bodies associated with Tonlé Sap. Impacts on water quality are most severe during the dry season when shallow waters quickly become stagnant and temperatures can be high. Oils spills pose a threat to waterways and associated habitats around ports and waste oil, sludge and bilge are often discarded into the water in these locations.

Invasive, non-native species are an additional threat to aquatic and wetland plants in the Tonlé Sap. *Eichornia crassipes* appears to be increasing greatly in abundance along the shore of Tonlé Sap (McDonald *et al*. 1997). *Mimosa pigra* invades fallow fields and disturbed ground; once established it forms dense impenetrable thickets, provides very little value as wildlife habitat, and is detrimental to fisheries. Two grass species have also widely invaded wetland margins of Tonlé Sap; *Brachiaria mutica* and *Echinochloa stagnina* were introduced in the past from Africa (Rundel 2000) as high quality species for grazing and have become dominant in many areas of the lake.

In addition to all of these factors which directly affect Tonlé Sap, all of the actions adversely affecting the Mekong River (Box 7.2) have potential for secondary impacts on Tonlé Sap. Certainly, the combination of dam construction, enabling regulation of flows and blasting of rapids to facilitate navigation could disrupt the hydrology of the river to the extent that the annual flooding of Tonlé Sap is significantly disrupted.

Conservation

In 1997 Tonlé Sap Lake and most of its floodplain were designated as the Tonlé Sap Biosphere Reserve under the UNESCO Man and the Biosphere Program (UNESCO 2005); recognised within Cambodia in 2001 by the Royal Decree for the Establishment of the Tonlé Sap Biosphere Reserve. The Biosphere Reserve consists of a core area which is strictly protected, although subsistence and commercial fishing are permitted within it. Surrounding this are buffer and transitional areas where sustainable extraction and human occupancy are permitted (Davidson 2006). In 1999, 28,000 ha of the Boeung Chhma Core Area was designated as a site of international significance under the Ramsar Convention (Ramsar 2012), one of only three Ramsar sites in Cambodia (Davidson 2006).

There is no conservation action specifically for wetland plants in Tonlé Sap. There is an urgent need to document the distribution and status of species of conservation concern, combined with data on their ecological requirements, to inform conservation action.