Chapter 4. The status and distribution of freshwater molluscs of the Indo-Burma region

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4.1 Biogeography of the freshwater environments in the Indo-Burma Hotspot

The Indo-Burma region is one of several biodiversity hotspots for conservation priorities as defined by the exceptional concentrations of endemic species and exceptional loss of habitat (Myers et al. 2000). The region covered here contains fourteen eco-regions according to the global map of biogeographic regionalization of Earth’s freshwater systems (Abell et al. 2008; see Figure 2.3, Chapter 2). These ecoregions were delineated based on the distributions and compositions of freshwater fish fauna and by reference to major ecological and evolutionary patterns, including borders of major river drainages.

Only a few larger natural lakes exist in the Indo-Burma region, with only Inlé Lake in Myanmar being sufficiently large, deep or geologically old enough to support a significantly diverse and endemic freshwater mollusc fauna. The largest lakes are the Tonlé Sap in Cambodia and Inlé Lake in Myanmar. Both lakes vary dramatically in size according to season and have a maximum surface area of about 16,000 km². They are comparatively shallow, with only a few meters of average depth, dominated by macrophytes, geologically young and suffer anthropogenic pressures (for example, Akaishi et al. 2006, Ohtaka et al. 2011). Lake Inlé is an exorheic lake in the Shweyaung Rift valley, central Myanmar, about 22 km long and 6 km wide, with 17 known fish species endemic to the lake and its tributaries and a high diversity of gastropods. Its watershed boasts a diverse snail fauna consisting of 44 nominal species (30 thereof supposedly endemic) mainly from the families Viviparidae, Pachychilidae and Bithyniidae and four bivalves from the families Unionidae, Cyrenidae and Sphaeriidae (Annandale 1918, Annandale and Rao 1925, Strong et al. 2008). However, no recent comprehensive study of the molluscan fauna is available and thus the distribution and the taxonomic and conservation status of many of these taxa has remained unclear. By contrast, the Tonlé Sap harbours no endemic species of freshwater molluscs. In addition, a number of artificial lakes created by the construction of dams and reservoirs are scattered across the region. Most abundant are smaller habitats of stagnant and slow flowing freshwater habitats, such as rice paddies, irrigation canals, reservoirs and lower sections of larger rivers. Snail and bivalve species that are well-adapted to the characteristically low levels of oxygenation, high sediment loads, soft substrates, large fluctuations in water levels, partly ephemeral nature, and presence of macrophytes, such as many basommatophorans, thiarids, viviparids and ampullariids, are usually widely distributed across the region and found in large abundances in all sorts of habitats.

Lotic systems, such as rivers and creeks, account for the largest and most ecologically diverse freshwater ecosystems in the Indo-Burma region. Indo-Burma’s rivers belong to a number of major drainage systems; most importantly the Sittaung, the Ayeyarwaddy, the Salween, the Chao Praya, the Mekong, and the Red River (Sông Hồng) in northern Viet Nam.

The drainage evolution of all these major river systems has significantly been shaped by two principal geological processes during the Cenozoic era: Tectonic uplift of the Tibetan Plateau over the last 40 million years or so and sea level fluctuations during the mid and late Tertiary (Clark et al. 2005, Köhler et al. 2010b, Peng et al. 2006). The beds of major rivers formed between 10 and 20 million years ago (mya) by cutting into the relict landscape (Clark et al. 2005). During younger stages of the Cenozoic, several river systems underwent dramatic changes due to tectonic processes, such as the uplift of areas and lava flows (Gregory 1925, Hutchinson 1989, Rainboth 1996). For example, the Ayeyarwaddy, Salween and Mekong drained into the bed of the Chao Praya until around 1.5 mya when volcanic activities separated the Ayeyarwaddy and Salween rivers from this system. The midstream of the Mekong had also become isolated from the Salween River and ran through the bed of the Ping River (Chao Praya drainage) until around 1.5 mya. Late Cenozoic faulting diverted the Mekong further eastwards along its present course towards Vientiane until, later in the mid-Pleistocene (c.1 mya), the Mekong once again drained into the Chao Praya, this time via the valley of the Loei and Pa Sak Rivers. Eventually, it changed its course again around 50,000 years ago towards the east where it has undergone further course changes. In addition, the Chao Praya lost its headwaters to the growing Mekong during the middle to upper Pleistocene. Since then, the Mekong changed its river bed repeatedly to successively more easterly directions. Further details on the evolution of the river network are given in Box 3.1.

While the details and exact timing of the geological history of the Mekong drainage are not fully understood (Gupta 2008), it is clear that the courses of many smaller rivers were similarly affected by tectonic processes. Some of them even reversed their original direction of flow due to uplifts that affected their upper or mid-streams, such as the Loei River that was once part of the southward-flowing proto-Mekong but today flows in a northeasterly direction, or the Mun River that once drained in a westerly direction into the Chao Praya until it reversed its course towards the east due to the sinking of the Khorat Plateau during the mid-Pleistocene (Hutchinson 1989). Redeposits of drainage systems and river captures have occurred in the whole of Indo-Burma and evidence has emerged that they have influenced the composition of the freshwater biota, including snails and bivalves, by mediating contact or isolation of river faunas, which may have led to lineage differentiation or hybridisation on smaller geographic scales (Attwood and Johnston 2001, Köhler and Deen 2010, Köhler et al. 2010b).

Throughout the Tertiary and Quaternary periods, sea level fluctuations have constantly changed coastlines due to the marine incursions of vast inland areas. For instance, sea levels were apparently higher than today during the Miocene (+150–220 m, at 24–13 mya) and Plioene (+100 m, at 5.5–4.5 mya) (Woodruff 2003), while they were considerably lower during the Pleistocene (up to 120 m below today’s level) (Martinson et al. 1987). Elevated sea levels of 100 m or more would have resulted...
in a northward extension of the Gulf of Siam and the flooding of large parts of the Chao Praya river basin in central Thailand, as well as other low-lying coastal areas in Southeast Asia. These marine incursions would have wiped out the freshwater mollusc fauna of the lower floodplain river channels at the time.

However, the current river system configuration has been in place for several million years in all major drainage systems of Southeast Asia, allowing the evolution of a large number of endemic mollusc species. The development of catchment faunas in parallel with drainage-specific endemic species has generated an overall highly diverse and endemic fauna of freshwater snails in the Indo-Burma region. Amongst all rivers of the region, the lower Mekong stands out by supporting about 140 species mainly in the Indo-Burma region. Amongst all rivers of the region, the lower Mekong ranks amongst the global hotspots of freshwater snail diversity (Groombridge and Jenkins 1998, Bogan 2008, Strong et al. 2008).

Various mollusc species treated herein inhabit brackish water habitats, such as mudflats and mangroves in river estuaries or along shallow coastlines. These brackish water molluscs are not very diverse because of the unfavourable combination of heavy sediment load, acidic and anoxic soil, constantly varying salinity and inundation, and intense predation (Reid et al. 2008). However, particular families such as Potamididae, Neritidae and Iravadiidae have attained a close association with such intertidal habitats where some of them have radiated quite extensively (for example, Reid et al. 2008, Ozawa et al. 2009, Reid et al. 2010, 2012). The mangrove ecosystem has an ancient history. The earliest appearance of a modern mangrove genus, the palm Nypa, has been documented in the Late Cretaceous, and most genera of the Rhizophoraceae are known by the Early Eocene (Reid et al. 2008). By the Middle to Late Eocene most modern mangrove genera showed a worldwide tropical and subtropical distribution. Their once continuous distribution was disrupted by the closure of the Tethyan Seaways at the end of the Early Miocene, which initiated the vicariant separation of the Pacific and Atlantic mangrove-associated biota, including molluscs (Reid et al. 2008).

### 4.2 Overview of the freshwater molluscs of the Indo-Burma Hotspot

Freshwater molluscs (bivalves and gastropods) are found in a wide range of freshwater habitats, have varied life-history strategies and exhibit complex ecological interactions, all of which underscore their use as proxies for understanding our changing freshwater diversity. Freshwater molluscs fall into two main groups, the Bivalvia and the Gastropoda, with the latter dividing into two informal groups, the ‘prosobranchs’ and the ‘pulmonates’. Ponder and Lindberg (1997) revised the higher phylogeny of Gastropoda, noting that ‘Prosobranchia’ could no longer be supported as a formal taxon designation, as it was polyphyletic. This view has been followed in the latest systematic treatment of the Gastropoda by Bouchet and Rocroi (2005). Currently there are two major clades, the Caenogastropoda and the Heterobranchia, along with smaller clades such as Neritimorpha. Within the informal group ‘Pulmonata’, similar problems have also been found (for example, Jörger et al. 2010), however most of the freshwater species lie in the Basommatophora, within the Eupulmonata. The Bivalvia, divided among nine families, are less numerous than the Gastropoda, with the ‘pulmonates’ containing a higher proportion of the widespread, more cosmopolitan species. Most research efforts in Asia in recent years have, however, concentrated on the freshwater unionid mussels and the gastropod Family Pachychilidae. However, we need to recognise that the tropical freshwater molluscs have not yet received the same level of attention as European and North American faunas, and that as taxonomic reviews continue – especially those utilising molecular systematics – the number of known species may well multiply, as has happened in studies of some genera already.

#### 4.2.1 Freshwater Gastropods

The freshwater gastropod fauna of the Indo-Burma area comprises 325 currently known species belonging to 20 families.

The freshwater gastropod fauna is reasonably well known in large parts of the region, in particularly in Thailand. The first records of freshwater snails originate from colonial times in Myanmar (for example, Nevill 1877, 1885) as well as in Cambodia and Viet Nam (for example, Brot 1887, Dautzenberg and Fischer 1905, 1906, 1908, Morlet 1885, 1887, 1893). The fauna of Myanmar was summarized by Preston (1915) and more recently reviewed by Subba Rao (1989). In addition, the work of the Indian Zoological Survey in this area was included in works of Annandale (1918) and Prashad (1920, 1928).

More recent and comprehensive systematic treatments of mollusc fauna are available for Thailand (Brandt 1968, 1974), which list several hundred species for the country. No such overviews exist for the freshwater molluscs of Cambodia, Lao PDR, Viet Nam and Myanmar. In general our knowledge of the distribution, abundance and ecology of molluscs for most countries in the region remains limited.

However, some elements of mollusc fauna have been studied for particular geographical areas. The gastropod fauna of the Mekong is particularly well documented largely because certain species (for example, *Neotricula aperta*) act as intermediate hosts for economically important trematodes of humans and domestic animals (i.e., Mekong River schistosomiasis) (Brandt and Temcharoen 1971, Davis 1979, Davis et al. 1976, Hoagland and Davis 1979). Apart from these systematic works of 20th century authors, very few more recent taxonomic works are available and they usually cover single taxa and/or smaller areas (for example, Attwood et al. 2008, Dang and Ho 2007, Glaubrecht and Köhler 2004, Köhler 2008, Köhler and Glaubrecht 2006, Köhler et al. 2009, Liu et al. 2010).
4.2.2 Freshwater Bivalves

Early work on the descriptions of freshwater bivalves sent from southeast Asia by European explorers were described by naturalists including Lea, A. Morelet, Pfeiffer and Redfield, Rochebrune, Mabille, Prime and Brot. Lists of the freshwater fauna were compiled by Fischer (1891) and Fischer and Dautzenberg (1904). The work of the Indian Zoological Survey in this area was included in the works of Annandale (1918) and Prashad (1920, 1928). Higher classification of freshwater bivalves from southeastern Asia began with Lea (1836, 1838, 1852, 1870), was continued by Simpson (1900, 1914), and discussion of the fauna and descriptions of Asiatic unionids was initially monographed by Haas (1910–1920, 1924). The worldwide classification of freshwater bivalves continued with the work of Modell (1942, 1949, 1964) and more recently by Haas (1969a,b). An alternative classification was presented by Starobogatov (1970). Further refinements of the higher classification of bivalves and their relationships have been provided by Bieler et al. (2010) and Carter et al. (2011).

No recent overviews exist of the bivalve fauna of Cambodia, Lao PDR and Myanmar. However, the work of Brandt (1974) is based on fieldwork in Thailand, Myanmar, Lao PDR, Cambodia and west Malaysia. Fieldwork in the Mun River basin and lower Mekong River associated with water born diseases, including schistosomiasis, was carried out in the early 1970s (Heard 1974). The freshwater bivalve fauna of Myanmar was summarized by Preston (1915) and more recently reviewed by Subba Rao (1989). Nagachinta et al. (2005) documented the utilization of freshwater molluscs for food, jewellery and art work in Thailand and provided distribution maps for 15 unionids and three cyrenids. More recently, Jivaluk et al. (2007) provided an overview of the freshwater bivalve fauna of Thailand with colour pictures and a key to the 72 species recognized.

Early work on the freshwater bivalves of Viet Nam, included the description of new species and development of species lists, especially for the former Tonkin Province of north Viet Nam (Dautzenberg and Fischer 1905, 1907, 1908). Demange (1918) provided a list of land and freshwater molluscs of Indochina with information on species distributions and morphological characters. The freshwater bivalve fauna of Viet Nam was last monographed by Dang et al. (1980) but no maps were provided and limited species descriptions, with line drawings of the shells, were included.

The known freshwater bivalve fauna of the Indo-Burma area is comprised of 116 species in 38 genera belonging to ten families. Five families are each represented by a single species in freshwater (Arcidae, Cultelidae, Margaritiferidae, Phariidae and Solecurtidae). Two families contain the majority of the diversity; Cyrenidae (= Corbiculidae) with 20 species in two genera accounting for 17.4% of the species and 20.0% of the genera, and Unionidae with 79 species in 26 genera accounting for 68.1% of the species and 68.4% of the genera.

4.3 Knowledge gaps and taxonomic problems

The distributions and taxonomy of the molluscan fauna of the Indo-Burma region is poorly known and requires further study.

4.3.1 Freshwater Gastropods

Considerable gaps in the knowledge of gastropod fauna prevail, particularly in the more remote and less well studied regions of Myanmar, northern Lao PDR and, to some extent, in Viet Nam and Cambodia. While Brandt (1974) approximately doubled the number of species known from Thailand, similar comprehensive treatments are unavailable for Cambodia, Lao PDR, Myanmar and Viet Nam. As a result, the level of documentation of the freshwater snail fauna is patchy. Figure 4.1 exemplifies the extent of current knowledge gaps by displaying all records available in the international biodiversity database GBIF (www.gbif.org) for two of the most diverse and abundant snail families in the region, the Viviparidae and Lymnaeidae. This figure illustrates that the distributions of these two major gastropod groups are only patchily documented. Corresponding knowledge gaps exist for all other groups of freshwater gastropods in the region.

Available data records are predominantly based on digitised records from museum collections world-wide, which date back to the early collections undertaken in colonial times. The usefulness of these museum-based data to monitor faunal changes is limited by problems relating to unreliable or uncertain species identifications, imprecise locality information and historically outdated records. Even though these records represent only a fraction of all data available from scientific publications, including local species lists, it becomes apparent that distribution data in general are highly fragmented and incomplete.

Moreover, our current knowledge of many species, their distribution, ecology and taxonomy, is based on morphology-based works from the 19th and 20th century that reflect previous concepts of species delineation. More comprehensive, modern
revisions employing more detailed morphological and/or molecular evidence to resolve taxon limits have remained scarce. Thus, even after almost 150 years of systematic work, we are far from having a comprehensive understanding of the diversity and ecology of the freshwater gastropod fauna in the Indo-Burma region.

Assessments of the conservation status of species have been hampered by the patchy distributional data as well as an incomplete understanding of their taxonomy. Many species names were introduced in late 19th and early 20th century – frequently based on identification of conchological characters, in some cases a few dry shells from one or few localities. The historic, predominantly shell-based taxonomy is particularly prone to errors due to misidentifications as the range of variation within species is still largely unknown. Recent studies have shown that due to such misidentifications, species of freshwater molluscs can be overlooked, as they are very similar in shell form to other species, and hence cryptic lineages may also exist, especially in regions with high endemicity. Conversely, some species have been named more than once by different authors.

The extent of the taxonomic confusion that results from such problems is highlighted by recent systematic revisions for various groups. Specifically amongst the freshwater gastropods in the Indo-Burma region, the Family Pachychilidae are the only group that has been comprehensively revised in modern taxonomic studies that employed a combination of morphological and molecular evidence (Köhler 2008, Köhler and Dames 2009, Köhler and Deein 2010, Köhler et al. 2010a, Köhler and Glaubrecht 2001, 2006, 2010; Köhler et al. 2009, Köhler et al. 2010b). In the previous taxonomic treatment, Brandt (1974) recognised 21 species or sub-species of pachychilids in Thailand. The recent studies have resulted in a changed taxonomic treatment of most of these species either with respect to their generic placement or the delimitation of species, such that, seven of these species were delimited differently while three species were recorded anew. Furthermore, eight new species from the Family Pachychilidae were described from parts of the Indo-Burma region not covered by Brandt (1974), demonstrating the level to which the region is under-recorded. Given that the Pachychilidae are represented by comparatively large and conspicuous animals, it is plausible to postulate that in other groups a similar or even higher proportion of species await taxonomic revision or discovery.

Further confusion is caused by the arbitrary and inconsistent use of taxonomic names for snails that were identified by means of shell comparison only. While this practise is widely used for the compilation of local or regional species inventories or in ecological studies, such secondary literature records are notoriously unreliable in particular when species are known to be difficult to recognise by their shells or when they belong to taxonomically complicated groups.

4.3.2 Freshwater Bivalves

The identification of the freshwater bivalves of the Indo-Burma region has primarily been based on shell characters. Only recently has there been any work on the higher level relationships of some of the genera of this region using DNA sequence data (Bogan and Hoeh 2000, Graf and Cummings 2006, Hoeh et al. 2009, Whelan et al. 2011). The phylogenetic work on the relationships of species and genera is urgently needed for the unionid taxa. We have difficulties in assigning some species to the proper genus because of shell shape variation and convergence of shell characters. An example would be the confusion with the genera Parreysia, Indonasia and Radiatula. Some authors have considered these subgenera, genera and even synonyms.

The family Cyrenidae (formerly Corbiculidae; Bieler et al. 2010) contains the genus Corbicula which for Thailand alone has 28 recognized species and of these, five were introduced as new species (Brandt 1974). These species are differentiated on the basis of shell shape and degree of inflation. Electrophoretic analyses of representatives of 21 nominal species of Corbicula from Thailand across 24 allozyme loci proved to be identical and 20 Thai species were considered synonyms of Corbicula fluminea with another seven species considered possible synonyms (Kijviyira et al. 1991). Studies in Japan have documented some Corbicula species that are hermaphroditic and triploid (Komaru et al. 1997) or tetraploid in China (Qiu et al. 2001). Work on two species of Corbicula in Europe has found that there is hybridization between two different evolutionary lineages (Pfenninger et al. 2002, Pigneur et al. 2011). Evidence for two widely divergent clades within Corbicula has been detected, a freshwater and an estuarine clade. Taxa within Corbicula reproduce using diverse reproductive strategies (ranging from free-swimming larvae to incubation of larvae in gills) (Glaubrecht et al. 2006).

All of this evidence points to the problems of assessing what is a valid species within the genus Corbicula (see Glaubrecht et al. 2006). There appear to be several valid species but the conservation status of these taxa and the myriad of other named taxa must await a detailed phylogenetic analysis of both mitochondrial and nuclear DNA of all of the named taxa assigned to Corbicula.
4.4 Conservation status

The summary presented here is based on the assessment, following application of the IUCN Red List Categories and Criteria (IUCN 2001), of 431 species of freshwater molluscs that we have identified as being present in the Indo-Burma Hotspot assessment region. This assessment includes 319 species of Gastropods and 112 species of Bivalves. Of the extant species for which sufficient data are available to assess the risk of extinction (one species, *Pila conica*, has not yet been assessed, and a further 25 species are awaiting review and have draft Red List assessments), 48 (16.6%) are assessed as threatened (Table 4.1, Figure 4.2).

Many of the gastropod species are poorly known, and much greater distributional data are required especially from the Mekong River system. However, given the level of threats through proposed major damming projects, assessments were made using the current data on distributions, so that a baseline conservation assessment is in place to allow an initial assessment of impact of threats to specific sites on these river systems.

Of the extant species for which sufficient data are available to assess the risk of extinction, nearly three-quarters are assessed as Least Concern (73.8%); many of these species have been reported over long stretches of river systems. Where there are three or four records over a long stretch of river, it was considered that the species may well exist in suitable habitat between these points, so the overall range took the species above the thresholds for qualification as threatened species.

There are an additional 140 species that are assessed as Data Deficient (Table 4.1) of which 94 are gastropods and 46 are bivalves, representing almost one-third of all known species in the region. Some of the DD species are known only from 19th or 20th century descriptions and have not been collected since, and further expert surveys across the region are required to determine the conservation status of these species, whilst other species have been considered DD due to taxonomic uncertainty. The level of Data Deficient species is somewhat higher than equivalent conservation assessment for freshwater molluscs in Europe (25%; Cuttelod et al. 2011) and Africa (18%; Darwall et al. 2011a).

4.4.1 Freshwater Gastropods

Of the 319 freshwater gastropods considered here to be present in the Indo-Burma region, 318 have been assessed according to the IUCN Red List Categories (Tables 4.2, 4.3; Figure 4.3). The majority of these species have been defined on conchological characters and the distribution of most species is not well known. Some of the species have not been recorded since they were first described over 100 years ago, the major reason for a species being assessed as Data Deficient.

The majority of the species assessed as threatened or Near Threatened are known to occur at fewer than five locations and these are potentially threatened by hydropower development. Some of the species listed as Near Threatened are known from very few sites and actually meet most of the criteria for listing as threatened species (i.e., range and number of locations), however at present the likely timing of the threat doesn’t qualify the species for listing under the ten year limit rule hence, if a threat is established with likely impact within ten years, then these species would move straight to Threatened, in some cases to Critically Endangered or Endangered. For example, the waterfalls on the Mekong River near Khone Island (southern Lao PDR) are the location for the proposed Don Sahong dam which would have significant impacts on the flow regime of the river, and is likely to impact mollusc species that are found in rapids.
such as *Lacunopsis globosa*. Other species such as *Cremnoconchus messageri*, part of a genus otherwise known from the Western Ghats, India, occur in the fast-flowing river waters of Viet Nam, where pollution is impacting their habitats.

The Critical Ecosystem Partnership Fund ecosystem profile (CEPF 2007) noted that the family Pomatiopsidae has a remarkable centre for radiation in the Mekong Basin; the current assessment shows that this is the most threatened Family of mollusc in the Indo-Burma region. The other highly threatened families are the Family Pachychilidae. These two families have species that have extremely restricted ranges, often in specialised habitats, such as river rapids, requiring highly oxygenated unpolluted waters. By contrast the Family Viviparidae, have species that are more tolerant of pollution and disturbance, and these species are frequently used as food sources.

### 4.4.2 Freshwater Bivalves

One hundred and twelve freshwater bivalves are recognized from the Indo-Burma area. The greatest numbers of taxa fall into the IUCN Categories of Least Concern (48 species, 42.9%) and Data Deficient (46 species, 41.1%). Categories of conservation concern include Critically Endangered (six species, 5.2%); Endangered (nine species, 8.0%) and Vulnerable (one species, 0.9%). A total of 16 taxa (14.3%) are considered to be threatened (Tables 4.4, 4.5; Figure 4.4).
All of the threatened species are from the larger freshwater bivalves in the Family Unionidae and the Margaritiferidae rather than the smaller bivalves (Corbicula, Sphaerium, Pisidium spp).

All species in the Unionidae and Margaritiferidae have complex life histories requiring the presence of fish-hosts for the parasitic larval stage resulting in metamorphosis into juvenile mussels. However, in this region, our knowledge of the known fish host species is lacking for the majority of the species. The species are typically longer-lived than many of the Freshwater Gastropods, so the conservation assessment period of three generations will be more than ten years.

Some families, such as the Arcidae, Cultelidae, Solencurtidae, Pharidae, Mytilidae are largely marine, and the few species recorded are found in brackish water habitats along the coast, so have been included in the assessment, as it covers brackish waters. The major families containing the freshwater species are the Unionidae, Sphaeridae, Cyrenidae and the Margaritiferidae.

### 4.5 Patterns of species richness

The Oriental biogeographic region with the Indo-Burma hotspot at its heart boasts a highly diverse and largely endemic fauna of freshwater snails (Strong et al. 2008) and freshwater bivalves (Graf and Cummings 2007, Bogan 2008). Within this region, the Mekong River basin stands out in terms of the diversity of species and the level endemism in freshwater molluscs (Figure 4.5).

In the first global assessments of the status of freshwater biodiversity (Groombridge and Jenkins 1998, McAllister et al. 2001), the Mekong River basin is listed as possessing one of the most diverse freshwater molluscan faunas in the world, second only to the Mobile basin in the southeastern United States (Neves et al. 1998, Bogan 2008, Groombridge and Jenkins 1998). This comprehensive assessment is the first for the region, and upholds the original findings from the overviews published in 1998 and 2001.

### 4.5.1 All molluscs

The species richness within the Indo-Burma region is shown in Figure 4.5, highlighting the diverse areas of the fauna in the central Mekong. In general, most larger catchments host between 14 and 34 species, but in parts of the Mekong catchment over 83 species are found, with replacement of taxa in similar habitats in different localities. Species are not evenly distributed across

### Table 4.5 The threatened freshwater bivalves in the Indo-Burma assessment region.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Category</th>
</tr>
</thead>
<tbody>
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<td>MARGARITIFERIDAE</td>
<td>Margaritifera laosensis</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Cristaria truncata</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Cuneopsis demangei</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula blaisei</td>
<td>VU</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula contritus</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula crassa</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula liedtkei</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula nodulosa</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lamprotula ponderosa</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Lanceolaria bilirata</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Modellaia siamensis</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Oxynaia diespiter</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Oxynaia micheloti</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Physuna ferrugineus</td>
<td>CR</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Protunio messageri</td>
<td>EN</td>
</tr>
<tr>
<td>UNIONIDAE</td>
<td>Pseudodon resupinatus</td>
<td>EN</td>
</tr>
</tbody>
</table>
the course of the Mekong but most species are restricted to a relatively short stretch between Pakse in southern Lao PDR and Kratie in Cambodia where the river flows over a series of rapids.

### 4.5.2 Threatened species

The majority of threatened species (Figure 4.6) are found in the central Mekong River system, where there are a suite of endemic species located at sites which are proposed for dam construction in Lao PDR, Cambodia and Thailand. Other threatened species are found in the rivers draining northern Viet Nam, especially those with headwaters in China, where damming has impacted the flow levels of the rivers in Viet Nam and pollution from agricultural, industrial and urban sources impacts habitats. A further concentration is found at Inlé Lake in Myanmar.

### 4.5.3 Endemic species

The endemic species, based on the current data, are mainly found in the central Mekong River and its sub-catchments, such as the Mun River in eastern Thailand. A smaller centre of endemism is found in the Kaek River, in the Chao Praya catchment, central Thailand (Figure 4.7).

### 4.5.4 Data Deficient species

The high level of freshwater bivalves assessed as Data Deficient is a result of the lack of detailed surveys and the lack of basic biological information for these taxa.

---

**Figure 4.5 The distribution of freshwater mollusc species across the Indo-Burma region.**

![Map showing distribution of freshwater mollusc species across the Indo-Burma region.](image)

- **No. species per sub catchment**
  - 112 - 158
  - 83 - 111
  - 63 - 82
  - 47 - 62
  - 35 - 46
  - 14 - 34

- **Legend:**
  - Project area
  - Major rivers

**Coordinate system:** World Cylindrical Equal Area

**Source:** IUCN Indo-Burma Freshwater Biodiversity Assessment

The boundaries and names shown and the designations used on this map do not imply any official endorsement, acceptance or position by IUCN.
There are two key reasons for a species’ assessment as Data Deficient:

a) Inadequate distributional data: Without accurate information on the distributions of the species, it is not possible to make a good assessment of the conservation status of these species. Some of these species have not been recorded for more than 60 years, such as *Diaurora aurorea*, and hence without new surveys, a conservation assessment is not possible. Other species, for example, *Chamberlainia hainesiana*, are listed as DD, but this species is already considered Vulnerable in parts of its range in Thailand and Viet Nam, and it is known to be heavily collected across its range for food for consumption and sale locally, as well as for use in the production of decorative items and producing artificial freshwater pearls. The species is likely to be impacted by habitat modification and destruction due to dams, canalisation and pollution (siltation and contaminants associated with construction, agriculture, mining, and forestry practices). However, lack of data on levels of exploitation and decline in populations mean this widely distributed species cannot be confidently assessed as threatened.

b) Taxonomic status uncertain: for example, most of the species of *Corbicula* described from the region are poorly defined, and hence the species limits have been questioned for these taxa. Further data are needed on the status of the species and then new distributional data will be required to make an informed conservation assessment.

Other recent analyses of the number of Data Deficient taxa in crayfish, freshwater crabs and dragonflies showed that Data Deficient species are widespread across the Indo-Burma region. The distribution of these species is shown in Figure 4.6.

Figure 4.6 The distribution of threatened freshwater mollusc species across the Indo-Burma region.
Deficient species were globally non-randomly distributed in freshwater crabs and dragonflies and geographically non-randomly distributed in all three groups examined (Bland et al. 2012). They concluded that conservation priorities based on these data require more and better data obtained at a large expense. Since the Data Deficient taxa are so numerous and the biological characteristics and threats for extinction not easily determined these taxa should be given high priority to determine their conservation status.

4.6 Major threats to freshwater molluscs

The Mekong River and its tributaries are increasingly vulnerable due to a wide variety of anthropogenic activities. Through this study the major threats to Indo-Burma freshwater mollusc faunas have been identified as river regulation and dam construction, water pollution from various sources (agricultural pollutants, domestic sewage, industrial effluents and mining waste) and over harvesting.

The rate and extent of environmental change in Asia are having impacts on the aquatic biota that may be greater than anywhere else on the planet. Large and growing human populations and the rapid pace of development have led to the degradation of freshwater ecosystems throughout Southeast Asia, including Indo-Burma, and many habitat types are under grave threat (Dudgeon 2000a).

On a global scale, the threats to freshwater biodiversity can be grouped under five interacting categories (Figure 4.8): overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species (for example, Dudgeon 1992, 1995, 2000a; Dudgeon et al. 2006, Malmqvist and Rundle 2002, Rahel 2002, Revenga et al. 2005). Environmental changes occurring at the global scale, such as changes in climate and nitrogen deposition (for example, Poff et al. 2003, Canfield et al. 2010), are superimposed upon these specific threats. Amongst these diverse influences on freshwater
ecosystems, three major threats are considered particularly significant for the freshwater snails in the Indo-Burma region: (1) degradation of river drainage basins, (2) regulation and control of rivers and streams, and (3) pollution (Dudgeon 1992, Strong et al. 2008). How susceptible individual species are to these impacts, depends on their ecology, population structure and distribution.

From a conservation point of view, the most sensitive species are those that are characterised by particular life history traits, such as low vagility, strict habitat specialisation, restricted geographic range, long maturation time, low fecundity, obligate parasitic larval stage on gills or fins of host fish and longevity (Strong et al. 2008). These traits prevent species from adapting to significant alterations of the natural habitat, including but not restricted to changes in flow regimes, siltation and pollution, while ecologically more generalist competitors, such as introduced species, are going to benefit from the anthropogenic influence. This effect is going to contribute to on-going homogenisation of the fauna. Particularly vulnerable species are found especially in the endemic groups with localised distributions, for example, in the Mekong groups, the Pomatiopsidae (70 species) and Stenothyridae (40 species), but potentially also amongst the Pachychilidae and some Viviparidae, which are also known to occupy short distributional ranges. Many of these small range species are not assessed as threatened here for the absence of known, immediate threats. However, if such threats should emerge in the future, for example, the development of major dams, these species may also need to be considered threatened.

Spring snails are particularly vulnerable for most of them are narrow-range endemics, which can go from being unthreatened or Vulnerable to Extinct without any transitional level of threat due to the destruction of relatively small habitats. However, little information is available on the diversity of spring snails in Indo-Burma and on the imminent impacts to their extremely localized habitats.

4.6.1 River regulation and control

River regulation and control has been practised widely in the region for centuries but, with the planned development of massive projects throughout the region on both mainstream and tributary rivers, the potential for environmental damage has increased. Flow regulation reduces flood-season peaks, changing the magnitude and extent of floodplain inundation and land-water interactions. Fish breeding migrations may be disrupted, because dams block migration routes or changed flow regimes fail to stimulate reproduction, with potential impacts on mollusc reproduction in the case of species dependent on fish as part of their reproductive strategy. All countries in the region have embarked on major expansions of hydropower capacity, which is going to drastically transform most, if not all major river systems in these countries (Figure 1.5, Chapter 1). China has also proposed or already developed a large number of dam construction projects, so there is already a loss in the volume of water passing down the Mekong River. Hence in the Indo-Burma region, the most significant and imminent cause of declines in native mollusc populations is certainly dam construction for flood control, hydroelectric power generation

Figure 4.8 The five major threat categories and their established or potential interactive impacts on freshwater biodiversity. Environmental changes occurring at the global scale, such as nitrogen deposition, warming, and shifts in precipitation and runoff patterns, are superimposed upon all of these threat categories (redrawn from Dudgeon et al. 2006).
and water storage (for irrigation or drinking water supplies), which has converted species-rich riffle and shoal habitats into low-energy and often low-water bodies, greatly reducing and fragmenting suitable habitats and resulting in a cascade of effects both up and downstream. Hydroelectric power generation will have an increasing significance throughout the region in the next 20 years with a multitude of larger dams being operated, currently constructed or planned.

The impact of large dams on biodiversity is a key threat (McAllister et al. 2001), as they are frequently sited on species-rich rapids, and this is considered to be a major factor in the extinction of freshwater molluscs in North America (Bogan 1993, Hughes and Parmalee 1999) and as a threat to species in Africa (Seddon et al. 2011). Dams impact molluscan biodiversity both upstream and downstream of the structure (McAllister et al. 2001). Downstream, the water temperature and the flow levels are subject to variation. Increased water temperature impacts gamete development in the Unionidae (Galbraith and Vaughn 2009). Decreased water levels impacts sex ratios of species of freshwater mussels (Galbraith and Vaughn 2011). Unless potential biodiversity impacts are mitigated through the planned release of waters following construction, the subsequent low water levels can lead to a decline of populations and ultimately extinctions. Upstream, and especially within the extent of inundation, species may also be lost as the habitat quality declines, or if obligate hosts fish are lost. Increased standing water areas also has the potential to result in increased populations of species that act as vectors for disease, leading to a subsequent increase in levels of medical problems for the local human populations adjacent to the reservoir (Seddon et al. 2011). Attwood (1996) reported that the operation of the Pak Mun dam on the Mun River in Thailand resulted in an increase in the population density of *Neotricula aperta*, the snail intermediate host of *Schistosoma mekongi*, suggesting that the impoundment of the river created conditions favourable to the disease vector. Harinasuta et al. (1970) reported a high prevalence of intestinal and liver fluke infections following the construction of the Ubol Ratana Dam, Khon Kaen Province in Thailand.

It is not just large dam projects that modify water flow patterns. Small-scale modification schemes, such as weirs,
dams and canals, also have a ubiquitous presence in the
region. Hundreds of multi-purpose reservoirs for water supply,
irrigation, hydropower and fisheries have been constructed,
as well as numerous barrages for water diversion and storage.
These small-scale projects may also lead to a decline in native
mollusc populations if environmental impact assessments
(EIAs) are not carried out prior to the installation and if the
presence of sensitive species is not taken into account in the
subsequent release patterns for water flows.

Although most current studies on the impact of impoundment
of rivers and anthropogenic modification of habitats on freshwater
bivalves have been undertaken in North America and Europe, the
results can be extended to the biodiversity hotspot of Southeast
Asia.

The effects of these newly constructed dams on the biodiversity
of so far generally unspoiled river systems is going to be dramatic
as can be derived from the impact of already operational dams
in the region and elsewhere (Dudgeon 2000b, Rosenberg
et al. 2000, Carew-Reid et al. 2010). The influence of dams
on biodiversity, including freshwater snails, are complex and
great causing, amongst other disturbances, habitat loss and
fragmentation, impediments to species migrations and genetic
exchange between populations, propagation of invasive species,
deterioration of water quality, changes in flow regime and
sedimentation. These factors are going to lead to a significant loss
of riparian species. Narrow-range endemics with usually specific
adaptations to well oxygenated, fast flowing riparian ecosystems
are going to be particularly affected and many of them are at high
risk of extinction. By contrast, a few ecologically tolerant snail
species, including invasive species and some intermediate hosts of
waterborne pathogens such as Biomphalaria glabrata, are going
to benefit from the creation of artificial stagnant water bodies.

Currently proposed dams or dams under construction will
affect all major rivers and many tributaries across the region.
The expected loss of species in the Mekong is considered to
be significant as this river harbours speciose radiations of
pomatiopsid and stenothyrid snails. The majority of these species
are currently known from a relatively short (c.200–300 km)
stretch between the Thai-Lao border and Kratie in Cambodia,
where the Mekong flows over a series of fast-flowing rapids. Along
this stretch there are five proposed dams, which if realised will
significantly transform the fast flowing, seasonally fluctuating
river into a chain of stagnant or slow flowing water bodies. These
modified habitats are going to be uninhabitable for most riparian
and narrowly endemic species, which are not adapted to live in
largely lacustrine environments.

Dam development can also be a cause of the loss of the host-
species required for the reproduction of the freshwater bivalves.
Unionoids are unique amongst the bivalves in the adaptation
of their larvae to the parasitic use of a host, usually fish, for
development. This reproductive dependency on fish in some
unionoid bivalves makes them vulnerable, as any modification or
loss of the requisite host fish will be followed by extinction of the
freshwater mussel taxa using that fish as a host. It is interesting
to note that some species of bitterling fish (Rhodeus species of
Cyprinidae) depend on bivalve molluscs as the intermediate host
of eggs and larvae (for example, Reichard et al. 2007), with the
relationship being species-specific.

4.6.2 Sedimentation due to deforestation and
degradation of drainage basins

The degradation of drainage basins in particular caused by
deforestation and agricultural use of vast areas is an on-going
process in the region, resulting in an increased suspended
sediment load and altered flow regimes, including more extensive
flooding or running dry of water bodies in periods of drought.
Excessive floodplain siltation alters habitats. Sedimentation can especially impact the juvenile stages of mollusc species, including the large mussels (Families Unionidae, Margaritiferidae), which cannot survive in the lower oxygen content where the river bed is smothered by sediment (Seddon et al. 2011). In many areas deforestation has taken place in the past, meaning that the fauna sampled in the present may simply represent a product of past habitat declines, such that we may be unable to reconstruct the earlier conditions of these affected habitats and the original composition of their faunas.

4.6.3 Pollution

River pollution is a serious problem throughout many parts of the region, especially in lower parts of river drainages, and constitutes the third major threat to freshwater molluscs. Pollution from point and diffuse sources is a major threat to the aquatic biota in general (Dudgeon 2000a). For example, current surveys in the Red River showed that in polluted areas, there were few mollusc species, often at low densities. Species tolerant of pollution (Melanoides tuberculatus, Tarebia granifera and invasive species such as Pomacea canaliculata) were prevalent, whilst almost all species of freshwater mussel were absent (Do Van Tu pers. comm. 2011).

Sources of water pollution in the Indo-Burma region include:
- Urban sewage: Untreated sewage is a particular problem in densely populated areas, and waste waters are largely untreated.
- Agricultural sources of water pollution: intensive cultivation of vegetables and livestock rearing in cities, as well as diffuse pollution from nitrogen, phosphorus and pesticides from agricultural land (Dudgeon 2000a).
- Sedimentation: clearance of forests for agriculture and development resulting in high sediment loads, especially in hill areas.

4.6.4 Mining and aggregates extraction

There are two impacts from mining in the region. The first is water pollution, especially from the mine waste and ore processing (for example, cyanide use in gold extraction). In Viet Nam this is a recognised threat to some of the large unionid bivalves that require stable river bed habitats and fast flowing well oxygenated waters.

The sands and gravels from the river beds in part of the Indo-Burma region are used as sources of aggregates for building. This

Freshwater snails (Viviparidae) and mussels (Unionidae) for sale at a market in Viet Nam. © Frank Köhler

Sand and gravel exploitation in the Cầu River, northern Viet Nam. © Do Van Tu
disrupts the river bed habitats of the freshwater molluscs, as well as causing change in the flow regimes of the river.

4.6.5 Over-exploitation of molluscs

Many of the freshwater bivalves and larger gastropods are harvested throughout the region for food, jewellery, decorative and art work, and for construction materials, as Nagachinta et al. (2005) documented for the utilization of freshwater molluscs in Thailand.

However, the impact of use on species populations is not well documented. Organisms with a long lifespan and slow rate of reproduction are particularly vulnerable to over-harvesting. Throughout Southeast Asia, several larger species of freshwater gastropods and bivalves are widely used for human consumption. This applies particularly to species within the gastropod families Viviparidae, Ampullariidae and Pachychilidae, and the larger bivalves (Family Unionidae). These freshwater mussels are mostly collected locally for subsistence use but throughout the region snails and mussels are also shipped in larger quantities to cities to be sold in markets. Most of the traded snail species are widespread and locally abundant and are therefore easy to collect in large quantities (Families Viviparidae, Ampullariidae) and, due to their generally ubiquitous life style and rapid reproduction, the volume taken for human consumption has apparently had little effect on populations of these snails. By contrast, many snail species of the Family Pachychilidae, in particular Brotia spp. (Köhler and Glaubrecht 2006), and certain species of the Family Viviparidae are potentially more susceptible to over-exploitation as they have narrowly endemic distributions.

Some unionid mussels are probably most susceptible to over-exploitation for their endemism and complex life history.

One local study in Viet Nam (Table 4.6) demonstrated that the level of extraction or harvest for mussel species was such that the species may be potentially over-harvested in the Red River Basin.

Further studies of this type are urgently needed in order to understand the potential impact on populations and to identify species that may benefit from aquaculture to maintain populations.

At present there are no species known where harvesting has significantly impacted wild populations of snails, however, the question of whether regionally heavy utilisation of molluscs may be a local threat to some populations requires further research.

4.6.6 Climate change

At present few freshwater molluscs are known to be directly threatened by climate change in the Indo-Burma region. Increased frequency of drought events will in most cases be a secondary threat to those freshwater species where there are already problems, such as the over-abstraction of water for domestic and agricultural purposes. In the near future, these threats are likely to be exacerbated by the impact of changing climate, including altered rainfall patterns, more extreme weather conditions, and the increased frequencies of droughts or floods.

4.6.7 Untargeted use of molluscides

The control of waterborne disease vectors (for example, parasitic flukes that cause diseases such as angiostrongyliasis, echinostomiasis, opisthorchiasis, schistosomiasis, heterophyiasis, paragonimiasis, and fasciolopsiasis), can impact local populations of freshwater molluscs, with potentially severe impacts on range restricted species, which are often non-target species. In Africa such uncontrolled use was shown to be a cause in the decline of populations for range-restricted species to a level where they became threatened (Seddon et al. 2011). Control measures should prioritise education, health monitoring, improved water supply and sanitation, above molluscicide use or environmental management, which should generally only be used for pest/invasive species such as Pomacea canaliculata.

4.6.8 Invasive species

A future threat in some parts of the region is introduced mollusc species, such as Pomacea canaliculata and similar species. At present, the majority of species that are threatened

<table>
<thead>
<tr>
<th>Tributary</th>
<th>Length of river (km)</th>
<th>Number of households</th>
<th>Yield/household/day (kg)</th>
<th>Days of harvesting/year</th>
<th>Total yield (tonnes)</th>
<th>Estimated stock (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lo River (Viet Tri)</td>
<td>13</td>
<td>5</td>
<td>19.5</td>
<td>300</td>
<td>29.250</td>
<td>37.95</td>
</tr>
<tr>
<td>Da River (Thanh Thuy)</td>
<td>13</td>
<td>4</td>
<td>16.5</td>
<td>300</td>
<td>19.800</td>
<td>35.86</td>
</tr>
<tr>
<td>Thuong Tin (Ha Noi)</td>
<td>13</td>
<td>6</td>
<td>27</td>
<td>300</td>
<td>48.600</td>
<td>52.36</td>
</tr>
<tr>
<td>Ninh Co River</td>
<td>15</td>
<td>7</td>
<td>26</td>
<td>300</td>
<td>54.600</td>
<td>64.77</td>
</tr>
<tr>
<td>Mouth of Red River</td>
<td>5.5</td>
<td>9</td>
<td>7.5</td>
<td>300</td>
<td>20.250</td>
<td>23.86</td>
</tr>
</tbody>
</table>

Table 4.6 Estimated stock of freshwater mussels in some branches of the Red River (Song Hong) in Viet Nam. (Source: Hoang 2010)
in the region are primarily impacted by other threats. However, where *Pomacea canaliculata* has been widely found, native molluscs have declined, suggesting that the species may potentially impact range-restricted native species in the future.

### 4.6.9 Other threats

Additional sources of habitat degradation prevalent throughout the region include dredging and channelization, agrochemical and heavy metal loading, acidification, salinisation (from decreased freshwater flows in estuarine areas), fish and mollusc farming, wetland conversion through urban and agricultural development, and unsustainable water extraction for irrigation, livestock and urban use. However, it has frequently proven to be difficult to assess the significance of most of these factors for the global survival of individual species.

#### Table 4.7 Gastropod species and nematode disease hosts.

<table>
<thead>
<tr>
<th>Species</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bithynia siamensis</em></td>
<td>Angiostrongyliasis, Echinostomiasis</td>
</tr>
<tr>
<td><em>Bithynia umbilicalis</em></td>
<td>Opisthorchiasis (Opisthorchis viverrini)</td>
</tr>
<tr>
<td><em>Bythinia faniculata</em></td>
<td>Opisthorchiasis (Opisthorchis viverrini)</td>
</tr>
<tr>
<td><em>Neotricula aperta</em></td>
<td>Schistosomiasis (Schistosoma mekongi)</td>
</tr>
<tr>
<td><em>Neotricula burchi</em></td>
<td>Schistosomiasis (Schistosoma mekongi)</td>
</tr>
<tr>
<td><em>Tricula bollingi</em></td>
<td>Schistosomiasis (Schistosoma mekongi)</td>
</tr>
<tr>
<td><em>Melanoides tuberculatus</em></td>
<td>Paragonimiasis, Echinostomiasis, Heterophyiasis</td>
</tr>
<tr>
<td><em>Tarebia granifera</em></td>
<td>Paragonimiasis, Echinostomiasis</td>
</tr>
<tr>
<td><em>Thaia saba</em></td>
<td>Paragonimiasis, Echinostomiasis</td>
</tr>
<tr>
<td><em>Brata swinhoei</em></td>
<td>Paragonimiasis, Echinostomiasis</td>
</tr>
<tr>
<td><em>Indoplanorbis exustus</em></td>
<td>Cercarial Dermatitis, Echinostomiasis</td>
</tr>
<tr>
<td><em>Gyraulus convexiculatus</em></td>
<td>Echinostomiasis</td>
</tr>
<tr>
<td><em>Hippopus umbilicalis</em></td>
<td>Fasiolopsisiasis (Fasiolopis buksi)</td>
</tr>
<tr>
<td><em>Segmentina hemisphaerula</em></td>
<td>Fasiolopsisiasis (Fasiolopis buksi)</td>
</tr>
<tr>
<td><em>Segmentina trochoidea</em></td>
<td>Fasiolopsisiasis (Fasiolopis buksi)</td>
</tr>
<tr>
<td><em>Radix rubiginosa</em></td>
<td>Fasioliosis (Fasiola hepatica)</td>
</tr>
<tr>
<td><em>Radix swinboei</em></td>
<td>Fasioliosis (Fasiola hepatica)</td>
</tr>
<tr>
<td><em>Radix viridis</em></td>
<td>Fasioliosis (Fasiola hepatica)</td>
</tr>
</tbody>
</table>

#### 4.7 Understanding the impact of molluscs on human health and livelihoods

In Asia, many gastropods carry parasites that cause disease in humans (see Table 4.7). For example, several freshwater snails serve as intermediate hosts for the nematode *Angiostrongylus cantonensis* which, when ingested by people, penetrate the central nervous system and cause eosinophilic meningitis (*Angiostrongyliasis*).

The impact of diseases such as human schistosomiasis carried by molluscs is difficult to estimate in economic terms because of problems in accurately measuring the effects of subtle variables like absenteeism, childhood mortality, loss of productivity and reduced education on a continent-wide or even national scale (Seddon *et al.* 2011).

There are active disease control programmes in the region, involving health education and local participation in prevention and disease control campaigns run by government agencies though local government organisations. These concentrate on the detection and treatment of disease, improved sanitation and safe water supplies. The use of molluscicides or environmental management should only be used for pest/invasive snail such as *Pomacea canaliculata*.

Animal fascioliasis is known across the continent where it affects a range of stock animals and chronically infected animals show reduced growth, lower milk production and lower calving rates (Seddon *et al.* 2011), with consequential impacts on human food security and nutritional availability.

#### 4.8 Conservation recommendations

Considering that even the more charismatic megafauna, such as river dolphins, have failed to trigger decisive and effective conservation actions in the region, it becomes clear that the conservation of freshwater invertebrates, including snails, faces particular challenges as a result of the lack of awareness of the magnitude of their importance to ecosystems and human livelihoods (Dudgeon 2000a).

This assessment of the impact of threats to molluscan biodiversity is complicated by limited knowledge of the freshwater mollusc fauna in the region. From the current assessment, we can anticipate a loss in biodiversity and gradual homogenization of the regional biota unless conservation actions are put in place. Reversal of these trends will require a change of focus by limnologists and water-resource managers, and the urgent adoption of a conservation agenda for freshwater science in Asia (Dudgeon 2000a, Dudgeon *et al.* 2006).

Whilst in North America and Europe, freshwater molluscs (such as the spring snails, river rapids species and the large Unionid
mussels) have benefitted from the extension of protected areas as conservation actions for the species, in the Indo-Burma region there are, with the exception of Ramsar Sites, few protected areas designed specifically for protection of freshwater fauna. Protected areas for freshwater systems need to be designated to specifically protect upper catchments and to include entire river and lake systems within their boundaries, if they are to provide effective protection to freshwater species (Darwall et al. 2011b).

To our knowledge there are no current conservation actions in place to conserve freshwater molluscs in Thailand or Lao PDR, however, there are general education programmes aimed at raising awareness of environments and the biodiversity of the region. By contrast in Viet Nam, three gastropod species and 15 bivalves are listed as requiring conservation actions, and a project establishing inland water protected areas has commenced and by 2015 is intended to have 53 protected freshwater areas, although, the impact of this project in the field of conservation of aquatic resources is still limited.

Research capacity and the awareness of the value and ecological importance of molluscs needs to be improved in the region. Rarely do relevant governments or indigenous communities appreciate the value of their molluscan biodiversity, so capacity-building projects are recommended to raise awareness and facilitate monitoring of local mollusc populations, especially where they are utilised for food or other purposes. Some such initiatives are ongoing in Thailand and Viet Nam through community outreach and collaboration with local wildlife and fisheries departments (P. Sri-Aroon pers. comm.).

Environmental Impact Assessments (EIA) need to include assessments on the impacts to mollusc diversity, and should be mandatory for proposed developments such as dam construction, fish farm developments, large-scale timber extraction involving clear-felling of gallery forests, and mining developments. Monitoring after the completion of the project also needs to be incorporated into large project developments in the region.

Proposals to use molluscides need to be carefully assessed, as they can cause the decline of populations of non-carrier endemic species that do not provide a threat to human health or livelihoods. The loss of these species has two major effects; a) increase in the carrier species, filling the niche vacated by the non-carrier species; and b) decline of food supplies for the other native species that predate these molluscs, such as crabs, aquatic birds and fish.

Finally, sewage treatment needs to be improved, and there needs to be tighter control on the import of invasive species to reduce the impact on native species.

4.8.1 Species-specific conservation requirements

Species with small distributional ranges deserve particular attention through suitable management of habitats required for the survival of these species, especially those in riffle habitats susceptible to the impacts of dam construction.

Species that require a host-fish during their life cycle (e.g. the large Unionid mussels) may need to have a conservation plan.
that includes the host fish’s habitat requirements as well as their own requirements.

4.8.2 Research actions

At present, despite a few omissions from our species list and the number of Data Deficient species, we believe that the data presented are reasonably representative of the status of molluscan biodiversity and the threats to these species across the Indo-Burma region.

There are, however, certain key research actions that will improve our knowledge and allow better management of molluscan biodiversity:

1. Improve general information on molluscs

For all freshwater molluscs in the region, there is an urgent need for a better understanding of their distributions, populations (where possible), fish-hosts, ecology, tolerance to pollution, impact of invasive species and habitat requirements, as well as better understanding of their taxonomic status, based on traditional systematic studies and the analysis of the mitochondrial and nuclear DNA sequences to establish species boundaries and species relationships. Such new information would potentially allow the large number of Data Deficient species to be moved into an IUCN Category for risk of extinction.

2. Research on groups where current diversity is possibly under-recorded

There are likely to be cryptic species lying within some Families such as the Pachylidae, Lymneidae, Planorbidae, Cyrenidae and possibly other families. More research therefore needs to be focussed on known areas of high biodiversity, where these families have wide-ranging, but morphologically variable, species to determine whether such variability is masking a group of species, rather than a single widespread but variable species.

3. Field surveys for Data Deficient species

Many freshwater molluscs in the region are known from only a relatively small number of specimens, and most of those have not been corroborated by recent collecting.

4. Document traditional uses and establish volumes of species used in supporting local livelihoods

The scale of consumption and use of molluscs in supporting livelihoods (i.e., through direct consumption or utilisation in construction, jewellery, etc.) is not well understood. In southern India, some species are used as local remedies for human and animal diseases (Aravind et al. 2011). It is likely that similar knowledge is available in the Indo-Burma region, however, we haven’t captured or collected this information in the current assessment. Hence the traditional uses of freshwater molluscs by people and the traditional knowledge associated with this use needs to be documented.

4.8.3 Legislation and policy

Legislation governing development and water resource protection varies across the region. In Thailand, the Office of Natural Resources and Planning (ONEP) determines if hydropower dam projects require an Environmental Impact Assessment. In this case an EIA is normally required if a dam or reservoir has:

- a storage volume of over one million cubic metres of water
- a storage surface area of more than 15 km²
- an irrigation area of 12,800 ha or more

In general these EIA studies take a period of one to three years and should include surveys for freshwater molluscs and their parasitic diseases. The EIA report has to be approved by ONEP, and the Cabinet before construction starts, however after construction studies of the ongoing environmental impact are not generally required, except when serious impact occurs.

In contrast, in Viet Nam, conservation of freshwater molluscs has been initiated with the production of the Red Data Book of Viet Nam (MoSTE 2000) which includes 17 mollusc species: two gastropods and 15 bivalves- all of the threatened bivalves are in the family Unionidae.

Recommendations for Policy include: a requirement for all major developments to conduct Environmental Impact Assessments, and these should include surveys for all threatened and Data Deficient species of molluscs; mitigation plans to be put in place for sites of high biodiversity value, including restoration of habitats post-project and flow
management to maintain biodiversity; and, implementation of water pollution management and prevention across river basins.

### 4.8.4 Freshwater molluscs and livelihoods

Freshwater molluscs are utilised throughout the region by local communities for direct consumption and for sale for a range of uses (see Section 4.8.2, above). Open-access freshwater resources such as molluscs can play a vital role in sustaining local livelihoods within the region (Allen et al. 2008), underpinning food security and providing a source of cash income. Cultivation (mariculture) of molluscs (primarily bivalves, for pearl and shell, occasionally for food) is not common, but has been promoted in some areas (for example, oyster cultivation in Viet Nam; Braidotti 2011).

However, at present although current harvesting levels do not appear to be impacting populations, further research is required on whether heavy utilisation of molluscs may be a local threat to some populations, especially those species considered to be narrow endemics.

### 4.9 Conclusions

The Mekong basin within the Indo-Burma region is considered to have one of the highest freshwater mollusc diversities in the world. However, in spite of this, there has been relatively little focus on research into the species and their distributions. In light of the number of the threats recognised in the region there is a need for better data to allow a more comprehensive assessment of the status of the Data Deficient species. If all of these taxa are later found to be threatened, with around 40 Percent of species threatened it would also become one of the most threatened freshwater mollusc faunas, second only to Europe (Guttelod et al. 2011).

### 4.10 References


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