Freshwater molluscs of Africa: diversity, distribution, and conservation.

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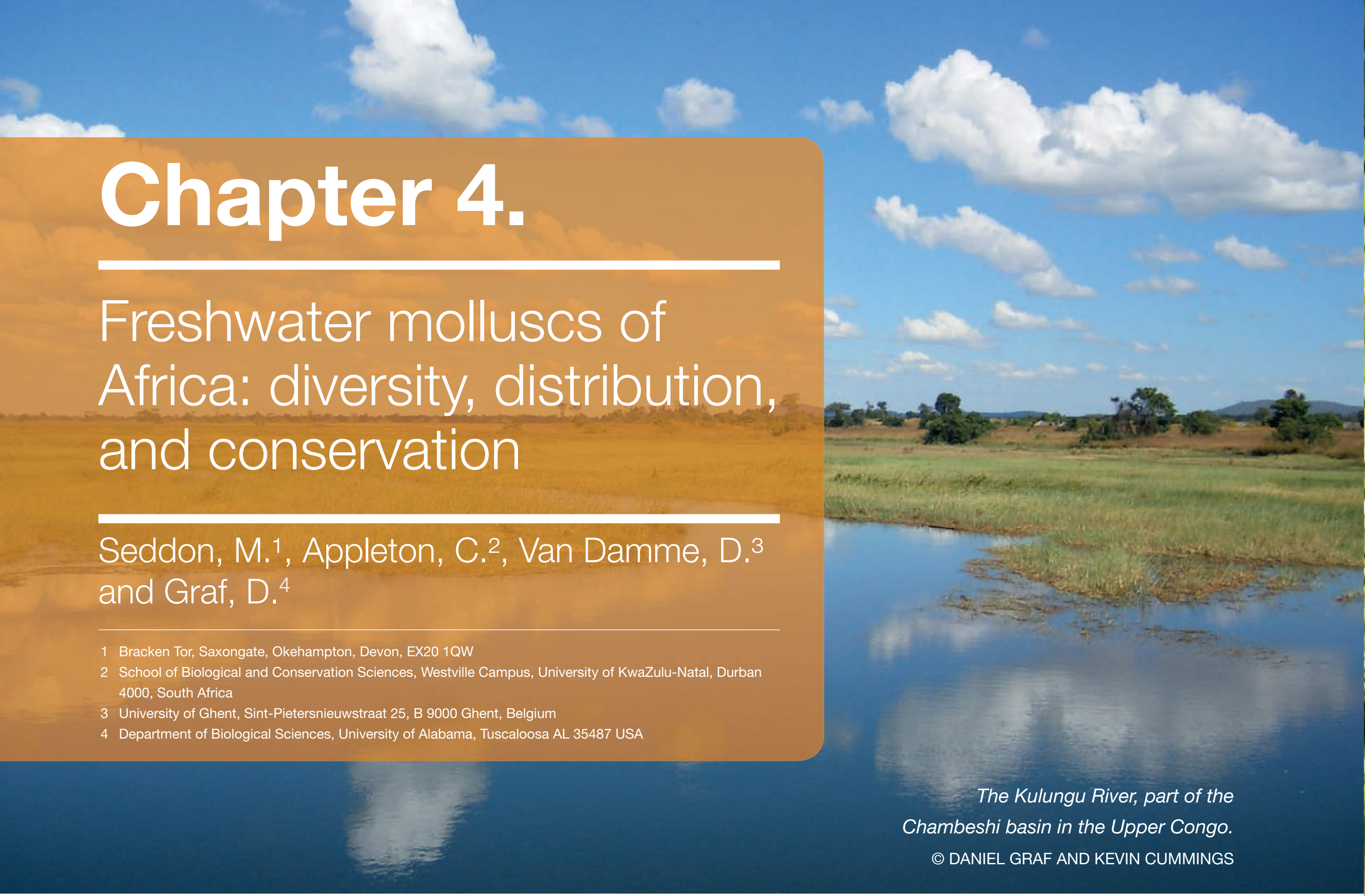

Chapter 4.

Freshwater molluscs of Africa: diversity, distribution, and conservation

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The Kulungu River, part of the Chambeshi basin in the Upper Congo.
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Diving for mussels in the Upper Chambeshi River, Upper Congo.
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Children washing clothes in a steam near the Sanaga River in Cameroon, potentially exposed to diseases hosted by freshwater molluscs. © KEVIN SMITH

Introduction

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. In general, the freshwater molluscs of Africa are less diverse than some continental faunas such as in North America and Europe, with only an estimated 560 species compared to around 880 species for North America and around 1,540 species for the Palaearctic (of which there are about 780 European species) (Seddon pers. comm.; Bogan 2008). 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. The Bivalvia are less numerous than the Gastropoda, with the pulmonates containing a higher proportion of the widespread, more cosmopolitan species. Most research efforts in recent years have, however, concentrated on the freshwater Unionid mussels and the prosobranchs. 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. In northern Africa, the level of field survey, combined with review of historical collections, is rapidly changing the number of known species (Van Damme *et al.* 2010), as is also the case in Lake Tanganyika (West *et al.* 2003), and these areas can be expected to have an increased number of endemic species described over the next five years.

From 2003 to 2009, the regional status of molluscs in eastern, southern, western, northern and central Africa were determined through a series of assessments (Darwall *et al.* 2005; Kristensen *et al.* 2009a,b; Van Damme *et al.* 2010; Graf *et al.* 2011). This chapter synthesises the results for the entire pan-African molluscan fauna, providing an overview of the threats to the continental fauna and highlighting the regions and species that require further conservation actions. For a synthesis of results presented by taxonomic grouping rather than region, please see the accompanying DVD.

Exploration of African freshwater molluscs commenced during the periods of colonial expansion throughout the continent (Brown 1994). Adanson was one of the earliest malacologists in Africa, and described some of the first molluscs from regions including western Africa. Some regions, such as southern Africa, have received attention throughout the last two centuries, with Connolly's various monographs (e.g., Connolly 1939) as well as Germain's studies for Mozambique (Germain 1935). In comparison north-eastern Africa, central Africa and western Africa have received relatively little attention in the last 50 years. The eastern African fauna received more attention, partly due to the unusual fauna of the ancient Rift Valley. The early studies of Lake Tanganyika by researchers such as E.A. Smith and K. von Martens have been considerably revised as the result of more recent survey work. In the 1950s, E. Leloup (1935) and G. Mandahl-Barth both published volumes on East African lake faunas. More recently, a revised handbook to Gastropods of Lake Tanganyika has been produced (West *et al.* 2003), and further research incorporating molecular systematics continues on selected prosobranch families. Recent research by C. Albrecht is revealing more on the origins of the Ancylinae (now a subfamily in the Family Planorbidae), and further research efforts are looking at the origins of other pulmonate genera. Africa has, for the last 50 years, also been the focus of attention for taxonomic studies related to molluscs of medical importance. Two notable scientists contributed the majority of the work in the early days, Mandahl-Barth and D. Brown. Brown's monograph (Brown 1994) remains the most complete handbook to the identification of the freshwater gastropods to date. Mandahl-Barth established the Danish Bilharzia Laboratory, which hosted many training programmes supporting a generation of young scientists in Africa, and produced many research papers and small handbooks. Many of the host species are pulmonates, and as such, these taxa have been the focus of various studies over the last 30 years.

By contrast, there are few studies of the Bivalvia, with most activity presented in the catalogues of Daget (1998) and Mandahl-Barth (1988). These volumes provide two rather different views of the status of bivalves, reflecting the nature of the two taxonomic schools of splitting and lumping, but neither is based on definitive data, mainly on opinions of the variability of the form of species shells (Graf pers. comm.). As such, the regional treatments in this project have differed depending on which was taken as the initial basis for the taxonomic list. For example, in freshwater mussels, the genus *Chambardia* has been assigned in different ways in the various regional reports. Through the late 1990s, Mandahl-Barth (1988) and others referred to the genus as *Spathopsis*. However, given the species circumscribed under this taxon, it has since been recognized that the name *Chambardia* has nomenclatural priority (Vaught 1989; Daget 1998). The basis for the confusion seems to have been that the type species of *Chambardia, C. letourneuxi*, was described from (sub)fossil shells, and neontologists took a conservative approach to relating that material to living forms (Graf, pers. comm.). Regardless, while the name has changed, the taxonomic concept of the genus *Chambardia* is interchangeable with that of *Spathopsis*, so confusion should be limited. As such, there are some species which the pan-African project considered valid, that were omitted in the earlier regional assessments, and hence could not be evaluated for their overall pan-African status. Most of these would

Tiphobia horei *(LC), a species endemic to Lake Tanganyika, where it is locally impacted by sedimentation, dredging and collection for the shell trade.* © HEINZ H. BÜSCHER

be assessed as Data Deficient or Least Concern. This variability in knowledge from family to family and between regions presented a considerable challenge to this assessment and, although ongoing research has considerably increased our knowledge of the fauna, there remains a pressing need for continued investment and training to build on the current knowledge base.

Freshwater gastropods

Freshwater gastropods represent about 75% of all freshwater molluscs in the African continent, dividing into two informal groups, the prosobranchs and the pulmonates. Bouchet and Rocroi (2005) revised the higher phylogeny of Mollusca, noting that "Prosobranchia" could no longer be supported as a formal designation, as it was polyphyletic, with multiple origins within the group. Now 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, however most of the freshwater species lie in the Basommatophora, within the Eupulmonata. Brown (1994) estimated that there were 326 species in Africa, but more species have been recognised in this current study as new species have been described and molecular systematics allowed some taxa to be revised.

Freshwater prosobranchs are most varied within the lakes and larger river systems, whereas freshwater pulmonates are more often associated with small water-bodies and many are tolerant of seasonal drying. In total, 353 species of prosobranch and 143 species of pulmonates are recognised here, in the families Lymnaeidae, Planorbidae, and Ancylinae. There are also a number of introduced species in the family Physidae that have not been evaluated given that Africa is outside their native range.

Freshwater bivalves

The freshwater bivalves represent approximately 25% of the freshwater mollusc fauna of the African continent. In total, we recognise 158 species (28 genera, nine families, two orders) of bivalves in Africa, including 17 species that were not evaluated as part of this project due to differences in taxonomic treatments in the regional assessments that provide the basis for the final pan-African assessments.

The bivalves are divided into two globally distributed orders: Unionoida (otherwise known as freshwater mussels) and Veneroida (otherwise known as clams and pea-clams). Freshwater mussels contain the higher number of species (82 species). All unionoid species are strictly freshwater, and in Africa these molluscs are common and often locally abundant inhabitants of both rivers and lakes. Similarly, the Veneroida (56 species, including five species not evaluated) occupy a wide range of habitats, from brackish estuarine waters to interior lentic and lotic environments, although there are more cosmopolitan taxa in the pea-clams (Sphaeriidae). All of the freshwater bivalves possess a common suite of adaptations to life in freshwater. These include larval brooding, direct development, and, in the case of freshwater mussels, obligate larval parasitism upon freshwater fishes (Wächtler *et al.* 2001; Cummings and Graf 2009). Despite these common characters derived

Unionid mussels collected from Malebo Pool in the Republic of the Congo; Chelidonopsis hirundo *(LC),* Mutela legumen *(VU),* Aspatharia pfeifferiana *(LC),* M. "rostrata"*,* Coelatura rotula *(VU),* C. gabonensis *(LC) and an unidentified snail.*

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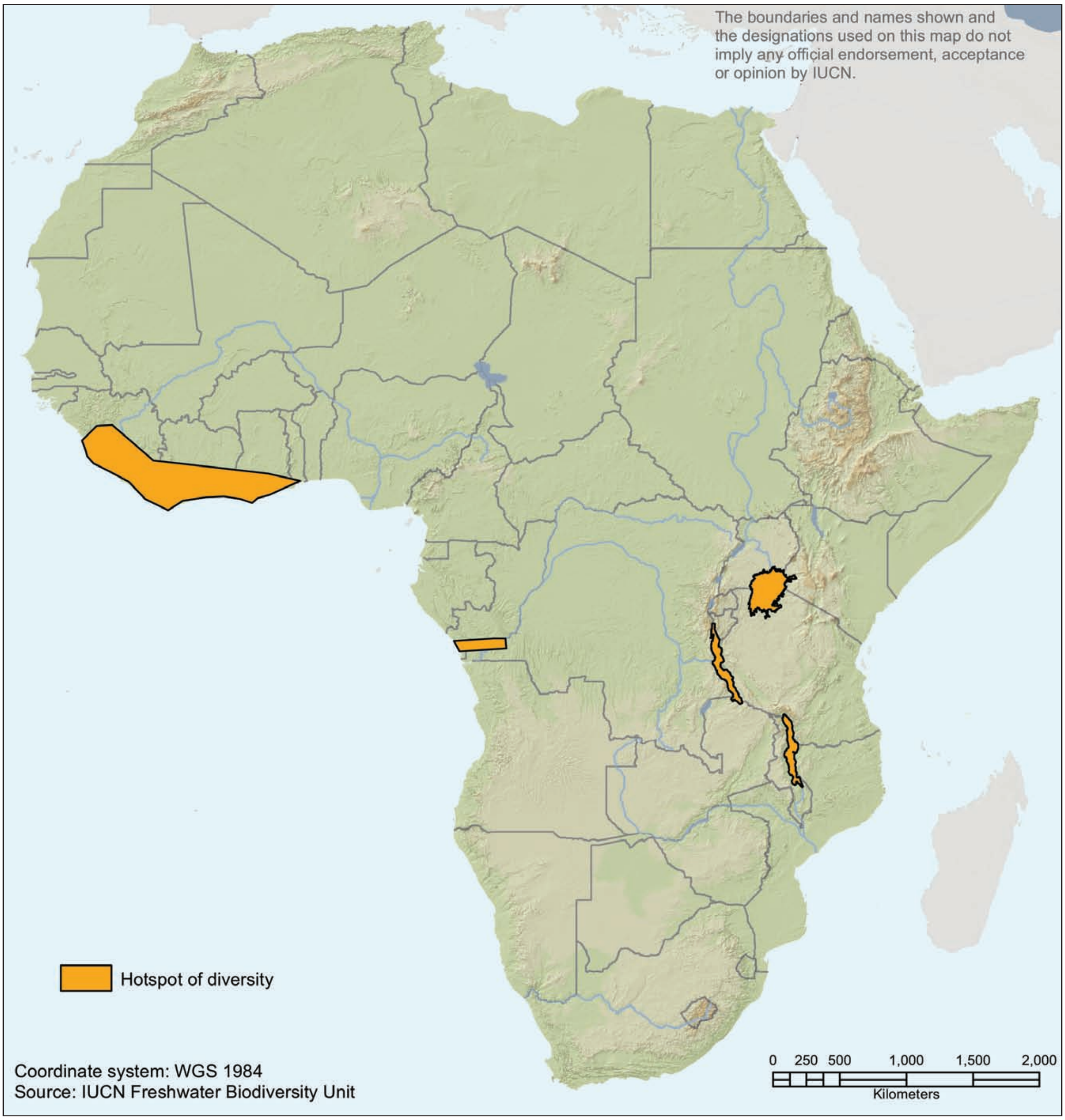
Figure 4.1. Hotspots of freshwater mollusc diversity across continental Africa (highlighted in orange) (data compiled by Bouchet and Gargimony, adapted from Groombridge and Jenkins 1998).



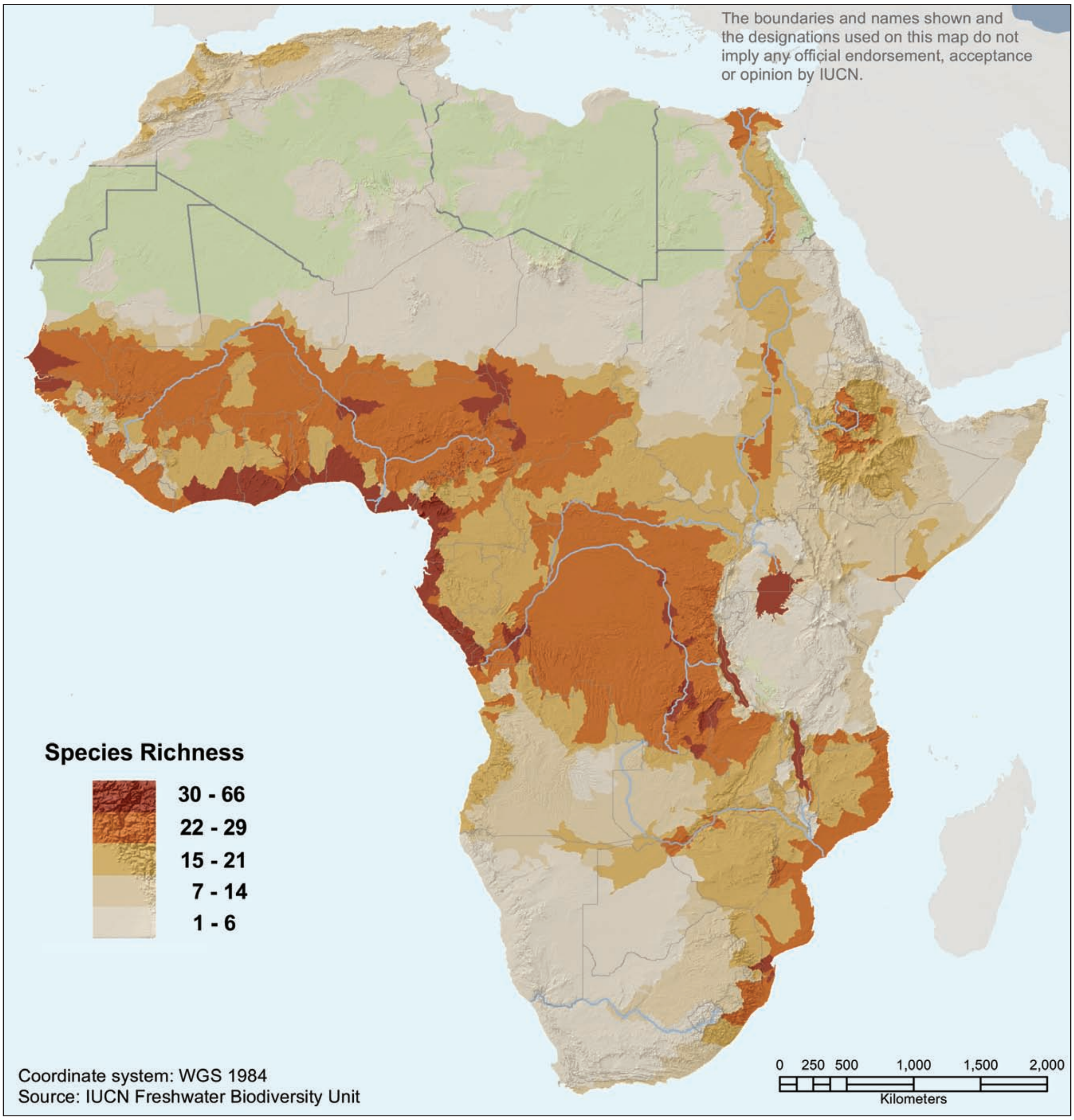
from shared environmental pressures, these bivalve taxa represent different evolutionary lineages and, as a result of their disparate life histories, demonstrate a range of patterns of dispersal and abundance.

4.1 Overview of freshwater molluscan diversity in Africa

Freshwater molluscs find their highest levels of endemism and diversity in ancient lakes, large river basins and artesian basins (Seddon 2000), and all of these habitats can be found in the different regions of Africa. Bouchet and Gargimony (in Groombridge and Jenkins 1998) provide a generalised map of the projected hotspots of molluscan freshwater diversity in the world, highlighting various parts of Africa, namely the East African Rift Valley Lakes and the river rapids of western Africa (Figure 4.1). The outputs of the current pan-African project now allow an in-depth comparison (Figure 4.2) of the hotspots of species diversity of Africa as defined in 1998, and enable this picture to be refined on the basis of actual mapped species distributions, rather than experts' best estimates.

African freshwater mollusc fauna is geographically divided into the regions north of the Sahara, where the affinity of the fauna lies with the Palaearctic fauna, and the regions south of the Sahara where an Afrotropical fauna dominates. The exception is north-eastern Africa which has elements shared with the Palaearctic fauna, the Arabian fauna and

Figure 4.2. Patterns of species richness for all mollusc species. Species richness = number of species per river/ lake sub-catchment.



the African fauna (Van Damme *et al.* 2010). The southern line for the Palaearctic fauna is generally drawn through the Ahagger Mountains, north-east towards Libya and west to Mauritania (Sparks and Grove 1961).

The regions highlighted in this study as having the highest species diversity (Figure 4.2) include the East African Lakes (Lake Victoria, Lake Tanganyika and Lake Malawi), the Upper Congo catchments around Lake Mweru, the river rapid regions of western Africa, and the Lower Congo Rapids. Additional regions of interest not previously highlighted in Bouchet and Gargimony's analysis (Figure 4.1) include the North African spring-snails, the East African coastal rivers, Lower Nile River, the Lake Chad basin and Malebo Pool in the Congo Basin.

4.1.1 Molluscan diversity in river basins

The two largest freshwater systems in Africa are the Nile and the Congo rivers. The habitats of the largest, the Congo River, are the less diverse, consisting mainly of rainforest rivers and large rift lakes (Thieme *et al.* 2005). Brown (1994) and Van Damme and Van Bocxlaer (2009) compared the species richness of the fluvial mollusc faunas of these two river basins, with exclusion of the large lakes. Brown pointed out that the number of gastropods known from the Nile Basin (51) is about half that of the Congo (96) (if we take the taxonomically deficient genera *Ferrissia* and *Burnupia* as genera only), and the proportion of basin endemics is much lower, namely 10 out of 51 species. Similarly, for the bivalves, species diversity is lower in the Nile Basin, with a

The Kulungu River, part of the Chambeshi basin in the Upper Congo. © DANIEL GRAF AND KEVIN CUMMINGS

total of 28 species compared to 38 in the Congo drainage, and the degree of bivalve endemism is dramatically lower in the Nile Basin with only five species endemic to the Nile Basin as compared to 18 in the Congo Basin (Daget 1998; Graf and Cummings 2007a,b). Van Damme and Van Bocxlaer (2009) also observed dissimilarity in the habitats where this diversity is found. While the highest species richness of the Congo Basin is for specialist taxa that live in the rivers and lakes, the highest diversity in the Nile Basin is of generalist taxa living in fringe habitats, such as temporary pools. In the Congo Basin prosobranch snails and unionoid bivalves are overwhelmingly dominant, while in the Nile Basin pulmonate snails and smaller clams and pea mussels (Families Sphaeriidae and Corbiculidae) are more abundant. In the Lower (Egyptian) Nile and in the Ethiopian Highlands, as with the Maghreb zone (Morocco, Algeria, Tunisia and Libya), components of the Palaearctic fauna occur, including widespread species at the southern limits of their range, along with a limited number of endemics with a Palaearctic origin. Van Damme *et al*. (2010) suggest this pattern stems from the main invasion of freshwater molluscs into Africa via the Horn of Africa in Middle and Late Miocene times (23 to 5.3 million years ago).

Congo Basin: The fauna from the Congo Basin includes some rare and range restricted species. For example there are three monotypic genera in the family Bithyniidae, *Gongodoma, Liminitesta* and *Funduella,* which are all adapted to life on stones in fast flowing streams, and are exclusively found in the Lower Congo area. These genera are probably relicts, as are the similar taxa in western Africa. In the family Ampullaridae, another species, *Lanistes neritoides,* which was recently discovered in a tributary of the Kouilou River (Republic of the Congo), inhabits similar habitats, where it lives like a limpet fixed on rocks in shallow fast flowing water. This species is the only *Lanistes* species listed as Critically Endangered. In the family Assimineidae, one of the five genera recognized in Africa by Brown (1994) is *Assiminea* (which is fairly cosmopolitan, as it is spread by birds), another (*Eussoia)* is African and ranges from Somalia to Mozambique (four species), whilst *Pseudogibbula*, *Valvatorbis* and *Septariellina* (four species) are restricted to the fast flowing part of the Lower Congo River. All representatives of these three genera are listed as Critically Endangered due to their restricted ranges and identified threats. In the family Paludominidae, the genus *Pseudocleopatra* is restricted to the Lower Congo and the Volta River, and its representatives are rare within these basins. Fossil evidence shows that this is a relict distribution and that the genus' range formerly extended to eastern Africa (Van Damme and Pickford 2003). In the family Thiaridae the Afro-Asian genus *Melanoides* is highly speciose, but only one species, *Melanoides tuberculatus*, is found throughout Africa (and Asia), while most of the other *ca* 30 parthenogenetic species are restricted to the large African lakes and the Congo, with the highest species richness found in the Congo Basin, where 12 species are recorded. Species of *Potadoma* (which was moved from Thiaridae to Pachychilidae on the basis of molecular research (Köhler and Glaubrecht 2002)) are found in the rapids of the Lower Congo and also in eastern and north-eastern Congo, and some of these are threatened.

Western Africa: The western African region is recognised as one of the hotspots of terrestrial biodiversity (Mittermeir *et al.* 1998), and the presence of some unique Prosobranch genera in the short, fast-flowing rivers draining the west Africa plateau is a reflection of the area's high diversity. The rivers draining the west Africa plateau have localized range restricted species, including two genera, *Sierraia* and *Soapitia* (family Bithyniidae), that are adapted to life on stones in fast-flowing streams in Sierra Leone and Guinea, and these genera are considered to be threatened as well as being potentially quite ancient and relict in origin. The River Niger is less diverse than many of the smaller, fast-flowing rivers that drain the west African plateaus (Thieme *et al.* 2005). In this region and in the Congo, the *Potodoma* species in the family Pachychilidae has a disjunct dispersion (in the Atlantic rivers from Liberia to Lower Congo and also in eastern and north-eastern Congo). This ancient taxon formerly had a much wider distribution, reaching as far east as the Turkana Basin (Van Bocxlaer *et al.* 2008). The highest species richness is found in Cameroon, with seven species, most of which are threatened. Within the freshwater mussels the genus *Nitia* is limited to Nilo-Sudanic Africa, including the Senegal, Niger, Chad, and Nile Basins. The species of this genus have frequently been subsumed under the catchall genus, *Coelatura* (Mandahl-Barth 1988; Scholz and Glaubrecht 2004), but we regard *Nitia* as a morphologically distinct group of species, worthy of separate recognition (Daget 1998; Graf and Cummings 2007a). Three species of *Nitia* are listed from Africa (plus one that was not evaluated), all of which are assessed as either Least Concern or Data Deficient.

The Niger River basin contains fewer endemic species of freshwater molluscs than the Congo and Nile river systems. Similarly, other rivers such as the Senegal, Orange, and Zambezi, whilst having reasonable species diversity, have relatively few endemic species. Some of these western African rivers do, however, require specific conservation actions to safeguard the few rare and unique species occurring in the fast-flowing, highly oxygenated waters of the river rapids.

North-west Africa: The freshwater mussels of this region are largely within the genera of *Unio, Anodonta, Leguminaia* and *Potomida* that inhabit the Palaearctic region of northern Africa, the Maghreb, and parts of Europe. The genus *Anodonta* is a widespread Eurasian and North American genus that, in the western Palaearctic, reaches

The Oued Za in Morocco, a typical river of the Maghreb.
© JEAN-PIERRE BOUDOT

its southern limit in north-western Africa. Populations in the Maghreb are represented by two species, although there is disagreement among malacologists as to which two species of *Anodonta* they are. The more traditional view has been that the populations in Morocco and Algeria are conspecific with two widespread but declining European species, *A. cygnea* and *A. anatinus*. Those taxa are both morphologically variable and widespread in the western Palaearctic, extending east from the British Isles and Iberia into Russia and Central Asia (Araujo *et al.* 2009). However, the traditional concepts of Palaearctic genera and species are holdovers from early in the last century, and they have only just begun to be re-evaluated using modern analytical methods and species concepts (Graf 2007). More recent work (Van Damme *et al.* 2010; Araujo pers. comm.) suggests that these north-western African populations may represent endemic species *A. pallaryi* and *A. lucasi*. Due to their restricted distribution ranges, and the threats to the rivers they inhabit, both species are ranked as Critically Endangered. *Unio* is another typically Palaearctic genus, but with a wider distribution in northern, eastern, and southern Africa. In total, four *Unio* species are recognized from the continent, three of which are threatened. Four new species, *Unio gibbus*, *U. delphinus*, *U. ravoisieri*, and *U. mancus*, have recently been recognized as occurring in the Maghreb of north-western Africa; all four are also found in the adjacent Iberian peninsula (Araujo *et al.* 2009). Neither *U. ravoisieri* nor *U. delphinus* were evaluated as part of this project, being only recently removed from synonymy with other species. Here we treat the north-western African populations of *U. gibbus* as a separate endemic species, *U. foucauldianus* (Critically Endangered). Moreover, we regard the African populations of *U. mancus* to be another African endemic species, *U. durieui* (Endangered). The latter species is the most widespread of the Palaearctic-*Unio* assemblage, extending from the Maghreb to the Nile, as well as the Turkana Basin.

4.1.2 Molluscan diversity in ancient lakes

In Africa, the ancient lakes are mainly located in the rift valleys that lie between eastern and central Africa and have long-been recognized for their high endemism and diversity of molluscs (West *et al.* 2003; Michel *et al.* 2004), and this is confirmed here (Figure 4.2). Other smaller lakes do not have the same levels of isolation and evolutionary change recognized in the ancient lakes, although Brown (1994) points out that even these small lakes may have been isolated for sufficient periods for the presence of distinctive species to evolve.

A Lake Tanganyika gastropod (demonstrating shell repair) from the genus Lavigeria. © HEINZ H. BÜSCHER

In general, the prosobranchs are most diverse in the three largest lakes, Tanganyika, Victoria and Malawi (Table. 4.1), whilst there is a more limited diversity and endemism of the pulmonates (Brown 1994).

Lake Tanganyika is viewed as one of the oldest and deepest of the East Africa Rift Valley lakes, with approximately half of the Metazoan fauna being endemic to the lake (West *et al.* 2003). The endemic prosobranchs are principally found in the littoral and sub-littoral zones (Leloup 1953; Brown 1994), and some endemic species have spectacular ornamentation, with shell-forms called thalassoid, meaning

Table 4.1. Freshwater gastropod fauna of the largest African lakes (Based on Brown 1994 and additional data):

Lake	Altitude (m)	Area (km²)	No. of species	No. of lake endemics
Lake Tanganyika	773	32,900	83	65 species
Lake Victoria	1,240	75,000	28	12 species/subspecies
Lake Malawi	473	29,600	27	17 species
Lake Chad	280	20,000	21	3 species/subspecies
Lake Albert	615	5,600	16	8 species/subspecies
Lake Mweru	922	4,850	15	8 species/subspecies
Lake Edward	920	2,150	15	4 subspecies
Lake Tana	1,829	3,156	10	0 species
Lake Kivu	1463	2,700	7	1 subspecies
Lake Turkana	375	7,200	4	1 subspecies

Table 4.2. Freshwater bivalve fauna of the largest African lakes.

Lake	Altitude (m)	Area (km²)	No. of species	No. of lake endemics
Lake Victoria	1,240	75,000	17	6 species/subspecies
Lake Chad	280	20,000	12	1 species/subspecies
Lake Mweru	922	4,850	12	4 species/subspecies
Lake Tanganyika	773	32,900	11	8 species
Lake Turkana	375	7,200	10	1 subspecies
Lake Malawi	473	29,600	8	3 species

'sea-like', as there is a marked convergence with marine shells. Brown (1994) suggests that few molluscs are found below 125m depth, due to the concentration of hydrogen sulphide.

Freshwater prosobranchs: In the family Paludomidae, 20 genera belong to the subfamily Hauttecoeuriinae, and 19 of these are restricted to Lake Tanganyika. The most speciose genus is the non-thalassoid rock dwelling genus *Lavigeria,* which is thought to include 18 species. However, although a diagnostic key does exist, a number of these species have not yet been fully described, being indicated by *Lavigeria* sp P, *Lavigeria* sp X, etc. (West *et al.* 2003). These species vary in their threatened status, depending on their range and the localized impacts of sedimentation along the lake shore. These species groups would benefit from review once the taxonomy has been revised, as more species may be found to be threatened if their ranges are more restricted than currently thought. The numerous prosobranch species, with extremely variable shapes, led Michel *et al.* (2004) to suggest that the lake molluscs formed species flocks in the same way as the cichlid fishes (West *et al.* 2003). Various fish, also endemic to the lake, are dependent on the presence of these molluscs as their food source.

Freshwater bivalves: Richness of bivalves is lower than that of gastropods in the largest African Lakes (see Table 4.2) There are three genera of African freshwater mussels that are each monotypic and endemic to Lake Tanganyika. *Grandidieria burtoni* and *Pseudospatha tanganyicensis* are assessed as Least Concern, but *Brazzaea anceyi* is considered Vulnerable. Other mussels, such as *Nyassunio ujijiensis*, are known from few specimens, and as a result their status is Data Deficient. Another genus, *Moncetia,* is represented by a single species *M. anceyi,* which is apparently also endemic to Lake Tanganyika and is listed as Near Threatened. Mandahl-Barth (1988) considered *Moncetia* to be a synonym of *Chambardia* (and *Spathopsis*), and reported that this species had never been collected alive; however he was apparently unaware of the study by Kondo (1984).

Lake Malawi is less saline and shallower than Lake Tanganyika, with a mollusc fauna which is about 60% endemic to the lake and with no gastropod taxa shared between the two lakes (Brown 1994). The shore is mixed, with rocky shores separated by sandy bays and small estuaries, and the lake-level is known to be subject to seasonal changes in rainfall since the Quaternary Period. Currently, no endemic genera are recognized in Lake Malawi, unlike in Lake Tanganyika. Again, there are a number of lake endemic molluscivorous fish that are dependent on the presence of molluscs as their food source. A number of genera are highly specious in Lake Malawi. For example, the family Thiaridae includes eight endemic species in the genus *Melanoides* (Brown 1994). Recent molecular studies have shown that these eight endemic species, with highly distinctive shells, do not differ genetically and are parthenogenetic clonal lineages (Genner *et al.* 2007). Some of the more widespread families also include localized endemic species, such as *Lanistes nasutus,* an apple-snail (Ampullaridae) that is restricted to Lake Malawi. *L. nasutus* is a thin shelled elegantly shaped deep-water species found at a depth of 46 to 82m. Of the freshwater mussels endemic to Lake Malawi, two species, *Mutela alata* and *Chambardia nyassaensis*, are categorized as Vulnerable, due to impacts of sedimentation, *Coelatura hypsiprymna* was assessed as Near Threatened, whilst the other endemics such as *Nyassunio nyassaensis* were considered Least Concern.

Lake Victoria is shallower than the other great lakes (maximum depth of 80m), has a lower salinity than Lake Tanganyika, and possesses a shoreline with extensive papyrus swamps, open sandy beaches and stony shores (Brown 1994). There is considerable variability within some species, and Brown (1994) suggests these may either be in a status of partial speciation from periods of low lake levels, or are just poorly defined requiring further investigation of their genetic distinctness. The African viviparid fauna in the lake included six species in the genus *Bellamya*. Ongoing investigations by Lange (pers. comm.) should provide better knowledge of the true distribution ranges of populations within the lake as, for example, *Bellamya phthinotropis* has a restricted range within the lake, being currently only found in the south-west part. Freshwater mussels of note are *Eupera crassa*, which is assessed as Critically Endangered, and *Aspatharia divaricata*, which is considered Vulnerable (Graf *et al.* 2011), and the taxonomic status of *Mutela bourguignati* in Lake Victoria has yet to be rigorously determined.

View of the Great Lakes region from near Kigali, Rwanda. © IUCN/ INTU BOEDHIHARTONO

Lake Mweru, a lake in the upper part of the Congo Basin in Zambia, has several endemic species of mollusc. Some of these species are restricted to the lake, whereas others are also present in the lower reaches of the Luapula River which drains into the south edge of lake, which is very shallow (15m depth (Brown 1994)), with extensive marshes and papyrus swamps along the fringes. Pilsbry and Bequaert (1927) commented on the vulnerability of the fauna, and Brown (1994) commented on the unusual richness of this shallow lake. There are eight endemic Gastropoda taxa, as well as two endemic monotypic freshwater mussel genera. Species of note are *Mweruella mweruensis*, which is regarded as Vulnerable, and *Prisodontopsis aviculaeformis*, which is assessed as Endangered.

4.1.3 Molluscan diversity in artesian basins

The highest diversity of freshwater molluscs is, as for many other parts of the world, found in artesian basins, and largely comprises the spring-snails from the family Hydrobiidae. In Africa, especially the Maghreb region, spring-snails form a lower proportion of the endemic fauna (69 species – 11%), in contrast with Europe (around 610 species – 69% (Seddon pers. comm.)), North America (around 105 species – 18%) and Australia (252 species – 49% (Strong *et al.* 2008)). The majority of this diversity in the Maghreb region is found in springs fed by aquifers in the limestone mountainous regions (Ghamizi 1998; Van Damme *et al.* 2010). More than 75% of the Maghrebian prosobranchs are assessed as threatened or are locally extirpated (Van Damme *et al.* 2010). By contrast, there are proportionately few endemic hydrobiids in the Afrotropical fauna south of the Sahara, possibly a reflection of the origin of these radiations and the lack of limestone regions. One of these, *Lobogenes*, is a central and southern African endemic genus. In neighbouring Europe, the greatest radiations are found in the limestone regions south of the glacial limit (e.g., the Balkans and the Iberian peninsula (Arconada and Ramos 2003; Benke *et al.* 2009)). In northern Africa, the Maghreb is a centre of evolution and radiation of subterranean hydrobids. At least 13 genera are known from the region, but it is likely that further investigation, in particular in Algeria, could raise the number to more than 20 genera. There are, however, large parts of the region with artesian waters that remain to be surveyed, largely due to the difficulty of sampling interstitial groundwaters and, as such, there may be further unknown diversity within these systems.

The freshwater bivalves and most of the pulmonates found in these habitats are typically more widespread species tolerant of drying-out and, as such, are not considered to be threatened.

4.1.4 Molluscan diversity in saline lagoons, saltmarshes and mangroves

Molluscs of the coastal habitats of Afrotropical Africa show little spatial variation. However, some of the more range-restricted species are found in the saline lagoons, saltmarshes and mangroves that fringe large parts of the coastline. The saline lagoons have some very restricted range species, such as the species of *Tomichia* found in southern Africa. All species of *Tomichia* are sensitive to changes in their habitats caused by pollution and interference with the seasonal wet-dry regime (Kristensen *et al.* 2009a), so the majority have been assessed as threatened.

By contrast, the mangrove species tend to be more widespread, and are found in suitable habitats throughout the continent. For example, the family Littorinidae is a cosmopolitan family represented in Africa by a few species of *Littoraria*. Most of the African littorinids are not considered to be threatened. However, in some regions, such as the coastal swamps of western Africa, you find the "living fossils", *Afropomus* and *Saulea,* which are monotypic, are considered to be rare, and are threatened.

Three families of bivalve are typically found in brackish water habitats, and these families are mainly comprised of marine species. Recent checklists have listed 19 species of the family Donacide from tropical western Africa (Daget 1998; Bogan 2010). However, only 14 of these have been evaluated for the IUCN Red List. Ten species of *Egeria* occur in coastal western Africa (plus four species of unknown distribution that were not evaluated; one species that was evaluated is now considered invalid). Two species of *Cyrenoida*, of the family Cyrenoididae, are found in brackish/estuarine habitats in tropical western Africa, extending from Senegal to the Congo. The sole Afrotropical representative of the Dreissenidae is *Mytilopsis africanus*, which is distributed widely in the estuarine/brackish waters of coastal western Africa, from Senegal to the mouth of the Congo. Most of these species are assessed as Least Concern, although some, where the distributional data were uncertain, are categorized as Data Deficient.

4.1.5 Molluscan diversity in crater lakes

Crater lakes are present in many parts of Africa, including Cameroon, Ethiopia and eastern Africa. These small, sheltered, but deep lakes are usually species-poor, as they are often oxygen deficient below 20m depth and, in some cases, are too saline for molluscs. Some species have, however, managed to colonise these lakes, probably though transportation by birds, and their relative isolation may have driven their evolution into new species. The Cameroon crater lakes have a richer fauna than might be expected, including one possibly endemic species, *Bulinus camerunensis* (EN). In the western Uganda crater lakes eight gastropods and three bivalves were recorded by Mandahl-Barth, including two endemics, *Gabbiella kichwambae* and *Bulinus tropicus toroensis*; these taxa require further investigations, using molecular systematics, to establish their status (Brown 1994).

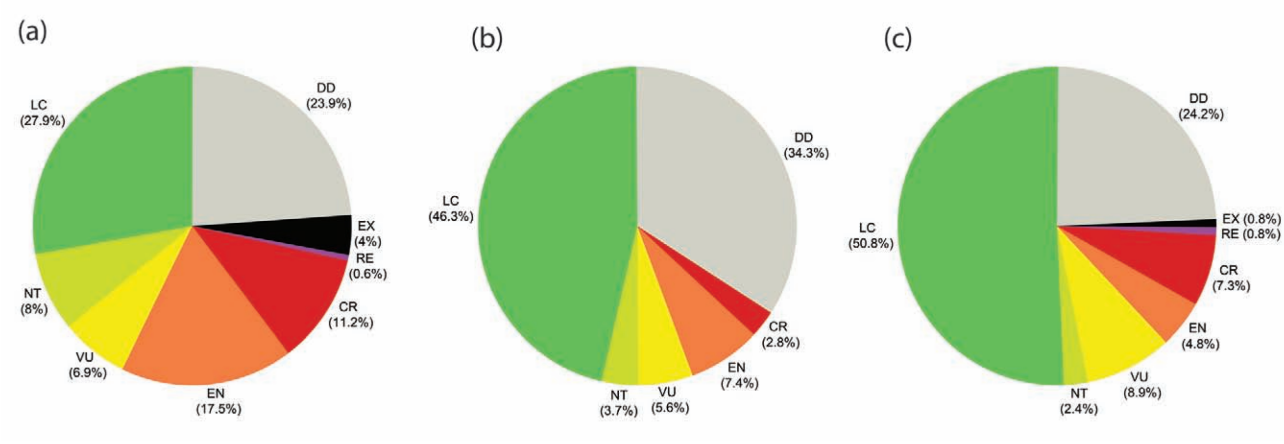
A team of Moroccan and Spanish malacologists aided by local youngsters collecting Margaritifera marocana *in the Oued Abid (Morocco). After tissue samples were taken, the animals of this last viable population of the species were placed back in the river.*

© MOHAMMED GHAMIZI

Lake Awing, one of the crater lakes in Cameroon.

© KLAAS-DOUWE DIJKSTRA

Figure 4.3. The proportion (%) of freshwater mollusc species in each regional IUCN Red List Category in mainland continental Africa, in the gastropod groups: a) the prosobranchs; b) the pulmonates; and c) the bivalves.



4.1.6 Molluscan diversity in montane lakes

The high mountain areas in eastern Africa and Ethiopia have small tarns (a mountain lake or pool) at high altitude. As for the crater lakes, these are isolated, and support some endemic species, possibly also as a result of their isolation. Although most species of the Afro-tropical pea-clams (*Pisidium* spp.) are assessed as being of Least Concern (six species) or Data Deficient (six species), some species, such as *P. ethiopicum,* are considered Critically Endangered, having a distribution limited to a few lakes in Ethiopia. Two more species occurring in high-elevation montane lakes in Eastern Africa (Warui *et al.* 2001) are assessed as Vulnerable (*P. artifex*) and Near Threatened (*P. montigenum*). Species in these montane lakes are threatened by the introduction of non-native fish species for sport fishing, as well as by their vulnerability to potential changes in lake levels due to climate variability and increased frequency of drought.

4.2 Conservation status of freshwater molluscs

The first species from the region to be placed on the IUCN Red List of Threatened Species came from a major review of the freshwater gastropods undertaken by David Brown in 1994. This survey used the first set of quantitative IUCN criteria (version 2.3) and resulted in the listing of 68 species, mainly those found in the regional hotspots in the African Rift Valley lakes and western Africa. However, Brown's review, published by IUCN (Baillie and Groombridge 1996) did not include assessments for any of the Data Deficient or Least Concern species, and so the figures obtained could not provide an overview of the status of freshwater biodiversity for the continent.

This IUCN pan-African project is the first study that provides a comprehensive overview of the conservation status of the region's freshwater molluscan fauna. In this project, the conservation status of each species of freshwater mollusc was assessed by applying the IUCN Red List Categories and Criteria: Version 3.1 on a regional scale (IUCN 2001). For those species endemic to continental Africa, their regional IUCN Red List status is equivalent to their global status, such that assessments for all endemic species are added to the global IUCN Red List. For those species with distributions extending beyond Africa, regional assessments have also been completed to determine their status within the African part of their ranges. These regional assessments will contribute to an ongoing global assessment of all freshwater molluscs.

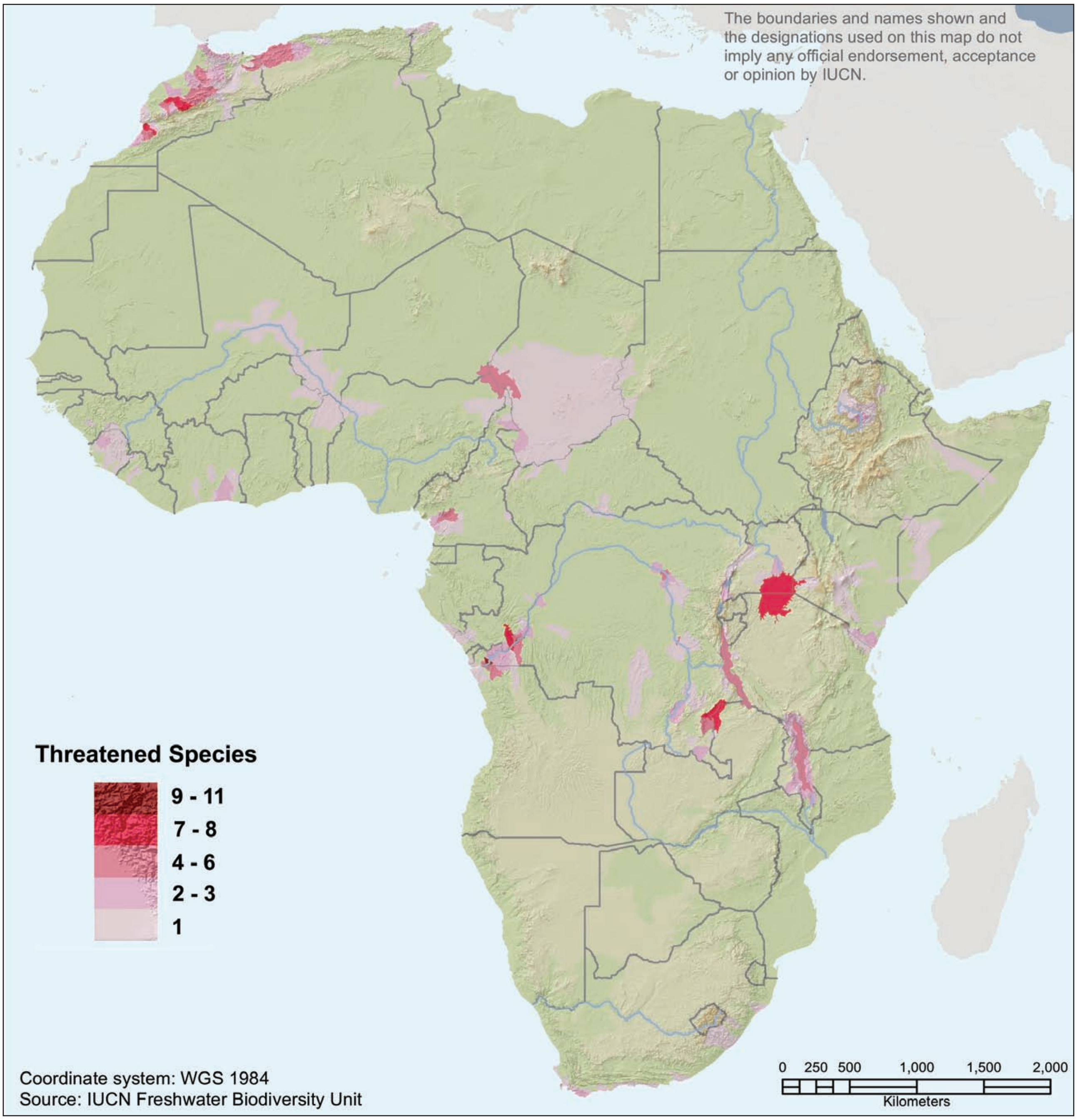
There is considerable variability between the regions in the proportion of threatened species and the proportion of Data Deficient species. This, in part, reflects the level of recent

Table 4.3. The number of African mollusc species in each IUCN Red List Category, by region.

Region	No of Species	% Threatened	% Data Deficient
Eastern Africa	228*	22%	38%
Southern Africa	122	9%	24%
Western Africa	95	12%	16%
Central Africa	159	31%	19%
Northern Africa	155	45%	17%
Pan-Africa	**624***	**29%**	**28%**

*Some subspecies regarded as species in regional treatments, and undescribed taxa included in regional treatments, are as a precautionary measure not included in the pan-Africa listings for endemic species.

Figure 4.4. The distribution of threatened freshwater mollusc species across mainland continental Africa. Species richness = number of species per river/lake sub-catchment.



taxonomic research, the amount of recent field survey, the application of molecular systematic, and the number of local scientists and overseas researchers working on each taxonomic group. In general, the prosobranchs are the most threatened of the freshwater molluscs group, followed by the bivalves and then the pulmonates (Table 4.3; Figure 4.3).

4.2.1 Threatened species distribution patterns

Apparent regional variations in the distribution patterns of threatened species in part reflect regional differences in the status of taxonomic research, levels of survey work, and numbers of range restricted endemic species, which are often threatened. These factors should be taken into consideration when interpreting the species distribution maps.

Sites highlighted as having the most threatened species include the Maghreb, the East African Lakes (Lake Victoria, Lake Tanganyika and Lake Malawi) and the Congo Basin (Figure 4.4). The Lake Chad catchment is shown to include a number of threatened species, but these require taxonomic review and, as such, have not been highlighted as requiring conservation actions. In the Congo Basin, the majority of endemic species in the Lower Congo Rapids and Malebo Pool were assessed as threatened, representing a quarter of the total molluscan richness in those areas (Graf *et al.* 2011). Most of these were range-restricted species living within specialised habitats, such as rapids.

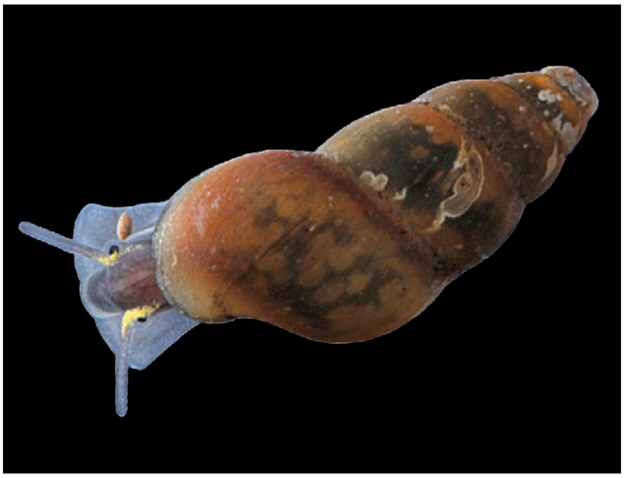
Pilsbry and Bequaert (1927) commented on the vulnerability of the fauna of the Lake Mweru in central Africa to its gradual infilling. There is, however, an ongoing debate as to whether the rate of infill is likely to impact both the endemic species and those species also present in the lower reaches of the Luapula River that were not considered threatened. Here, we have followed the precautionary approach, such that the three endemic species in the genus *Bellamya* are assessed as Critically Endangered. Two monotypic freshwater mussel genera are also endemic to Lake Mweru, of which *Mweruella mweruensis* is regarded as Vulnerable and *Prisodontopsis aviculaeformis* is assessed as Endangered.

In southern Africa, some of the more unusual endemics are found in the coastal regions in habitats ranging from temporary saline pans to perennial freshwater streams. Herbert (1998) noted that of the seven species of *Tomichia* occurring in South Africa, three species were included in the 1996 IUCN Red List (Baillie and Groombridge 1996), one assessed as Extinct (*Tomichia cawstoni*), one Critically Endangered (*Tomichia natalensis*), and one Endangered (*Tomichia rogersi*), as the habitats of all were considered vulnerable to destruction by man (Brown 1994). This more recent review of the present status of populations of all *Tomichia* species in South Africa noted that although *T. rogersi* has a restricted range, it cannot be assessed as threatened, as there are no known plausible threats to the springs that these snails inhabit, and it is therefore assessed as Near Threatened. Taking into consideration its limited occurrence, it is still important that populations are monitored closely.

The Zambezi headwaters were considered important for other groups of threatened freshwater taxa (Darwall *et al.* 2009), but less so for molluscs, as the majority of the species are relatively widespread.

4.2.1.1 Changes since the 1996 assessment

There have been several major changes in taxonomy since the previous assessment in 1996, and some of these have changed the total number of species and the number of



Tomichia cawstoni*, a Critically Endangered species currently only known from one location, a stream near the Eastern Cape Province, South Africa.* © DAI HERBERT

range restricted species, with consequent impacts to species conservation status.

The family Melanopsidae was split from the family Thiaridae on the basis of anatomical characters (Houbrick 1988). One genus in this family, *Melanopsis,* occurs in the Maghreb, where it is represented by about 13 species, some of which are Critically Endangered. These are currently considered as distinct species (Heller *et al.* 2005) rather than belonging to a single species, *M. praemorsa*, as was Brown's (1994) opinion. Brown considered them a single species, arguing that asexual reproduction creates clonal lineages that differ spectacularly in shell form and colour but vary very little in genetic make-up. Heller *et al.* (2005) reviewed the geological history and found that the different morphs have been very stable, and that their descendants are exact copies of the mothers. As a single species, *M. praemorsa* was considered widespread and therefore Least Concern; however, now the species has been spilt into more than 13 species, some are regarded as range restricted, with threats from exploitation of water sources, and hence are now considered to be threatened.

There have also been new species descriptions within the Lake Tanganyika gastropods resulting from recent research and survey work by West *et al.* (2003). This work, along with the GEF Lake Tanganyika Biodiversity Project, has increased our knowledge of the distribution of the previously known fauna and the newly described species.

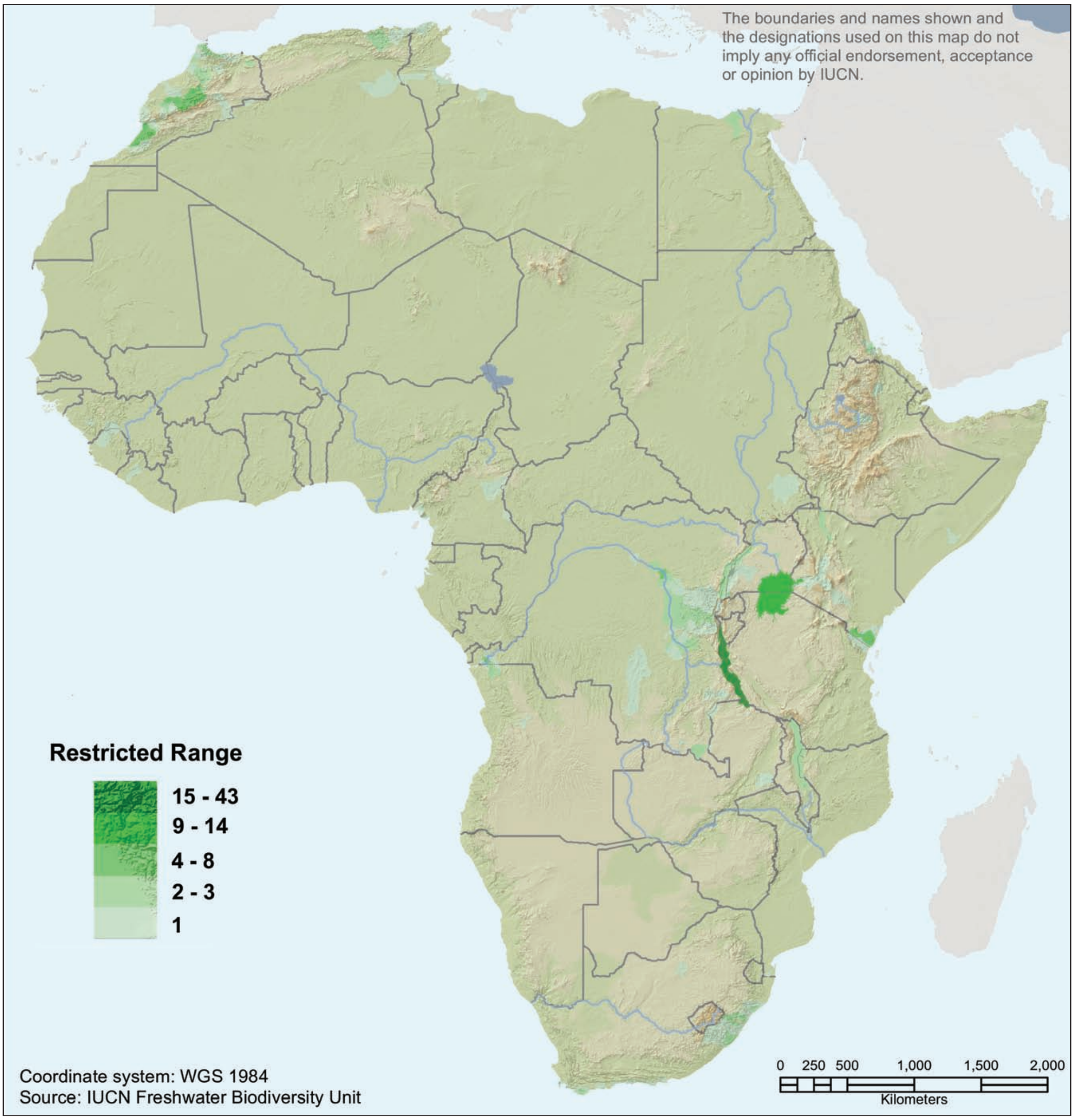
In addition to the taxonomic changes and increased survey effort mentioned above, the latest version of the IUCN Categories and Criteria (version 3.1) and the guidelines have led to a number of changes in the way assessments are conducted, including, for example, the way that range data should be interpreted. In conclusion, few of the observed changes in category from the 1996 assessments made by Brown (1996) reflect genuine changes in the status of the species but rather taxonomic changes, new information, and changes to the thresholds of the Red List criteria themselves.

4.2.2 Restricted range species

Africa is a continent with many restricted range freshwater gastropods, most of which are prosobranchs. This is partly due to a number of reasons: the great relative age of some of the smaller coastal drainages, particularly in the southern part of western Africa and in Cameroon; the presence of the large lakes in the eastern rift system, and of the vast, diversified and old hydrographic system of the Congo; and the isolated Haut Atlas, Atlas Saharien, Anti Atlas, and Moyen Atlas mountain ranges in the Maghreb.

Restricted range species are found only exceptionally throughout the rest of Africa. This is true for most of the northern African region, as well as south and east

Figure 4.5. The distribution of restricted range mollusc species in mainland continental Africa, showing hotspots of diversity in the Maghreb and the Rift Valley Lakes. Species richness = number of species per river/ lake sub-catchment.

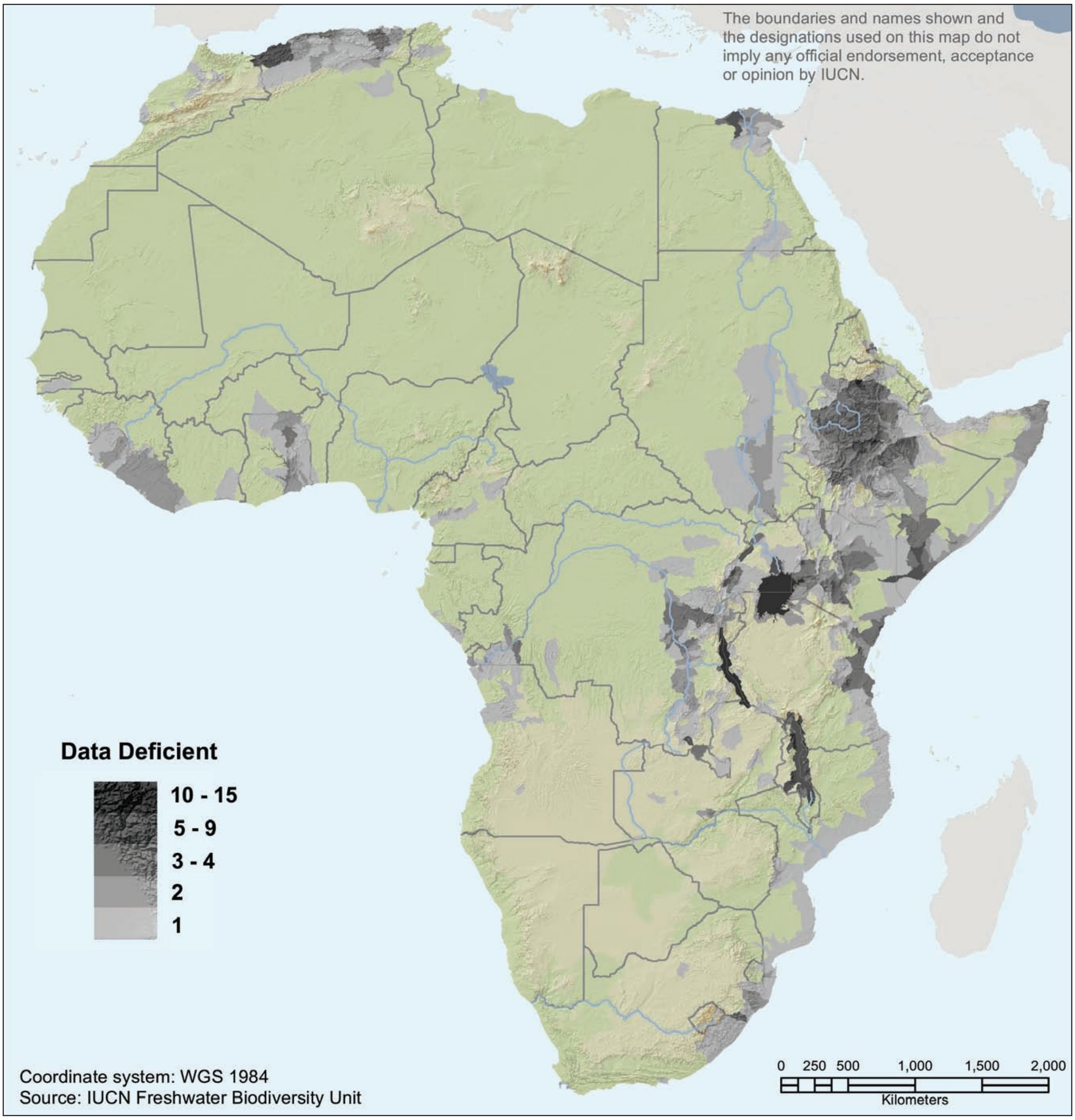


of the Atlas range, i.e., Mauritania, Mali, Libya, central and southern Algeria and Egypt, the whole of the north-eastern African Region (Eritrea, Sudan, Ethiopia, Djibouti and Somalia), with the exception of a couple of endemic species in south Somalia and south Ethiopia. The same is also true for the northern part of the western African region, i.e., the basins of the Niger and Senegal that suffered severe drying events during the Pleistocene some 20,000 years ago.

In southern Africa, severe climate fluctuations during the Pleistocene made this region inhospitable for Afrotropical prosobranchs, so there are no restricted range species with the exception of species within the genera *Septaria* (found on the coast of Natal) and *Tomichia,* some of which are confined to small stretches of the coast of Natal and the Cape Province.

Species with the most restricted ranges, sometimes of only a few square metres, are the Maghrebian hydrobids that are found in one or two springs or wells. Although their true range underground may be more extensive, they are assessed as threatened on a precautionary basis, as the extent of their range in artesian waters is uncertain; some species may be truly restricted to the wells, whereas others which are only seen in flood events at outlets are actually distributed more widely in the groundwater supplying the outlets.

Figure 4.6. Distribution of the freshwater molluscs assessed as Data Deficient, showing that large numbers of species in the centres of diversity in the African lakes and northern Africa require additional taxonomic research, field survey, and information on relevant threats in order to make an assessment of their conservation status. Species richness = number of species per river/lake sub-catchment.



In small river basins and marshes along Africa's Atlantic coast, from Côte d'Ivoire to the Republic of the Congo, as well along the coast of the Indian Ocean from southern Somalia to Mozambique, a number of species and even monotypic genera (e.g., *Soapitia dageti* from the Konkouré River near Soapiti, Liberia, and *Valvatorbis mauritii* in the Congo River at Ango-Ango near Matadi, Republic of the Congo) are only known from the type locality. This is only the case for small sized species belonging to the families Hydrobiidae, Assimineidae and Bithyniidae, which are easily overlooked. While their true range must be larger than the type locality (the stretch of rapids near Matadi is not the easiest place to sample), many are habitat specialists confined to a specific habitat of limited extent, such as stones in rapids. These species have, therefore, also been assessed as threatened.

Finally, there are the endemics of the large Rift Valley lakes. In the report on the molluscs of the eastern African region (Darwall *et al.* 2005), the original assessors apparently did not apply the same criteria for all lakes, some considering threats likely to spread throughout and impact a whole rift lake, while others did not. Admittedly, it is not an easy exercise, as this depends on the level of threat and the area over which it can impact within a short period of time. In deep, meromictic lakes like Lakes Tanganyika and Malawi,

Diving for mussels in the Upper Chambeshi River, Upper Congo. © DANIEL GRAF AND KEVIN CUMMINGS

the benthic fauna is confined to a small oxygen-rich stretch close to the coast (upper 80m in Lake Malawi, and upper 100 to 200m in Lake Tanganyika). In the anoxic or hypoxic zones there is no macro-life. Barring a few exceptions, all Lake Tanganyika endemics have been assessed as not threatened (Least Concern, Data Deficient or Near Threatened) as many, whilst range-restricted, occur in a greater number of locations than meets the threshold for a threatened category, given the localized nature of the threats to the lake's sublittoral zone. In contrast, some Lake Malawi endemics, though found throughout the sublittoral (e.g., *Lanistes nyassanus* and *L. solidus*) are considered as Endangered, but poor quality of data available at the time of assessment may require the assessments to be revised. Ongoing investigations leading to a better knowledge of the real distribution ranges of populations in these lakes will soon be available. The same is true for the prosobranchs of other lakes where current information shows species to have restricted distributions within lakes, such as *Bellamya phthinotropis*, which is reported as only being found in the south-west part of Lake Victoria, and *Gabbiella neothaumiformis*, which has only been recovered from a very restricted area in the south-west part of Lake Chad (Kristensen *et al.* 2009b). Such species have been assessed as threatened. For other endemics, such as *Gabbiella humerosa alberti* of Lake Albert, the status of Endangered may need re-evaluation during the next assessment as more information becomes available.

4.2.3 Data Deficient species

The two main reasons for Data Deficiency in molluscs are taxonomic uncertainty and poor geographic knowledge. The regions with the highest proportion of Data Deficient species are northern Africa, the east African Lakes, and western Africa (Figure 4.6).

In southern Africa, taxonomic issues relating to a number of small limpet species in the genera *Ferrissia* and *Burnupia* are the main reasons behind these species being classified as Data Deficient. This contrasts with western Africa, where there is little recent survey data available and, as such, more species were identified as Data Deficient due to lack of recent data on distributions (Figure 4.6). In the eastern, western and southern African regions, knowledge is, in general, reasonable due to surveys conducted in the second half of the 20th century, funded by the World Health Authority (WHO) to study African freshwater snails that play a role in the transmission of schistosomiasis and other parasites. As no schistosomiasis occurs in northern Africa, this region was not incorporated in the research campaigns funded by WHO, and there are subsequently a higher number of species listed as Data Deficient due to a lack of distributional data. In northern Africa, the high level of taxonomic disarray within the freshwater molluscs is largely a consequence of many species being described by members of the 19th century French "Ecole Nouvelle",

Table 4.4. Extinct mollusc species in Africa.

Family	Genus	Species	IUCN Status
Bithyniidae	*Bithynia*	*tentaculata*	Regionally Extinct
Bithyniidae	*Bithynia*	*leachii*	Regionally Extinct
Hydrobiidae	*Bythinella*	*limnopsis*	Extinct
Hydrobiidae	*Bythinella*	*mauritanica*	Extinct
Hydrobiidae	*Bythinella*	*microcochlia*	Extinct
Hydrobiidae	*Bythinella*	*punica*	Extinct
Hydrobiidae	*Hydrobia*	*gracilis*	Extinct
Hydrobiidae	*Mercuria*	*letourneuxiana*	Extinct
Hydrobiidae	*Pseudamnicola*	*doumeti*	Extinct
Hydrobiidae	*Pseudamnicola*	*globulina*	Extinct
Hydrobiidae	*Pseudamnicola*	*barratei*	Extinct
Hydrobiidae	*Pseudamnicola*	*desertorum*	Extinct
Hydrobiidae	*Pseudamnicola*	*oudrefica*	Extinct
Hydrobiidae	*Pseudamnicola*	*ragia*	Extinct
Hydrobiidae	*Pseudamnicola*	*latasteana*	Extinct
Hydrobiidae	*Pseudamnicola*	*singularis*	Extinct

where all variants were given a different species name. Few recent taxonomic revisions have been made, so that, for quite a number of species described between *ca* 1850-1920, there remains doubt as to their taxonomic validity, and we still lack sufficient information on the status of their populations since that period. This situation is gradually changing as a new generation of Maghrebian malacologists has emerged who are starting to do some outstanding work. In Egypt, Ethiopia and Sudan the number of Data Deficient species is relatively low, as these countries were also included in the WHO campaigns.

In north-eastern Africa, the regions of Eritrea and Somalia have received little attention. Eritrea has virtually no freshwater, and hence there has been little survey effort in the region. However, by contrast, the brackish water fauna is quite rich, but apparently no efforts have been made to re-examine it since the late 19th century. As such, many mangrove species, some of which were described from the Eritrean islands only, are also recorded as Data Deficient.

Difficulties in accessing some countries due to political unrest have also limited the available knowledge for a number of areas. For example, there are virtually no data available for Somalia since 1930, and even before 1930 only a few malacologists ventured into the region. Similarly, countries in southern Africa, Angola and Mozambique, all with a long history of conflicts, have large areas where little survey work has been conducted. These regions require extensive field survey in order to better understand species distributions patterns and the impacts of threatening activities.

4.2.4 Extinction patterns

There are a few possible extinctions or regional extinctions in Africa south of the Sahara, but most confirmed extinctions lie in the Maghreb region of north-western Africa (Morocco, Algeria and Tunisia), where 14 species are considered to be Extinct (Table 4.4). This region has a high proportion of small hydrobid snails that are range-restricted, occurring in only one or two springs, wells or thermal sources. These species have suffered from a combination of water pollution and the over-abstraction of water from the springs and underlying aquifers, which has led to many springs drying out. The number of extirpated species may be considerably higher, as this subterranean malacofauna was taxonomically lumped in the 19th century. By the time researchers such as Boeters (1976) tried to re-investigate the sites in the 1970s the water sources and freshwater springs were already lost or disturbed at many locations, so it was no longer possible to review the taxonomy such that the true number of extirpated species will never be known; they could be two or three times the number cited above.

The Regionally Extinct gastropods are also restricted to northern Africa. These are widespread Palaearctic species still found throughout Europe and Asia Minor that have been lost from the southern edges of their ranges in a few localities in Mediterranean Africa. In the rest of Africa there are no prosobranchs listed as Extinct, though it is probable that some of the central African species, such as *Potadoma kadeii* (here listed as Critically Endangered) from Cameroon and *Tomichia cawstoni* (also listed as Critically Endangered) from South Africa, may be already Extinct, but more extensive field surveys are required before this can be confirmed.

Table 4.5. Undescribed threatened freshwater molluscs endemic to Africa.

Family	Genus	Species	Subspecies	RL Category
Hydrobiidae	*Belgrandiella*	sp. nov. 'ramdanii'		CR
Hydrobiidae	*Bythinella*	sp. nov. 'tiznitensis'		CR
Hydrobiidae	*Heideella*	sp. nov. 'valai'		CR
Hydrobiidae	*Heideella*	sp. nov. 'kerdouensis'		CR
Hydrobiidae	*Heideella*	sp. nov. 'makhfamanensis'		CR
Hydrobiidae	*Semisalsa*	*aponensis*	subsp. nov. 'taramtensis'	CR
Hydrobiidae	*Giustia*	sp. nov. 'meskiensis'		EN
Hydrobiidae	*Heideella*	sp. nov. 'boulali'		EN
Hydrobiidae	*Heideella*	sp. nov. 'salahi'		EN
Hydrobiidae	*Horatia*	sp. nov. 'aghbalensis'		EN
Hydrobiidae	*Horatia*	sp. nov. 'haasei'		EN
Hydrobiidae	*Mercuria*	sp. nov. 'mirlheftensis'		EN
Hydrobiidae	*Belgrandia*	sp. nov. 'wiwanensis'		VU
Hydrobiidae	*Heideella*	*andraea*	subsp. nov. 'boulanouari'	VU

4.2.5 Undescribed species

There are some recognized species in northern Africa and Lake Tanganyika that have not yet formally been described which are clearly threatened with extinction (Table 4.5). These species require formal descriptions in order to be included in the IUCN Red List. Other species that have yet to be described also exist in Africa, and have yet to be fully investigated (Table 4.6).

Most of these are range-restricted species known from northern Africa, where the water sources in which they are found have been severely depleted through habitat loss due to over-abstraction of water, and through habitat degradation resulting from pollution and saline intrusions into their groundwaters (Van Damme *et al.* 2010). In Lake Tanganyika, Michel *et al.* (2004) and West *et al.* (2003) report many new possible *Lavigeria* species along the lake margins. Many of these appear to be quite widespread, and hence, when formally described, will probably be assessed as Least Concern. However, at least three, possibly four, of these undescribed taxa have a limited range, and once confirmed as valid species may be classified as threatened by sedimentation and pollution from adjacent urban areas.

Table 4.6. Undescribed Data Deficient freshwater molluscs endemic to Africa.

Family	Genus	Species	Source	RL Category	Possible Status
Paludomidae	*Lavigeria*	sp. B	West *et al.* (2003) p. 55	DD	Probably LC
Paludomidae	*Lavigeria*	sp. C	West *et al.* (2003) p. 51	DD	Probably LC
Paludomidae	*Lavigeria*	sp. D	West *et al.* (2003) p. 53-4	DD	Probably LC
Paludomidae	*Lavigeria*	sp. F	West *et al.* (2003) p. 52	DD	Probably LC
Paludomidae	*Lavigeria*	sp. G	West *et al.* (2003) p. 50	DD	Probably LC
Paludomidae	*Lavigeria*	sp. H	West *et al.* (2003) p. 54	DD	Probably LC
Paludomidae	*Lavigeria*	sp. J	West *et al.* (2003) p. 41-2	DD	Limited range, but uncertain threats
Paludomidae	*Lavigeria*	sp. K	West *et al.* (2003) p. 42	DD	Limited range, but uncertain threats
Paludomidae	*Lavigeria*	sp. M	West *et al.* (2003) p. 52	DD	Probably LC
Paludomidae	*Lavigeria*	sp. N	West *et al.* (2003) p. 47	DD	Probably LC
Paludomidae	*Lavigeria*	sp. O	West *et al.* (2003) p. 43	DD	Uncertain range extent and threats
Paludomidae	*Lavigeria*	sp. P	West *et al.* (2003) p. 45-6	DD	Probably LC
Paludomidae	*Lavigeria*	sp. Q	West *et al.* (2003) p. 46	DD	Probably LC
Paludomidae	*Lavigeria*	sp. R	West *et al.* (2003) p. 49	DD	Uncertain range extent; DD?
Paludomidae	*Lavigeria*	sp. S	West *et al.* (2003) p. 56	DD	Probably LC
Paludomidae	*Lavigeria*	sp. T	West *et al.* (2003) p. 56-7	DD	Probably LC

These are all species that have been listed in books or PhD. theses but are yet to be formally described, so are not yet placed on the IUCN Red List.

4.3 Main threats

4.3.1 Regional patterns of threat

There are multiple sources of threats to freshwater molluscs in Africa. In the majority of cases there is usually a series of threats that combine to lead to declining populations (Figure 4.7). The most significant of these threats is habitat loss or degradation, through multiple actions such as agricultural expansion, infrastructure development (e.g., dams) and deforestation, with 58% of threatened species suffering the consequences. Although this problem is widespread throughout Africa, the causes of habitat decline vary between regions, as explained below. Water pollution from a range of sources is another major threat, which impacts 63% of threatened species, but again, the sources of the pollution vary from region to region. A number of species are also suffering from the direct impacts of molluscicides employed to reduce gastropod species, which are vectors of bilharzia (Kristiansen and Brown 1999). In contrast to other taxa, such as fishes, invasive species do not appear to have had a notable impact on native species of mollusc. Invasive mollusc species are present and have had an impact on some species, but they are only recorded as a significant threat for fewer than 5% of threatened species. Finally, some species are threatened by "natural disasters", which in this case refers largely to the increased frequency of drought.

In western Africa, the habitat quality in rivers is declining primarily as a result of the extensive use of pesticides in crop plantations, expansion of bauxite mining and damming river flows for hydro-electric power generation. This impacts a number of restricted range endemic species from Sierra Leone, Côte d'Ivoire and Guinea, through the combination of water pollution, sedimentation, altered river flow regimes and increased water temperature. *Sierraia outambensis* (CR) and *Soapitia dageti* (CR) are two notable species facing these combined threats.

In eastern Africa, threats from declining habitat quality are due to increased levels of sedimentation from agricultural activity in the catchment, use of molluscicides, and the impact of invasive species such as water hyacinth and Nile Perch. Although, as yet, there are no specific studies on the impact of sedimentation on molluscs, the impact of increased sedimentation is recognised to impact most benthic organisms in Lake Tanganyika (McIntyre *et al.* 2005). Lake Victoria and the Ethiopian lakes have been stocked with introduced fish species, many of which are molluscivores or omnivores, whose predation on molluscs could have long-term impacts on the population levels of the native species.

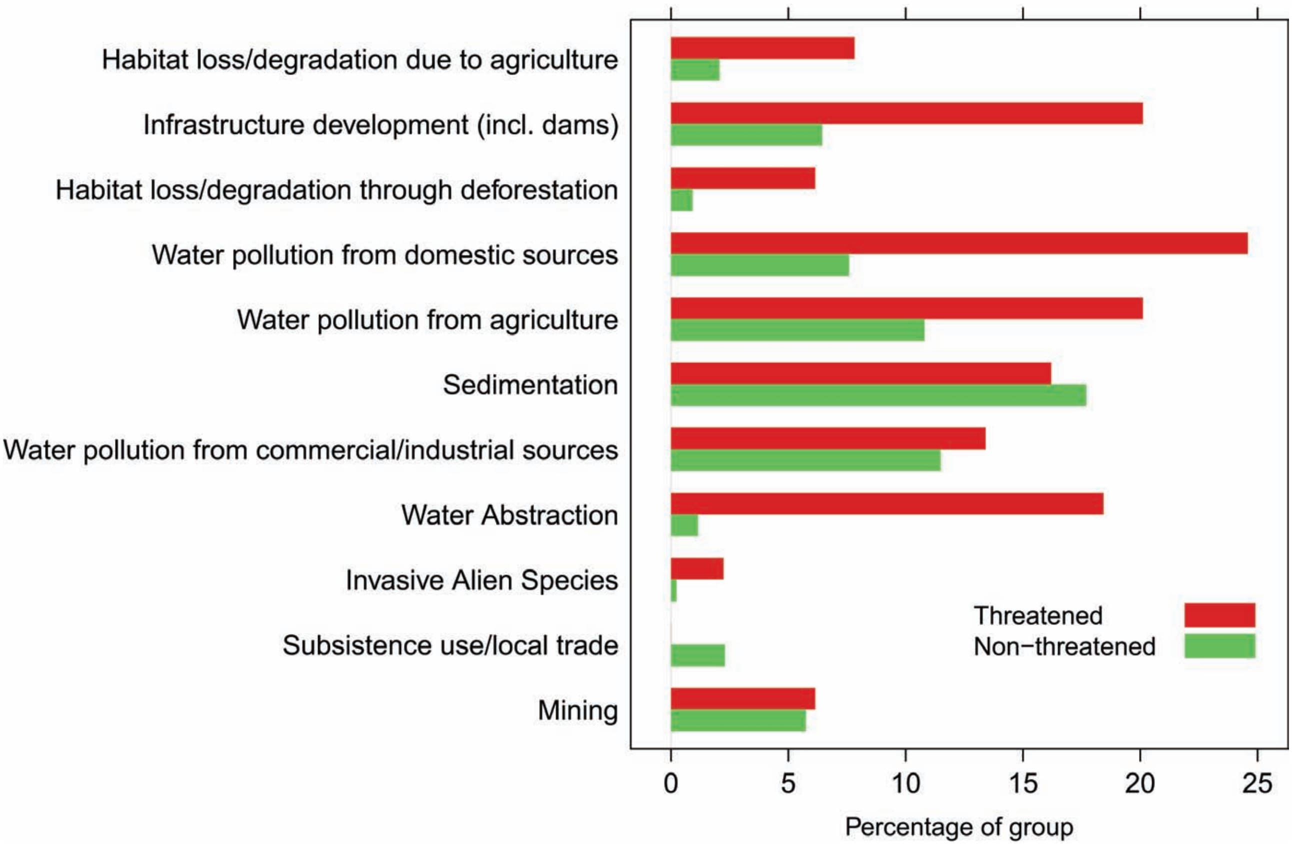
In southern Africa, the decline in habitat quality is associated with dam construction for hydro-electric power generation, over-abstraction of water for irrigation, water pollution from domestic and industrial sources, sedimentation from mining waste, dune mining in southern Africa, and use of molluscicides (Kristiansen *et al.* 2009a).

In northern Africa, habitat quality has declined as a result of the over-abstraction of surface and underground waters for domestic, industrial and agricultural use, and the subsequent return of waters that are heavily polluted and untreated (Van Damme *et al.* 2010). Even in regions that are sparsely populated, water pollution is often quite significant, in many cases as a result of the now common use of detergents, chemical fertilizers and pesticides (Van Damme *et al.* 2010). The most dramatic effects can be clearly observed in the Mediterranean part of the northern African region which is relatively green and fertile, and where demographic growth has by far overreached the ecological carrying capacity of the environment (Van Damme *et al.* 2010). In this area, species are rapidly disappearing, particularly in the lowlands, where urban expansion and agricultural exploitation are highest. In the Maghreb, with its numerous underground hydrobid endemics, water extraction from the aquifers has resulted in the intrusion of seawater into the karstic underground systems, changing the water quality and leaving the habitats in aquifers unsuitable for many species. In Egypt, the reduced flow of the Nile has resulted in a retreat of the Nile Delta with subsequent impacts on the local ecology (Van Damme *et al.* 2010).

Pollution of a small river close to Ouagadougou, the capital of Burkina Faso. © TIMO MORITZ

Newly built dam for irrigation, south-west Burkina Faso. © TIMO MORITZ

Figure 4.7. Principal threats to freshwater molluscs in mainland continental Africa.



In tropical western and central Africa, the major threat is the siltation and flow alteration of clear streams shaded by gallery forest, often resulting in open waters coloured red from laterite muds during the rainy season. Pollution by raw sewage is another important threat in this region, as is fish farming. After clearing gallery forests, areas of swamp are often formed that are too wet for farming and too dangerous for raising cattle. As a consequence, and in an effort to diversify local livelihoods, the FAO has introduced methods and provided material for stocking fish in existing lakes as well as in man-made fish ponds along riverbeds. Such actions have changed the ecology, which is now no longer suitable for many of the endemic prosobranchs.

4.3.2 Dams

In North America, dam construction during the early 1900s led to severe declines in the native molluscan faunas (Bogan 1993, 2008), and similar patterns are now beginning to be seen on other continents. In Africa, large dams are already constructed or proposed for many of the river catchments, to generate electricity for industrial and domestic use. The impacts of these dams are already being seen for a number of species, and the scale of this development is set to expand greatly over the next few years (Economic Commission for Africa 2003). Dam construction can impact freshwater molluscs in different ways, depending on the life-history strategy of the animal, making the impact of the construction of dams neither uniformly negative nor positive (Seddon 2000). Dams and their reservoirs form insurmountable barriers that will:

a) Cut off upstream populations of molluscs from downstream populations;

b) Lead to a loss of the underlying riverine habitats and their fauna;

c) Cause changes downstream of the dam, where part of the river is impacted by fluctuations in water level plus changing water-chemistry and water temperatures, potentially impacting life-cycles through changing reproductive patterns and reproductive success; and

d) Cause a loss of fish-host movement, potentially changing freshwater mussel reproductive success.

There are examples of beneficial construction. For example, Van Damme *et al.* (2010) reported that the gastropod fauna of the Nile downstream of the Aswan Dam seems to have improved, although this might alternatively be an effect of cessation in the use of huge amounts of molluscicides, as employed during the anti-bilharzia campaigns. According to Brown (1994), large prosobranch populations have also developed in the man-made Lake Kariba, but that seems to be an exception. In contrast, after the construction of Lake Volga in Ghana, there was an increase in the number of bilharzia-carrying species, and a corresponding loss of the native pulmonate species (Seddon 2000), with an overall decline in species diversity and species richness. In general, data from Europe and North America indicate biodiversity loss following dam construction, with the exception of opportunistic species such as *Melanoides tuberculatus* and some *Gabbiella* and *Hydrobia* species that appear to be transported by birds (Van Damme 1984). Studies of the effects of dam construction on gastropod faunas in Africa have not yet been carried out, but it is generally assumed that hydrological alterations from reservoirs, in particular reservoir release, are one of the two main causes of the local extirpation of gastropod populations in the USA (Pyron *et al.* 2008), and there is no reason to suspect that this is not also the case in Africa.

The planned Gibe III Dam on the Lower Omo River in Ethiopia will decrease the amount of water reaching Lake Turkana, which is the most alkaline of the African Great Lakes that still harbours a gastropod fauna, albeit a strongly impoverished one. One described species, *Gabbiella rosea*, is endemic to this lake, and a second species, referred to as "*Tomichia* sp.", is probably also an endemic. *Gabbiella rosea* presently occurs in vast densities, and is currently assessed as Least Concern, but it may rapidly become Extinct if water levels decline, increasing the alkalinity in the lake.

In central Africa, plans for the Grand Inga and the Inga III dams (see section 1.2, this volume) may have significant impacts on the high diversity hotspots, as any changes to the patterns of water flow and water quality may impact these species (Graf *et al.* 2011).

4.3.3 Water pollution

Decline in habitat quality in freshwater rivers and lakes is a problem throughout Africa. The causes of habitat decline are, however, quite variable. In western Africa, water quality in rivers is declining due to the expansion of bauxite mining. Some restricted range endemic species from Sierra Leone, Côte d'Ivoire and Guinea are impacted by a combination of mining waste and sedimentation, along with changing flow regime and increased water temperature. The most notable of these species are those in genera which are restricted to western Africa, such as *Sierraia outambensis* (CR) and *Soapitia dageti* (CR) (García *et al.* 2010; Kristiansen *et al.* 2009b). Raw sewage is also a problem in many parts of Africa. In most cases, domestic waste water and sewage is discharged directly back into rivers and lakes, polluting the downstream or local waters. In some areas these have had distinct impacts on range restricted species – for example, downstream of Brazzaville and Kinshasa on the Congo River, and bays close to Kigoma on Lake Tanganyika. Even in regions that are sparsely populated, water pollution is often quite dramatic because of the now common use of detergents, chemical fertilizers and pesticides.

4.3.4 Sedimentation

In tropical western and central Africa and in the East Africa lakes, a major threat to molluscs is siltation and subsequent alteration of the microhabitats required by some freshwater snails. Most African prosobranch species (unlike pulmonates) are benthic or epibenthic, tracing furrows through the surface of the bottom sediment, or they live within the sediment (e.g., *Melanoides* species). When river banks are cleared of their forest cover, nutrient-enriched soils rapidly accumulate in the rivers. These accumulations change the physical and chemical characteristics of the sediments through increased quantities of fine organic muds and depleted oxygen levels. Prosobranchs adapted to life on hard surfaces in swift running forest waters are also impacted as there is an increase in films of mud and fine silts that cover these stones, and the sediments foul their gills. Increased exposure to sunlight and decreasing stream velocities will also favour aquatic plant growth, which may benefit most pulmonates and some small prosobranch species, but it causes problems for the bottom dwelling prosobranchs that do not tolerate the change to extreme fluctuations in diurnal dissolved oxygen levels.

4.3.5 Invasive species – water hyacinth and other plants

Herbert (1998) noted that alien and highly invasive aquatic weeds (e.g., *Pistia stratiotes* and *Eichhornia crassipes*) present major environmental and economic problems in southern Africa. Although their influence on the native molluscan fauna in general has not been evaluated, they are known to increase habitat available to bilharzia-carrying snails (*Bulinus* spp. and *Biomphalaria* spp.). Lange (pers. comm.) noted that the increase in invasive weed species has also led to an increase in the abundance of bilharzia-carrying snails (*Bulinus* spp. and *Biomphalaria* spp.) in Lake Victoria.

4.3.6 Invasive species – fish farming

The stocking of non-native fish, such as trout in the upper tarn lakes of eastern Africa, the various fish farmed in Lake Victoria, and the development of fish farming in western Africa, has possibly had an impact on the native molluscs in these habitats, although there have not been any studies that have confirmed this. As mentioned above, the clearance of gallery forest cover along rivers and streams in western Africa has led to changes in land use, and the expansion of aquaculture as an alternative source of income, but again the impact on the mollusc fauna is yet to be evaluated.

4.3.7 Invasive species – molluscs and their impact on indigenous species

Invasive mollusc species do not, at the moment, pose significant problems across Africa but do have localized impacts. Fourteen alien gastropod species have been reported in Africa within the past two decades, belonging to five families, two prosobranchs and three pulmonates. Eleven of these species originated in South America or Asia. Four species, *Thiara granifera, Pseudosuccinea columella, Physa acuta* and *Aplexa marmorata* have become invasive in Africa, and a further three, *Pomacea difusa, R. rubiginosa* and *Gyraulus chinensis*, could potentially become so, as they

Danger crocodiles! Field survey has to be conducted with care! © DANIEL GRAF AND KEVIN CUMMINGS

are invasives in other countries. The other thiarid, *Melanoides tuberculatus*, may represent an invasive morph of the species from Asia, but this needs to be confirmed by DNA analysis. Several species that have been reported as introduced seem not to have survived. Only one alien freshwater bivalve, the introduced Asian clam *Corbicula fluminea*, has been recorded in African waters (Van Damme *et al.* 2010a).

Most invasive freshwater snails in Africa originated in tropical or sub-tropical regions of the world and, in terms of their thermal tolerances, are warm water species. Introductions can also be divided into those introduced (i) accidentally, often via the aquarium trade, and those introduced (ii) deliberately, usually for the biological control of the intermediate hosts of schistosomiasis. Inter-basin transfer water schemes and, on a much smaller scale, tanker transport of water, may also distribute freshwater molluscs to new water bodies, as has happened in Namibia (Appleton pers. comm.).

Some invasives have been recorded widely across Africa, while others are known from only a few or even single countries. Despite the wide distributions of several species, quantitative information on their impacts on indigenous African molluscs is scarce and often anecdotal. Several species, notably the apple-snails, *Pomacea* spp. and *Marisa cornuarietis*, and the thiarid *Tarebia granifera*, have been identified as potential biocontrol agents of schistosomiasis host snails because they prey on or compete with pulmonates such as *Biomphalaria spp.* and *Bulinus spp.*. Whether this competition is for resources, such as food, or due to interference (e.g., physical contact) facilitated by the invasives' greater population densities, is not clear. Each case seems to be different and more-or-less unique. Nevertheless, these are species that should be monitored. It may be that some or all of these invasives have not been in Africa long enough to have had impacts as serious as the extirpations reported in other parts of the world, such as the Caribbean islands. Inevitably, recourse has to be made to research done on these same invasives elsewhere, but even here it is unlikely that observations in, for example, small tropical islands such as Puerto Rico and Martinique can be extrapolated directly to Africa. Valuable quantitative information is, however, coming from N.A.F Miranda's ongoing study (Miranda *et al.* 2010) of the impact of *T. granifera* on the indigenous gastropods of the coastal lakes of northern KwaZulu-Natal, South Africa.

Some introduced species have caused major changes and impact on native species, whereas others aren't known to have had any significant impact. In some cases, such as *Melanoides tuberculatus,* the native forms are being displaced by the south-east Asian morph. For example, where the south-east Asian morph has invaded Lake Malawi it has displaced the indigenous form in the southern parts of the lake (Genner *et al.* 2004). The characteristic pattern of shell ornamentation and sculpture of this invasive morph of *M. tuberculatus* falls within the wide range of characters seen in the polymorphic indigenous form (Brown 1994; Samadi *et al.* 2000), making it unlikely that its introduction and spread will be easily noticed. Just as the invasive morph of *M. tuberculatus* has displaced the indigenous form in Lake Malawi, there is evidence that it may also have happened in western Africa and in KwaZulu-Natal province, South Africa, in recent years.

Another parthenogenetic south-east Asian thiarid species in the family Thiaridae, *Tarebia granifera,* probably has the greatest potential of any invasive species to threaten native species. Following its discovery in South Africa in 1999, *Tarebia granifera* has spread rapidly through the provinces of KwaZulu-Natal and Mpumalanga, as well as Swaziland (de Kock and Wolmarans 2008; Appleton *et al.* 2009). Although it is currently also moving southwards towards the Eastern Cape, its spread is predominantly northwards, and it will undoubtedly reach Mozambique and Zimbabwe soon if it has not already done so. In fact, the three northernmost rivers in which it has been found (Pongolo, Sand and Crocodile) all flow into southern Mozambique. There seems no reason why it should not continue spreading northwards into eastern and central Africa. The high salinity tolerance exhibited by *T. granifera* has allowed it to invade several estuaries, lagoons and coastal lake systems in KwaZulu-Natal (Miranda *et al.* 2010). Although *Tarebia granifera* is often regarded as a detritivore, its diet includes large quantities of benthic microalgae – up to 68% of daily primary benthic productivity (Miranda *et al*. unpublished data). Where *T. granifera* is present in large numbers, it is likely to have an important impact on primary production, consuming as it does a substantial portion of the available food resource, which may explain the dominance of *T. granifera* over pulmonates and may be the cause of the loss of *M. tuberculatus* at some sites. Another

Children washing clothes in a steam near the Sanaga River in Cameroon, potentially exposed to diseases hosted by freshwater molluscs. © KEVIN SMITH disruption caused by *T. granifera* is sediment disturbance, as it is an active snail that ploughs its way through the sediment leaving "trails" several millimetres deep as it does so. The freshwater mussels (families Unionidae and Iridinidae) are unlikely to be severely affected, since they occur mostly in water deeper than is favoured by *T. granifera*. However, pea-clams (*Sphaerium* and *Pisidium*) are common in shallow water and could be exposed to impact. The invasion of the brackish water zone along the south-east and east coast of Africa by *T. granifera* is worrying, since it will surely endanger the prosobranch community there (including the rarer species of *Septaria* spp. and *Neritina* spp.). This factor may become more significant in the future, as invasions by thiarids are documented to have resulted in great reductions in numbers or, in some cases, the extirpation of several indigenous gastropods and bivalves in several Caribbean islands and the USA (Pointier 1999; Karatayev *et al.* 2009).

4.3.8 Climate change

At present few freshwater molluscs are known to be directly threatened by climate change. In most cases, an increased frequency of drought events will be a secondary threat to these freshwater species where there are already problems, such as over-abstraction of water for domestic and agricultural purposes, that are leading to low water levels in the rivers and springs.

In western Africa, the decline of water levels in Lake Chad has been consistent and ongoing since the 1970s, leading to the reduction in the size of the lake. This has led to the listing of four endemic taxa within a threatened category, although, as mentioned above, these taxa are all in need of taxonomic review to confirm their status as full species.

4.4 Understanding the impact of molluscs on human health and livelihoods

The economic importance of African freshwater molluscs rests primarily on their roles as intermediate hosts for parasites causing disease in people and domestic stock. They serve as intermediate hosts for a wide variety of trematode flukes. Porter (1938) reported 112 morphologically distinguishable types of larval trematode in 28 mollusc species from across South Africa, while Loker *et al.* (1981) recovered 38 types in 14 mollusc species from the Mwanza region of Tanzania. Several of these trematodes cause economically important diseases in people and domestic stock, with those causing schistosomiasis and fascioliasis by far the most important.

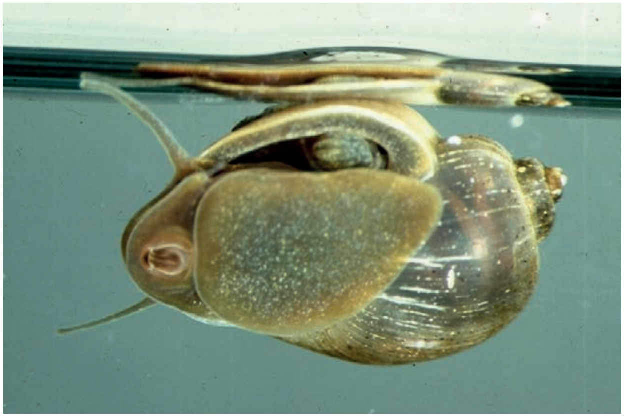
Many freshwater snails serve as intermediate hosts for the nematode *Angiostrongylus cantonensis*. Rats are the usual definitive hosts for *A. cantonensis*, but when people ingest its larvae, either by eating infected snails or in mucus trails left by infected snails on salad material, they penetrate the central nervous system and cause eosinophilic meningitis. Although predominantly an Asian parasite, isolated reports from northern, western and southern Africa suggest that angiostrongyliasis may have become widespread in Africa too. Yousif and Lämmler (1975) and Yousif and Ibrahim (1978) reported natural infections in *Lanistes carinatus* in Egypt, and showed experimentally that species of *Biomphalaria* and *Bulinus* as well as the invasive *Physa acuta* were also susceptible to infection.

Schistosomiasis

Human schistosomiasis occurs in every country in Africa, except Lesotho. It has been known since the early decades of the 20th century that the life-cycles of the two most important schistosomes, *Schistsoma haematobium* (cause of urogenital schistosomiasis) and *S. mansoni* (cause of intestinal schistosomiasis), involve species of *Bulinus* and *Biomphalaria* (Gastropoda: Planorbidae), respectively, as intermediate hosts. A third human parasite, *S. intercalatum*, affects people in parts of western Africa, and also uses species of *Bulinus* as its snail host.

The number of people, mostly children, infected with either *S. haematobium* or *S. mansoni*, or both, in sub-Saharan Africa is estimated at around 170 million, with another 600 million at risk of infection (WHO 2002; Southgate *et al.* 2005). Approximately 300,000 people are estimated to die each year from the disease (Hotez and Fenwick 2009), mostly from kidney failure in the case of *S. haematobium* infections and haematosis in the case of *S. mansoni* infections.

The economic impact of human schistosomiasis is difficult to gauge in monetary terms because of difficulties in accurately measuring the effects of subtle variables like absenteeism, loss of productivity and reduced educability on a continent-wide or even national scale. Certainly, costs to Africa run into hundreds of millions of US dollars per year. A widely used alternative measure of morbidity is the DALY



Bulinus tropicus *(LC), a widespread species in southern Africa and beyond is known to act as the intermediate host for the conical fluke* Calicophoron microbothrium, *a common parasite of domestic animals. Within the genus* Bulinus *is found the intermediate host species for urinary schistosomiasis, a serious human disease.* © CHRIS APPLETON

Preserving specimens after a field survey at Lake Bangweulu, Zambia. © DANIEL GRAF AND KEVIN CUMMINGS

(disability-adjusted life year), which measures the number of years lost to a disease due to morbidity, disability and early death. Recent estimates of DALYs lost to schistosomiasis in Africa are as high as 70 million – more than losses due to malaria or tuberculosis, and almost equivalent to HIV/AIDS (Hotez and Fenwick 2009).

Veterinary schistosomiasis is also common, and is due mostly to the ungulate schistosomes *S. bovis* and *S. mattheei*. Like the common human parasites, these veterinary schistosomes are widespread over the continent. Both *S. bovis* and *S. mattheei* use species of *Bulinus* as intermediate hosts, as do three other less widely distributed veterinary species, *S. curassoni*, *S. leiperi* and *S. margrebowiei* (Brown 1994). Heavy infections may result in death, with prevalence in cattle of up to 90% in some areas. Localized outbreaks accompanied by significant morbidity and mortality have been recorded. Sheep are more susceptible than cattle.

Fascioliasis

Species of *Lymnaea* serve as intermediate hosts for the liver flukes that cause fascioliasis; *L. natalensis* for *Fasciola gigantica*, the most common fasciolid in sub-Saharan Africa, and *L. truncatula* for *F. hepatica* (Mas-Coma 2004). Studies elsewhere have shown that the North American *L. columella*, which is invasive in Africa, is susceptible to both *F. hepatica* and *F. gigantica*, so its role in the transmission of fascioliasis in Africa needs investigation.

Human *Fasciola* infections are uncommon in Africa, except in Egypt where fascioliasis is regarded as an emerging disease. An estimated 830,000 people are thought to be infected in the country, most in the Nile Delta, with prevalences up to 17% (Soliman 2008). The severe pathology caused by the immature flukes as they migrate through the liver has resulted in the disease being recognized as a public health problem in Egypt. In chronic infections the bile duct and gall bladder become inflamed as well.

Animal fascioliasis is more common than the human disease, and is known across the continent where it affects a range of stock animals. Prevalences above 50% are frequently reported in cattle and chronically infected animals show reduced growth, lower milk production and lower calving rates. The marketability of such animals is poor, due to condemned livers and underweight carcasses. These effects are, however, difficult to quantify. Nevertheless, significant economic losses are experienced by farmers in fascioliasis-endemic areas. Infections in sheep are more difficult to assess.

4.5 Recommended conservation measures

At present, despite the few omissions from our species list and underestimates incurred as we wait for species to be described, we believe that the data presented are reasonably representative of the status of molluscan biodiversity and the threats to these species across Africa. Even with these omissions, the conclusions and suggested actions would still apply once additional data have been included.

There are no known targeted conservation measures in place to protect any of the threatened freshwater molluscs of Africa. In fact, the freshwater mollusc faunas get little conservation attention, more often being the focus of eradication programmes as part of bilharzia management schemes to improve the health of local populations (Kristiansen and Brown 1999). Whilst in other parts of the world freshwater molluscs, such as the river rapids species and the spring-snails, have benefited from the extension of protected areas as conservation actions for the species, in Africa there are, with the exception of Ramsar Sites, few protected areas designed specifically for protection of freshwater fauna. The majority of protected areas include rivers and lakes as boundary markers rather than as targeted conservation features in their own right (Darwall, pers. comm.), and, in cases where they are included, the protected area boundary will not stop the spread of threats such as pollution, invasive species, sedimentation, and altered flow regimes. Protected areas need to be designed specifically to protect upper catchments and to include entire river and lake systems within their boundaries, if they are to provide effective protection to freshwater species.

Capacity and awareness of the value and ecological importance of molluscs needs to be raised. Rarely do the relevant governments or indigenous communities appreciate the value of their molluscan biodiversity, so capacity building projects, such as is ongoing in Morocco (IUCN 2010) through community outreach and collaboration with local wildlife and fisheries departments, are recommended to raise awareness and facilitate monitoring of local populations of gastropods and bivalves.

Environmental Impact Assessments need to include assessments on the impacts to mollusc diversity, and should be mandatory for any proposed developments likely to impact mollusc species, such as: dam construction; fish farm developments; large-scale timber extraction involving clear-felling of gallery forests; and mining developments using open surface extraction methods.

The indiscriminate use of molluscides needs to be better controlled, as it currently also causes 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 on 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.

4.5.1 Recommended research actions

i) Description of new species

Although the freshwater molluscs of Africa, with an estimated 560 species (Bogan 2008; Strong *et al.* 2008), are less diverse than some continental faunas, the current number of species is underestimated. There are some regions, such as the north African Maghreb and eastern Africa lakes, where there are many recognised species that have yet to be named (Ghamizi 1998; West *et al.* 2003). There are also regions in western and central Africa where there has been little active field survey or taxonomic research since the 1960s, and these regions will be under-recorded and may potentially support unrecognised species. The current estimates of species diversity may well, therefore, need revision over the next 10 years. The lack of "value" placed on new species descriptions by the scientific community has led to pressure to publish overview papers or synthesis papers, rather than traditional alpha-taxonomy. This, combined with a decline in journals that will take large papers dealing with descriptions of new species, is undoubtedly slowing the speed with which new species are described.

ii) Facilitate information flow for conservation management

It is critical to ensure that information on range-restricted endemic species is passed to the relevant authorities, and that any proposed developments in these regions take account of these endemic species.

iii) Research studies on species demography and ecology

For many freshwater molluscan taxa in Africa, demographic, ecological and life history data are insufficient to make meaningful predictions about how gastropod and bivalve species will respond to changing freshwater environments. For example, information on the host-fish for the parasitic larvae of freshwater mussels of the families Unionidae, Iridinidae and Etheriidae are minimal, prohibiting evaluation of the specific impacts of dam construction, overfishing or aquaculture on these bivalves (Graf *et al.* 2011). The decline in native freshwater mussels could also lead to fundamental changes in the river ecosystems, as the mussels provide water purification services, as well as habitat for commensal species living on the mussels (e.g., freshwater acari). Many such studies could be suitable as undergraduate and MSc. student projects if small sources of funding could be provided.

iv) Field survey 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. For example, as Graf *et al*. (2011) note, in western Africa the freshwater mussel *Mutela joubini* (Iridinidae) is known from only five museum lots, mostly in the Chad-Chari Basin of the western African region. As another example, the family Ancylidae is represented by 49 species belonging to two main genera, *Burnupia* and *Ferrissia,* as well as a few species of *Ancylus*. Most of these species are assessed as Data Deficient, awaiting the results of ongoing research by C. Albrecht. As these freshwater limpets are very small they are likely to be overlooked by collectors in the field, which may explain why they are so poorly known. Identifications are currently best made on the basis of proximity to the type localities of the described species. Finally, the genus *Burnupia* is usually considered to be indigenous to Africa, but a species of *Burnupia* has recently been identified from South America by dos Santos (2003), raising biogeographical questions as to the true distribution of the genus. Species such as these are clearly in need of further field-survey and taxonomic review in order to make informed conservation and management decisions, especially in the more poorly surveyed regions of Africa, such as the smaller lakes in eastern Africa (e.g., Lake Albert), the fast-flowing rivers in western Africa, and parts of the Congo basin where many of the least known species were described in the last century.

v) Control of invasive species

Research to better understand the impacts of invasive species, especially in regions where *Tarebia granifera* has become established, should be a priority.

Species in the spotlight

Freshwater molluscs are important – especially to the African openbill stork

Appleton, C.C. [1] and La Hausse de Lalouvière, P[2]

It is not an easy task to convince people outside of the conservation community (or in some case even within it) that molluscs are important and should be conserved, but in this short essay we can see clearly how important they are to the African openbill stork, *Anastomus lamelligerus*. The openbill stork feeds almost exclusively on freshwater snails and mussels. In particular, it feeds on large operculate snails of the family Ampullariidae (*Lanistes ovum* and *Pila* spp.), and less commonly on *Bellamya* spp. (Viviparidae), as well as unionoidan bivalves such as *Unio caffer* and *Coelatura framesi* (Unionidae), and *Chambardia wahlbergi* and *Mutela zambesiensis* (Iridinidae). Terrestrial snails, such as the Achatinidae, are sometimes also taken. The question is: how does a bird use a great big beak to extract the bodies of snails and mussels from inside their protective shells?

Photo 1. The African openbill stork with its characteristic "open" bill. © DAVID ALLAN

Various books and scientific papers on African birds have reviewed literature on the stork's feeding behaviour and the role that the iconic "open" bill plays in extracting the soft parts from their molluscan prey (e.g., Huxley 1960; Kahl 1971; Hockey *et al.* 2006). Not only is the function of the gap in the storks' bill still the subject of debate, but so also is the actual technique used by the birds to extract the soft parts from the shells of their prey. The characteristic gap between the mandibles, 5mm on average for South African storks, is not thought to be used for crushing shells, but is proposed to enable the tips of the mandibles to operate like pincers and pick up and manipulate individual molluscs prior to removing their soft parts. The process of manipulating shells to remove the soft parts is intricate and difficult to observe because it is usually done under water or amongst vegetation, but apparently always with the prey resting on some kind of solid surface. Examination of shells discarded by openbill storks in the Okavango Delta, Botswana, and the Pongolo floodplain in north-eastern KwaZulu-Natal, South Africa, and comparison of the damage to the shells with the shape of the birds' bills, presents new hypotheses on this unresolved question.

On two occasions in July 2000, near Chief's Island in the Okavango Delta, accumulations of *L. ovum* shells were found on flattened

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platforms, approximately 40cm across, made by openbill storks at a height of 30-40cm above the water, in clumps of the reed *Vossia cuspidata* (Photo 2). A total of 46 shells were collected from these platforms, and all were large adults of 40 to 55mm shell height. These shell larders seem analogous to the accumulations of empty shells reported from river banks in eastern Africa, and suggest that the openbill stork reuses the platforms as surfaces for extracting the soft parts from prey snails over a period of time – a sort of kitchen workbench! No bivalves were found here, but since they live in deep water, they are inaccessible to the birds. Curiously though, no *Pila occidentalis*, a second large ampullariid occurring in the delta (Appleton *et al*. 2003), were present even though they grow to 55mm and form part of the openbill's diet elsewhere in Africa.

Most shells from these platforms (72%) had a single more-or-less triangular notch in the apertural lip 5 to 21mm (mean 15mm) deep (Photo 3). A further six had shallow chipping and the remaining seven showed only slight irregularities to the outer lip – not very different from empty shells found elsewhere in the delta. Allowing for uneven breakage of the shell, the shape and depth of these notches match the storks' lower mandible which is also triangular in cross section.

Photo 3. L. ovum *collected from the reed platforms in the Okavango Delta, Botswana, showing the triangular notches in the lip of the basal whorl.* © CHRIS C. APPLETON

A comparison of these notches with the bills of museum specimens of the openbill stork suggests that the birds use a sophisticated technique to extract the soft parts of snails like *L. ovum*. Having picked the shell up, and secured it between the tips of its grooved upper mandible and the knife-like lower mandible, the stork uses the lower mandible to take a triangular notch out of the outer apertural lip to expose the operculum. Using the upper mandible to hold the snail firmly on a surface like the reed platform described above, it then pushes the sharp lower mandible through the notch to sever the operculum and then the columellar muscle, probably in one movement. The lower mandible of the openbill stork is, in fact, slightly curved, and Kahl (1971) proposed that this curvature made it easier for the bird to sever the snails' operculum and columellar muscle. Five of the museum specimens examined had the lower mandible curved to the right, one to the left, and three were not curved at all. Nevertheless, this action frees the snail's soft parts from its shell so that they can be eaten by the bird.

A similar technique is used by openbill storks for bivalves or mussels, but with the difference that bivalve prey is initially held crosswise in the bird's bill. This allows the stork to chip into the ventral margins of both valves with its lower mandible. It then flicks the shell into a lengthwise position with its dorsal hinge line lodged in the grooved under surface of the upper mandible (or puts the mussel with its notched valves onto the bank), inserts its lower mandible between the valves via the notch and, starting at the posterior end and drawing it towards the anterior end, severs the two adductor muscles as it does so. Once these muscles have been cut, the soft

Photo 2. An openbill storks' larder – a platform in a clump of Vossia cuspidata *with numerous empty* Lanistes ovum *shells.* © CHRIS C. APPLETON

parts can be removed and eaten. These adductor muscles are cut so close to their scars on the shell's inner surface that the discarded shells are remarkably clean.

Triangular notches, seldom as deep as in *L. ovum*, were also present near the posterior ends of the ventral margins of articulated valves of approximately 60% of *Co. framesi* and *Ch. wahlbergi* collected on the Pongolo floodplain (Photos 4a-d). A smaller number of valves of both species had shallow chips taken out of the posterior end (Photos 4c and d).

Using the characteristic damage to bivalve prey described above as markers, and bivalve density data for 1983/4 from Appleton and la Hausse de Lalouvière (1987), we have assessed the extent of predation by openbills on the standing crop of *Co. framesi* and *Ch. wahlbergi* on the Pongolo Floodplain in KwaZulu-Natal.

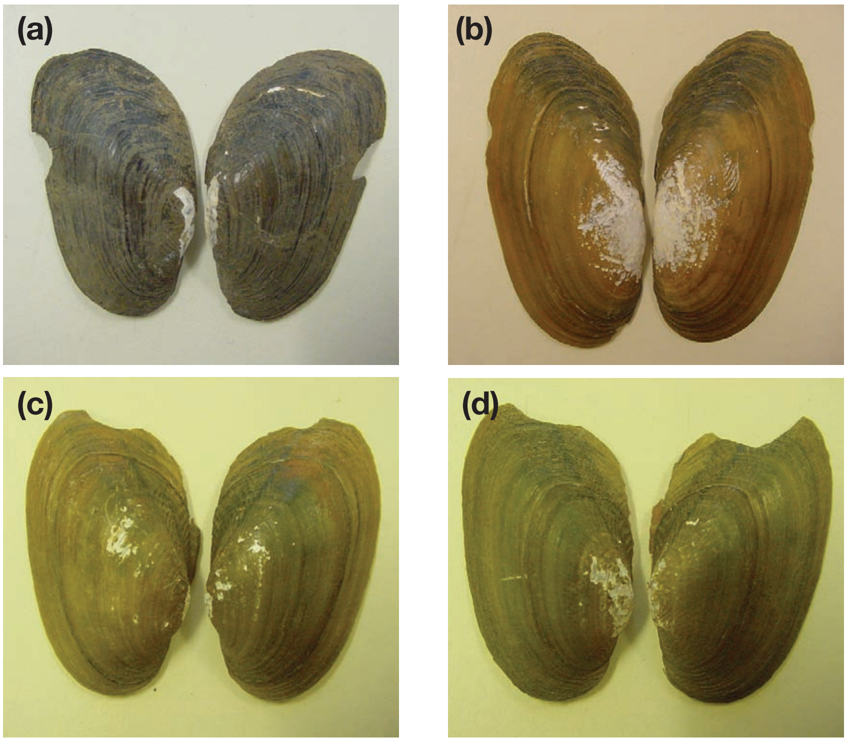

Photo 4(a-d). Examples of notched Co. framesi *(a,c and d) and* Ch. wahlbergi *(b) valves from the Pongolo River floodplain. Photos a and b show characteristic notches in the posterior half of the valves' ventral margins, while c and d show shallow chips at the valves' posterior ends.* © CHRIS C. APPLETON

> **Unionoidan bivalves are in decline worldwide, and in South Africa the endemic *Unio caffer* is classified as Near Threatened**

We estimate that openbill storks consumed 13.0% of the standing crop of *Co. framesi* (or 27 x 106 individuals) and 4.6% of the standing crop of *Ch. wahlbergi* (or 591,560 individuals). These data suggest that bivalves represent a substantial part of the diet of openbill storks on the Pongolo floodplain, with an estimated 20 flocks comprising almost 450 birds counted on the floodplain's lakes in 1983 (P. la Hausse de Lalouvière, unpubl. data). *L. ovum* also occurs on the floodplain, and is eaten by openbill storks, but we have no quantitative data to estimate the numbers consumed in this case.

Various authors, including Huxley (1960), had previously concluded that the openbill stork crushed the shells of its prey using the gap between its mandibles to do so, but the types of shell damage described here are quite different from that resulting from crushing. Crushing is akin to being hit with a blunt object, which was the technique used by Iron Age people in Zambia to open similar shells of *L. ovum*, *Co. mossambicensis* (probably synonymous with *Co. framesi*) and *Ch. wahlbergi*, for food (Appleton 1985). *L. ovum* shells from these archaeological deposits had typically lost their spires and parts of their basal whorl but kept their apertures intact, while the bivalves were represented mostly by fragments incorporating the umbonal areas and anterior ends of the valves.

So how do threats to molluscs such as these potentially impact dependent species such as the openbill stork? Unionoidan bivalves are in decline worldwide, and in South Africa the endemic *Unio caffer* is classified as Near Threatened, probably due to increasing pollution, use of molluscides, and the impact of invasive fish on the indigenous species that serve as hosts for the mussels' parasitic larval stage. This may explain recent reports in birdwatchers' blog sites of openbill storks expanding their range in southern Africa, and foraging in built-up areas and on golf courses for the common garden snail *Helix aspersa* and probably indigenous achatinids too. In conclusion, the humble mollusc is important after all, and often in ways which may not at first be apparent, except to a select few. The challenge now is to spread this understanding to those who make decisions which might determine the fate of these unobtrusive but important species.

Species in the spotlight

Can the last populations of the giant African freshwater pearl mussel be saved?

Ghamizi, M[1] and Van Damme, D[2]

For decades this large mussel was believed to be Extinct, until surveys in the area rediscovered it just a few years ago. Formerly, *M. marocana* was considered to be a local race of the European *Margaritifera auricularia,* found over a large part of western Europe. However, a few specialists, such as Dr. Douglas Smith, disagreed with this view. But on the basis of shell characteristics from a handful of museum specimens collected at the beginning of the 20th century, this taxonomic problem could not be solved. It was only after live specimens were rediscovered three years ago that DNA research by Araujo *et al*. (2009) provided the irrefutable evidence for *Margaritifera marocana*'s specific distinctiveness. The species is, hence, a Moroccan endemic, whose range is restricted to two rivers belonging to the same hydrographical basin. The area that they occupy within these rivers is extremely limited. So far, only two small populations have been found, both at sites strongly affected by human activities. Both populations consist exclusively of specimens of old age-classes, all shells measuring more than 10cm. With no evidence of juvenile mussels, recruitment appears to have been halted, and recruitment patterns remain an unknown.

The same is true for the species of fish host or hosts on which the larvae of *M. marocana* are parasitic. As with other representatives of the genus *Margaritifera*, the larvae (of the glochidium type) attach themselves to the skin and

Margaritifera marocana *(CR) is a large naiad species endemic to north-west Morocco.*

gills of their host fish, and after metamorphosing into a young mussel, detach and drop to the sediment. This way, the fish ensures the distribution of the clam. Host specificity in all *Margaritifera* species is high, restricted to a single or a few fish species. It is not yet known which and how many fish species are used by *M. marocana* as hosts. If its host specificity is very narrow, it may be that the particular fish host has disappeared from the rivers where they are known (for example, as a consequence of the construction of dams), therefore preventing reproduction and the completion of the life cycle of *M. marocana*. Virtual complete extinction of its main host fish, the Atlantic sturgeon, led to the extirpation of the European *Margaritifera auricularia* except in two rivers where populations are associated to another host, and it is feared that the same thing will happen to *M. marocana*, which may result in it being lost forever.

All habitats in Moroccan rivers from which populations of *M. marocana* have been recorded during the early 20th century are heavily degraded, threatened by desiccation and polluted by domestic and agricultural effluents. Some Moroccan types of *Margaritifer*a, such as the one originally described as *M. dernaica* from the Oued Derna, are completely gone. Are *M. dernaica* and *M. marocana* one and the same species? Only in the unlikely event that live *Margaritifera* specimens would be rediscovered in the Oued Derna could this question be solved.

The conservation of *M. marocana,* considering the recent IUCN assessment of its threatened status, warrant investigations concerning not only the biological questions already cited above, but should also include sociocultural research on the Amazigh communities that reside along the river at the two sites where *Margaritifera* still occurs.

Nowadays, local children swim, particularly during summer, at both sites without paying attention to the mussels, which look like flattened stones, wearing sandals to protect their feet against cuts from the valves' edges. In 2009, when collecting material for

> **“So far, only two small populations have been found, both at sites strongly affected by human activities**

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genetic research, these children enthusiastically joined the research team and helped by diving for mussels. There were mixed feelings about their interest because, due to the fact that part of the team consisted of Europeans, the local youngsters were wondering about the potential commercial value of the mussels.

On returning to these sites on several occasions, it was a great relief to see that no one was offering these large river pearl shells (up to a length of 20cm), with their beautiful nacre (mother of pearl), for sale to tourists, especially given that the most important site for these mussels is also a main stopping point for tourist cars and buses. Fortunately as well, no culinary tradition appears to be linked to these freshwater mussels, at least not in the villages in the vicinity of the two sites. Consumption of clams, oysters and other sea produce in Morocco seems to be confined to the inhabitants of the coastal zone. Yet it should be kept in mind that the villagers living near the two *Margaritifera* sites would, with no hesitation, exploit the last remaining populations if they should discover any use for them.

Margaritifera marocana is presently dying in silence, its disappearance being hastened by the degradation of its habitat and climate changes, in particular the increasing irregularity of precipitation and river flow regime that causes periods of drought and desiccation interrupted by massive floods, during which mussels are swept away or buried in sediment.

It is, therefore, not only imperative that awareness campaigns are set up for the conservation of the species, but it is also equally important to continue our biological research on this species in order to find solutions for the problem of recruitment. This species is Critically Endangered and we should all be concerned for its continued existence.

Species in the spotlight

A mollusc with a bit of muscle

Graf, D.L. [1]

Chambardia wahlbergi (LC), a freshwater mussel, is one of the most widespread species of mollusc in Africa. Whilst the majority of mussel species in the Afrotropics have small distributions, restricted to particular basins, *C. wahlbergi* is recorded from most regions across the continent. The geographical success of this mollusc (in a truly mollusc-hostile continent) can be attributed to the animal's ability to survive the punishment of the dry season. However, there is still a great deal that we don't know about *C. wahlbergi*, and this is typical of tropical freshwater mussels in general. For the majority of species, we are merely aware that they exist and have only an inkling of their true distributions based on the places they have been collected. It is rare to have detailed field observations from living mussels in Africa, and this inhibits our understanding of how these molluscs interact with their environment (including us).

Freshwater mussels of the order Unionoida belong to a species-rich, globally distributed, and ancient group of bivalve molluscs. They originated at the same time as the dinosaurs, and today there are more than 850 species worldwide in six families. Four of these families occur in Africa: Unionidae, Margaritiferidae, Etheriidae, and Iridinidae. The iridinids are known only from Africa, and it is to this family that *Chambardia wahlbergi* belongs. Relative to other regions, the African freshwater mussel

Chambardia wahlbergi, *collected from a fisheries pond. This specimen will be used to study the evolutionary relationships of African freshwater mussels.* © DANIEL L. GRAF

[1] University of Alabama

The Lutemwe River (Luangwa Basin) in Zambia at low water. © ALEC LINDSAY

fauna is restricted, with only about 80 species (compare this to 300 in North America, or more than 200 in south-eastern Asia). Africa is a tough place for molluscs, with waters poor in calcium (needed for their shells), and the dry climate limiting for aquatic organisms.

Chambardia wahlbergi ranges from South Africa north to Somalia and west to Senegal. In southern and eastern Africa, *C. wahlbergi* is able to thrive where other mussels cannot because of its ability to survive when rivers dry up seasonally. In 2005, samples were taken from the Lutemwe River of Zambia. During that time of year, the stream is reduced to a mere trickle, but with the generous assistance of the local people who use the subsurface waters for both irrigation and laundry, several living specimens of *C. wahlbergi* were obtained from deep within the sediment. With at least 40% of Africa dominated by desert-like habitats, this ability gives *C. wahlbergi*, and freshwater mussels like it, a distinct advantage.

Chambardia wahlbergi, *collected from a fisheries pond.* © DANIEL L. GRAF

Unfortunately, most of our knowledge of the biology of *Chambardia wahlbergi* is limited to such anecdotes. We can only infer its life history from better-studied freshwater mussels, assuming a great deal from the traits of temperate species. For example, almost all mussel larvae are parasitic upon freshwater fishes. It is very likely that *C. wahlbergi* larvae do the same. In 2008 and 2009, with the help of Alex Chilala of the Zambian Department of Fisheries, it was possible to collect *C. wahlbergi* from artificial ponds stocked with tilapia. This provides strong evidence that the larval mussels had hitchhiked along with the parental stock of fish, but the dynamics of the reproductive cycle of this mollusc remain to be explained.

To the uninformed, freshwater mussels like *Chambardia wahlbergi* may be mere "clams", but they have the potential to capture the imagination of anyone open to acknowledging the complexity and interrelatedness of aquatic ecosystems. However, these animals are threatened worldwide due to the degradation of fresh waters. Basic biological research on the freshwater molluscs of Africa will be crucial for establishing informed conservation priorities, not only for the protection of biodiversity but for the sustainable management of fresh waters into the future.

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