What do we know so far about the biological diversity of our land and freshwater habitats? What are the most pressing conservation priorities for these habitats and the species they support? How can our terrestrial and aquatic diversity be safeguarded in the natural environment, and what facilities exist for ex situ conservation of material in gene banks and biological gardens? This chapter addresses these questions, and summarises taxonomic richness, endemism, conservation status, and related issues for terrestrial and freshwater species.

2.1 Ecological diversity in Namibia

The search for patterns is a basic aim of any science, indeed of most human endeavours. Ecologists have long tried to classify species, communities, habitats, ecosystems and biomes as a way to simplify the complex natural world.

Ecological diversity is often described broadly in terms of biomes or ecosystems. Namibia’s four main terrestrial biomes (below) are a broad-brush representation of the country. Ecosystems, a middle level of organisation, are generally regarded as self-contained groups of organisms and their physical environment which together form a recognisable entity. However, Namibia has no scheme for classifying ecosystems, and the Biodiversity Task Force opted not to develop one afresh, finding the concept ill-defined. Existing classification schemes for biomes, vegetation types and wetlands were felt to summarise Namibia’s terrestrial and freshwater variety adequately, even if they need fine-tuning in specific areas. This chapter therefore summarises the most widely used classifications at these three levels, as indices of Namibia’s ecological wealth and variety on land and water. A wetland classification has not previously been published for Namibia, so the following wetland section is longer than the terrestrial summaries.

Biomes

The most widely used classification of Namibian terrestrial biomes is that of Irish,² portrayed in map 2.1a. This uses an ‘objective categorisation’ approach³ based on dominant and codominant vegetation life forms or structures, correlating with indices of summer aridity and rainfall seasonality (Figs. 2.1-2.8). The scheme distinguishes four major terrestrial biomes (desert, Nama-Karoo, succulent Karoo and savanna). Although animal distribution data on their own cannot realistically be used to delineate biomes, insect distribution data have helped confirm the general validity of this objective categorisation method.² Distributions of sedentary and non-
Terrestrial and freshwater habitats

Fig. 2.1 Semi-arid savanna (HH Kolberg)

Fig. 2.2 Moist savanna (J Irish)

Fig. 2.3 Typical Nama-Karoo (J Irish)

Fig. 2.4 Edaphic Nama-Karoo of Etosha Basin (J Irish)

Fig. 2.5 Lowland succulent Karoo (J Irish)

Fig. 2.6 Succulent Karoo (M Müller)

Fig. 2.7 Southern Namib (J Irish)

Fig. 2.8 Central Namib in fog zone (J Irish)
Map 2.1 Terrestrial ecological classifications of Namibia: (a) Irish’s biome scheme and (b) the SABAP scheme

host-specific insect families correspond to these biome patterns better than to previous classification schemes. Irish’s scheme is a very useful framework on which more detailed analyses can be done of certain regions. Classification of the endemics-rich northwestern Namib escarpment as Nama-Karoo, for example, is debated by some biologists, but the overall validity of the scheme is agreed. A similar biome classification (map 2.1b) has been used by Africa’s largest biodiversity project, the Southern African Bird Atlas Project (SABAP), and by a recent diversity analysis of Namibian birds (see sections 2.6 and 2.9).

Vegetation communities

At a finer scale, most botanists in Namibia use the system of vegetation types proposed over 25 years ago by Giess, who divided the country into fourteen zones in three broad categories (map 1.8, summarised in section 1.1). As floral diversity and phytogeography underpin the diversity and geography of so many other taxa, many of the conservation status accounts for taxa in this chapter are based on Giess’ vegetation types as an index of habitat diversity.

Giess’ influential scheme is broadly endorsed today, although he regarded it as preliminary and based on patchy data in some areas. The escarpment also requires more detailed analysis in this scheme: it is categorised as Semi-desert and Savanna Transition in central-western Namibia, but is misclassified as Mopane Savanna in its northern sections. Ongoing work at the National Soil Laboratory and National Botanical Research Institute to develop an agro-ecological zone system may help clarify the floristic nature of some areas.

The SABAP scheme also uses nine ‘avivascular zones’ to explain patterns of bird distribution and abundance: Namib Desert, Namibian Escarpment, Succulent Namib, Nama Karoo, Mopane Savanna, Northern Kalahari Woodland, Central Kalahari Savanna, and Southern Kalahari Savanna. The SABAP scheme attempts to merge avifaunal and floristic distribution patterns, and differs from Giess’ scheme where bird distributions warrant amalgamation of vegetation types. Other minor differences appear in the classification of the northern escarpment and mopane belts.
Wetland habitats

Wetlands in an arid country like Namibia can take many unusual forms (map 1.7). The Wetlands Working Group of the Biodiversity Task Force uses the Ramsar Convention on Wetlands definition of wetlands: areas of marsh... or water, whether natural or artificial, permanent or temporary (ephemeral), with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. The classification of wetlands used by the Ramsar Convention has been adapted for Namibia in a previously unpublished scheme (Table 2.1; Figs. 2.9-2.11):

**Riverine systems:** flowing or *lotic* systems such as rivers and their floodplains and estuaries, including river mouths and freshwater lagoons.

**Lacustrine systems:** standing or *lentic* open water systems such as lakes, pans and impoundments.

**Palustrine systems:** well-vegetated lentic systems such as swamps, marshes, *vleis* or *mulapos*, springs and seeps.

**Marine systems:** shallow ocean overlaying the continental shelf and coast, such as mudflats, lagoons and rocky shores. Namibia has no mangrove swamps or coral reefs.

Since this chapter focuses on terrestrial and freshwater systems, Table 2.1 does not deal with marine wetlands (see Chapter 3).

Riverine systems

River systems in Namibia include both perennial rivers and their floodplains as well as the more typical ephemeral rivers, called *omiramba* in the northeast (maps 1.5, 1.7). Perennial rivers occur only on our national borders and are shared with neighbouring states. The Kunene River originates in Angola, the Okavango is shared with Angola and Botswana, the eastern Caprivi rivers (the Zambezi, Kwando, Linyanti, Chobe) originate in Zambia, and the Orange originates in Lesotho and is shared with South Africa. These rivers carry large volumes of water. Most of the mean annual runoff of the Zambezi (40 000 million m³), Orange (11 000 Mm³), Okavango (10 000 Mm³), Kunene (5500 Mm³), and Kwando-Linyanti rivers (1300 Mm³) originates in the upper catchments in neighbouring countries, and local rainfall contributes very little.
# Terrestrial and freshwater habitats

## Table 2.1  Freshwater wetland systems of Namibia

<table>
<thead>
<tr>
<th>Classification</th>
<th>Defining characters</th>
<th>Namibian examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Riverine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial rivers</td>
<td>Rivers that flow throughout the year</td>
<td>Kunene, Okavango, Zambezi, Orange, Kwando-Linyanti-Chobe Rivers</td>
</tr>
<tr>
<td>Floodplains and backwaters</td>
<td>Low-lying areas and depressions next to rivers</td>
<td>Okavango and eastern Caprivi floodplains</td>
</tr>
<tr>
<td>River mouths</td>
<td>Predominantly freshwater wetlands which form where rivers meet the sea</td>
<td>Kunene and Orange river mouths</td>
</tr>
<tr>
<td>Ephemeral rivers or omiramba</td>
<td>Rivers flowing only after heavy rains, sometimes not for several years</td>
<td>Kuiseb, Nossob, Ugab, Huab rivers, Omatako Omuramba</td>
</tr>
<tr>
<td>Oshanas</td>
<td>Seasonal, shallow, interlinked pans with inflow from rain and seasonal floods</td>
<td>Cuvelai drainage area</td>
</tr>
<tr>
<td><strong>Lacustrine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floodplain and oxbow lakes</td>
<td>Shallow lakes in depressions or old rivercourses in floodplain areas</td>
<td>Lake Liambezi (now dry), small lakes in the eastern Caprivi floodplains, <em>e.g.</em> Lake Lisikili</td>
</tr>
<tr>
<td>Sinkhole lakes and caves</td>
<td>Small, deep, permanently filled caverns and sinkholes</td>
<td>Otjikoto and Guinas Lakes, Aigamas and Dragon's Breath Caves</td>
</tr>
<tr>
<td>Pans</td>
<td>Shallow, ephemeral, unvegetated pools in depressions filled by local rainfall or endoreic rivers</td>
<td>Nyae-Nyae Pan, Etosha Pan, Kalahari <em>pannetjesveld</em>, Sossuvlei, Tsondabvlei</td>
</tr>
<tr>
<td>Dams and impoundments</td>
<td>Man-made lakes formed when rivers are impounded by a dam wall</td>
<td>Hardap, von Bach, Olushandja Dams and numerous small farm dams</td>
</tr>
<tr>
<td><strong>Palustrine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamps</td>
<td>Well-vegetated wet areas with open standing water associated with perennial rivers</td>
<td>Linyanti Swamp</td>
</tr>
<tr>
<td>Marshes</td>
<td>Well-vegetated, water logged areas with little visible open water, found along perennial rivers</td>
<td>Confluence of the Okavango and Cuito Rivers</td>
</tr>
<tr>
<td>Vleis or mulapos</td>
<td>Seasonal or permanent shallow, vegetated pools dependent on local rainfall or fed by groundwater rising to the surface</td>
<td>Tsumkwe <em>vleis</em>, <em>e.g.</em> Makuri Pan</td>
</tr>
<tr>
<td>Seeps and springs</td>
<td>Permanent vegetated pools and streams formed by artesian waters</td>
<td>Sesfontein, Karstveld, Naukluft springs</td>
</tr>
<tr>
<td>Geothermal springs</td>
<td>Small permanent pools fed by hot groundwater rising to the surface from a great depth</td>
<td>Ai-Ais, Gross Barmen, Rehoboth, Warmquelle, Klein Windhoek springs</td>
</tr>
<tr>
<td><strong>Estuarine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estuaries</td>
<td>Wetlands at the mouths of perennial rivers subject to both tidal and river inflows</td>
<td>Kunene River mouth</td>
</tr>
</tbody>
</table>
Most of Namibia’s rivers, however, are ephemeral (map 1.7). They flow only for a few days each year, and often not for several years, but may store important volumes of surface- and groundwater (Box 2.1). Sub-surface flow and water stored in sediments can support vegetation.

The west-flowing ephemeral rivers drain higher rainfall areas inland, channelling runoff across the Namib Desert to the Atlantic in ‘linear oases’ which support species normally found only in wetter areas. Omuramba Omatako is the largest north-flowing omuramba (maps 1.5, 1.7), but its waters have not reached the Okavango River in living memory due to blockage by dunes and vegetation. The east-flowing Nossob River and its tributaries historically fed into the eastern Orange River catchment, but have not done so since 1934. By contrast, the south-flowing Fish River and its tributaries regularly feed the Orange.

These rivers are the focus of human settlement in otherwise dry regions. Sandy rivercourses and alluvial aquifers provide year-round groundwater to riparian forests, people, their stock, and wildlife. Groundwater seeps to the surface in some places; in others the water table can be reached by digging. Gemsbok, zebra and elephant are adept at this, and the holes they dig are used by a myriad of other wildlife.

Floodplains are seasonally or periodically flooded areas adjacent to perennial or ephemeral rivers (Box 2.2). Three types occur on our rivers: The most common are fringing floodplains, found along rivers where flat terrain allows seasonal inundation with rising floodwaters. Less common are riverine swamps, more permanent wetlands found at river confluences such as the junction of the Cuito and Okavango rivers. The Okavango Swamps in neighbouring Botswana are a good example of an endoreic floodplain (one with no outflow).

![Box 2.1 Ephemeral river dynamics](image)

Unlike perennial rivers, in which a ‘flood’ is a dramatic rise in water levels, spilling the banks and inundating surrounding areas, in the normally dry ephemeral rivers a flood is any flow at all. The frequency, intensity, duration and distance of floods vary greatly. Runoff in the catchment is influenced by topography, land use, soil types and vegetation cover as well as the intensity and duration of rain.

Strong localised thunderstorms can cause very sudden floods, characterised by a wall of water which moves rapidly down a dry rivercourse, often sweeping away plants and animals. Longer periods of rain bring about more sustained floods, with single or multiple peaks. Multiple peak floods can occur with consecutive rains over many days, or rains in different parts of the catchment. Ephemeral river floods redistribute sediment, nutrients and organic debris which have accumulated in dry rivercourses and deposit these downstream or, in rare events, in the sea. Much of the water transported in an ephemeral river soaks into the sandy riverbed or evaporates, and water volumes tend to decrease with distance downstream. The recharge of alluvial aquifers beneath the rivers is vital for sustaining the ribbon of riverine vegetation associated with ephemeral rivers in Namibia. A cross-section of a typical ephemeral river shows the interdependence of surface flow in the river channel, recharge into the alluvial aquifer, and the availability of this groundwater to trees and via boreholes to man.

--- Source: Jacobson et al. (1995) ---

![Fig. 2.12 Sinkhole lakes: Lake Otjikoto. Courtesy K Roberts](image)
Estuaries and river mouths are found at the lowest part of a river and usually contain a mixture of fresh and salt water. River mouths are predominantly freshwater, while estuaries are subject to both tidal and river inflows. Water, nutrients and sediment flow out with river floods and in with the incoming tide. Sediments deposited as the water meets the resistance of the sea form wide mudflats.

Although dominated by river water inputs, the river mouths of the Orange and Kunene rivers have been termed estuaries, and are indeed subject to some tidal influence. The Kunene River mouth and lagoon are vulnerable to flow alteration caused by the proposed Epupa Hydropower Scheme. A dam built upstream would reduce the volume of river water reaching the mouth, as well as the duration and intensity of floods. This will, in turn, reduce the scouring necessary to keep the river mouth from silting shut, and decrease essential nutrient inputs.

**Lacustrine systems**

Most large standing waterbodies in Namibia are man-made, including 12 government dams on ephemeral rivers and numerous smaller farm dams. The proposed Epupa Dam, at 280 km², would be by far the largest of these. Namibia has few natural lakes, of three main types:

- small, deep, permanent sinkhole lakes and caves (e.g. Lake Otjikoto, Lake Guinas, and Aigamas Cave) (Fig. 2.12);
- larger, relatively shallow ephemeral floodplain or oxbow lakes on seasonally flooding rivers (e.g. Lake Liambezi, now dry, in eastern Caprivi) (Box 2.3, Fig. 2.15);
- very shallow ephemeral lakes and pans (e.g. Etosha Pan, Lake Oponono, Sossusvlei, Tsondabvlei, Tsumkwe Pans such as Nyae Nyae, and Kalahari ‘pannetjiesveld’ pans).

Sinkhole lakes and caves are characteristic of dolomite, and form as water penetrates cracks in the dolomite and leaches away the rock. This process gradually forms larger water-filled underground caves; sinkholes
form when the roof of an underground cave collapses. The sinkholes and caves of the Mountain Savanna and Karstveld vegetation type (map 1.8) near Otavi, Grootfontein and Tsumeb are ecologically extremely important due to the presence of endemic invertebrates and fish (see section 2.9). For example, southern Africa’s only true cave fish, the endangered cave catfish *Clarias cavernicola*, is found only in Aigamas Cave.13,14,15,16 These habitats and their unique fauna are especially vulnerable to pollution and groundwater level changes, and great care must be taken when planning large scale abstraction.

**Box 2.3 The vanishing lake: Liambezi**

Lake Liambezi in eastern Caprivi is Namibia’s best known temporary floodplain lakes. The explorer Selous reported a large water-filled lake in 1879. Large floods in the Zambezi in 1952 and 1958 filled the previously-dry lake, but throughout the 1980s lake levels steadily declined until the lake dried up in 1989.17 It has not filled since then. In 1988 the lake covered 406 km², of which 169 km² was open water and the rest well-vegetated marginal marsh.18 At this stage the lake was about 3 m deep and mostly covered by a variety of submerged plants. Phragmites reedbeds and stands of cattail (*Typha*) and papyrus (*Cyperus*) lined the lake margins and shallower areas. Water lilies *Nymphaea capensis* and *N. lotus* shaded the water surface, along with dense mats of the invasive aquatic weed *Salvinia molesta*. The lake supported a wide diversity of species including 54 types of algae, 28 of zooplankton19 and 43 species of fish20,21 in the open water. For a short time a small commercial fishery of about 60 fishermen on the lake supplied the Katima Mulilo market.20

Pans are shallow depressions periodically filled by rain or discharge from endoreic rivers (map 1.5), which dry out too rapidly to sustain much plant growth. For example, the Etosha Pan fills via the Cuvelai Drainage System only after very large floods (*efundja*) once every 7 - 10 years. On these occasions, it is briefly transformed into important habitat for aquatic invertebrates such as fairy shrimps which are adapted to ephemeral habitats, and for amphibians and wetland birds, particularly breeding flamingos and pelicans.22,23 The *oshana* system (Fig. 2.14), which is classified as riverine, is a series of smaller, linked pans in the Cuvelai system, which when inundated support up to 151 plant, 43 crustacean, and 19 fish species.24,25 The largest *oshana* is Lake Oponono, which receives floodwaters about twice every three years. The flooding *oshanas* recharge groundwater, supply both surface and shallow groundwater to people, wildlife and livestock, renew grazing, and bring fish southwards (see section 2.9 and Chapter 4). The Cuvelai system supports more people per unit area than any other non-urban region in Namibia.26

Sossusvlei, in the central Namib dunefields, forms the end of the Tsauchab River. The catchment receives less than 200 mm of rain a year; floodwaters only reach this endoreic pan after exceptional rains. The 15 km² pan is surrounded by some of the world’s highest dunes, as well as camelthorn trees *Acacia erioloba*, spiny *Cladoraphis spinosa* grasses, and *Inara* plants, *Acanthosicyos horridus*. During the brief wet periods, several types of algae, copepods, ostracods, cladocerans and wetland birds have been recorded.27
The many smaller ephemeral pans scattered across Namibia are of ecological importance as a temporary water source for people and as habitats for unique communities of aquatic biota. When wet, they support a variety of desiccation-resistant crustaceans with rapid life cycles. The harsh conditions have led to speciation: 42 ostracod species have been collected from ephemeral pans or pools in the northern Namib, 18 of which are thought to be endemic to Namibia. There is still much to learn about these very arid ephemeral pans.

Impoundments are created by the damming of rivers for water storage or hydroelectricity generation. All large state dams in Namibia are water storage reservoirs built on ephemeral rivers (map 1.7). Many central Namibian towns depend on this water; for example Windhoek is supplied by the von Bach (50 million m³) and Swakoppoort Dams (69 Mm³) on the Swakop River, and the shallow Omatako Dam (45 Mm³) on the Omuramba Omatako. The largest dam is Hardap Dam (300 Mm³) on the Fish River, which supplies the town of Mariental and the Hardap Irrigation Scheme. Much of this water is wasted by extremely inefficient flood-irrigation practices.

Aside from storing water, impoundments support a variety of aquatic and wetland biota. Unlike natural lakes, there is often no marginal zone of plants, due to water level fluctuations caused by water withdrawals and irregular inflows. Rooted plants never become established since water levels rise and fall unpredictably. This has profound ecological effects, as it prevents the establishment of sheltered areas for young fish and invertebrates.

The creation of an impoundment can have serious environmental consequences. A dam creates a water body where none existed, such as on an ephemeral river, or alters a perennial river into a lake, in which case the river biota must either adapt to non-flowing conditions or die. New dams are often extremely unstable ecosystems. Nutrients from decaying, previously terrestrial plants may promote nuisance plant growth, such as the explosive growth on Lake Kariba of *Salvinia molesta* in the 1960s, which characterised a 14-year unstable phase.

Namibia is one of very few countries in the world which builds dams on ephemeral rivers. Although extremely valuable for water supply, impoundments have two main drawbacks. First, they effectively cut off the natural supply of water, nutrients and silt essential for downstream ecological functioning. Second, the long retention times of water in the dam can cause water quality problems.

**Palustrine systems**

Palustrine systems or well-vegetated standing waters include permanent marshes and swamps, less permanent *vleis* or *mulapos*, and seeps and springs fed from groundwater. They occur mainly in wetter parts of Namibia, and are associated with perennial rivers, higher rainfall, or shallow groundwater.

Marshes and swamps are well-vegetated lentic wetlands with permanently waterlogged soils, often found alongside perennial rivers and lakes. They are very important in terms of high biodiversity and productivity, nutrient cycling, and moderation of floods. Marshes typically have little visible surface water, while swamps have visible open water or lagoons, as in the case of Botswana’s Okavango Delta.

The ecologically valuable marsh at the confluence of the Cuito and Okavango rivers resembles a vegetated floodplain at the peak of productivity. In the dry season the water is shallow, stagnant, and often oxygen-poor due
to rotting organic debris. Such marshes support dense stands of reeds and some papyrus, and a variety of sedges and trees adapted to waterlogged soils, such as the forest waterberry *Syzygium gerrardi*. They serve as refuges for floodplain fish such as African pike *Hepsetus odoe* and blackspot climbing perch *Ctenopoma intermedium*, and are habitat for bilharzia and malaria vectors.29

The little-known Linyanti Swamp in eastern Caprivi closely resembles the much better-known Okavango Delta, with a ‘permanent swamp’ section supporting a rich array of species, and a ‘seasonal swamp’ or floodplain which fluctuates between terrestrial and aquatic phases. Vegetation includes emergent plants such as reeds and papyrus, rooted submerged plants such as oxygen weed (*Lagarosiphon*), rooted plants with floating leaves such as water lilies (*Nymphaea*), and free floating plants such as duckweed (*Lemnaceae*).

*Vleis or mulapos* are shallow, well-vegetated lentic pools, seasonally filled with water and covered with grass. They are usually smaller than swamps and marshes, and often depend on local rainfall. Namibian examples include the rainwater pools in forests of the Caprivi, Okavango and Otjozondjupa Regions (map 1.10) and the Kalahari sandveld (map 1.3). These are analogous to the *dambos* of Zambia and Zimbabwe. Although temporary, these wetlands support a wide variety of animals adapted to surviving dry periods. For example, the rainwater pools of eastern Caprivi support a remarkable endemic fish, the Caprivi killifish (*Notobranchius*). Like the invertebrates of temporary ponds, these fish reach maturity before the ponds dry out, and lay drought-resistant eggs which survive in the dry mud until the ponds fill again.

Springs and seeps form small permanent or semi-permanent wetlands, fed by ground-water which rises to the surface and flows away. They are scattered throughout the arid and semi-arid areas of the country, such as Sesfontein and Orupembe in the Kunene Region, where they provide the only permanent source of water to wildlife and people. Typical springs and seeps have a freshwater "eye" where the water surfaces, but water becomes more saline with distance from the eye. As water evaporates rapidly, the edges of these wetlands are often encrusted with salt. The animal communities living in these springs vary along these salinity gradients. Some more permanent seeps, such as those along tributaries of the Kunene River, support endemic fish such as *Kneria maydelli* (see Appendix 13).

Fifty-seven geothermal (hot water) springs are known to occur in Namibia, of which 24 are natural springs and the rest are artificially tapped sources or artesian boreholes. Ten of these have been studied in some detail,30 and range in temperature from 24.9°C for Osterode Süd to 66°C for Gross Barmen. These springs feature 28 kinds of algae. Green algae (*Chlorophyceae*) occur only in cooler springs but diatoms and blue-green algae (*Bacillariophyceae* and *Cyanophyceae*) occur in all, with blue-green algae dominating the hotter waters. The three hottest springs, Ai-Ais, Gross Barmen and Rehoboth, have been developed as tourist resorts. Geothermal springs in Windhoek also induced the first settlement of the capital over a century ago.

— Shirley Bethune

Fig. 2.17 Geothermal spring. Courtesy K Roberts