

Australian Freshwater Ecology

Processes and Management

Second Edition

ANDREW J. BOULTON
MARGARET A. BROCK
BELINDA J. ROBSON
DARREN S. RYDER
JANE M. CHAMBERS
JENNY A. DAVIS



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Figure 5.6 Current velocity can be measured using various meters: (a) a propeller design that counts revolutions of a spinning blade, (b) an electromagnetic meter that measures changes to the electromagnetic field around its bulb to estimate velocity. (Source: Darren Ryder.)

Figure 5.7 Heavy rain can cause overland flow when infiltration capacity is exceeded or when water is forced to the surface by saturation of low-lying ground. Other flow pathways towards the channel (far right) include interflow and the much slower and deeper groundwater flow. (Source: Boulton and Brock 1999.)

Figure 5.8 Two flood hydrographs showing hypothetical responses to a rainfall event (shaded) in a catchment with low storage (solid line) versus one with high water storage (dashed line). In the latter, the flow peak is reduced and delayed.

Figure 5.9 Cross-sections of (a) a gaining or effluent stream, (b) a losing or influent stream, and (c) a perched stream. Arrows show predominant direction of the vertical movement of water. (Source: Boulton and Brock 1999.)

Figure 5.10 The Finke River, in central Australia, drains a geologically ancient and dry landscape. This river exists mainly as a channel of sand with infrequent pools of varying degrees of permanence, and surface water flows only after large, unpredictable rainfall events. (Source: Jenny Davis.)

Figure 5.11 Categories of transported materials in a stream. Suspended load includes particulate organic

matter, suspended bed material and washload. Particles moving on the streambed represent bedload, and most is shifted during floods. Together, these categories along with flotation and dissolved loads comprise the total load of a stream. (Source: Gordon *et al.* 2004. Redrawn with permission of John Wiley & Sons.)

Figure 5.12 Flotation load - a raft of organic matter moving downstream during a flood in the Bellinger River, NSW. (Source: Darren Ryder.)

Figure 5.13 Mass wasting is evident along the eroding banks of this tributary of the McDonald River, northern NSW. (Source: Darren Ryder.)

Figure 5.14 The limiting velocities required for erosion, transport and deposition of uniform particles differing only in size are represented by Hjulström curves. (Source: Hjulström 1939. Reproduced with permission of American Association of Petroleum Geologists.)

Figure 5.15 In upland streams, the spatial arrangement of habitats such as pools, riffles and runs is largely determined by the interplay of flow regime and sediment processes in the channel. (Source: Darren Ryder.)

Figure 5.16 Woody debris enhances structural diversity in this small tributary of the Wannon River, western Victoria. In the foreground, the fallen tree has collected other drifting debris and has slowed the current upstream and among the branches. In the distance, a log across the channel forms a small waterfall, creating a pool upstream and a faster-flowing run downstream. (Source: Edwin Chester.)

Figure 5.17 Cross-section of a typical active floodplain. Waterbodies at various elevations typically require

different flood heights for filling. The darker the shading, the greater the water permanence.

Figure 5.18 Formation of a billabong or ox-bow lake. Progressive erosion and deposition in a meandering river transform a meander (a) through increased erosion on the outer bends (b) into a straighter channel and a billabong (c).

Figure 5.19 Longitudinal changes in physical features expected along a perennial temperate free-flowing river. These trends may not apply to dryland or wet-dry tropical rivers or those with cleared catchments or spanned by impoundments. (Source: Boulton and Brock 1999.)

Figure 6.1 The web of factors potentially influencing the chemical composition of running waters. Unidirectional flow and the physical processes of erosion and deposition interact with most of these factors, either directly or indirectly. (Source: Boulton and Brock 1999.)

Figure 6.2 Turbulent water, such as here in Ebor Falls, northern NSW, results in most dissolved gases being close to or exceeding saturation immediately downstream. (Source: Darren Ryder.)

Figure 6.3 Diel changes in percentage saturation of dissolved oxygen (solid line) and water temperature (broken line) in a shaded, turbulent upland stream (top panel) and a lowland river with beds of aquatic plants (lower panel). Note the lower thermal variability typical in lowland rivers. The bar at the bottom represents night (shaded) and day (open). (Source: Boulton and Brock 1999.)

Figure 6.4 When flow ceases and waterholes, like this one on Kanyaka Creek, Flinders Ranges, SA, start to

shrink, concentrations of ions increase through evaporation. (Source: Andrew Boulton.)

Figure 6.5 Dust storms can mobilize and deposit large amounts of nutrients and ions in standing and running waters. (Source: NASA, Image 23 October 2002. Reproduced with permission of NASA Visible Earth catalogue (<http://visibleearth.nasa.gov/>).)

Figure 6.6 A Gibbs diagram of ionic composition of some Australian rivers. These sites are grouped into clusters of coastward-flowing rivers in south-western WA (CFWA), inland-flowing rivers (IF) and coastal rivers in the eastern states and Tasmania (CRE). The broken line is the envelope of rivers surveyed by Gibbs (1970). (Source: Hart and McKelvie 1986.)

Figure 6.7 A Gibbs diagram showing the relationship between total dissolved salts and cation composition for the water column in tributaries and main-stem reaches of the Murrumbidgee River, NSW. (Source: Data from Ryder and Vink 2007.)

Figure 6.8 Nutrient spiralling in a non-retentive ('leaky') reach (a) and a retentive one (b). Spiral length (S) is the distance a nutrient atom travels as it completes one cycle from release (R) and then transport in the water column (S_w) until biological uptake (U) and then movement downstream (if any) by the biota (S_p). before release again as an available form. (Source: (a) Darren Ryder, (b) Andrew Boulton.)

Figure 6.9 Nutrient retention in running waters is enhanced by channel features such as protruding rocks and riffles (a), seen here retaining leaf litter in the Never Never River, NSW, or by woody debris (b) such as in Sassafras Creek, Victoria. (Source: (a) Darren Ryder, (b) Jenny Davis.)

Figure 6.10 Major pathways of solute transfer in running waters. Arrow thickness represents the relative importance of these pathways although this varies among streams and over time. Broken lines represent pathways that may not be substantial. (Source: Boulton and Brock 1999.)

Figure 6.11 In this pool in the western MacDonnell Ranges, NT, solute processes during periods of surface water disconnection in intermittent rivers likely mimic those of standing waters. (Source: Belinda Robson.)

Figure 6.12 Longitudinal changes in chemical features expected along a hypothetical permanently flowing river. These generalizations may not apply to all rivers, especially those with variable flow regimes or that flow off tablelands.

Figure 7.1 Unidirectional flow is the characteristic feature of running waters, influencing lotic organisms and biological processes across a range of spatial and temporal scales. (Source: Andrew Boulton.)

Figure 7.2 Steeper channels of many running waters have sequences of pools, riffles and runs with varying depths, turbulence and current velocities. Within these three major habitats, smaller microhabitats such as leaf packs and detritus, woody debris, moss, biofilms and filamentous algae provide food and shelter for diverse plants and animals. There are also broad zones along the channel (edge zone), the bank (riparian zone) and within the river-bed where groundwater exchanges with surface water (hyporheic zone) as well as the open-water zone and air-water interface. Further downstream where gradient declines, riffles become less common but backwaters and floodplains are more frequent, providing further habitats for many aquatic organisms. Dashed

lines represent subsurface flow. (Source: Image drawn by Belinda Cale.)

Figure 7.3 Habitats in flowing waters can be sampled using a pond-net (a), Surber sampler (b), drift net (c) or from artificial substrates (d). (Source: (a) Jenny Davis, (b) Judy Davies, (c) Belinda Robson, (d) Edwin Chester.)

Figure 7.4 In fast flows, some invertebrates, such as this blepharicerid net-winged midge larva (a) that is temporarily turned half on its back, use suction cups (the dark rings visible down the middle of the underside) to cling to smooth rocks in swift flow. Other invertebrates, such as the larval water penny (Psephenidae: Coleoptera) are flattened (b, c) and lie in the slow laminar flow (illustrated by the even flow lines) of the boundary layer. Raising the last abdominal tergite (c) creates turbulent eddies that enhance oxygen uptake and water transport without increasing drag. (Source: (a) Gooderham and Tsyrlin 2000. Reproduced with permission of John Gooderham and Eddie Tsyrlin. Images (b) and (c) drawn by Belinda Cale.)

Figure 7.5 Examples of lotic producers. Mount Emu Creek (a), Victoria, has extensive beds of submerged and emergent plants. These aquatic plants dominate the biomass of producers, and epiphytic algae on the stems and leaves of the plants provide food for aquatic invertebrate grazers such as snails. Another unshaded Victorian stream, Merri River (b), is dominated by floating plants during summer and autumn, mainly the native fern *Azolla filiculoides*. (Source: (a) Edwin Chester, (b) Belinda Robson.)

Figure 7.6 Some examples of producers in running waters: (a) bryophytes in Dans Rivulet, Tasmania; (b) filamentous algae growing on cobbles in Susannah Brook, WA, and (c) on sand in the Harvey River, WA; and

(d) algal biofilm on a stream stone. In (d), the rows of growth are a response to flow conditions across the stone and the glossy appearance is caused by polysaccharide mucus that reduces friction. (Source: (a) Danielle Warfe; (b), (c) and (d) Belinda Robson.)

Figure 7.7 Examples of aquatic plants in rivers: (a) water ribbons (*Triglochin procerum*) in the Thone River, NSW, and (b) riparian palms and eucalypts with a grassy understorey on the banks of the Noosa River, Queensland. (Source: (a) Darren Ryder, (b) Belinda Robson.)

Figure 7.8 Some examples of lotic herbivorous invertebrates: (a) herbivorous rotifer *Brachionus*; (b) introduced European pond snail (*Physa acuta*); (c) microcaddisfly larvae (Hydroptilidae), hanging underneath the stem of an aquatic plant. (Source: (a) Joan Powling; (b) and (c) Gooderham and Tsyrlin 2002. Reproduced with permission of John Gooderham and Eddie Tsyrlin.)

Figure 7.9 Time to pray. The plate-like labium of this aeshnid dragonfly nymph unfolds forward to twice its length and the toothed mandibles at the end seize the prey. (Source: Gooderham and Tsyrlin 2002. Reproduced with permission of John Gooderham and Eddie Tsyrlin.)

Figure 7.10 Macquarie perch *Macquaria australasica* (a) are suction feeders whereas mountain galaxias *Galaxias olidus* (b) are ram feeders. (Source: Tarmo A. Raadik.)

Figure 7.11 Two species of crocodile are common in some northern Australian streams and rivers: (a) the freshwater crocodile *Crocodylus johnstoni* and (b) the estuarine or saltwater crocodile *C. porosus*. (Source: Brad Pusey.)