Synopsis of the
International Symposium on the Role of Drought in Aquatic Ecosystems

A Symposium on the Role of Drought in Aquatic Ecosystems was held in Albury, Australia from the 12th to 14th of February 2001. Ninety delegates from five continents attended the symposium. This symposium brought together researchers from a variety of disciplines (including ecology, chemistry, hydrology and climatology) to explore the role that drought plays in the functioning of aquatic ecosystems.

Defining Drought

Drought is almost impossible to define; for every possible use of water there is a corresponding definition of drought. Because ‘drought’ means different things to different individuals, it is important to define what the individual researcher means by ‘drought’. There needs to be a differentiation between seasonal drought (e.g. tropical dry season) and supra-seasonal drought. Indeed, areas with predictable seasonal drought can be subjected to extended supra-seasonal droughts. Likewise one may need to differentiate between aridity and drought. Seasonal droughts in terms of a disturbance may be ‘presses’ whilst supra-seasonal droughts appear to be ‘ramp’ and have been viewed as ‘creeping disasters’.

Droughts exert both obvious direct effects on freshwater ecosystems by reducing water levels and availability. However, droughts also induce damaging indirect effects. For example, the conversion of a flowing stream into a series of stagnant pools may produce a harmful lowering of water quality with such features as low oxygen levels and elevated levels of dissolved organic matter-polyphenols.

Unfortunately, drought often carries with it negative cultural connotations, with images of dying sheep and cattle. However, it is clear that we must recognise that drought events are a natural part of many ecosystems and may play an important role in the functioning of these ecosystems. To this end Tom McMahon introduced the concept of ‘anti-drought’ — imposing flows in rivers for anthropogenic purposes that result in flows that are higher than normally would be expected, and which may thus eliminate natural droughts. On the other hand, climate change or river regulation may impose more excessive periods of low/no flows than normally would be expected. Such systems may, if studied, provide valuable information on the effects of extended droughts.

In terms of responses to droughts, a number of authors presented case studies that showed the importance of drying/drought events on the ‘health’ (or integrity) of particular ecosystems and the viability of selected aquatic species. It became obvious that more is known about the responses of fish, macroinvertebrates and plants (both aquatic and riparian) to drought than is known about the responses of microbes, microfauna and microflora. Further, it was also clear that more is known about the responses of populations and communities than about the responses of ecological processes and total ecosystems.

Scales of Drought

When studying the impacts of drought we must consider differences in both the temporal and the spatial scales of the study. The drivers of drought operate on the global scale, yet the impact of a particular drought may be studied at the local scale, e.g. ponds. Similarly, drought has been described with durations varying from weeks to months or years of lower than expected rainfall, resulting in reduced surface flow. Droughts with drying periods extend for long periods. Evidence was presented by Peter Kershaw of a drying trend in the Australian climate occurring over the last few hundred thousand years. Ancient, catastrophic drought events may also have an impact on the present day. Marlis Douglas presented data that suggested a drought 7500 years ago resulted in the near extinction of the flannel mouth sucker fish. The current populations of the flannel mouth sucker in the Colorado Basin show very little genetic variation, indicating the extant organisms are derived from a very small population base in the past.

River Fragmentation

In running waters, droughts can disrupt hydrological connectivity by weakening linkages — longitudinal (e.g. source to mouth), lateral (e.g. channel to riparian zone) and vertical (e.g. channel to groundwater). Continuous systems may become fragmented. When looking at responses to drought one must first consider the geomorphology of the river to understand the fragmentation of the ecosystem. Andrew Boulton described an hypothetical stepped fragmentation. As flow is reduced, it initially results in a disconnection of elements of the river channel (e.g. benches) from the main channel. As flow is reduced further, riffle zones may dry out, leaving the river as a series of pools. As the drought continues, the more shallow pools, or those pools that aren't fed by groundwater may dry out, leaving only a few pools as aquatic refugia. Emily Stanley suggested that the spatial distribution of these refugia is an important determinant on the rate of subsequent 'recovery' following drought. Whilst there is some understanding of the responses of biota to the fragmentation, very little is known about how fragmentation affects ecological processes.

Survival Strategies and Refugia

Organisms have adopted a number of strategies or refugia for dealing with dry phases. The forms of refugia may vary from the widespread use of drought resistant phases (such as resting eggs) to the directed movement in a stream to the refugia of persistent open water. To date descriptions of refugia that are used are few and there is a clear need for comparative studies on how the provision of refugia affects both the resistance and the resilience of organisms to drought.

Many aquatic organisms rely on refugia to sustain them through drought. Refuges are organism specific. While some organisms merely require a damp environment to survive (e.g. non-desiccated muds) other organisms require significant bodies of standing water. Many of these refugia are sustained by groundwater. However, often the period of greatest groundwater extraction for human use is during drought events. Therefore, excessive groundwater extraction during droughts can threaten the existence of refugia. In an interesting example, Troy Baker and Cecil Jennings show that one species of American bass use groundwater springs in a lake as thermal refuges during summer. Excessive groundwater pumping during drought years causes the springs to cease flowing, resulting in death by thermal shock to the bass.

Exclusion of native species from refuges by exotic species can also present a problem. A survey of mountain yellow-legged frog in the Sierra Nevada showed that the frogs were limited in their distribution to small shallow lakes. The deeper lakes had been stocked with trout that eat the frogs, spawn and tadpoles. During dry years the shallow ponds dry-up while water remains in the deeper, trout-infested ponds, resulting in significant mortality of the frog and, a subsequent low recruitment rate in following years.

It should be also pointed out that in the context of entire landscapes with widespread drought, terrestrial fauna might retreat to the refugia of riparian zones, which may be badly damaged during this time of stress.

Interspecific Interactions and Trophic Structure

In flowing waters with drought there may be major changes in trophic structure. Stream ecosystems driven by allochthonous energy sources may upon fragmentation change into more autochthonous systems. Conversely, when a drought breaks the developing trophic structure may be quite different from the structure prevailing in times of normal flow.

The nature and strength of interspecific interactions may change markedly with drought. The strength of predation by both terrestrial and aquatic predators may increase as the stream dries up. Drought may greatly alter the viability of one species at the expense of another. Examples were given of where exotic fish populations were depleted whilst native fish populations survived.

Studying Drought

Currently very little work is specifically designed to go out and actually study a drought. Most studies have been fortuitous in that a drought occurred during the study program. As such, long-term studies are more likely to encounter droughts than short-term studies. In all cases, it is important to have pre-drought data to compare to the drought and post-drought responses.

As our ability to more accurately predict drought events increases, it may be possible to plan to study drought events, including a pre-drought period. Whilst natural droughts are the most desirable to study, it should be recognised that controlled experiments in the laboratory and in the field may provide valuable information on responses and tolerances of biota and ecological processes to drought.

Like all ecological studies, the effects of drought events need to be studied over a range of temporal and spatial scales. Particular attention needs to be paid to the selection of key variables to monitor rather than simply choosing the most convenient or favoured biota.

Management Implications

Human activities have created drought-like conditions in many rivers. There are those rivers locked into permanent drought due to having waters upstream dammed and diverted. The high levels of water extraction from them during times of drought may exacerbate drought effects in rivers. There are rivers in ‘anti-drought’, with unnatural high flows occurring in normal low-flow periods. In the case of the latter, it is important to recognise that droughts may be a necessary ingredient of the normal functioning of rivers. It is also important to recognise that the capacity of a river’s biota to resist and recover from drought has been severely compromised by the depletion of refugia through such processes as channelisation and ‘river improvement’.

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