Sensitivity of wetlands and water resources in southeastern Australia to climate and catchment change

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Southeastern Australia lies within a temperate zone characterized by mild, but wet winters and hot summers with low ratios of precipitation:evaporation (P/E). Reconstructions of paleosalinity and water level from numerous crater lakes (e.g. Lake Keilambete) provide the means to monitor long-term changes to P/E, and have revealed a regional pattern of Holocene climate change (Bowler, 1981; Chivas et al., 1985; Gell, 1998; Jones et al., 1998). These records witness humid conditions and overflowing lakes in the mid-Holocene, a rapid decrease in moisture at 5.5 kyr BP followed by a gradual trend to a variable and drier climate at c. 3 kyr BP. From c. 2.2 kyr BP the lakes refilled, though not to the mid-Holocene levels. These lakes are therefore sensitive to changes in P/E on the scale of centuries to millennia but appear insensitive to short-term climate variability. In contrast, the diatom-inferred paleosalinity records from numerous fluvial lakes across southeastern Australia across this period do not reveal the same sensitivity to long-term changes in climate. For example, along the River Murray, Tareena Billabong experiences mid-Holocene freshness followed by increased connectivity to the River (Gell et al., 2005) but then a sustained period of stability until the arrival of European settlers c. 1840 AD. In the Coorong, a large back-barrier lagoon at the mouth of the River Murray system, stratigraphic and diatom evidence reveals relative resilience (Fluin et al., in press) to the P/E changes documented in the sensitive crater lakes to the east. Still further east in the coastal plain of the Snowy River, a diatom salin-
ity reconstruction (MacGregor et al., 2005) shows a strong geomorphic control on wa-
ter source but little of the variation in Lake Keilambete that would suggest a climatic
cause. These 3 records suggest that the water balance response to climatic fluctua-
tions, in water bodies within fluvial environments, is much more rapid. Therefore,
the 2 sets of water bodies respond to climate fluctuations on different timescales.

More recently, high lake levels were recorded in Lake Keilambete in 1859 but
from this time a decline in P/E in the or-
der of 15% has seen this ‘rain gauge’ lose
75% of its volume (Jones et al., 2001). This
change, which occurred in all rain-fed cra-
ter lakes in the region, was not due to hu-
man intervention in landscape processes.
However, in floodplain settings, processes
resulting from catchment modification do
appear to dominate the records of inferred
water quality from wetlands. For example,
in the lower Snowy River the salinity of
Lake Keilambete has increased 50-fold (Fig. 1),
mostly owing to the transfer of 98% of the
Snowy River’s mean flow to the River Mur-
ray catchment (MacGregor et al., 2005). The
Murray-Darling Basin (MDB) itself provides
40% of Australia’s agricultural gross domes-
tic product largely driven by an irrigation
agriculture industry that consumes the ma-
jority of the 80% of its flow diverted for hu-
man use. The diatom flora of over 30 cores
analyzed along the Murray-Murrumbidgee
River floodplains attest to widespread sa-
linization, eutrophication and increases
in sedimentation rate and water turbidity.
Very recently, elevated nutrients have com-
bined with drought to oxidize accumulated
sulfides, thus inducing wetland acidification
(Gell et al., 2006). In all cases, the diatom
flora in the base of cores is in contrast to
that in the upper sediments demonstrating
that no pre-impact, or reference, wetlands
exist within the subset studied. In most cas-
es, the recent flora is unprecedented within
the record demonstrating the wetlands of the
Murrumbidgee and Murray River flood-
plains are in a no-analogue state.

From these studies we can assert that
several wetlands have been subjected to
multiple stressors, sometimes coinci-
dentally. This is attributed to the causal
covariation between several drivers and
stressors on the system that has seen the
widespread impacts of overgrazing, rising
saline groundwater, regulation, abstraction
and severe drought (Fig. 2). This in-
cludes the link between sediment supply,
turbidity and eutrophication and between
salinization, sodicity and soil erosion. Thus,
these catchment change stressors are in-
ter-related, are moderated by climate, and
are ongoing and evolving into wetland
conditions that have historically provided the
bulk of streamflow (Jones et al., 2002). This,
in concert with the decline in effective
rainfall documented from the mid-19th
century, represents a phase of desicca-
tion that, in both magnitude and rate, is
unprecedented since the earliest Holo-
cene. Future reductions in streamflow of
5–25% in the southern temperate-zone
channels of the catchment are projected by
2030 (Jones and Durack, 2005), possi-
ably exceeding 50% by mid-century (Fig. 3).
While reduced P/E will lower water tables
reducing salt flux, the reduced flow will see
a net increase in stream salinity. Com-
mitments by the Australian Government
to return 500 GL/yr as environmental
flows to restore MDB wetlands are unlikely
to keep pace with climate change. Models
of water yield from the Bet Bet Creek sub-
catchment in Victoria suggest that wide-
spread revegetation, targeted to mitigate
climate change through carbon seces-
sion (which will also slow groundwater
rise and stabilize soil surfaces), will exac-
erbate climate-driven desiccation (Zhang
et al., 2005).

The last decade has seen historically
unprecedented low flows in a number of
catchments, including the MDB (Drever-
man, 2006). These changes are of a mag-
nitude similar to those projected for 2030.
It remains unclear whether these signify:
1) a short-term random fluctuation; 2) the
first significant shifts in rainfall as part of
climate change; 3) part of ongoing long-
term natural variability; or 4) some
combination of (2) and (3). The evidence
suggests the latter is most likely. As the
recent decline is unlikely to be a short-term
fluctuation in climate variability, a return
to the prevailing moister conditions that
prevailed during the period 1946–1996 is
the least likely of all plausible alternatives.
The highly contested nature of water al-
locations within the catchment and the
increasing influence of climate change on
water availability, suggests that the current

Figure 2: Flow diagram of interactions between drivers and stressors to Murray-Darling Basin wetlands.
bulk allocations of surface water are unsustainable. Abstraction and climate change, along with catchment modification leading to high water tables and degraded water quality, represent serious threats to the capacity to rehabilitate floodplain wetlands to a healthy, functioning state. Measures to adapt to climate change must be sensitively implemented. Environmental al-
locations need not relate solely to volume, but also to variability and timing, so that various uses are favored differently from one year to the next. The widespread and timely adoption of water use efficiencies is essential to avoid both long-term deleterious effects to aquatic ecosystems and to maintain an irrigation industry that is a significant provider of food to Australia and elsewhere. Without increased efficiencies, the trade-off of continued water use and land practices under a drying climate is to risk placing all lowland MDB wetlands beyond the reach of restoration to any natural condition defined by its past experience.

References


Special Section: Science Highlights

The rise and fall of atmospheric pollution: The paleolimnological perspective

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The catchments of remote mountain lakes often comprise sensitive geologies and sparse soils and these factors, in combination with severe meteorology, conspire to produce fragile ecosystems. Anthropogenic impacts in these areas are limited to long-range transported pollutants and large-scale effects such as climate change, but despite their isolation from direct contamination, the additional stress of atmospheric pollutant deposition often results in detectable chemical and/or biological change. Remote lakes can, therefore, act as ‘early warning’ indicators for less sensitive sites and as a result they have become a useful tool in monitoring the impacts of atmospherically deposited pollutants. Recent studies in Europe have shown that long-range transported pollutants have been impacting remote lakes for hundreds of years and that this deposition can result in the accumulation of both trace metals and persistent organic pollutants in biota sometimes to significant levels. The lake sediment record of remote lakes provides the temporal dimension to such observations. In remote regions long-term monitoring is often absent and so paleolimnology provides a means to determine directions of change (i.e. deterioration or improvement) as well as, via reliable chronologies, rates of these changes. Such information thus provides a historical context for contemporary measurements as well as a base-line against which to measure future impacts.

Paleolimnological records of pollutants from remote lakes have been produced from many areas of the world and consistently show significant increases in pollutant deposition in agreement with historical trends in industrial activities on regional and international scales. However, if we assume that the sediment record can faithfully record the past trends in anthropogenic emissions to the atmosphere then it must also be the case that these lake sediments will record the decline in pollutant emissions observed in many industrialized countries since the 1970’s. In some cases such reductions have been dramatic, for example, declines of over 80% and 75% for mercury (Hg) and lead (Pb) in the UK respectively. However, our studies at Lochnagar in Scotland have shown that while there have been considerable reductions observed in the emissions of metals to the UK atmosphere, and similar reductions recorded in the metal content of deposition across the country, the total amount of metal entering the loch and recorded in the sediments remains almost unchanged since the 1950’s (e.g., Pb: Fig. 1). As atmospheric deposition is known to have declined, this ‘additional’ metal can only be derived from previously deposited contamination being released from storage within the sparse catchment soils.

A number of hypotheses have been proposed to explain this observation (Rose et al., 2004). First, that this is due to a simple time-lag effect, i.e. metals deposited onto the catchment take a number of years to work through to the water body and thus the enhanced catchment inputs now observed are the result of high metal deposition decades ago. Second, increased erosion of the contaminated levels of catchment soils (possibly resulting from the effects of increased drought or episodes of high rainfall) are bringing the catchment-stored metals into the lake.

At Lochnagar, as in many areas of Scotland, there is significant catchment peat