Retraction notice to ‘Watching the tide roll away – advocacy and the obfuscation of evidence.’

Peter A. Gell

Water Research Network, Federation University Australia, Ballarat, Vic. 3350, Australia.
Email: p.gell@federation.edu.au


After due consideration of issues raised with respect to this paper, the Editor in Chief and the author agree to retract the paper from Pacific Conservation Biology.

Reason: The paper contains honest errors primarily associated with the presentation and interpretation of figures, but also in the interpretation of how others working on the same wetlands have interpreted and applied their data to management recommendations. These problems apply at more than one point in the paper, making it difficult to deal with them by publishing a correction. Therefore retraction, with the option of submitting a revised paper for review and potential publication, offers the clearest resolution. The Editor in Chief regrets and apologises for any inconvenience this may have caused.
Watching the tide roll away – advocacy and the obfuscation of evidence

Peter A. Gell

Water Research Network, Federation University Australia, Ballarat, Vic. 3350, Australia. Email: p.gell@federation.edu.au

Abstract. The Murray–Darling Basin Plan represents the largest investment in an Australian environmental management issue and remains highly conflicted owing to the contested allocation of diminishing water resources. Central to the decision to reallocate consumptive water to environmental purposes was the case made to keep the terminal lakes in a freshwater condition. This freshwater state was identified as the natural condition on the basis of selected anecdotal evidence and was enshrined in the listing of the site under the Ramsar Convention. Independent evidence from water quality indicators (diatoms) preserved in lake and lagoon sediment records, however, attested to an estuarine, albeit variable, condition before the commissioning of near-mouth barrages in 1940. Political pressure saw the interpretation for a naturally estuarine history published after peer review, revised and released under state government sanction without review or acknowledgement of the original research. This act of intellectual suppression was the outcome of scientists succumbing to the temptation of advocacy for environmental flows. In the end the clear contradictions between the published evidence and the advocated interpretation has diminished credibility in the science behind the Basin Plan and acted to fuel discontent in those affected by water reallocations.

Additional keywords: intellectual suppression, ecological condition, Murray–Darling Basin, palaeolimnology, Ramsar wetlands

Introduction

The Murray–Darling Basin is Australia’s largest catchment, spanning more than one million square kilometres. It is also its most productive, hosting over 40% of the nation’s agricultural domestic product. This productivity has been underpinned by an extremely high level of water abstraction to drive intensive irrigation agriculture and at cost to water-dependent ecosystems. Originally to sustain navigation, but ultimately to guarantee water supplies, the rivers of the basin became highly regulated after the commissioning of many dams and weirs, mostly after 1922. The initial efforts at irrigation were limited and focussed in the upper reaches of the Murray and Goulburn Rivers. Nevertheless, concern regarding the impact of off-take on the on-flows to South Australia was sufficient to warrant a presentation and debate within the South Australian Parliament as early as 1886. For example, the honorary John Rankine is quoted as saying in the House of Assembly in 1887 that ‘Many people imagined that there would be nothing to fear from only flood waters being taken, but this was a great mistake. All the floodwaters were required to drive out the salt water so as to keep the lakes and a portion of the lower river fresh for a few months in the year’ (Sim and Muller 2004: 26). This dispute intensified and became an important distraction to the nation’s Federation, signed in 1901. The interstate royal commission into the basin (Davis et al. 1902) was to resolve this issue and by 1907 the Murray River Commission was instituted to manage cross-state contests over water.

The Coorong and Lower Lakes lie at the mouth of the basin and are a lagoon and estuarine complex (Fig. 1). To preserve freshwater resources in Lake Alexandrina from the penetration of tidal waters barrages were commissioned and completed in 1940. These were situated near the river’s mouth and acted to raise the level of the lake and hold back incoming tides. They also slowed river flow, leading to the accumulation of salt-laden sediments, the formation of Bird Island, a tidal delta south of Hindmarsh Island, and the northward migration and ultimate closure of the river mouth (Bourman et al. 2000).

In 1985 the Coorong and Lower lakes were listed under the Ramsar Convention owing to the significant fish and waterbird populations and cultural significance. At the time the lakes were described as being mostly fresh (DEH 2000). Reinforcing this, a report entitled ‘A Fresh History’, funded by a regional government agency, defined the lake as being predominantly fresh (Sim and Muller 2004). This report was largely based on documentary and anecdotal evidence and focussed particularly on the observation that, in 1901, the lake had become salty for the first time. This was attributed to abstraction upstream for irrigation in the eastern states, particularly in neighbouring Victoria.

Advocacy to restore the ecosystems of the Murray–Darling Basin was in full swing by the late 20th century, with several reviews and audits conducted. Among the outcomes are the identification of the volumes required to return the system to...
ecological health (e.g. Jones et al. 2002) the South Australian Government argued for the allocation of large volumes of water to retain the lower lakes in a freshwater state. This was advocated on the basis of its natural ecological character, not least because that was the condition defined in the listing under Ramsar. This is the default baseline state under the Ramsar Convention in the absence of evidence for prior natural ecological character (Pittock et al. 2010). The decision to return 2750 GL year\(^{-1}\) to the river, through buybacks and water transfer efficiencies, was taken to no small extent, because it was effectively argued that Australia had an international commitment to retaining Lake Alexandrina as a freshwater lake. Federal and State Governments agreed to allocate a further 450 GL where it can be demonstrated that this would accrue no socioeconomic hardship to communities in the Basin (MDBA 2012).

Palaeolimnological research

Lakes and estuaries contain sediments that accumulate more or less continuously over time (Weckstrom et al. 2017). Buried with these sediments are chemical and biological remains that reflect the nature of the wetland at the time of sediment deposition. The collection of sediment cores, the subsampling of sediments and the identification of these remains allows for the condition of the wetland to be inferred. In estuaries this usually allows for a 7000-year history to be outlined as this was the point in geological history that sea levels last stabilised and geomorphic evolution of present-day coastal wetlands commenced. Diatoms are particularly useful fossil bioindicators of estuarine condition (Taffs et al. 2017) owing to their abundance, diversity and close association with, and widespread calibration to, water chemistry (e.g. Gell 1997).

Barnett (1994) analysed sediment cores from Lake Alexandrina and concluded that the lake was estuarine from 7000 years ago, but variable on account of climate variability, but was fresher in the modern period. A core taken, but not analysed, by Barnett (LA2), and another collected by Gell and Fluin in 1996 near the river entrance (LA1), formed the basis of analyses in Fluin (2002). The evidence derived from cores collected from the Coorong by Gell and colleagues was reported to the South Australian Department of Water, Land and Biodiversity Conservation in Gell and Haynes (2005) and is detailed in Gell (2017). The interpretation of the interactions between the river, the lakes and the Coorong were presented at the Past Global Changes ‘Salinity, Climate Change and Salinisation’ workshop in Mildura in September 2004 (Gell et al. 2007) and subsequently published as Fluin et al. (2007). The published records of fossilised diatoms in the two Lake Alexandrina cores reveal changes in key indicator taxa over the last 7000 years. Non-contiguous subsampling leaves out much of the record but the data reveal gradual changes, attributed to hydroclimate change, until the commissioning of the barrages.
Critical to the interpretation of the fossil records is the understanding of the ecological preferences of the taxa preserved in the sediments. This is largely achieved through the collection of modern diatom specimens and the calibration of the relative abundance of these to measured water quality parameters. This was achieved for diatoms from inland lakes (Gell 1997) and was completed for some Australian estuaries (Haynes et al. 2011; Saunders 2011; Logan and Taffs 2013). As diatoms are ecologically conservative and largely cosmopolitan, interpretation of Australian fossil sequences can benefit from the ecological preferences identified from databases developed elsewhere across the world. It is clear that the taxa considered marine or estuarine in Fluin et al. (2007) – *Cyclotella striata*, *Paralia sulcata*, *Thalassiosira lacustris* – are indeed reflective of marine conditions (see Appendix 1 for detailed review of the known ecology of these taxa). None were recorded from inland lakes (Gell 1997), and so their presence reflects saline or sub-saline conditions influenced by waters of marine origin. One key taxa in the LA2 record was *Staurosirella* (syn. *Pseudostaurosira*) *brevistriata* and *Pseudostaurosira* (syn. *Fragilaria brevistriata*). Both were recorded in inland lakes with weighted average salinity optima of 3.9 g L$^{-1}$ and 1.9 g L$^{-1}$ respectively. Gell and Haynes (2005) and Fluin et al. (2007) report *Staurosirella pinnata* to be abundant in the upper sediments of both the north and south lagoons of the Coorong, which, and has been in historic times, saline to hypersaline. It was also recorded to be abundant in lakes of 6.3 g L$^{-1}$ and above in Gell (1997). On the basis of this evidence *S. pinnata* appears to be highly salt tolerant; *P. brevistriata*, on the other hand, is regarded as an obligate freshwater taxon. While these diatoms are broadly tolerant, these inferred preferences are used to summarise the change in condition of Lake Alexandrina, as revealed from core LA2, and presented in Fig. 2.

The Fluin et al. (2007) interpretation

In reference to the high incidence of these taxa Fluin et al. (2007: 130) stated ‘The presence of *Thalassiosira lacustris*, *Cyclotella striata* and *Paralia sulcata* indicate marine influence at this time and the change in diatom community (after 5000 years BP) is likely to represent a decrease in lake level and increased penetration of seawater, possibly associated with the variable, dry climate phase after the mid-Holocene wet phase’.

The return to regional wet conditions is reflected in the passage ‘... The decline in *Thalassiosira lacustris* above 160 cm (~2200 years BP) marks a further increase in freshwater river input conditions, perhaps influenced by the increases in precipitation’ (Fluin et al. 2007: 130).

Acknowledging the prevalence of athalassic taxa, Fluin et al. (2007) stated: ‘The Holocene diatom assemblages of Lake Alexandrina reflect relatively freshwater conditions with long-standing and major inputs from the River Murray. Marine water indicators were never dominant in Lake Alexandrina’.

It did, however, clearly articulate the post-barrage change to freshwater conditions, stating: ‘The barrages completely separate both lakes from the Coorong, with infrequent fresh water flowing through the barrage gates. As a result, Lake Alexandrina is presently [my emphasis] a large, predominantly fresh water system with no salt water input’, and ‘The greatest change to the diatom flora is again near the surface, at 30 cm, mostly attributable to a strong increase in *Pseudostaurosira brevistriata* coinciding with the estimated time boundary for the onset of river regulation. Further this increase is associated with a small decrease in *Staurosirella pinnata* that may be attributable to the barrages controlling tidal flux to the Lake favouring *Pseudostaurosira brevistriata*, which has a lower salinity tolerance than *Staurosirella pinnata*’ (Fluin et al. 2007: 130).

In summary, it stated that salinity in the large terminal Lake Alexandrina was only moderately influenced by tidal inflow, particularly over the past ~2000 years. It is now [i.e. today] largely fresh as a result of isolation by a series of barriers completed by 1940 AD. Unequivocally, Fluin et al. (2007) stated that, before regulation, Lake Alexandrina was tidal with the balance between marine and river influence attributable to the regional hydroclimate as revealed in the water balance...
records of the ‘rain gauge’ lakes of western Victoria. The greatest change in the entire record, as revealed by the cluster analysis, was after the commissioning of the barrages, whereupon the diatom flora reflected unprecedented, freshwater conditions. The interpretation of Fluin et al. (2007) is consistent with those presented in Fluin (2002).

The fresh history (Sim and Muller 2004)

Coincident with the compilation of the palaeolimnological research of Fluin on Lake Alexandrina the River Murray Catchment Water Management Board published a report (Sim and Muller 2004: 1) that concluded that ‘Prior to European settlement, Lakes Alexandrina and Albert at the terminus of the River Murray were predominately fresh . . .’. Further, it stated (Sim and Muller 2004: 1) that ‘Contrary to what many believe today, saltwater intrusions into the Lake environment were not common until after 1900 when significant water resource development had occurred in the River Murray system’.

The interpretations of Sim and Muller (2004) are founded on anecdotes, particularly through the time of the Federation Drought, but also across the years ~1820–1940. As such, it provides a synthesis of the commentary within South Australia as to the changing nature of the lake and the lower reaches of the river. They noted (Sim and Muller 2004: 1) that ‘Short-lived intrusions of saltwater would occur during periods of low flow down river resulting in a lowered level of water in the lake’. Even in times of these low flows, it would appear that only small areas of the Lakes were affected and that ‘Saline invasions were more common after 1900 and the development of irrigation works because reduced river flows could not hold back the sea’ (Sim and Muller 2004: 1).

The years around 1900 were characterised by a series of significant droughts in documented history, and the construction of hydroclimate since 1788 (Gergis et al. 2012) it finds it to have coincided with a substantial increase in the Pacific Decadal Oscillation relative to 230 years of variability. This was conceded thus: ‘Irrigation schemes began at the same time as a long lasting, widespread drought that further diminished the amount of water in the river system (Sim and Muller 2004: 1)’.

What Sim and Muller (2004) reported as the findings of the Interstate Royal Commission was contrary to their selective position. The commission represented three states and sought counsel from across the Basin, and not just from South Australians. Davis et al. (2002) reported many observations including ‘One effect of a deep entrance channel would be to increase the salinity of the lakes, which, after a strong northwest or westerly gale, are brackish; the salt water being forced up channels as far as Wellington’ (Davis et al. 1902: 33).

Further, they reported the observations that ‘When the winds shift to the south-east it is again blown out of the lake, a greater quantity running out under these circumstances than during any river flood’ (Davis et al. 1902: 33–34) and that of the master of a trading boat who is quoted as saying ‘he had known the water of the lakes as salt in past years’ (Davis et al. 1902: 34). Ultimately, they concluded that: ‘Apart from verbal statements, the evidence of facts is against the hypothesis that there has been any increase in saltness in the Murray Lakes by reason of diversion of water from the river channel’ (Davis et al. 1902: 34).

Table 1. Alterations to passages found in both Fluin et al. (2007) and in Fluin et al. (2009)

<table>
<thead>
<tr>
<th>Passage in Fluin et al. (2007: 130)</th>
<th>Passage in Fluin et al. (2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘The presence of Thalassiosira latus, Cyclotella striata and Paralia sulcata indicate marine influence at this time’ (2007: 130)</td>
<td>‘The presence of Thalassiosira latus, Cyclotella striata and Paralia sulcata indicate minor marine influence at this time’</td>
</tr>
<tr>
<td>‘...the change in diatom community [after 5000 years BP] is likely to represent a decrease in lake level and increased penetration of seawater, possibly associated with the variable, dry climate ...’ (2007: 130)</td>
<td>‘...the change in diatom community is likely to represent a decrease in lake level and increased penetration of more brackish water, possibly associated with the variable, dry climate ...’</td>
</tr>
</tbody>
</table>

Fluin et al. (2004), given the evidence presented in Fluin et al. (2007), concluded that ‘Contrary to what many believe today, saltwater intrusions into the Lake environment were not common until after 1900 when significant water resource development had occurred in the River Murray system’. The new interpretation from Fluin et al. (2009)

In 2010 a new report was posted on the South Australian Government website. Entitled ‘An Environmental History of the River Murray and The Coorong’, this report on the paleolimnology of both Lake Alexandrina and the Coorong lagoon was produced by three of the five authors of the 2007 publication but was not published (nor paginated).

Using the same diagrams and descriptions as Fluin et al. (2007), Fluin et al. (2009) concluded: ‘There is no evidence in the 7000 year record of substantial marine incursions into Lake Alexandrina’, yet they also stated ‘There were substantial alterations to the diatom community in Lake Alexandrina following European settlement and particularly after barrage installation’. In contradiction to the evidence presented in Fluin et al. (2007) they asserted that: ‘Over the 7000 year record, there are minimal numbers (generally <10%) of estuarine diatoms’ and that ‘... estuarine conditions have essentially been absent from this section (LA1) of the lake (<5%)’.

The entire interpretation of the LA2 record in Fluin et al. (2009) can be found, word for word, from the same section in the 2007 paper but with two small, but significant, changes (Table 1). Specifically, the words ‘marine influence’ (Fluin et al. 2007: 130) are altered to ‘minor marine influence’, and ‘increased penetration of seawater’ (Fluin et al. 2007: 130) is altered to ‘increased penetration of more brackish water’. Both alterations diminish the interpretation of a tidal influence on the ecological character of Lake Alexandrina. The second alteration creates confusion as the term brackish cannot be qualified, it meaning salty waters, usually the result of freshwater mixing with seawater. So, the use of the terms ‘minor’ and ‘brackish’ serve to preclude the ocean as a source of lake water salinity.

Given that the relevant passage in Fluin et al. (2009) can be found word-for-word in Fluin et al. (2007), except for four
words that dramatically change the interpretation to one more consistent with a freshwater history, questions can be raised of the authors as to the justification for the new interpretation. Certainly, Fluin et al. (2009) offers no new palaeolimnological evidence, or new knowledge of the preferences of the key species, to lead to a reinterpretation. While a motive cannot be ascribed at this point, insight may be gained from a quote from a local from the Lake Darling Basin has intensified, a composition (coauthored by Gell) submitted to The Conversation (Finlayson et al. 2017) drew a particularly misguided post (https://theconversation.com/we-need-more-than-just-extra-water-to-save-the-murray-darling-basin-80188):

‘This has been studied using remains of diatoms, which neatly signal whether environments are saline, brackish or fresh, and they show unambiguously that for the last 7000 years Lake Alexandrina was a freshwater environment with only a few brief incursions of saltwater during extreme drought events (which over a 7000 time-span, you will have a few of).’

So yes, the lakes were indeed predominantly fresh for a long time, but one such paper detailing this evidence is: Fluin J, Gell P, Haynes D, Tibby J, Hancock G. (2007). Paleolimnological evidence for the independent evolution of neighbouring terminal lakes, the Murray Darling Basin, Australia. Hydrobiologia 591: 117–134.

The author of this post drew a conclusion as to the history of the condition of Lake Alexandrina over the last 7000 years and then cited the paper from which this conclusion was drawn, seemingly unaware that Gell was a coauthor of both the 2007 publication and the piece in The Conversation. Remarkably, the author’s summary does not reflect the conclusion of the paper cited.

These authors likely have used Fluin et al. (2007) to lend authority to a state they themselves had surmised. How did they get it so wrong? Possible alternatives include:

- they read Fluin et al. (2007) and concluded that the authors said, or intended to say, that the lake was ‘predominantly fresh’ thereby exhibiting ‘confirmation bias’ (sensu Berger and Johnston 2015);
- they assumed that the condition was ‘predominantly fresh’ and used Fluin et al. (2007) as an authority without checking;
- they took the opinion of Sim and Muller (2004) that the lake had been ‘predominantly fresh’ but sought, or were required under review, to cite peer-reviewed evidence to that effect, and failed to check;
- they had read Fluin et al. (2009), which provided them with the evidence that the lake was ‘predominantly fresh’ but, because it was not a published document, elected, or were required under review, to cite Fluin et al. (2007) as the authority;
- they read and fully understood the conclusions in Fluin et al. (2007) but elected to state that the lake was ‘predominantly fresh’ and still elected to cite Fluin et al. (2007) as the authority.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosley et al. (2012): 3925</td>
<td>‘The river channel discharges into the large (821.7 km²) total surface area and shallow Lower Lakes, which are freshwater, eutrophic, and highly turbid (Geddies 1984; Fluin et al. 2007; Cook et al. 2009).’</td>
</tr>
<tr>
<td>Mahon et al. (2015): 1491</td>
<td>‘The installation of tidal barrages and weirs near the mouth of the system (c.1940–50s) to prevent incursion of marine water resulting from upstream hydrological abstraction, modified the hydrology and ecology of extensive freshwater lakes known as the Lower Lakes (LL) and the Coorong estuary (Fluin et al. 2007; Wedderburn et al. 2002).’</td>
</tr>
<tr>
<td>Hammer et al. (2013): 807</td>
<td>‘This [regulation; flow reductions] has jeopardised the future of a long-term freshwater refuge and biodiversity hotspot (Phillips and Muller 2006; Fluin et al. 2007; Kingsford et al. 2011).’</td>
</tr>
<tr>
<td>Wedderburn et al. (2012): 36</td>
<td>‘… barrages were constructed in ~1940 in response to river regulation and water abstraction was causing periodic marine incursion in an otherwise predominately freshwater environment (Fluin et al. 2007).’</td>
</tr>
<tr>
<td>Kingsford et al. (2011): 257</td>
<td>‘Historically, the water in the lake was mainly fresh, indicated by freshwater diatom tests (95%) accumulated in the sediments over the past 7000 years (Barnett 1994; Fluin et al. 2007).’</td>
</tr>
<tr>
<td>Brookes et al. (2015): 192</td>
<td>‘Lake Alexandrina was estuarine prior to construction of the barrages, although palaeolimnological evidence suggests it was predominantly fresh (Fluin et al. 2007) as river flows restricted the tidally-driven, proximal lake Murray Mouth’.</td>
</tr>
<tr>
<td>Hammer et al. (2010): 221</td>
<td>‘In addition, the occurrence of N. obscura within MDB only in Lake Alexandrina supports information that this water body has been a predominantly fresh habitat over thousands of years (Sim and Muller 2007; Fluin et al. 2007).’</td>
</tr>
</tbody>
</table>
These options leave open as to whether these papers, and the post to The Conversation, reflect an instance of anything ranging from poor checking of the cited paper, to laziness, to deliberate obfuscation of the evidence presented. Maybe the authors have succumbed to confirmation bias or perhaps they were drawn, independent of the published evidence, to advocate a position that was consistent with the case calling for environmental flows under the Basin Plan. Irrespective, it seems that the science community has interfered with the honest representation of the palaeolimnological evidence and so has manipulated the socio-political decision-making process that has laid down a decision of great consequence.

Advocacy and evidence

Postmodern deconstruction of scientific evidence dispels the myth that science is always entirely objective. Head (1995), for example, neatly portrayed the likely inherent biases in the myth that science is always entirely objective. Head (1995), for Advocacy and evidence of great consequence. Palaeolimnological evidence and so has manipulated the socio-political decision-making process that has laid down a decision of great consequence.

In the acute regional contest under the allocation of water under the Murray–Darling Basin Plan, we have here evidence for the intrusion of political stakeholder bias in the reinterpretation of peer-reviewed published science. These interpretations may have been misled by the unpublished Fluin et al. (2009) report but this reveals poor attention to detail and a shallow review of the evidence. One fears that these contrary observations have suffered from an inclination to mix science with advocacy and the standards of one have been compromised by the pursuit of the other. In particular, in the absence of a case made to reinterpret the evidence presented. Maybe the authors have come to a position which is advocated.

While I have been trained to abide by the razor edge of representing the evidence and other advocates for either case in, for example, a development proposal, I personally understand when a scientist lapses into advocacy convinced that the best cause is served. Here, however, in my opinion, where this fatal step has undermined the quality of sound science, and steered the debate in another context when its original purpose, by way of its unique access to the time dimension, was to resolve the hitherto unresolvable. Perhaps the most critical lesson here is how this saga played out in the media and in the politics. Dr Jennifer Marohasy accused the duplicitous nature of the interpretation in Fluin et al. (2009) and labelled it as ‘Junk Science’ (Marohasy 2012), only to be pilloried in the ABC program Media Watch (19 March 2012; see also http://jennifermarohasy.com/2012/05/media-watch-watch-hunt/). Today, lobbyists seeking to limit the impacts of the Basin Plan on irrigation agriculture make use of this manipulation of evidence to seek to undermine the allocation of environmental flows.

In the end it is reasonable to ask why has a report that used and reinterpreted a published paper, and made conclusions that could not be substantiated by the evidence, been allowed to remain on a State Government website for others to misrepresent the science? The warning for us all in mixing science and advocacy is that the political process has no conscience and reputations are easily dashed. Upholding respect for our science demands that we report it with integrity and then, as members of society, seek to participate in the challenging processes that make decisions that affect people and their places.

Conflicts of interest

PG was an associate supervisor in the production of Fluin (2002) and was a co-author of Fluin et al. (2007).

Acknowledgements

Rosie Grundell drafted the appendix, Rob Mitchell drafted Fig 1 and Phuong Doan Fig 2. The author appreciates the comments of three anonymous reviewers and the associate editor whose inputs served to improve greatly the manuscript.

References


Finlayson, C. M., Baumgartner, L. & Gell, P. (2017). We need more than just extra water to save the Murray–Darling Basin. The Conversation, 30 June 2017.


www.publish.csiro.au/journals/pcb
Appendix 1. Ecological preferences of key fossil indicator taxa

Cyclotella striata

The Cyclotella striata species complex includes numerous species and subspecies with similar morphology (Håkansson 1996). Problems exist surrounding the identification of these centric species, in part because, in saline inland lakes, estuaries and lakes with high conductivities, there is a mix of marine and freshwater species and often the nomenclature has been guided by the ecology of the species being named (Håkansson 1996). Cyclotella has a wide environmental tolerance, but only eight species have been found in saline waters (Oliva et al. 2008), including those in the C. striata complex. Cyclotella striata sensu stricto has been described as being prevalent in brackish, marine, estuarine and inland saline lakes (Bradbury et al. 1981; Jiang et al. 1997; Saunders et al. 2008; Cook et al. 2016). It was regarded by Roetzel et al. (2006) as being allochthonous euryhaline (able to adapt to a wide range of salinities). Jiang et al. (1997) attributed a rapid increase in C. striata in a core from the north-eastern Atlantic margin to a decrease in sea salinity as a result of strong coastal currents and global sea level rise. They also observed it commonly in the spring plankton in estuaries along the North Sea coast. While Pokras (1991) reported C. striata as a brackish water species from the Zaire River, Africa, Marshall and Alden (1990) referred to it as being a freshwater species abundant in the estuarine rivers of the Lower Chesapeake Bay, USA. Declining abundance of C. striata in Chesapeake Bay cores was associated with increased turbidity and eutrophic conditions following European settlement in the 18th century (Marshall et al. 2005).

Paralia sulcata

Paralia sulcata has been reported in waters of varying salinities, from brackish to marine (McQuoid and Nordberg 2003); however, it is widely accepted as being predominantly marine (Snoeijis and Vilblaste 1994) where it inhabits the benthos and planktonic zones. It has a widespread cosmopolitan preference for marine littoral zones of the Baltic (Snoeijis and Vilblaste 1994) and has been recorded from the Arctic to the tropics. It preserves well in the sediments as water bodies and can be useful as a palaeoindicator species (McQuoid and Nordberg 2003) but can be resuspended by the water column from the benthos by tidal mixing and wind. This, and its broad tolerance, means that detailed study of the presence of this species can be difficult (McQuoid and Nordberg 2003). Commonly, the occurrence of P. sulcata in the sediment record has been interpreted as being an indication of high primary production caused by coastal upwelling (McQuoid and Nordberg 2003). McQuoid and Nordberg (2003) suggest that P. sulcata may have a competitive advantage in low light conditions as it is often recorded in increased abundances in winter (Gebühr et al. 2009) but this may also indicate an increase in the mixing of the benthos. It has also been found to have a negative correlation with salinity levels in the Inlets of British Columbia, showing its preference for estuarine, rather than marine, conditions and Gebühr et al. (2009) suggested that high salinity may be a limiting factor for this species. Declining abundances of P. sulcata have been attributed to an increase in deposition of fine, organic sediment (Mills et al. 2009), and freshwater or increased sediment flux in Chesapeake Bay (Cooper 1995). However, in contrast to the above studies, Zong (2007) reported P. sulcata in greater numbers in areas of fine-grained, organic-rich sediments.

Thalassiosira lacustris

The Thalassiosirales (from ‘thalassa’, meaning ‘of marine origin’) are known to include marine, planktonic, diatom genera, although there are freshwater or brackish water species recognised (Persson et al. 1987; Hasle 1978). Because of the diversity in valve morphology there is much confusion surrounding the taxonomy of the genus Thalassiosira (Smucker et al. 1998). Thalassiosira lacustris was first described in 1856 as being a freshwater species (Hasle and Lange 1989) but this species has since been recorded from both marine and freshwater environments (Hasle and Lange 1989), as reported by Hasle in 1980. Smucker et al. (2008) reported the species primarily in marine coastal regions but also from large rivers around the world. It was reported as spreading in North America, first being noted in environments such as coastal areas and large brackish rivers, but Smucker et al. (2008) collected it from several inland streams, although it was not recorded in any great abundance, except where moderate to high stream conductivities were also recorded. They concluded that T. lacustris can tolerate a wide range of habitats but is most likely to occur in brackish water as opposed to freshwater environs and was found in large numbers only in waters where moderately high conductivity also existed. Snoeijis and Vilblaste (1994) described it as a freshwater species with a brackish water affinity while Soons et al. (1997) used it to infer a freshwater zone above a brackish sediment sequence collected in Canterbury, New Zealand. John et al. (1997) served it in rivers in Western Australia, where he served it in rivers in Western Australia, where he described its habitat preference to be brackish with a salinity range between 2.5 and 15%, although he found it in the lower part of the Swan River estuary, where salinity levels were between 15 and 35%. The optimum electrical conductivity of T. lacustris collected from mostly freshwater samples in the Murray River was found to be 936 μS cm⁻¹ (Thiby and Reid 2004) but yet Smucker et al. (2008) reported that T. lacustris did not reach high numbers when the conductivity was <400 or >2000 μS cm⁻¹.