The effects of river stage fluctuations on the hyporheic and parafluvial ecology of the Hunter River, New South Wales

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Abstract

The hyporheic zone is the area of saturated sediments underlying many gravel-bed rivers where channel water actively exchanges with interstitial water. Through a series of biological, physical, and chemical filtration processes, the hyporheic zone influences the water quality of the surface stream. Lateral to the hyporheic zone is the parafluvial zone, the saturated area below gravel bars, which can have a similar filtration role. The ability of the hyporheic and parafluvial zones to act as filters largely depends on surface discharge. Fluctuations in discharge are needed to prevent the clogging of sediment pore-spaces, and to vary the rate at which nutrients and oxygen are transported into the hyporheic zone. Sediment packing, porosity and size, the amount of microbial and invertebrate activity, and stream topographical profile are other factors that control hyporheic filtration. Filtration efficiency is a measure of the rate at which dissolved nutrients and physico-chemical variables of a parcel of water are transformed during a period of interstitial flow. It can be gauged by measuring gradients of nutrients and physico-chemical variables along subsurface flowpaths.

From May 2000 to May 2001, the hyporheic and parafluval zones of seven sites along the Hunter River, a large coastal river in central New South Wales, were sampled using a hyporheic pump. Analysis of physico-chemical, nutrient, and invertebrate fauna samples revealed that all sites displayed some degree of hyporheic and parafluvial filtration. In general, the filtration efficiency declined with distance downstream, with the two upstream sites showing more biological activity than other sites. Despite this, there was no longitudinal increase or decrease in the net concentration of either nitrate/nitrite nitrogen (NOx) or soluble reactive phosphorus (SRP) in the downstream hyporheic zones. Most filtration occurred within the upper 40 cm of bed sediments. The most active part of the parafluvial zone was the area of sediments within 1 m of the upstream shore-line, and efficiency often declined within the first 10 m of the subsurface flow-paths. Deeper sediments and areas of the bar further from the stream appeared to act as storage areas for NOx.

Two unregulated sand bed tributaries of the Hunter River were also surveyed and displayed divergent trends in their bed filtration capacity. The fine sand of Wollombi Brook at Warkworth limited exchange substantially, so that most of the nutrient transformation probably occurred within the upper 10 – 20 cm of the bed. The

remainder of the bed and bar acted as slow-release nutrient storage areas, depending on upwelling groundwater or floods to facilitate exchange with the surface stream. In contrast, hydrologic exchange between bar and river at Sandy Hollow, on the Goulburn River, appeared to be less restricted than that at Warkworth, perhaps facilitated by spear-point pumping.

In all, 71 invertebrate taxa were collected from the interstitial habitats of the Hunter River and one of its tributaries. This fauna consisted of a mix of surface dwelling (epigean) species and groundwater fauna (stygobites). Three families of the stygobite crustacean superorder Syncarida were found during this study, as well as one amphipod family and a genus of blind isopod. The occurrence of stygobites at all sites emphasised the strong linkages between the hyporheic zone and the groundwater aquifer. These links have probably sustained the high hyporheic activity in the Hunter River, despite heavy anthropogenic modifications to its catchment.

Following these surveys, a conceptual model was developed and tested to examine the effects of stream fluctuations on hyporheic filtration efficiency and ecology. High, within-bank flows are predicted to enhance linkages between the hyporheic zone and stream. Strategically timed pulses of water temporarily increase discharge, covering more of the lateral bars and increasing the area available for hyporheic exchange. If the flow is great enough, fine particles will be flushed and sediment that has become compacted over time will be jostled loose, increasing the pore-space of the hyporheic zone. When this is coupled with the increased hydraulic pressure that comes with higher water levels, oxygen-rich surface water is able to travel further through the hyporheic zone and extend its oxidising margins both vertically and laterally. All of these processes are hypothesised to enhance bed filtration through stimulating microbial processes such as nitrification.

Glenbawn Dam regulates flow in the Hunter River and, in 1998-99 a series of flow rules was developed to promote environmental protection. Flow Rule 2 specifies that the first 12 h of each flow event be allowed to pass without abstraction, followed by a maximum abstraction of 50 %. The purpose of this rule is to re-establish small to medium flow events. Two flow experiments were conducted at three sites to test separate components of Rule 2 and understand its influence on the hyporheic zone. In the first experiment, an environmental flow of 15 000 ML was released over a period of three days, with all the restrictions on pumping specified by Rule 2. Combined sampling with a hyporheic pump and freeze corer indicated that the release increased porosity of the upper 20 cm of bed at two sites and stimulated microbial nitrification. Nitrification was also enhanced at the third site but porosity did not change, probably due to the coarser substrata. For the second experiment, a 12 h diversion of water over the bars at two sites revealed the effects of the initial ban on pumping. No changes in nitrogen dynamics were observed but soluble reactive phosphorus, initially flushed from the sediments, increased following the removal of the diversion. At one site, densities of epigean taxa increased in the interstitial habitat during the diversion. These experimental results show that Rule 2 enhances hyporheic processes in two ways. First, deeper infiltration of oxygenated water allows aerobically mediated microbial processes such as nitrification to occur in a larger volume of sediment. Second, by covering a larger portion of the bar, the size of the hyporheic filter is extended.

This study is the first broad-scale investigation into the hyporheic zone of any large Australian regulated river. It uncovered a rich invertebrate fauna, an active microbial biota, and significantly improves our understanding of how environmental flows benefit the hyporheic zone. In streams with strong connections to the aquifer, such as the Hunter River, hyporheic biological processes can be maintained through environmental flow releases in the surface channel. Controlled manipulations in river stage may be a useful means of improving surface water and groundwater quality through hyporheic and parafluvial filtration.

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