Summary: Investigating Trace Metal Transport Mechanisms in an Intensive Horticultural Catchment

Through funding from the Coffs Harbour Environmental Levy program, Southern Cross University Researchers conducted water quality monitoring in Double Crossing Creek, a tributary of Hearnes Lake estuary and the Solitary Islands Marine Park (SIMP), to assess the influence of upstream horticulture on water quality.

Our sampling site in Double Crossing Creek has many different farms upstream, from banana and blueberries, even hothouses that grow cucumbers and tomatoes. On these industrial scale farms chemicals such as fertilizers, fungicides, herbicides, and others are often applied. These treatment products often contain trace metal impurities. For example, fertilisers might contain trace amounts of mercury, cadmium, or zinc. Fungicides can contain zinc and copper to combat unwanted fungal growth. These chemicals accumulate on farm soils during dry times. When rainfall events occur, these chemicals can be washed away from the shallow soils and enter nearby waterways.

In this study we focused on the dissolved trace metal flow in creek waters draining the studied catchment. Trace metals are elements such as zinc, lead, mercury, cadmium, and many others. Dissolved simply means that our samples were passed through a filter, removing any solid particles before analysis. We sampled a location downstream of these farms during dry and wet periods. Samples were taken once a day until rainfall occurred. In order to observe chemical runoff from the rapid soil flushing upstream, we took water samples from Double Crossing Creek every 1 to 3 hours during times of heavy rainfall. We gathered a total of 107 samples over 66 days in the summer of 2018.

Dissolved trace metal concentrations were determined with highly specialized laboratory analysis. Our concentrations were compared to the Australia/New Zealand Environment and Conservation Council Water Quality Guidelines (ANZECC WQG). Trace metals mercury, zinc, copper, and manganese exceeded the WQG more than 20 % of our sampling events. Concentrations were found be elevated after rain events greater than 50 millimeters in a day. Concentrations over the guidelines could mean these metals are negatively affecting the aquatic organisms in Double Crossing Creek, and even further downstream in the SIMP, although our sampling did not test for any biological effects. How these elevate trace metal concentrations affect the local biota is a future research topic we would like to explore.

In addition to measuring dissolved trace metal concentrations, we measured the water volume of the creek at each sampling event. Our trace metal concentrations multiplied by our creek volume allow us to calculate the total flow of trace metals in the creek. These results indicated that when heavy rains occur, dissolved metals in Double Crossing Creek not only become more concentrated, but the water volume in the creek increases by orders of magnitude, meaning the total amounts of trace metals, or the metal 'loading' in the creek increase significantly. We estimated the 'export rate' of metals from each square meter of our upstream catchment in order to compare metal runoff amounts to other systems. As the soils flush during the rain, the metals that have accumulated during the dry periods are exported to Hearnes Lake and potentially the coastal ocean.

Hearnes Lake is an estuary known as an intermittently open/closed lagoon lake (ICOLL) of which is not always connected to ocean. During dry times, a sandbank prevents the water in Hearnes Lake from flowing to the coastal ocean. When there is sufficient rainfall, the lake can fill up, spilling over the sandbank and draining rapidly to the coastal ocean. In the first big rain event of our monitoring, Hearnes Lake began to drain to the coastal ocean. Hearnes Lake remained open to the ocean for the remainder of our time series measurements. The estuary being open may have special implications when considering the fate of metals being washed down Double Crossing Creek.

Our results indicated that many metals (for example aluminium, lead, zinc, and copper) followed rainfall patterns. Basically, the bigger the rain event, the higher the concentrations and subsequent export rates. Mercury was one exception to this pattern. Within 72 hours of the ICOLL bursting, 79 % of our total estimated upstream mercury catchment export occurred. This may mean that the mercury is being exported to the SIMP as Hearnes Lake rapidly drained. Mercury likely behaved different due to its chemical properties. At approximately 25° C, mercury can volatise into the atmosphere, becoming a vapour. We believe that mercury may be accumulating in the atmosphere during dry times, where it then falls out and washes into the creek during major rain events.

Our study did not test what happens to the metals after they pass our sample site. To help understand what the fate of metals may be as they enter Hearnes Lake estuary, we compared our catchment export rates to metal sediment burial rates from previous research within Hearnes Lake. Estuaries act as natural sediment traps, and can prevent inputs from upstream from reaching the coastal ocean. Our comparison indicated that the export rate of many metals which like to bind to soil particles (for example aluminium, lead, and copper) are similar to estuary sediment burial rates. This means the muds on the bottom of Hearnes Lake might be efficiently taking up large portions of the waterborne metals entering Hearnes Lake, preventing them from reaching the coastal ocean.

In contrast, our comparison revealed that other metals that typically remain dissolved in solution (such as mercury and cadmium) are being exported into the estuary at greater rates than they are being buried by sediments. This means that these specific metals could be may be exported to the coastal ocean and SIMP when the ICOLL is open. This result was only a comparison based off of previous data. Our study did not measure the oceanic export of any trace metals. Therefore, the exact fate of these metals is still unknown. For example, these metals could be buried in oceanic sediments, or taken up by biota.