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Report to the Community

WATER AND RIVERS COMMISSION
WILSON INLET MANAGEMENT AUTHORITY

SEPTEMBER 1999

Summary of the Estuarine Monitoring Programme Conducted in Wilson Inlet 1995 to 1998

Over the past decade there have been reports of algal blooms and excessive growth of the seagrass *Ruppia megacarpa* within Wilson Inlet. These observations of increased aquatic plant growth may be a symptom of nutrient enrichment, or eutrophication of the Inlet. If the nutrient enrichment of the Inlet is allowed to progress unchecked, over the course of several years (maybe decades) the Inlet water quality may degrade, and algal blooms and other nuisance plant growth could become more prevalent. Such a pattern of degradation has occurred in several West Australian waterways including the Albany harbours and the Peel-Harvey Estuary. To intervene effectively against the eutrophication of Wilson Inlet, it is important to understand the sources and processes that are contributing nutrients to the Inlet and the processes controlling the cycling and movement of the nutrients in the Inlet.

The Wilson Inlet Management Authority together with the Water and Rivers Commission commenced catchment and Inlet water quality monitoring in a response to the need for

information on the processes operating in the Inlet and its catchment. Regular water quality monitoring started in 1995, and has continued to the present day. This report presents the data that was collected between 1995 and 1998 with a discussion of the results, and is a summary of the full report entitled "Water Quality in Wilson Inlet 1995 to 1997, Water and Rivers Commission Report No. WRT 14, 1999". A glossary of terms is provided at the end of this report. The monitoring data collected on the tributaries of Wilson Inlet are the subject of subsequent reports.

What information does the Water and Rivers Commission collect in Wilson Inlet?

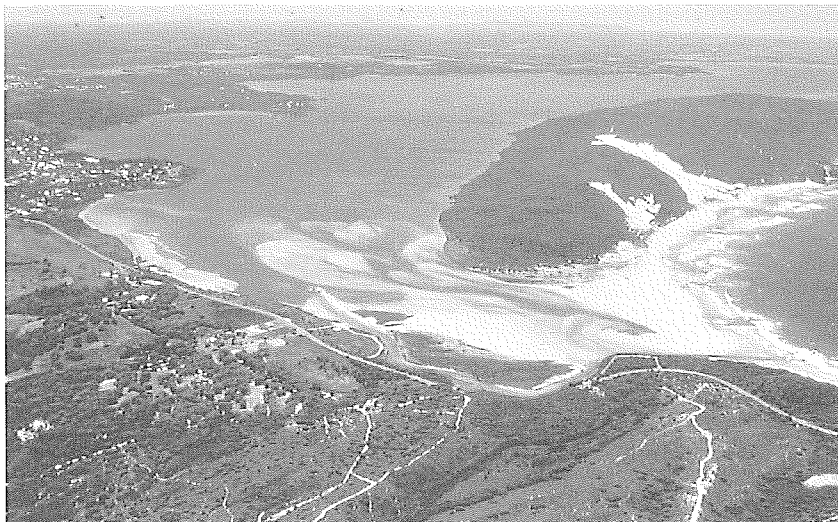
Over 1995 to 1998 estuarine water quality data were collected at the seven sites shown in Figure 1. At each site the following water quality information was collected every week.

Physical data: An oceanographic probe was used to collect data on the salinity, temperature and oxygen content of the water column.

Nutrient Data: Water samples were collected from the surface and the bottom of each site to give measurements of the nutrient content of the water. Three forms of nitrogen (ammonium, nitrate and total nitrogen) and two forms of phosphorus (phosphate and total phosphorus) were measured.

Phytoplankton Data: Samples were collected to identify the species of phytoplankton (single-celled algae) in the estuary.

In addition to water quality data the Water and Rivers Commission also collects water level information at two locations in the Inlet and wind data. In the catchment the major tributaries are routinely sampled for nutrient levels and the volume of river flow.



View of Wilson Inlet from the coast, photo by Simon Neville, 1995.

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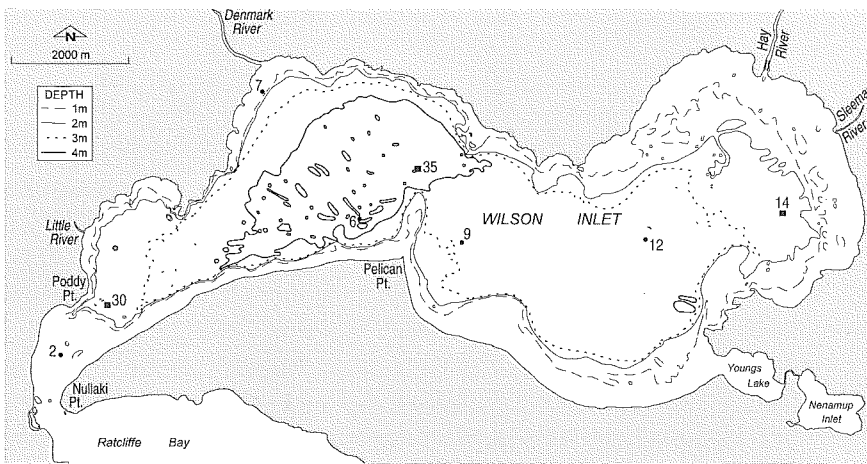


Figure 1: Wilson Inlet bathymetric map, showing the locations of the Water and Rivers Commission sampling sites.



Wilson Inlet sampling showing the oceanographic probe used to collect the physical data, photo by Mark Pheasant and Geoff Bastyan.

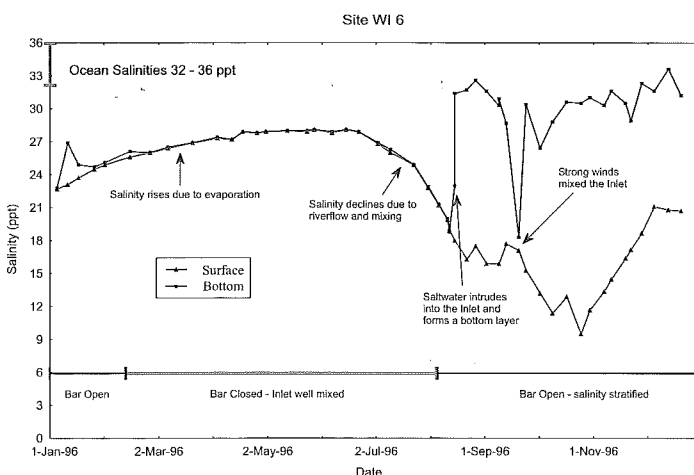
Results of the monitoring program

Physical conditions

The physical conditions control the Inlet environment and are important for the functioning of the whole ecosystem. The conditions change seasonally and are highly influenced by riverflow, winds and whether the sandbar at the mouth of the Inlet is open or closed.

When the sandbar at the mouth of the Inlet is closed, the Inlet behaves like a shallow lake. Winds act to mix the water column and the water composition is almost uniform throughout the entire Inlet. The salinity gradually rises over late summer and autumn due to evaporation. With the winter rains, freshwater runs into the Inlet and the salinity starts to fall and the water level rises (Figure 2).

Figure 2: The surface and bottom water salinities at site WI 6 over 1996. From March to August the surface and bottom readings are the same, indicating the water column is well mixed. When the bar is opened a saline bottom layer intrudes into the Inlet and there is a large difference in the surface and bottom readings.



When the bar is opened, the conditions in the Inlet are dramatically changed. For about three days Inlet water floods out, rapidly lowering the water level. After the intensity of this outpouring has declined, seawater is able to intrude into the Inlet on high tides. The saline seawater is denser than the brackish Inlet waters and sinks, forming a salty layer on the bottom (see Figure 3). This is known as a salinity-stratified state. With high tidal heights and suitable wind conditions, the bottom saline layer can penetrate up to 12 km into the Inlet. The saline layer can reach up to 1 m thick in the western basin and 50 cm thick in the eastern basin. The saline layer generally persists until there are strong winds that can mix the Inlet waters.

The dense bottom layer suppresses mixing and restricts the transport of oxygen. Biochemical processes in the sediments and water consume dissolved oxygen. If the oxygen is consumed faster than mixing is able to supply it, the oxygen levels decline. In Wilson Inlet, if the salt layer remains for over a week, the oxygen levels in the bottom water fall and anoxic conditions (complete absence of dissolved oxygen) can develop.

With the input of saltwater, the Inlet salinity rises over summer. As riverflow falls, the channel at the mouth of the Inlet reduces in size and less seawater gets into the Inlet. Eventually the bar closes completely and direct exchange with the ocean stops.

Nutrients in Wilson Inlet

Like the seasonal variations in the physical conditions of the Inlet, the nutrient levels within the water column vary considerably over a year. This is due to seasonal inputs from rivers and groundwater and the response of the biota to both the physical conditions and nutrient availability.

The levels of nutrients within the Inlet and catchment are monitored regularly to keep check on the amount of nutrients that are available to support plant growth and to determine the processes that are involved in the recycling of nutrients in the Inlet. Phosphorus and nitrogen are the two nutrients that are monitored in detail, due to their importance to plant growth.



Nitrogen (N) — the fourth most abundant element in living matter (after carbon, hydrogen and oxygen).

The parameter called Total Nitrogen (TN) measures all of the nitrogen in the water column. This includes all the dissolved forms and particulate nitrogen (this includes the nitrogen in phytoplankton and the nitrogen associated with other particles such as sediments). The nitrogen from the cellular material of organisms is referred to as organic nitrogen and can be in both dissolved and particulate forms. Not all of the nitrogen in the water column can be used directly by plants. The major forms of nitrogen readily available to phytoplankton, other plants and bacteria are the dissolved species, ammonium (NH_4^+) and nitrate

(NO_3^-). Ammonium is generally more rapidly taken up by phytoplankton and other aquatic plants than is nitrate.

Phosphorus (P) — an essential element in living matter that is required in smaller amounts than nitrogen.

The parameter called Total Phosphorus (TP) measures all of the phosphorus in the water column. This includes all the dissolved forms and particulate phosphorus (this includes the phosphorus in phytoplankton and the phosphorus associated with other particles). Phytoplankton can generally only use soluble phosphate (PO_4^{3-}) for growth.

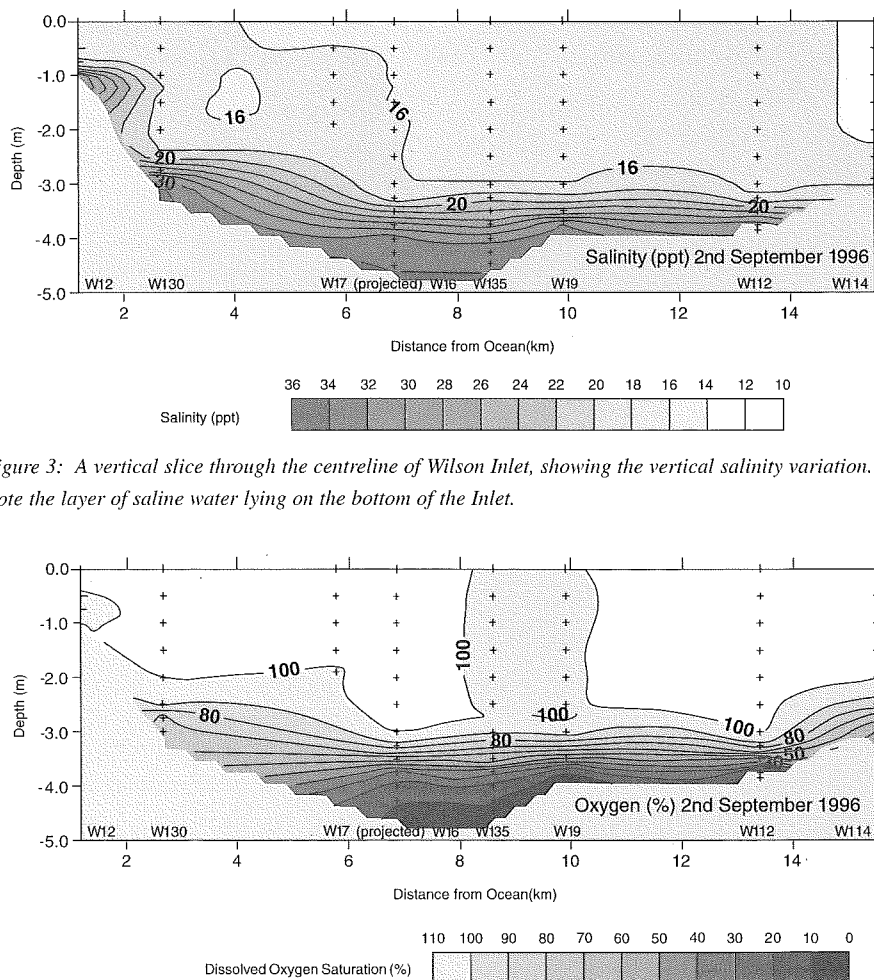


Figure 3: A vertical slice through the centreline of Wilson Inlet, showing the vertical salinity variation. Note the layer of saline water lying on the bottom of the Inlet.

Figure 4: A vertical slice through the centreline of Wilson Inlet, showing the vertical dissolved oxygen variation, expressed as percentage saturation. Note the very strong relationship between the location of the saline bottom layer (Figure 3), and the area of low oxygen.



Sources of nutrients

Most of the nutrients that reach Wilson Inlet today come from the land or from within the Inlet itself. Nutrients also come in from the ocean and from precipitation, but the quantities are insignificant when compared to the inputs from the catchment and from the Inlet sediments.

Catchment derived nutrients

High levels of total nitrogen, nitrate, total phosphorus, phosphate, other nutrients, organic matter and sediments all come from the catchment each winter, when the rainfall is high. Fertilisers, eroded soil, manures and septic tank wastes all contribute to the matter that ends up in the rivers and streams. Large proportions of the nutrients that are delivered to the Inlet are in the form of small particles, and may include large quantities of organic nitrogen from manures. In the Inlet the organic form of nutrients can be converted into forms that encourage phytoplankton growth. The seasonal fluctuation in nutrient levels is best demonstrated by the variation in nitrate concentration in the Inlet and tributaries over time, as shown in Figure 6. There is a large rise in the nitrate levels in the Hay River around June/ July of each year, due to the onset of heavy rainfall and hence riverflow (Figure 5). The flows associated with storms often carry the highest concentrations of nitrate and TN, due to the flushing of summer build up from the catchment. The delivery of the nutrients to the Inlet causes levels measured in the Inlet to rise. Because of dilution with the Inlet water and other processes that take up nutrients, the concentrations are lower than recorded in the rivers.

The biggest proportions of nutrients enter the Inlet in winter, however the Sleeman River and Cuppup Creek also deliver high concentrations of nutrients in summer. Although the river flow in summer is lower, any nutrients flowing into the river in summer are retained within the Inlet because the bar is closed.

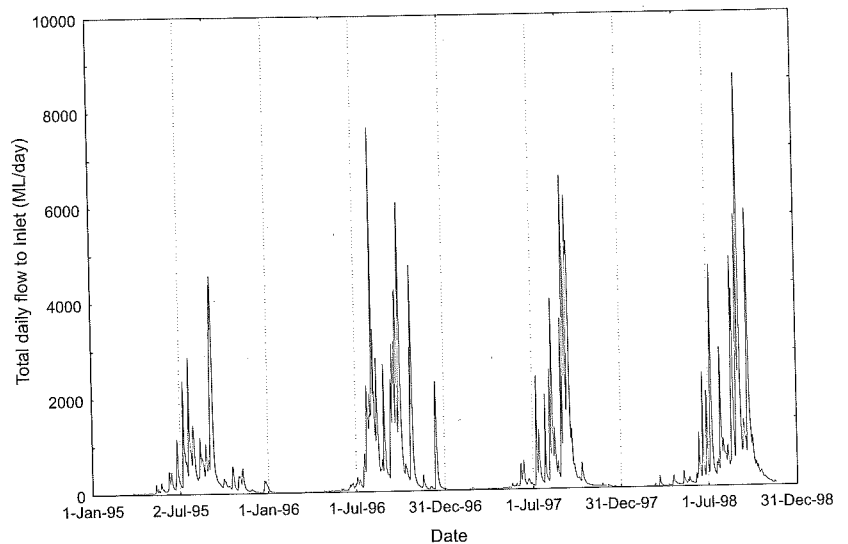


Figure 5: The total flow into Wilson Inlet, measured at Water and Rivers Commission gauging stations.

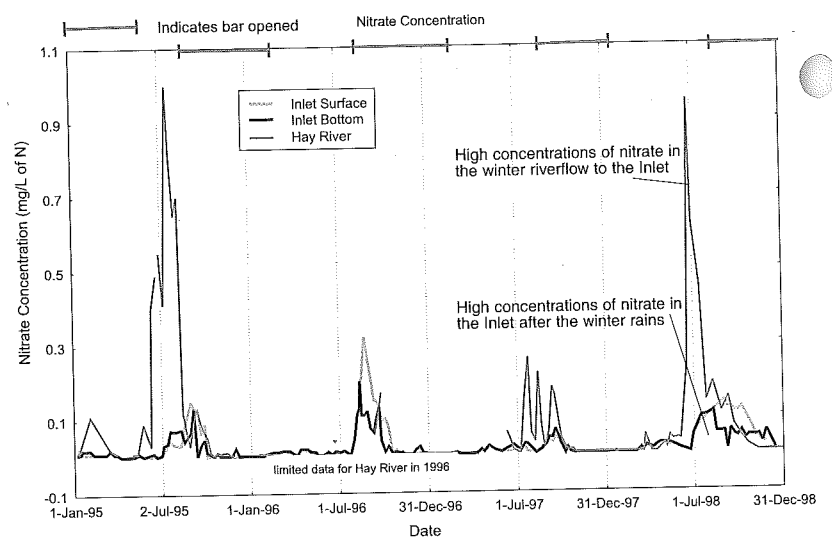


Figure 6: The nitrate variation at a central basin site (WI 6) in Wilson Inlet and in the Hay River. Both surface and bottom samples are shown for the estuary site.

Sediment-derived nutrients

The sediments and muds of Wilson Inlet contain organic matter, such as plant material from the catchment and decaying seagrass and algae. When this organic matter breaks down in the aquatic environment, carbon dioxide, water and forms of ammonium and phosphate are released. Certain minerals in the sediments can also contribute nutrients to the Inlet. This release of nutrients from decaying organic matter is an important natural ecological process that recycles nutrients. However, when nutrient enrichment causes excessive plant growth, this can lead to a greater store of organic matter in the sediments, and even further nutrient release as this material breaks down.



The variation in ammonium levels over 1995 to 1998 is shown in Figure 7. From Figure 7 it is evident that the behaviour of ammonium is quite different from that of nitrate. Ammonium comes down the rivers in winter, but in much lower concentrations than nitrate. Higher concentrations of ammonium are found in the Sleeman River and Cuppup Creek in summer. Unlike nitrate, there is very little ammonium in the surface waters of the Inlet throughout the whole year. The bottom waters are also low in ammonium for most of the year, however at certain times there are very high concentrations. High levels of phosphate can also occur at the same time as the high ammonium levels. This is because ammonium and phosphate are released from the sediments.

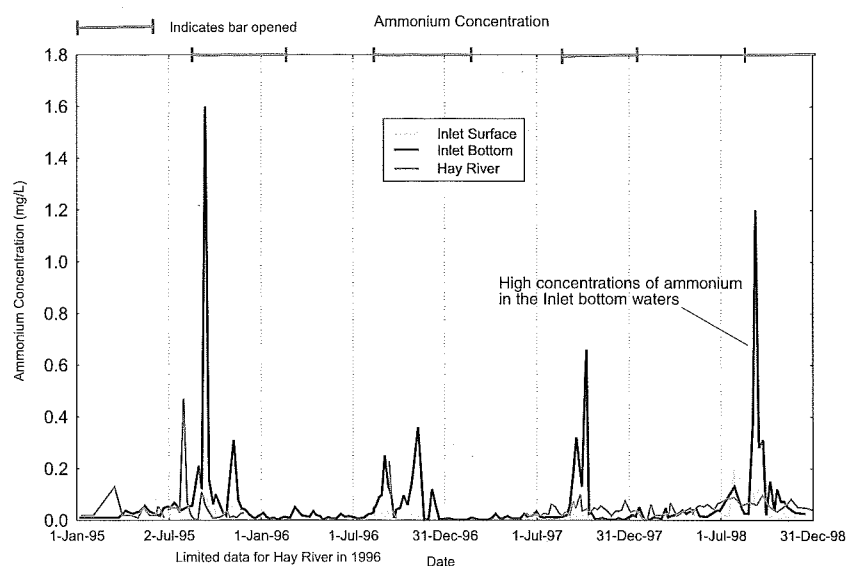


Figure 7: The ammonium variation at a central basin site (WI 6) in Wilson Inlet and in the Hay River. Both surface and bottom samples are collected for the estuary site. Note the big difference between the ammonium and nitrate data.

The high levels of ammonium occur for only a few weeks each year, when the bar is open and there is a saline layer of water on the bottom of the Inlet. This is because the saline layer restricts mixing and so de-oxygenated conditions can occur. Under oxygenated conditions, the ammonia released from the breakdown of organic matter can be removed from the water body as nitrogen gas by the action of bacteria which facilitates nitrification and denitrification. When the oxygen levels drop too low, nitrifying bacteria are unable to function and ammonium released from the sediments is trapped and stored within the saline layer, where very high concentrations can be reached.

High levels of phosphate also occur when the Inlet is stratified. As with ammonia, the phosphorus is released due to the breakdown of organic material in the sediments. An additional mechanism operates to release phosphorus to the water column because phosphate has a strong tendency to bind to the surface of particles, such as clays and other minerals. Under the anoxic conditions which

can occur when the Inlet is stratified, some of the particles, in particular some iron minerals dissolve and release their bound phosphate.

What happens to the nutrients once they are in the Inlet?

The levels of nutrients in the waters of the Inlet are relatively low for most of the year. This is despite the fact that there are significant inputs of nutrients from the rivers, creeks, groundwater and the sediments. In Figure 6 and Figure 7 it can be seen that the high concentrations of both nitrate and ammonium fall very quickly. Chemical transformations, uptake by bacteria, plants and algae and

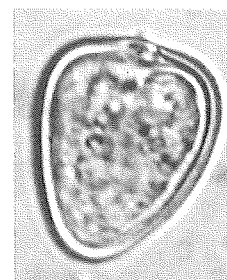
flushing to the ocean all remove the nutrients from the water column and hence influence the concentrations of nutrients observed in the Inlet.

Initial calculations of the quantities of nutrients that enter the Inlet and the quantities that are flushed out to the ocean, indicate that well over half of the dissolved inorganic nitrogen (nitrate + ammonium) and phosphate that comes in from the rivers and creeks is actually retained within the Inlet each year. There are many different pathways that can lead to nutrient retention, or storage, within the Inlet.

Some storage may remove the nutrients permanently, such as burial, while other methods, such as uptake by plants, may be temporary and can lead to nutrient release back to the Inlet at a later date. The most important forms of nutrient storage are discussed below.

Phytoplankton

The microscopic algae living in the water column, referred to as phytoplankton, take nutrients direct from the water for their growth and reproduction. Phytoplankton are a natural and important part of any aquatic environment, but when they occur in excessive numbers for long durations they are a nuisance, as they cause algae blooms and can even be toxic. Due to the importance of phytoplankton the Water and Rivers Commission monitors Wilson Inlet for phytoplankton at least every fortnight. This is done by microscopic identification and counting of the phytoplankton cells.



The dinoflagellate *Procentrum minimum* var. *triangulatum*, one of the species of phytoplankton which has reached bloom proportions in around September in each of the years 1995 to 1998. Average cell size is 20 μ m. [Photo by Wasele Hosja]

For most of the year the phytoplankton abundance in Wilson Inlet is low. The levels of nutrients in the water column are insufficient to support a large population of phytoplankton. However, in winter the levels of nutrients are high due to runoff from the catchment and the nutrients released from the sediments. As the weather starts to warm up, conditions become suitable for phytoplankton growth. A bloom has been reported in September/October every year from 1995 to 1998 (Figure 8). Diatoms and dinoflagellates are the main species involved. The species in Wilson Inlet are not toxic but do discolour the water. The number of phytoplankton cells in the water column during a bloom reach around 100 000 cells/ml, and levels as high as 450 000 cells/ml have been reported. At the peak of the bloom the nutrient levels are low, suggesting that the phytoplankton have taken up much of the available nutrients for growth. When the bloom collapses a small release of nutrients is observed in the bottom waters due to the breakdown of the cells, but this does not stimulate another bloom. There is currently no phytoplankton problem in Wilson Inlet.

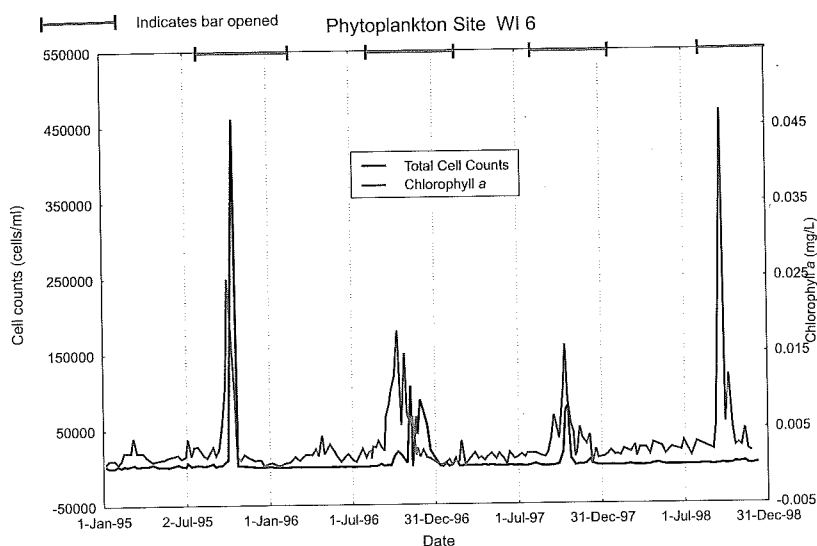


Figure 8: The total depth integrated cell counts and surface chlorophyll levels at site WI 6. Although the two parameters measure the same things, during a bloom the two parameters behave slightly differently due to the patchy distribution of the phytoplankton population.

Phytoplankton are not a major problem because there are other primary producers that compete with them for nutrients. In summer when the water is clear and solar radiation is high, there is a large population of algae which grow on the bottom on the Inlet. These particular types of algae, known as benthic algae, are ideally placed to intercept nutrients released from the sediments. Little is known about these bottom dwelling algae which may play an important part in removing nutrients from the waters of Wilson Inlet.

Seagrasses

The extensive meadows of *Ruppia* seagrass represent the largest amount of biomass in the Inlet, and are capable of taking up large quantities of nutrients. *Ruppia* is present all year round, and is important in removing nutrients from the water column, which prevents excessive phytoplankton growth for most of the year. *Ruppia* seagrasses can also take up nutrients from the sediments through their roots. Epiphytes (the brown furry material often seen on *Ruppia* leaves) which grow on the *Ruppia* are also important for removing nutrients from the water column.

Bacteria and chemical reactions

Bacteria also use nutrients. Some of the most beneficial bacteria are denitrifying bacteria, which convert nitrate to nitrogen gas, completely removing nitrogen from the Inlet to the atmosphere. The denitrifying bacteria require conditions low in oxygen, so most of their action occurs down in the sediments. These bacteria help to remove the nitrogen released from the breakdown of organic matter before it reaches the water column.

As well as biological uptake of nutrients, chemical reactions remove nutrients from the water column. This is particularly important for phosphate. Phosphate is a 'sticky' nutrient and is rapidly adsorbed (attached) and released from particles of clay and other minerals. Phosphate from the rivers may adsorb to particles and then settle to the bottom of the Inlet. If the particles are buried, then the phosphate is no longer available. If burial does not occur, then the bound phosphate can be re-released to the water column under certain conditions, particularly anoxic conditions.

The relative importance of each species or process in keeping Wilson Inlet free from excessive algal growth is not well known.

So, how healthy is the Inlet?

For the years 1995 and 1998 the concentration of dissolved nutrients within the Inlet for over half the year was very low. Evidence of nutrient enrichment during the period when the bar is closed and there is no riverflow is hard to detect as there are clear waters and very little phytoplankton activity in the Inlet. The levels of nutrients during this period were comparable or lower than the levels reported in the 1950s.



Considerable amounts of nutrients do however, reach the Inlet. The catchment data indicate that high levels of both nitrogen and phosphorus, significantly above the Australian Guidelines (ANZECC Guidelines, 1992) are measured in the inflows. It is quite surprising that the Inlet does not show further signs of nutrient enrichment. Several important factors act to maintain the water quality in the Inlet.

Although phytoplankton blooms generally occur only once a year, other excessive plant growth within the Inlet is evident. The *Ruppia* and its epiphytes, and benthic algae are responsible for utilising most of the nutrients that come into the Inlet and hence keep the level of nutrients in the water column low for much of the year. The Inlet biomass is thus a significant store of nutrients.

The fact that anoxic events occur in such a shallow water body as Wilson Inlet, indicate in itself that the Inlet is moderately nutrient enriched. The anoxic events are important as they can lead to the increased release of nutrients from sediments. The high concentrations of nutrients that are released from the sediments are only reported when the Inlet is stratified. Wind mixing is an extremely important process acting to breakdown the stratification and transporting oxygen to the sediment water interface. The strong winds that often buffet the south coast act to limit the length of time that severe stratification persists. The winds may thus be a factor moderating the eutrophic status of Wilson Inlet.

The Inlet is storing a significant portion of the nutrients that come in from the catchment, and this is a potentially dangerous situation, as the nutrients can be released back into the water column. Should the anoxic events that have been identified in the last three years increase in spatial extent or duration (due perhaps to very still conditions, or an increase in organic loading from the catchment), then the internal store of nutrients in the organic matter of the sediments could be released to the water column in far greater levels than is currently observed. Although much of the nutrient released could be internally recycled back into the *Ruppia*, faster growing species of phytoplankton would be favoured to rapidly utilise the nutrients. This could lead to a shift in species composition and head down the path to more severe symptoms of eutrophication, as occurred in Albany harbours.

What can be done?

There is much that can be done to maintain the health of the Inlet and prevent it from going down the same path as other West Australian waterways such as the Peel-Harvey Inlet and Albany harbours. The Water and Rivers Commission and the series of National Eutrophication Management Program (NEMP) studies are working to uncover more about the important nutrient cycling processes in the Inlet. The importance of the *Ruppia* seagrass and phytoplankton in using nutrients is being investigated. The role of the sediments in nutrient cycling in the Inlet is another topic of study. These projects will fill in vital information gaps and provide a very good understanding of how the Inlet works. This is essential for future management of the Inlet and the information can potentially apply to other estuaries.

Understanding and managing the Inlet is only a small fraction of the work that needs to be done to keep the Inlet healthy. The most important work must be done in the catchment where all the nutrients that end up in the Inlet came from initially. Fencing creeklines so that stock access is controlled is a very effective way of mitigating both soil erosion and nutrient export from cleared land. Revegetating creeklines with native vegetation is also effective as the vegetation can act as a trap for soil and nutrients. Converting septic tanks to sewerage systems and applying only the minimum of fertiliser necessary will reduce the amount of nutrients that reach the rivers and the Inlet. For more information on land management practices that will help protect Wilson Inlet contact the Denmark Office of the Water and Rivers Commission.

For more information contact



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Glossary

For the definition of other water related words please refer to Water words, Water and Rivers Commission, Water facts No. 1, February 1998.

Algae - A diverse group of aquatic plants containing chlorophyll and other photosynthetic pigments.

Microscopic algae are referred to as phytoplankton, whilst algae visible to the unaided human eye are referred to as macroalgae.

Anoxic - Absence of oxygen in the water.

Brackish - Saline water not as salty as the ocean.

Denitrification - The transformation of nitrate to nitrogen gas, which is carried out by bacteria under suitable low oxygen conditions.

Diatoms - Single celled algae, characterised by two overlapping silica cases surrounding each cell.

Diatoms are often the most abundant type of phytoplankton found in Wilson Inlet.

Dinoflagellates - Single celled algae characterised by two flagella. Dinoflagellates are found in Wilson Inlet.

Epiphytes - Small animals and plants, usually algae that grow on the leaves of seagrasses and macroalgae.

Macroalgae - Algae visible to the unaided human eye. Includes large green, red and brown algae often referred to as seaweeds or kelp.

Nitrification - The transformation of ammonia to nitrate, which is carried out by bacteria under oxygen rich conditions.

Nutrients - Minerals dissolved in the water, particularly compounds of nitrogen (ammonia and nitrate), phosphorus (phosphate) and silicon (silica) which are essential for plant growth.

Phytoplankton - Small algae (often single celled), identifiable under a microscope, e.g. diatoms and dinoflagellates.

Seagrasses - Marine flowering plants (angiosperms) found in coastal rivers, estuaries, protected coastal embayments and nearshore coastal areas. They are ecologically important as they provide habitat and food for many organisms, and stability for the seabed.

E.g. *Ruppia* species

Stratification - Formation of layers in a body of water (generally due to water of different salinity or temperature).

Further Reading on Wilson Inlet

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