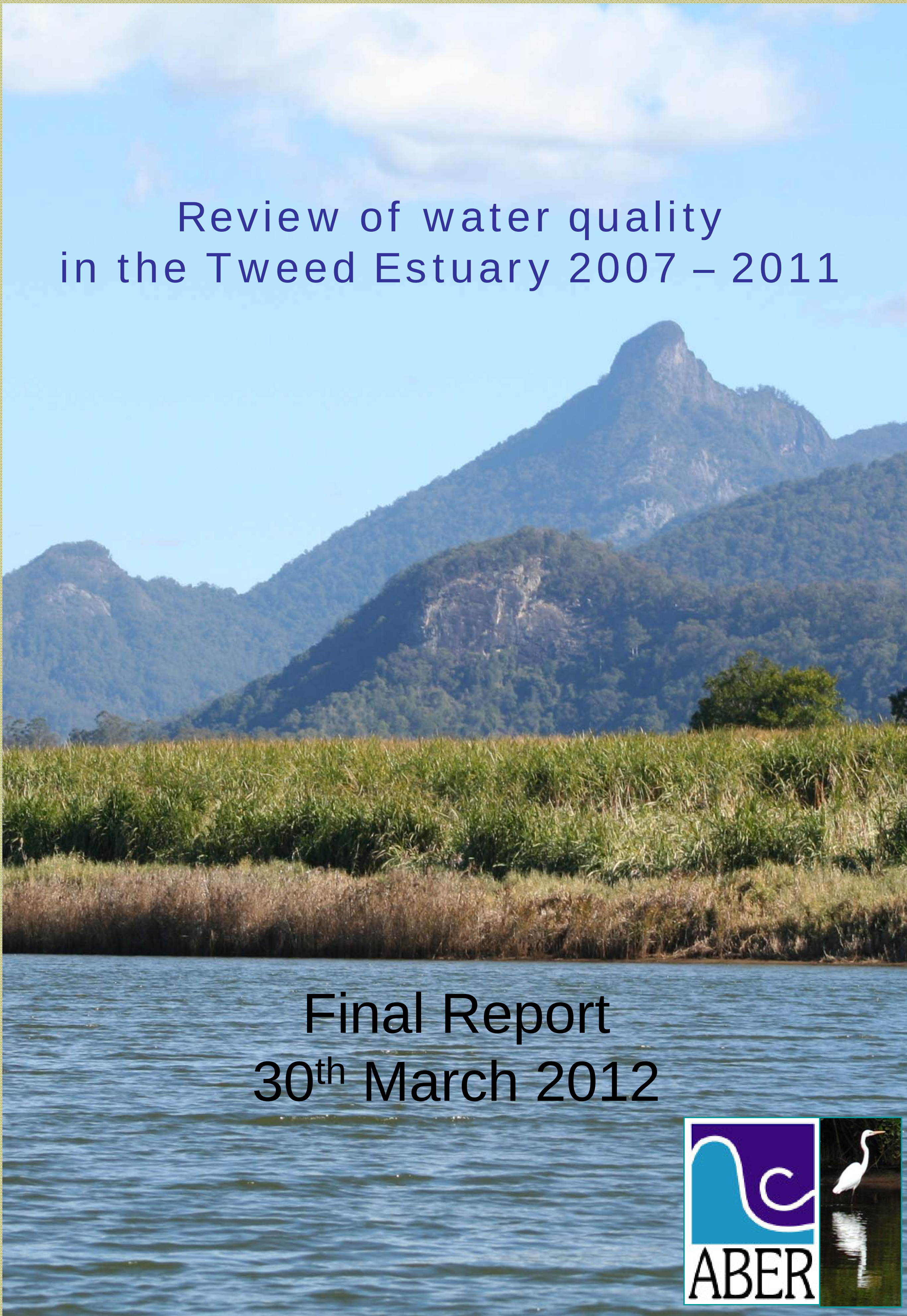
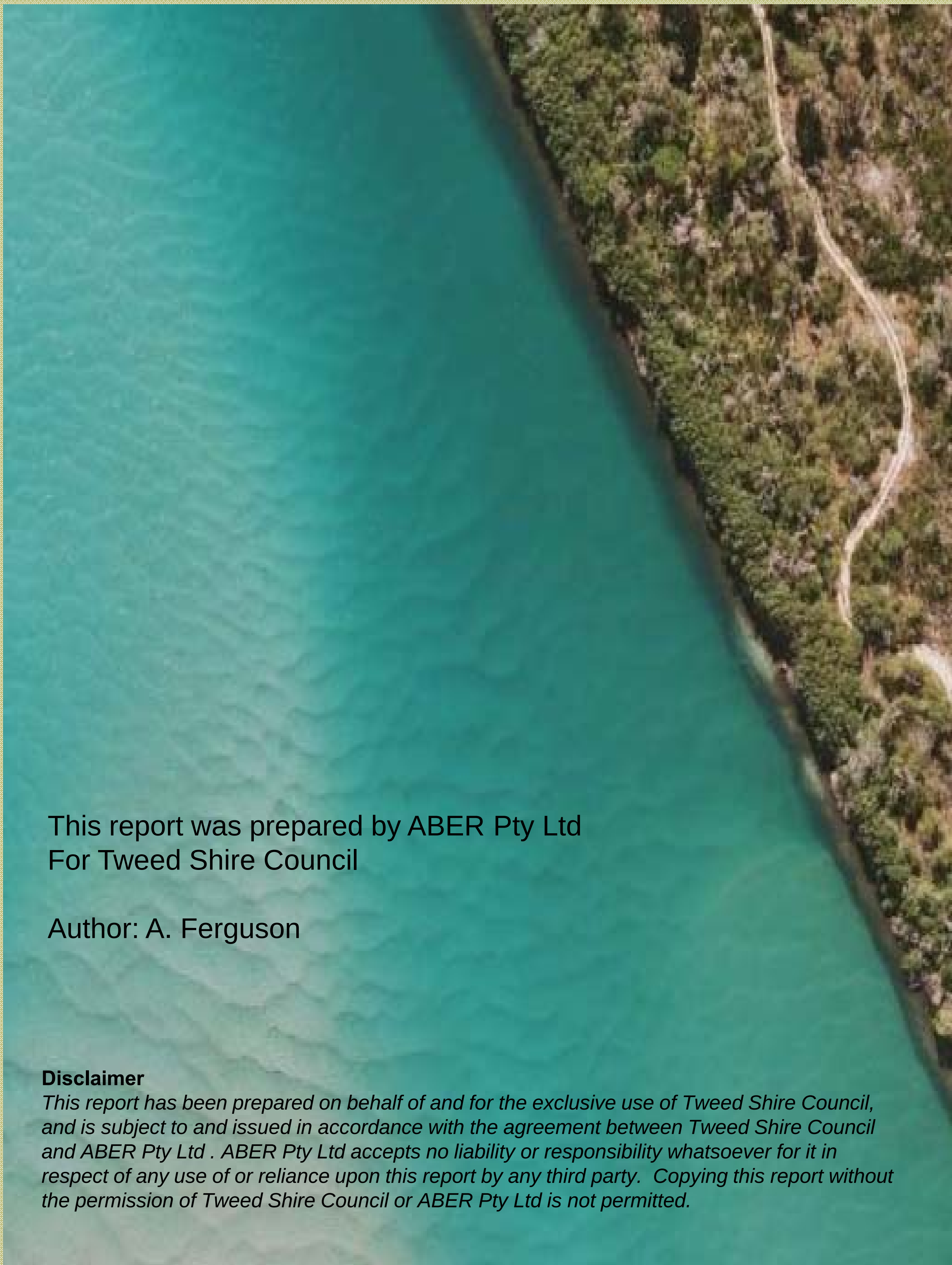
Review of water quality in the Tweed Estuary 2007 – 2011



Final Report

30th March 2012

ABER



This report was prepared by ABER Pty Ltd
For Tweed Shire Council

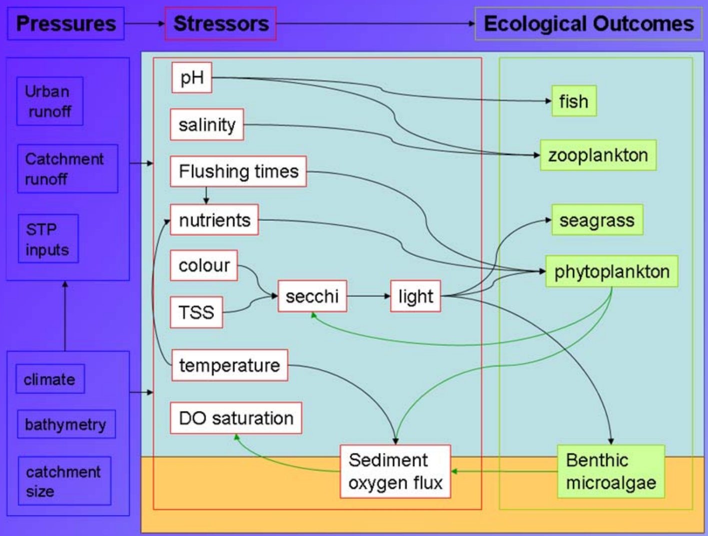
Author: A. Ferguson

Executive Summary

Introduction

Water quality monitoring in the Tweed River estuary

Tweed Shire Council has undertaken a water quality monitoring program in the Tweed estuary since 2007. The data span a wide range of wet and dry climatic conditions and therefore provide a comprehensive picture of water quality variation in the Tweed estuary. This report provides an analysis of temporal and spatial trends in water quality, identifies likely controlling processes and discusses ecological implications

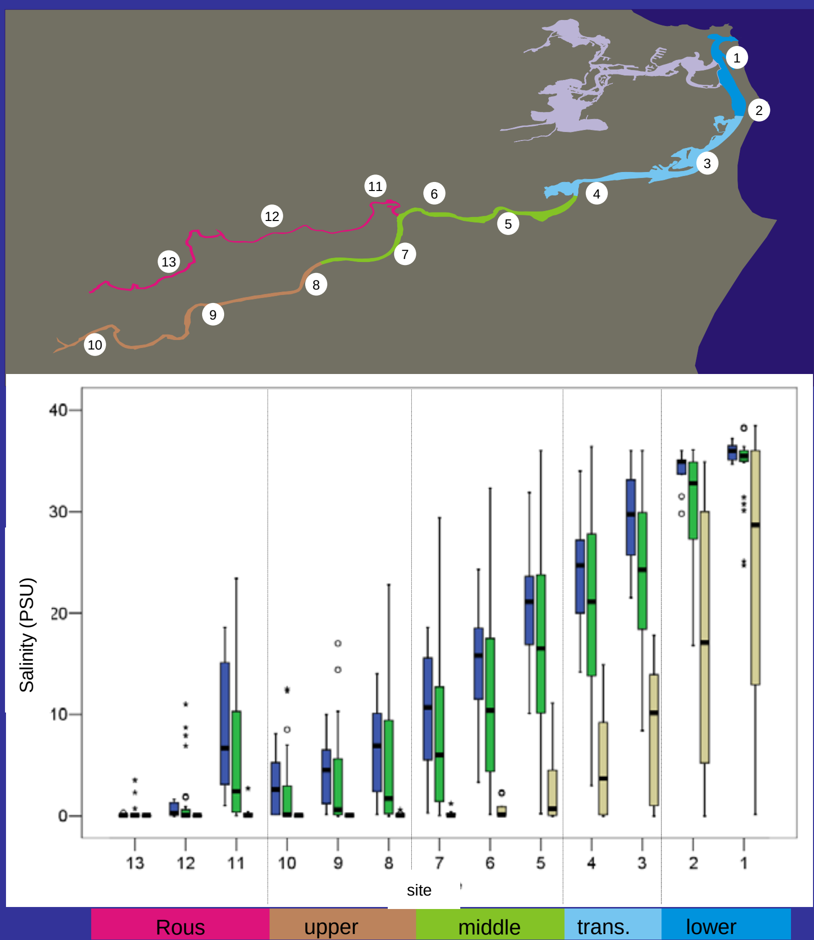


Interpretative framework

Data has been analysed to provide an understanding the linkages between catchment pressures, physico-chemical water quality attributes ('stressors'), and ecological outcomes in the estuary.

Pressures → Stressors → Outcomes

Pressures are defined here as human activities occurring in the catchment that have direct impacts on water quality (stressors) in the estuary, and indirect impacts on the ecology of the estuary. There are other natural pressures that impact on water quality stressors such as climatic controls (e.g. rainfall and seasonal temperature cycles). These natural pressures account for variation in stressors that is partly independent of, but also interacts with, human pressures.



Monitoring strategy

Water quality was monitored monthly at 10 sites along the main Tweed estuary and 3 sites along the Rous estuary. The sites were chosen to provide a comprehensive coverage of the estuarine gradient. Salinity data show a smooth decrease in salinity between sites up the estuary.

Importance of flow

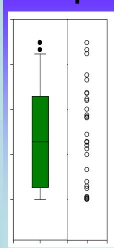
Freshwater inflow is a primary driver of water quality in estuaries. It controls physical, chemical and biological processes.

The data in this report have been grouped according to whether they were collected during low, median and high flows. This aids in the interpretation of the likely causes of water quality trends. Data are presented using boxplots which provide a statistical summary for each site under different flow.

flow

- high
- median
- low

Boxplots



Provide a visual summary of the data: 90% of observations lie between the whisker lines and 75% within the green box. The line within the green box indicates the median.

ABER *Aquatic Biogeochemical & Ecological Research*

Executive Summary

Water quality guidelines

Tweed Water Quality Objectives and ANZECC guidelines

Water quality objectives (WQO) for the protection of aquatic ecosystems in the Tweed estuary were adopted by TSC in 2000, based on a report by WBM Oceanics. The Tweed WQO used a number of theoretical assumptions and comparisons with undisturbed 'reference' systems in South-East Queensland to derive objectives. These objectives were compared with ANZECC (2000) guidelines for the protection of aquatic ecosystems, and both sets of guidelines were used to assess water quality in this report.

Rationale behind guidelines

The health of aquatic habitat in terms of water quality can be assessed by the primary stressors:

1) Oxygen saturation (ANZECC guideline = 80%)
2) Water clarity

Thresholds for water quality parameters such as TSS, nutrient and chlorophyll-*a* concentrations can be assessed in terms of their relationship to the primary stressors.

Data based guidelines

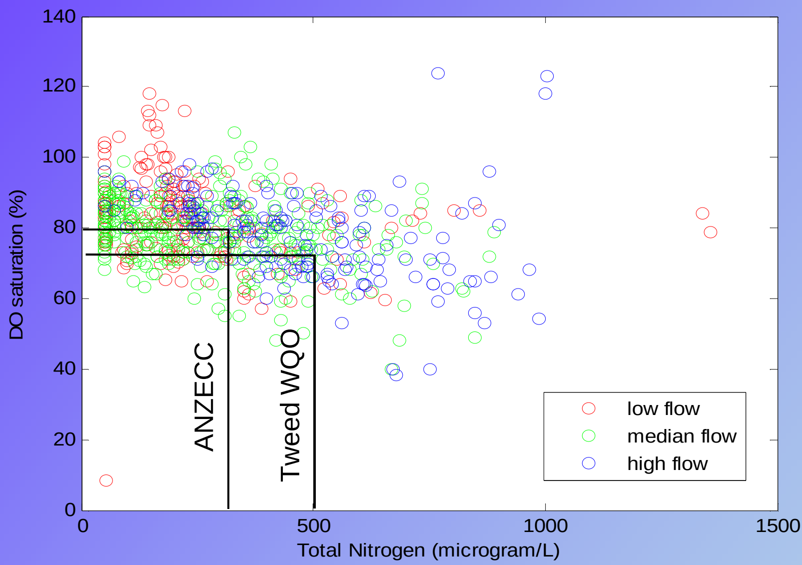
The data from this study showed clear relationships between total nitrogen and chlorophyll-*a* concentrations, and dissolved oxygen saturation (see figures right).

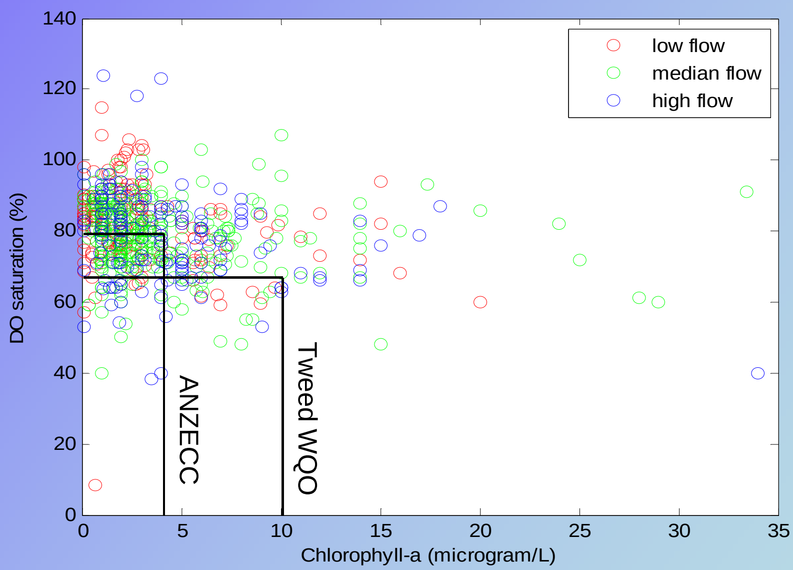
The Tweed WQO for TN (500 μg L^{-1}) corresponds to a median chlorophyll-*a* concentration of about 9 μg L^{-1} and a median oxygen saturation of ~70%. The WQO for chlorophyll-*a* (10 μg L^{-1}) corresponds to a median oxygen saturation of <70%. It is noteworthy that some very high chlorophyll-*a* concentrations also occurred above TN 400 μg L^{-1}.

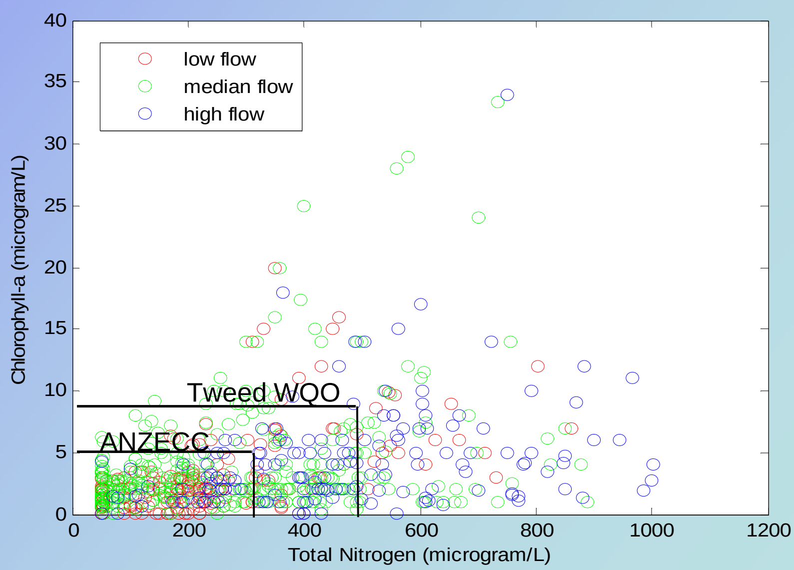
The **ANZECC** guideline for TN (300 μg L^{-1}) corresponds to a median chlorophyll-*a* concentration of about 5 μg L^{-1} and a median oxygen saturation of ~80%. The ANZECC guideline for chlorophyll-*a* (4 μg L^{-1}) corresponds to a median oxygen saturation of 80%.

Best guidelines?

The comparisons of guideline values with data collected during this study indicate that the ANZECC guidelines are most appropriate for the Tweed estuary. However, it should be stressed that it is optimum to develop guidelines specific to different reaches of the estuary that take into account hydrodynamic and morphological features which are important controls over ecological processes. Similarly, reach specific guidelines for water clarity need to be developed based on physical attributes as well as an understanding of biogeochemical processes.







Aquatic Biogeochemical & Ecological Research

Executive Summary

Estuarine Processes – Tweed and Rous estuaries

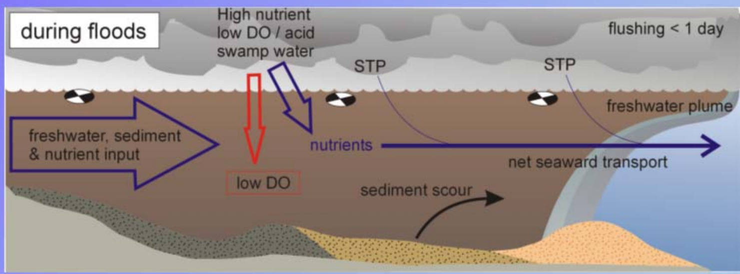
Estuaries - a dynamic environment

The estuarine system is dynamically changing throughout time within a set of natural extremes. Estuarine ecology has evolved to cope with this highly changeable environment, however when anthropogenic stresses cause a widening of environmental extremes (e.g. higher nutrient loadings, lower pH and hypoxia), the ecosystem can be changed (sometimes permanently) in various ways. The term "eutrophication" refers to the process of organic enrichment in an aquatic ecosystem, commonly caused by elevated nutrient loadings. Organic enrichment leads to higher rates of decay resulting in a decline in dissolved oxygen throughout the system and potentially leading to the local extinction of higher orders of the foodweb

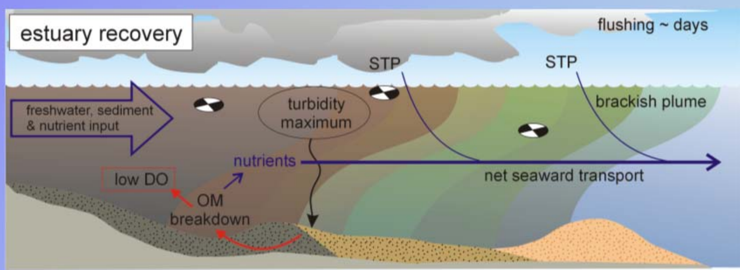
Seasonal cycles within the Tweed River estuary

The Tweed River estuary ecosystem has evolved with episodic pulses of high nutrients and organic matter to the system during floods, followed by opportunistic increases in primary (phytoplankton) and secondary (benthic invertebrates, detritivores, fish, birds) productivity during the months following the flood event. This seasonal process is a primary influence on water quality throughout the estuary and can be summarised into the four distinct stages illustrated below.

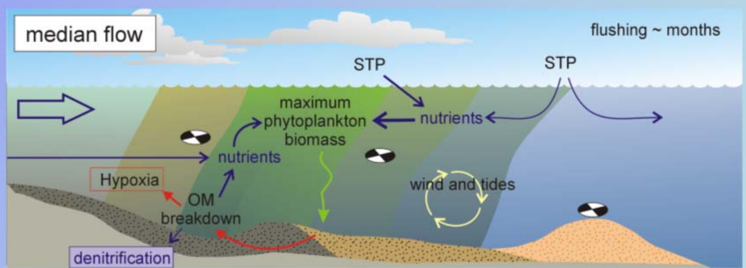
Flood/high flow - During floods and high flow conditions when flushing times are less than 1 day, internal estuarine processes are bypassed and dissolved and particulate materials are delivered to the nearshore coastal zone. Low lying catchments on the floodplain discharge water with low pH (acid) and low oxygen.



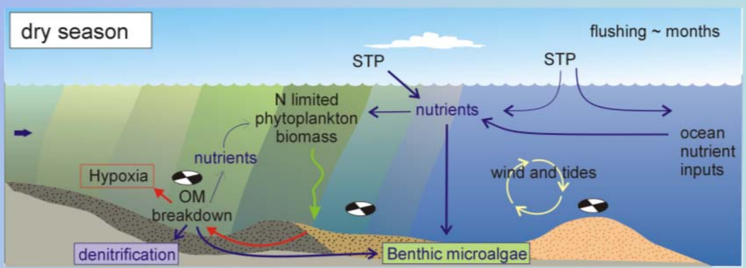
Post flood recovery - As tidal influence returns to the estuary, particulate organic matter/nutrients are deposited and bacterial remineralisation of this material in the sediments ("benthic fluxes") and in the water column recycles bio-available nutrients and depletes dissolved oxygen. At this stage, water column (inorganic) nutrients and light attenuation are high, and phytoplankton productivity is limited by light availability.



Median flow – Phytoplankton productivity increases as light climate improves. Benthic fluxes of bio-available, dissolved inorganic nitrogen (DIN) become relatively more important to phytoplankton productivity as flushing times increase, up to the point where sediment nitrogen stores become depleted and benthic fluxes decrease to zero. The depletion of sediment nitrogen is due to a combination of factors associated with the processing of organic matter by the benthic foodchain, all of which increase with improved water clarity towards low flow (dry season) conditions.



Dry season - Flushing times increase to >300 days, riverine inputs of nutrients all but cease and DIN becomes tightly recycled within the sediments and water column. Phytoplankton becomes N-limited and DIN concentrations in the water column approach zero. Inputs of nitrate from STP effluent and the ocean are the primary drivers of new productivity in the estuary at this time.



Light attenuation is a key factor influencing biogeochemical and ecological processes in the estuary. It determines the spatial and temporal nature of nutrient recycling processes, and controls key ecological communities such as benthic microalgae and seagrasses. Light attenuation is controlled by two primary factors: 1) suspended sediments during and immediately post flood, and 2) phytoplankton biomass as productivity increases in response to high nutrient loadings. An additional control is wind and tide-driven resuspension of sediments during the dry season.

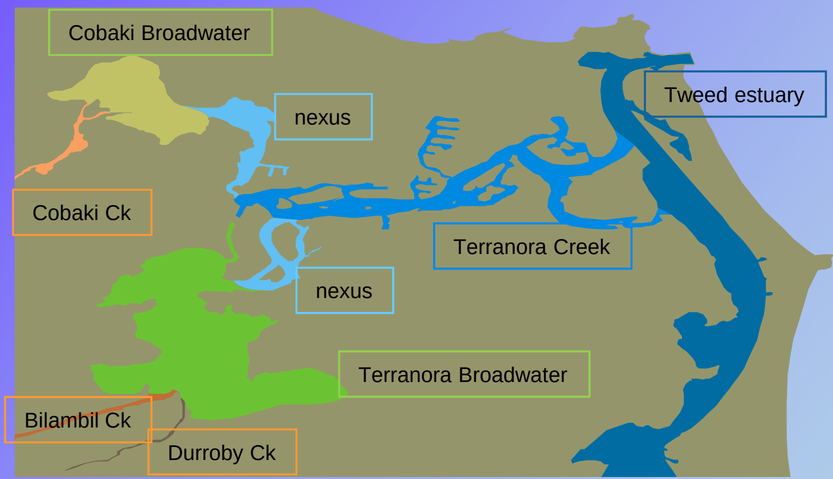
Aquatic Biogeochemical & Ecological Research

Estuarine Processes – Cobaki / Terranora

Cobaki – Terranora Broadwaters and Terranora Creek

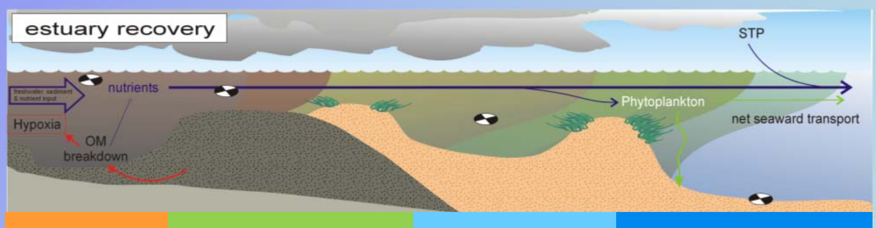
The Cobaki – Terranora Broadwater is an important shallow water ecosystem adjoining the lower Tweed estuary approximately 1.5km upstream of the estuary mouth. The system supports the most extensive areas of seagrass beds within the Tweed estuary and also large areas of intertidal mudflats which provide important habitat for wading birds. Fringing rainforest and mangrove communities provide vantage and roosting habitats for various birds. The catchment is highly modified and subject to a range of urban and rural pressures.

Aerial image of the Terranora Broadwater showing extensive shallow water habitat

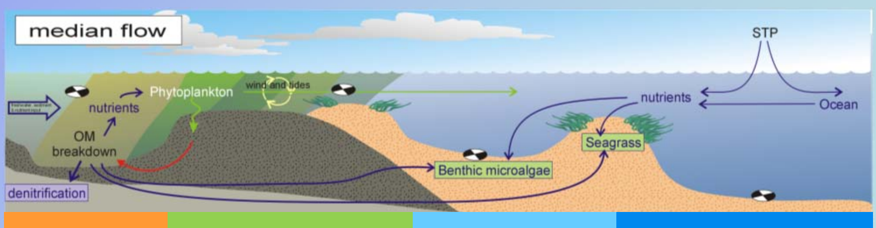


Flood/high flow - During floods and high flow conditions when flushing times are less than 1 day, internal estuarine processes are bypassed and dissolved and particulate materials are delivered to the nearshore coastal zone.

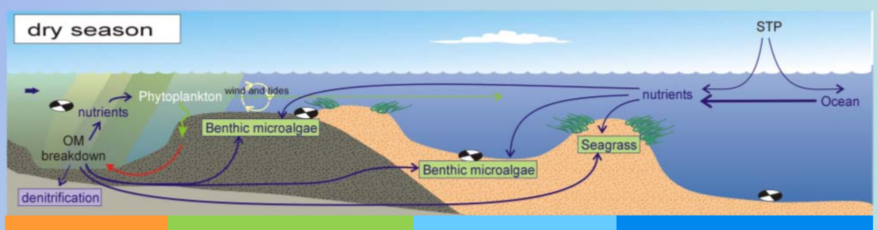
Post flood recovery – Tidal flushing is highly efficient in the Cobaki-Terranora system therefore estuarine conditions recover quickly after floods. High chlorophyll-*a* concentrations indicate rapid response by phytoplankton to nutrient inputs. Particulate organic matter/nutrients are deposited in the estuarine reaches of the creeks, with bacterial remineralisation of this material depleting dissolved oxygen.



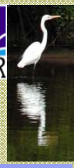
Median flow – Terranora Ck and the nexus reaches become marine dominated and the broadwaters are ¾ seawater. Light climate improves throughout the system, resulting in bio-available nutrients being rapidly assimilated by benthic microalgae and seagrass. This leads to nutrient limitation of phytoplankton productivity, except in the estuarine creeks where recycling of nutrients occurs from light limited sediments.



Dry season – The broadwaters become marine dominated and salinity in the estuarine creeks approaches ¾ seawater. Phytoplankton becomes N-limited and DIN concentrations in the water column approach zero. The broadwaters experience high turbidity events due to resuspension of sediments caused by tidal flows and wind waves.



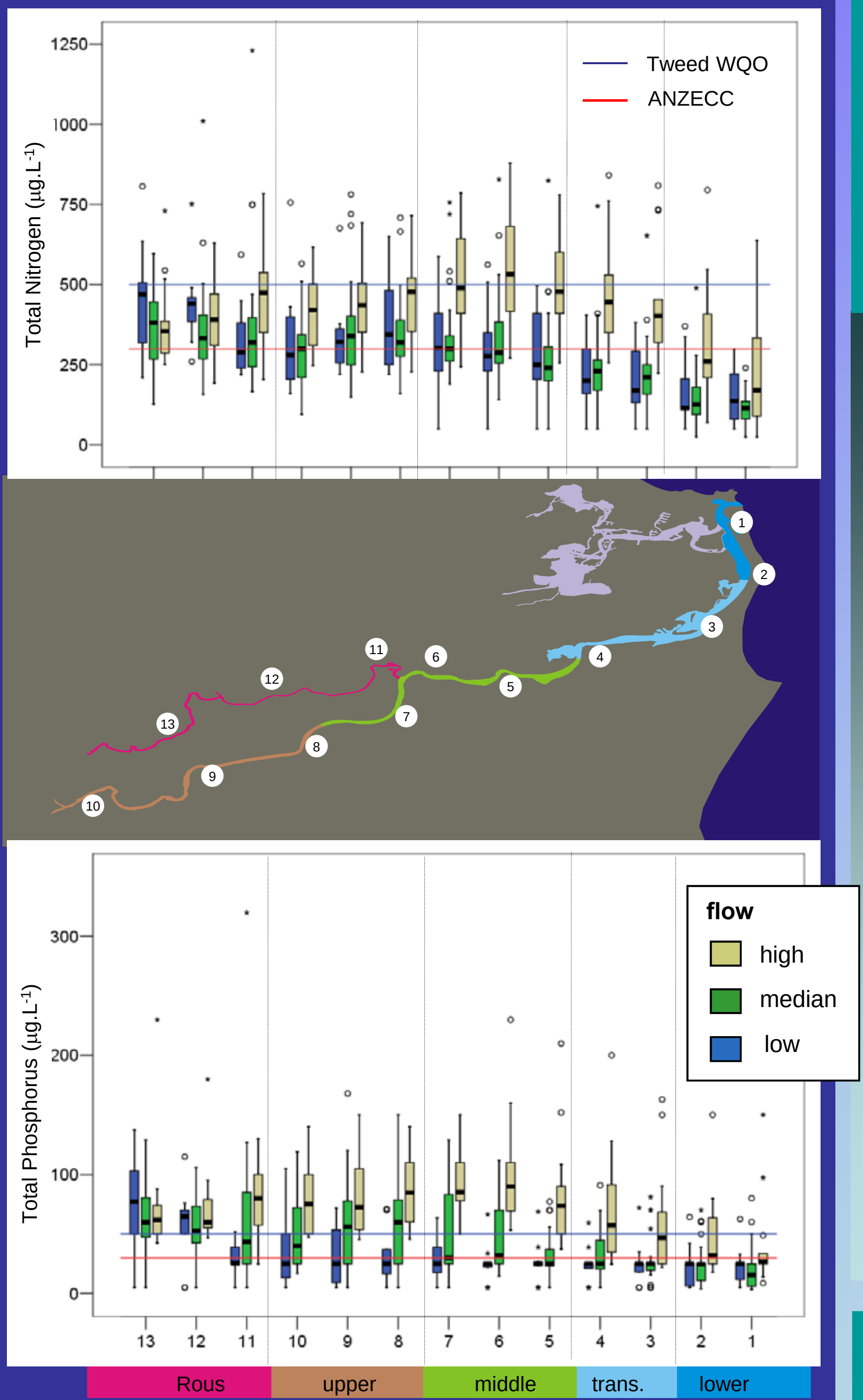
Executive Summary



Nutrients in the Tweed and Rous estuaries

Nutrients – basic elements for growth

Nitrogen and phosphorus are two of the primary nutrients required for the growth of aquatic plants. The ecology of Australian estuaries has evolved with relatively low nutrient concentrations, however catchment disturbance and urbanisation has greatly increased nutrient concentrations resulting in shifts in ecology due to the excessive growth of phytoplankton and macroalgae.



ANZECC guidelines

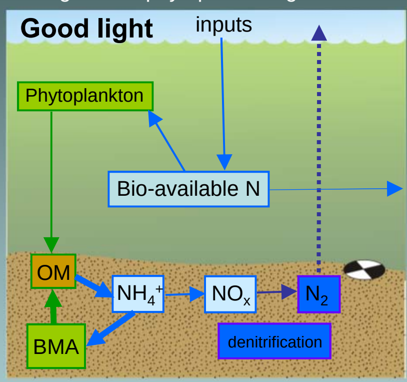
TN and TP concentrations exceed the ANZECC guidelines for the maintenance of aquatic ecosystems for more than 50% of the time in the middle and upper estuary.

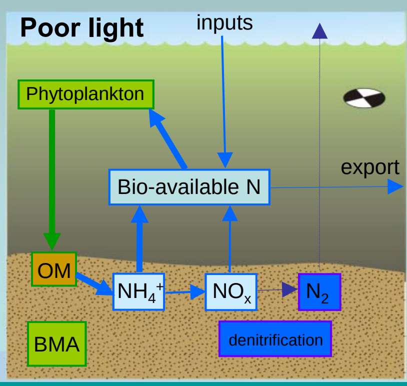
Nitrogen

Nitrogen is commonly held as limiting productivity in estuaries. The Tweed estuary has elevated concentrations of TN especially in the middle estuary which receives inputs of nutrient-rich wastewater. Concentrations are highest during high flows when diffuse catchment sources dominate. Bio-available N tends to be highest during higher flows due to a reduction in the relative importance of biological processing

Influence of light

Light plays a critical role in controlling bio-available nutrients. Good water clarity promotes the growth of benthic microalgae (BMA) which locks nutrients up in sediments. Poor water clarity shuts off BMA productivity and nutrients are returned to the water column, thereby fuelling further phytoplankton growth





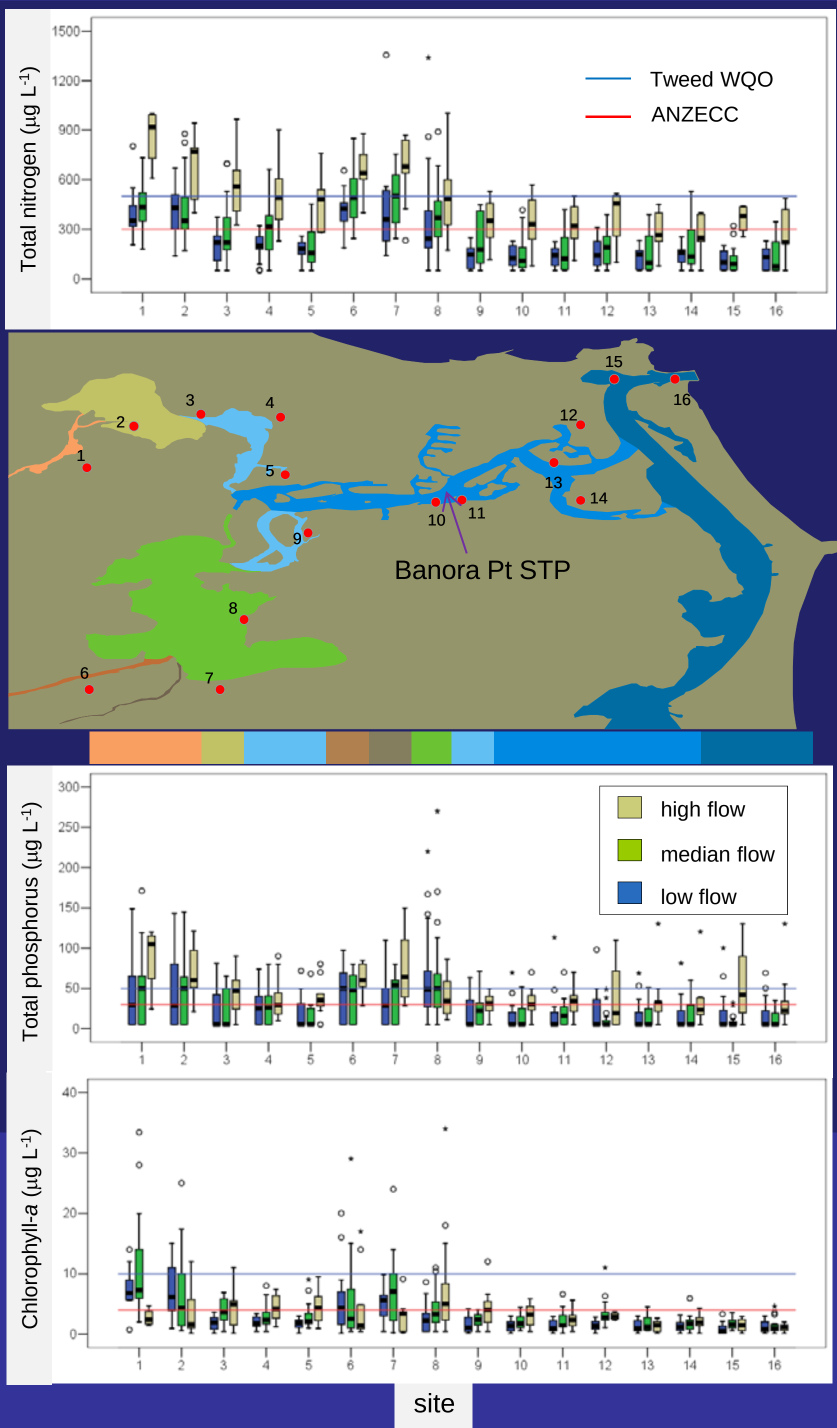
Phosphorus

Phosphorus is commonly held as not limiting productivity in estuaries, but this is currently under review. Phosphorus concentrations increase with flow. Bio-available P concentrations become very low during low flow due to biological processing and binding with sediments.

Executive Summary

Water quality in the Cobaki – Terranora system

A brief summary of nitrogen, phosphorus, chlorophyll-*a* concentrations and dissolved oxygen saturation are presented here. Please refer to the estuarine processes pages for details about ecological processes that control nutrients and phytoplankton biomass in the different reaches of the system.



Nitrogen

Total Nitrogen (TN) concentrations in the Cobaki – Terranora system are highest during high flow reflecting freshwater inputs from the estuarine creeks. There was no impact on TN concentrations due to effluent from the Banora Point STP. TN concentrations decreased with diminishing flow due to the influence of marine water and uptake by benthic microalgae.

Phosphorus

Total Phosphorus (TP) concentrations increase with flow. Bio-available P concentrations become very low during low flow due to biological processing and binding with sediments. There was a strong correlation between TP and suspended sediments.

Chlorophyll-*a*

Phytoplankton productivity is generally low in Terranora Creek, due to a combination of low ambient nutrient concentrations and short residence times. Chlorophyll-*a* concentrations in the creek are highest during high flows. In contrast, the broadwaters and estuarine creeks experience moderately severe phytoplankton blooms during low to median flow conditions.

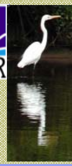
Dissolved oxygen

Dissolved oxygen saturation was consistently poorest at the estuary sites and best at the lower Terranora Creek and Tweed entrance sites. There was a general decrease in DO saturation with increasing flow throughout the broadwater and Terranora Creek sites, reflecting the influence of freshwater inflows. In contrast, flow dependence was not as clear at the estuary sites most likely due to the relatively greater influence of internal processes which influence DO saturation (e.g. phytoplankton O_2 production and sediment O_2 consumption). Internal processes are more important in reaches where residence times are longer..

ANZECC guidelines

TN concentrations exceed the ANZECC guidelines for the maintenance of aquatic ecosystems for more than 75% of the time at the estuarine creek sites. TN in the broadwaters exceeded guidelines ~50% of the time during median flow and more than 75% of the time during high flow. TN only exceeded guidelines in Terranora creek during high flow times.

Executive Summary

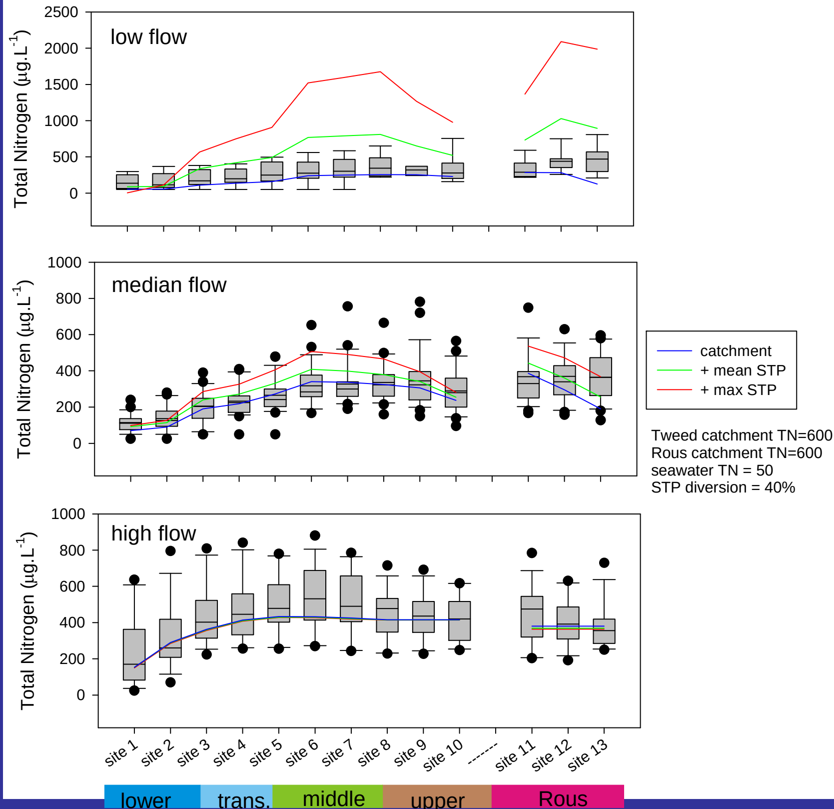


Impact of STP effluent

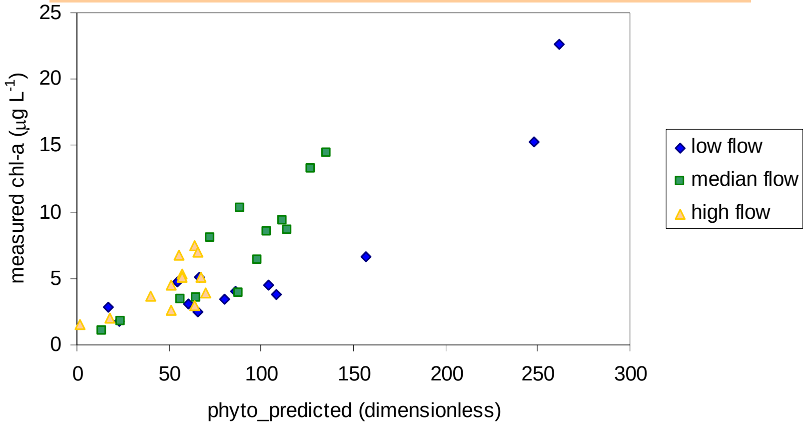
Impact assessment using a salt balance model

A simple one dimensional (1D) salt balance model was used to assess the relative impacts of different effluent release scenarios on nutrient concentrations throughout the Tweed estuary. The 1D salt balance model uses salinity as a tracer of mixing between seawater and freshwater flows, with the salinity at any point in the estuary determined by the relative importance of these two flows. The 1D salt balance model is used to predict the concentration of dissolved pollutants emanating from the effluent discharge as they are diluted along the estuary.

Comparison of model (lines) with measured data (boxplots)



Comparison of phytoplankton model with measured data



Model setup

The salt balance model accounted for inputs from 41 sub-catchments and the Murwillumbah, Tumbulgum, Kingscliff and Banora Point sewage treatment plants.

Influence of flow

The salt balance model provides a tool to assess the effects of freshwater flow on nutrient concentrations along the estuary.

The impacts of STP effluent discharge increased with diminishing flow. STP effluent accounted for up to 60%, 10% and 0.1% of total freshwater inputs during low, median, and high flows respectively. Effluent quality varied widely (primarily according to season) giving rise to a large range in potential impacts. The impact of STP effluent was imperceptible during high flow due to the massive dilution by catchment runoff.

Phytoplankton response

Phytoplankton use bio-available forms of dissolved inorganic nitrogen (DIN = NH_4^+ and NO_x) and phosphorus for growth. Due to the reactivity of these nutrients in the aquatic environment, measured concentrations rarely reflect inputs (especially during low flow).

The salt balance model allows concentration fields to be predicted which can then be integrated with water residence times to predict phytoplankton response.

The results highlight the importance of DIN loading from the STPs and water residence times in controlling phytoplankton biomass in the Tweed estuary. The interaction with freshwater flushing times arises from the increase in time available for utilisation of available DIN by phytoplankton. Biomass increase also proceeds much faster once water residence times exceed the cell doubling time of phytoplankton.

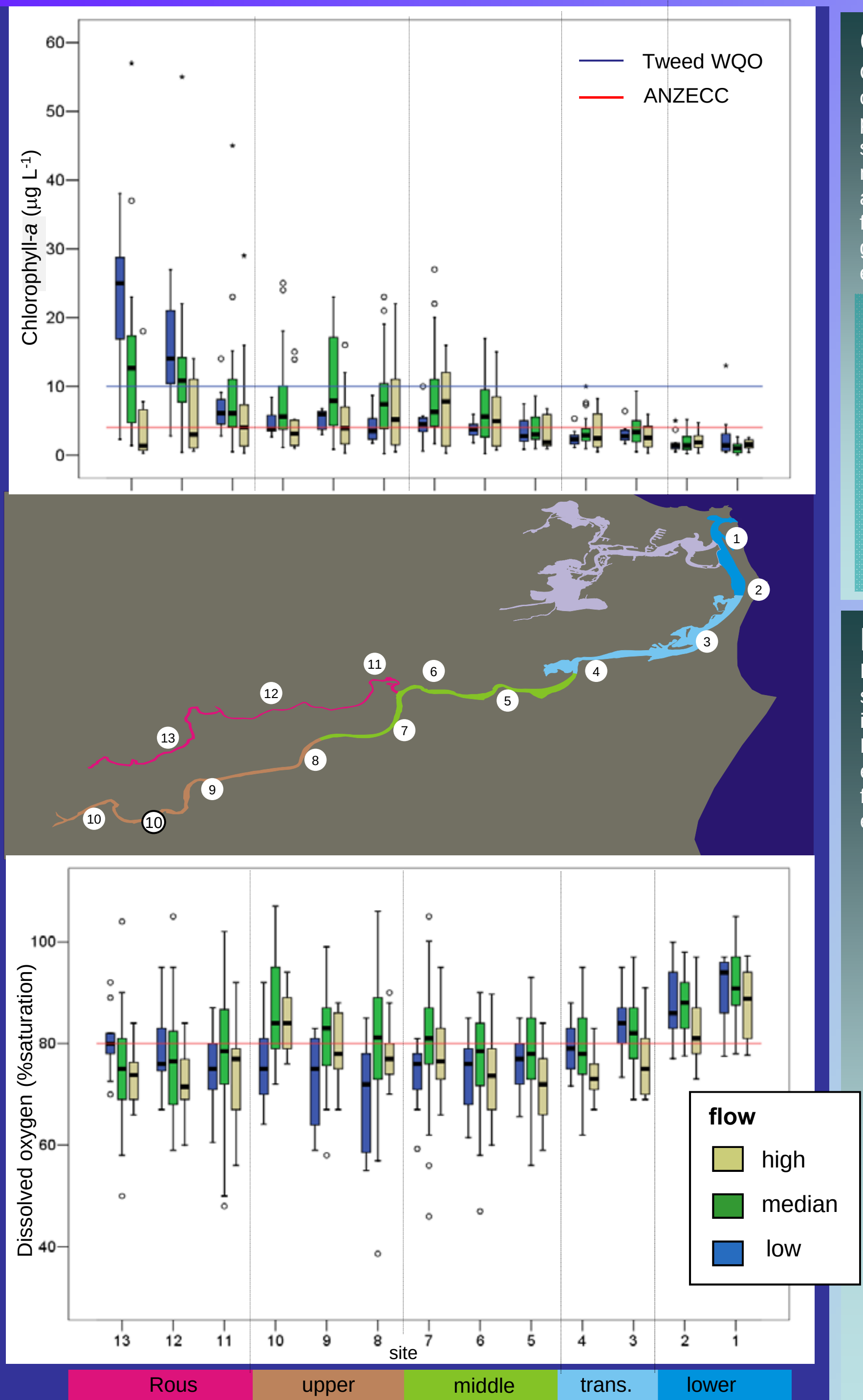
The results also show that the slope for the dimensionless output versus measured chlorophyll-*a* is lower for low flow conditions. This is most likely to the competition for DIN by benthic processes (BMA uptake and denitrification (see Nutrients summary).

Executive Summary

Chlorophyll-*a* and Dissolved Oxygen

Ecosystem indicators of eutrophication

Eutrophication is defined as an increase in organic matter supply to an ecosystem, which can occur due to direct inputs of organic matter (e.g. organic-rich effluent with a high BOD), or as the result of nutrient enrichment which causes algal blooms within the system. The common expression of eutrophication in estuaries like the Tweed is phytoplankton blooms in the upper and middle reaches caused by excessive nutrient loadings. Deposition of phytoplankton biomass causes organic matter (OM) enrichment of sediments. Breakdown of OM by bacteria consumes oxygen, and can cause low dissolved oxygen (DO) saturation in the water.



Chlorophyll-*a*

Chlorophyll-*a* concentrations are commonly used as a proxy measure of phytoplankton biomass in aquatic systems. Phytoplankton are one of the major primary producers in estuaries and are therefore an important base for many foodchains. Stimulation of phytoplankton growth due to nutrient pollution is a major expression of eutrophication.

Phytoplankton blooms

The Tweed estuary experiences moderately severe phytoplankton blooms in the middle and upper estuary and Rous estuary. Modelling shows that blooms are controlled by wastewater inputs of bio-available nitrogen and water residence times. Phytoplankton tends to be nutrient limited during low flow times (see Nutrients).

DO saturation

Low DO saturation (hypoxia) can cause stress to a range of estuarine biota and impacting on biogeochemical cycling. Hypoxia can occur in response to acute events (e.g. “blackwater” runoff following flood events), or as a chronic impact of eutrophication.

Low to median flow

The Tweed estuary is prone to moderate hypoxia along the middle to upper estuary reaches during low to median flow conditions. Hypoxia is due to high sediment oxygen demand caused by organic matter enrichment from phytoplankton blooms. The lower estuary is more resilient to eutrophication due to more rapid flushing and shallower morphology.

High flow

During high flow, oxygen-poor flood waters draining from low lying swamps and cane land cause hypoxia to extend to the lower estuary transition zone.

ANZECC guidelines

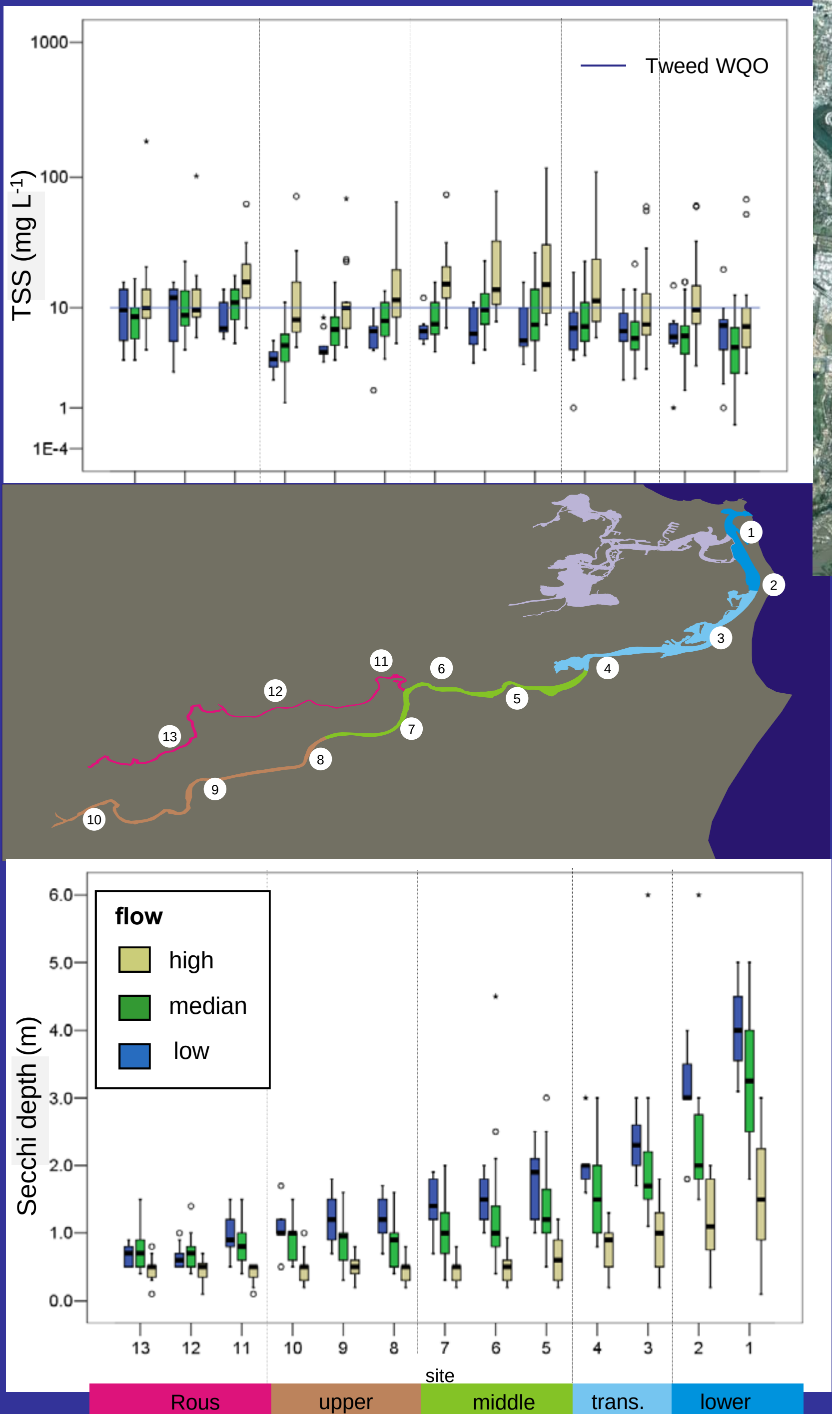
Chlorophyll-*a* concentrations and DO saturation exceed the ANZECC guidelines for the maintenance of aquatic ecosystems for more than 50% of the time in the middle and upper estuary.

Executive Summary

TSS and Light

TSS – a major ecological driver

Total suspended solids (TSS) is a measure of the combined concentration of particulate matter (comprising inorganic sediments, organic matter and phytoplankton) in the water column. The relative contribution of these constituents varies widely according to position along the estuary, state of tide and state of flow. TSS is a major driver of water clarity, impacting on the light climate of the water column and sediments.



High flow TSS

The Tweed estuary experiences greatly elevated TSS concentrations during floods and high flow conditions reflecting the erosion of sediments from the catchment. Much of this material is deposited in the estuary as flows subside.

Aerial image of the lower Tweed estuary showing turbid floodwaters impacting the lower transition zone

Low flow TSS

During low to median flow conditions, the material deposited during floods is resuspended by tidal currents, casuing high turbidity in the middle estuary.

Light attenuation

Secchi depth is a measure of light attenuation (water clarity) caused by suspended particulates and dissolved organic matter. Light attenuation is a critical ecological driver impacting on productivity, oxygen and nutrient cycles

Good light climate is essential for the maintenance of seagrass and benthic microalgae which help alleviate poor oxygen saturation.

Poor water clarity

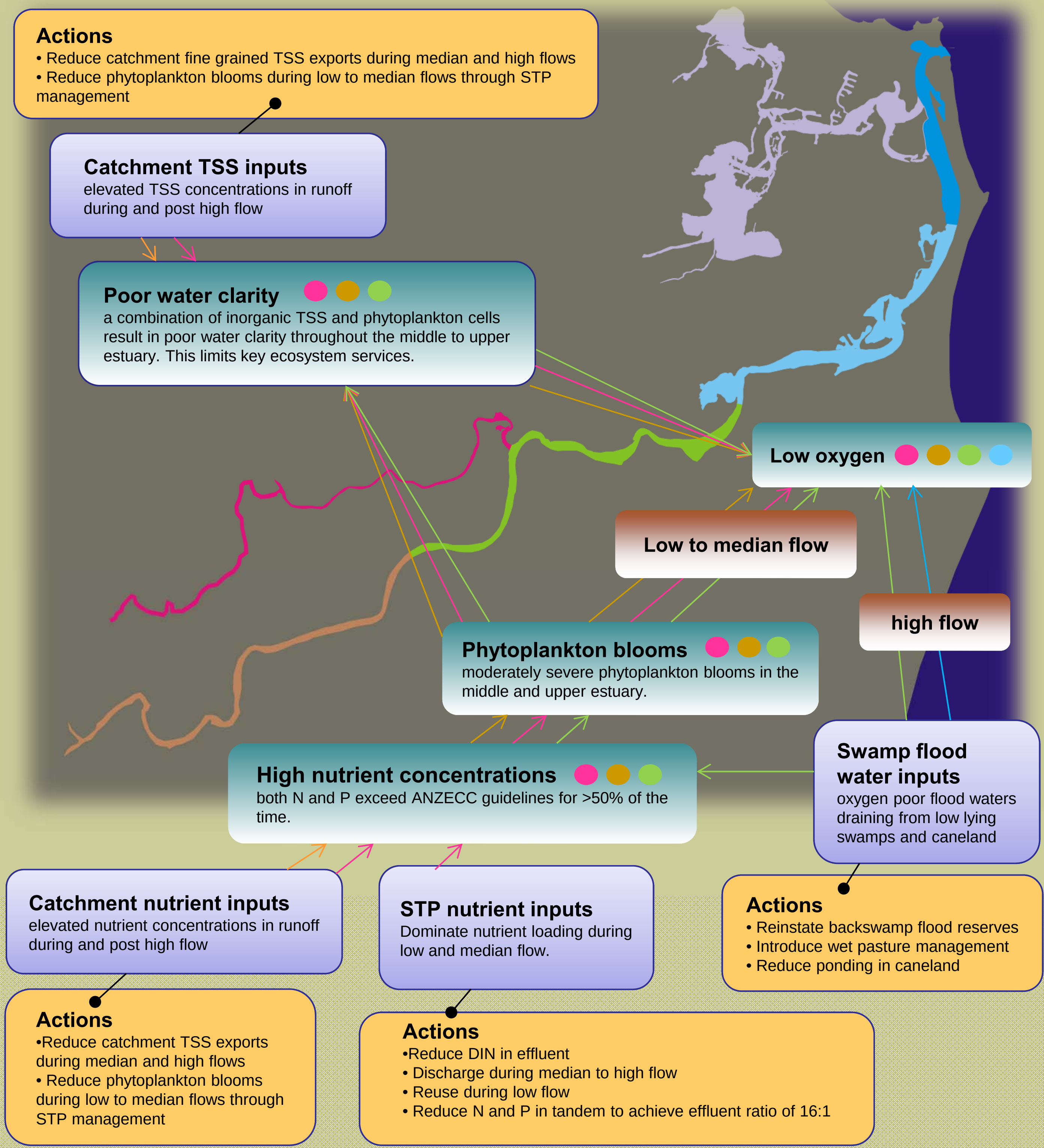
The Tweed estuary experiences extremely poor water clarity during high flow conditions due to catchment derived TSS. Water clarity improves as flow subsides and becomes increasingly influenced by phytoplankton cells.

Executive Summary

Management implications – Tweed and Rous

Water quality issues and management strategies

Data show that water quality in the Tweed estuary failed to comply with ANZECC guidelines for the maintenance of aquatic ecosystems for a significant amount of the time. In particular, the middle to upper reaches of the estuary experiences moderate hypoxia, which can be directly linked to phytoplankton blooms caused by excessive nutrient loadings. Water quality issues identified in this review have been summarised below, with the colour coded dots indicating the relevant reaches impacted by each issue. The primary stressor related to water quality issues is identified and possible management actions listed.



Executive Summary

Management implications – Cobaki / Terranora

Water quality issues and management strategies

Water quality issues identified in this review have been summarised below, with the colour coded dots showing the relevant reaches impacted by each issue. The primary stressor related to water quality issues is identified and possible management actions listed.