NRM North

Tamar Estuary and Esk Rivers

Natural Resource Management in Northern Tasmania

Tamar Estuary & Esk Rivers

ECOSYSTEM HEALTH ASSESSMENT PROGRAM

MONITORING REPORT 2011

Monitoring period October 2009 - September 2010

M. Attard, M. Thompson, R. Kelly and A. Locatelli

December 2011

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Executive Summary

This report has been developed to describe data produced by the Tamar Estuary and Esk Rivers (TEER) Ecosystem Health Assessment Program (EHAP) which has been used in the 2011 report card for the Tamar estuary. Monthly water quality samples were taken from October 2009 to September 2010 at 20 sites, in five functional zones of the estuary. At all sites, water quality parameters including temperature, salinity, pH, dissolved oxygen, turbidity, chlorophyll a and conductivity were measured within the water column. Secchi disk depths were also recorded, and surface and bottom water samples were analysed for total and dissolved nutrients, dissolved metals (zones 1 and 4 only), chlorophyll a and total suspended solids.

This is the first Tamar estuary report that has been produced using data specifically collected as part of TEER's EHAP monitoring program. Water quality in the estuary improves with distance downstream towards the ocean. This is partially due to the well flushed nature of the lower estuary, and due to the concentration of pollutants entering the system from the more urbanised upper estuary (zone 1) area surrounding Launceston. Pollutants are also delivered from a large catchment (10,000 km2) area via the North Esk and South Esk rivers. Urban and rural areas generate loads of nutrients, sediments, pathogens and metals which are delivered to the estuary through stormwater systems, wastewater treatment plants and catchment tributaries.

- The 2011 report card grades are comparable to the 2010 report card 10-year baseline results suggesting that there has been no significant decline or improvement in parameters used to measure the health of the estuary.
- Wetter periods, occurring during winter months correspond to poorer water quality as pollutant loads to the estuary increase during these times. This is expected given the higher flows and more erosive events during these times. Higher rainfall is also associated with more inputs from wastewater treatment plants.
- Recreational water quality scores are poorer in the upper estuary (zones 1 and 2) but are within guidelines in the mid to lower estuary (zones 3, 4 and 5). It was expected that the upper estuary would have poorer recreational water quality due to the proximity to high-density urban areas and the corresponding higher load of bacteria generated in the upper catchment areas. During floods wastewater treatment plants can become overloaded and discharge into the river systems resulting in high bacteria loads.
- Elevated nutrient and bacteria levels are key drivers of the poor grades in the upper estuary.
- Elevated copper and lead levels in zone 1 and lead levels in zone 4 are due to historic mining activities and other industry, as well as urban runoff. No data was collected in other zones as previous studies had not found significant metals in these areas.

The TEER EHAP sampling operates on a four-year cycle of two years of intensive monthly monitoring of the estuary followed by two years off, where a focus is placed on undertaking discrete scientific studies, and reviewing data from the routine monitoring. The sampling ceased in October 2011 after 24 months of data had been collected and it is envisaged that monitoring will recommence again in 2013/2014 for a further two years. During the EHAP "off years", from October 2011 to September 2013, several future studies have been identified to take place to improve current knowledge:

- **Zone 1 study** to investigate the anthropogenic impacts in the upper most reaches of the Tamar estuary.
- **Mass loads study** providing greater understanding of the link between the estuary and freshwater tributaries that enter the system.
- **Seafood safety study** to re-assess levels of metal contaminants in finfish and shellfish and to create awareness within the community.
- **Freshwater Ecosystem Health Assessment Program (FEHAP)** to produce a catchment-based health report card complementary to the estuarine report card.
- **Water quality objectives** developed specifically for the Tamar estuary.
- **Identifying a biological indicator for the Tamar estuary** for use in the EHAP monitoring program and report card.
- **TEER Storm Water Working Group** is undertaking activities to gauge the impacts of stormwater in the catchment.

Data and information collected as part of the TEER EHAP and other discrete projects will be, and are currently being utilised to help inform management and develop actions for the Tamar estuary. TEER has actively been providing EHAP data to TEER partners and non-partner organisations that use the data in a variety of activities such as modelling, development applications, research projects and environmental assessments.

TEER products and publications also help educate, communicate and foster awareness about the Tamar estuary and surrounding catchments. Developing the Tamar estuary water quality triggers will be made possible by analysing 24 months of EHAP collected ambient water quality data, enabling a more rigorous and sensitive understanding of the impacts and processors occurring in the estuary.

Acknowledgments

This report has been prepared as part of the Tamar Estuary and Esk Rivers (TEER) program and has received valuable input from many people and organisations. TEER would like to acknowledge and thank the following people and organisations for their financial and technical contributions:

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Extracts are included from both the original 1997 State of the Tamar Estuary Report (Pirzl and Coughanowr, 1997) and the 2008 State of the Tamar Estuary Report (Aquenal and The Department of Environment, Heritage and the Arts, 2008). Major text segments from these two reports are attributed to Christine Coughanowr from the Derwent Estuary Program.

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Abbreviations

Al	Aluminium
AMC	Australian Maritime College
ANZECC	Australia and New Zealand Environment and Conservation Council
BOM	Bureau of Meteorology
Chl -a	Chlorophyll a
Cumecs	Cubic metres per second
Cu	Copper
DEP	Derwent Estuary Program
DEPHA	Department of Environment, Parks, Heritage and the Arts
DPIPWE	Department of Primary Industries, Parks, Water and the Environment
DRP	Dissolved reactive phosphorus
EHAP	Ecosystem Health Assessment Program
EHI	Ecosystem Health Index
EPBCA	Environment Protection and Biodiversity Conservation Act, 1999
EPN	Environmental Protection Notice
Fe	Iron
GTC	George Town Council
LCC	Launceston City Council
N	Nitrogen
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NOX	Nitrogen oxides (nitrate plus nitrite)
NRM North	Northern Tasmanian NRM Association
NRM	Natural resource management
NTU	Nephelometric turbidity units
Pb	Lead
PCDDs	Polychlorinated dibenzodioxins
ppt	Parts per thousand
TAFI	Tasmanian Aquaculture and Fisheries Institute
Tamar NRM	Tamar Region Natural Resource Management Strategy Reference Group
TEMCO	Tasmanian Electro Metallurgical Company
TEER	Tamar Estuary and Esk Rivers program
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
UTAS	University of Tasmania
WHO	World Health Organisation
WWTP	Wastewater treatment plant
Zn	Zinc

1 Introduction

This inaugural Tamar estuary Ecosystem Health Assessment Program monitoring report is a summary of data collected from October 2009 to September 2010 as part of the Tamar Estuary and Esk Rivers (TEER) Ecosystem Health Assessment Program (EHAP). The ambient water quality monitoring program aims to better understand the ecosystem health of the Tamar estuary through collecting and analysing water quality and biological data. This data has been analysed and used to generate the Tamar estuary report cards which grade the ecosystem health in five defined functional zones along the estuary. The methods used to generate the 2011 report card are documented in this report in Appendix 1.

This report presents the Tamar estuary data collected for the first monitoring year of the program from October 2009 to September 2010 and provides background to grades given in the 2011 Tamar estuary report card. The grades published in 2010 Tamar estuary report card were based on historical data (baseline 10 years from 1999-2009) and a comparison with a single reference year, 2007. The 2011 report card is the first time that the grades have been determined by the current data collected by the TEER EHAP ambient water quality program.

This report is divided in five main sections. The introductory section provides background information on the estuary, including a brief physical description; more information can be found in the TEER publication State of the Tamar Estuary 2008. The second section describes the monitoring program before an analysis of observed water quality in the estuary is provided in the third section. The fourth section describes the report card grades. Summary findings and future directions for the monitoring program based on the 2009-2010 data collection are given in the final section. More detail on the methods used to derive report card grades is presented in Appendix 1.

1.1 About TEER

The TEER program was established in 2008 and represents a regional partnership between the agencies responsible for the management of the Tamar estuary and Esk rivers waterways. Major sponsors include the Tasmanian Government, Launceston City Council, West Tamar Council, George Town Council, Meander Valley Council, Northern Midlands Council, Ben Lomond Water and Hydro Tasmania. Other key industry and supporting partners are Rio Tinto Alcan, Van Diemen Aquaculture, BHP Billiton TEMCO, BCD Resources, the University of Tasmania, the Australian Maritime College, Tamar NRM and Forestry Tasmania. The TEER program aims to provide a coordinated management approach and guide for solutions and strategic investment in activities that will protect, maintain and enhance the Tamar estuary and Esk river systems. A key goal of the program is to improve scientific understanding of the issues impacting upon the health of the TEER waterways to better identify and target priority areas requiring investment in on-ground works. The TEER program fosters collaborative partnerships and works closely with a range of industry, community, government, research and business partners to monitor and report on ecosystem health as well as coordinating activities to reduce pollutants entering waterways.

In 2008 the TEER Strategic Framework was developed through a process of community consultation. The framework describes the five key strategies that TEER works towards achieving with our partners and the community.

1. Protect, maintain and enhance natural values.
2. Build sustainable futures.
3. Work together to provide integrated governance, planning and management.
4. Build community knowledge and awareness of the Tamar estuary and Esk river systems.
5. Improve the amenity of the Tamar estuary and Esk river systems.

1.2 Tamar Physical Setting

The Tamar estuary is located in the north-east of Tasmania and is one of the largest estuaries in the state. It begins at the confluence of the North Esk and South Esk rivers, where the city of Launceston is established, and flows north-east for 70km before discharging into Bass Strait. It covers an area of approximately 100km2 and is bordered by three local councils - Launceston City, West Tamar and George Town. The estuary is a drowned river valley with deep channels, in some areas reaching up to 45m in depth (Aquenal and DEPHA, 2008). Strong tidal currents with a height difference of 3m, and a 1-hour lag time between the confluence and the mouth make natural and anthropogenic inputs extremely mobile in the system.

There are six catchments that drain into the Tamar estuary: the North Esk, South Esk, Macquarie, Brumby's-Lake, Meander and Tamar catchments (Figure 1), which cover an area of approximately 10,000km2, over one-fifth of Tasmania's land mass. The principal land uses within these catchments are forestry and agriculture.

Flows into the South Esk also include diversions for hydro-electric power generation which divert flow away from the Derwent catchment via the Great Lake and subsequent power stations at Tods Corner, Poatina and Lake Trevallyn.

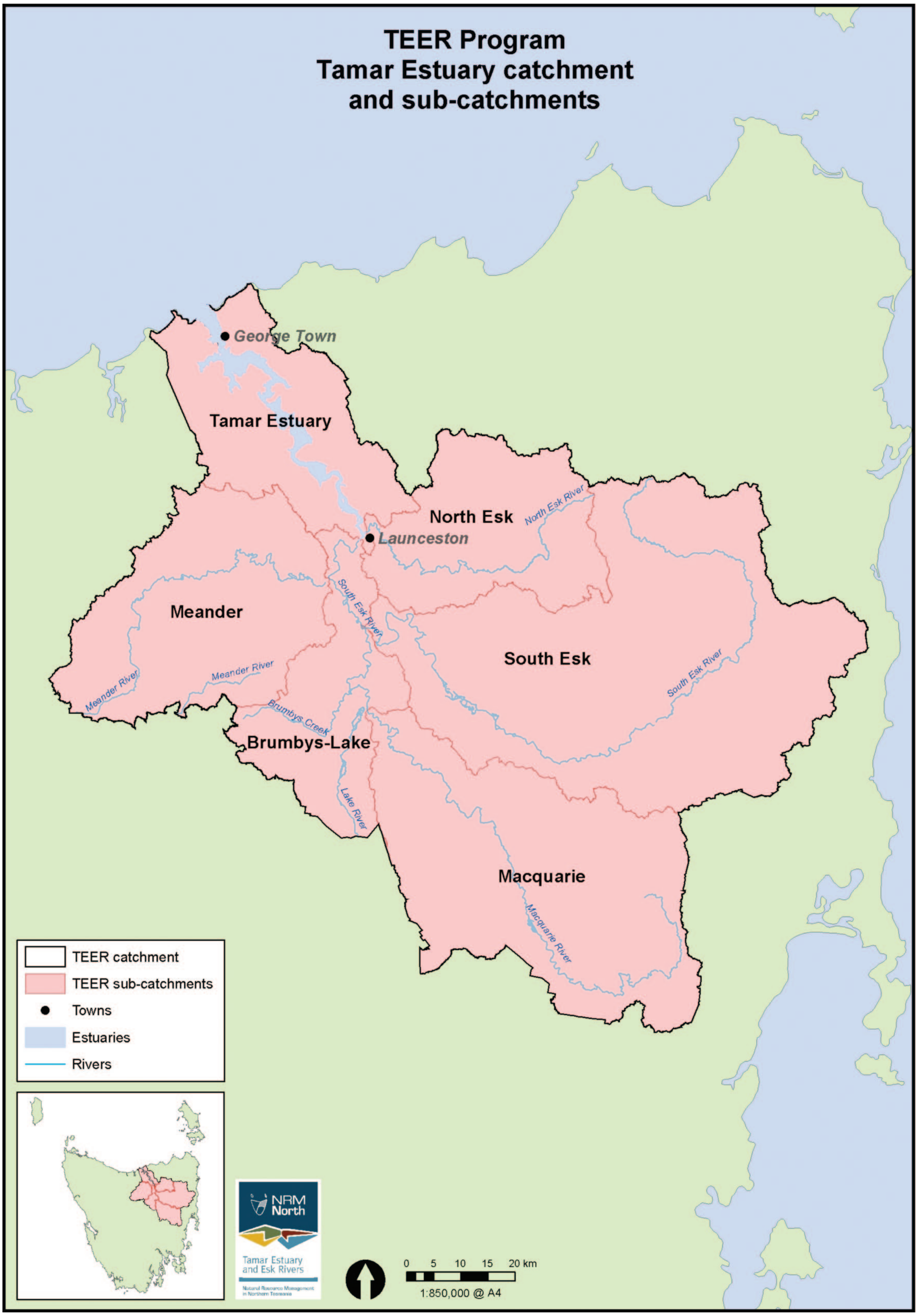


Figure 1. Tamar Estuary Catchments

1.3 Uses

Launceston is the largest city in the north of Tasmania with a population of approximately 100,000. Smaller towns spot the length of the estuary with a concentration in George Town on the eastern foreshore. The Bell Bay area is an industrial hub with a major shipping port and heavy industries such as Rio Tinto, BHP Billiton TEMCO and the site of the proposed Gunns Ltd pulp mill.

Several aquaculture farms are established on the Tamar estuary growing and harvesting species such as Atlantic salmon, seahorses and abalone. The estuary is netted by a small number of commercial fishers who provide fish for the seafood industry and aquarium trade.

The Tamar estuary provides significant recreational use for local residents and tourists. Recreational fishing, boating and water sports are popular in most reaches and boardwalks have been constructed to encourage greater interaction with the estuary.

1.4 Values

Estuaries are generally considered to have high natural values due to the varied natural features occurring in a single area. As a natural border between freshwaters and marine waters, estuaries support various habitats and are some of the most productive environments on Earth. The Tamar estuary supports a rich and diverse range of flora and fauna, and provides a stronghold and breeding ground for several threatened species listed on the Australian Government's Environment Protection and Biodiversity Conservation (EPBC) Act, 1999, such as the Australian sea lion, Wedge-tailed eagle, white bellied sea eagle and native fish the Australian grayling. The estuary is recognised as a ''hotspot'' for coastal bird species and supports critical habitats including coral reefs, sponge gardens, seagrasses, mudflats and sand flats (Aquenal and DEPHA, 2008). The Tamar Island wetlands that fringe the south-western reaches provide valuable habitat and help to maintain water quality by acting as a natural buffer. The estuary's natural values are closely integrated with the social fabric of the region. People are attracted to the Tamar estuary for the many opportunities that the estuary offers, including aesthetics, recreational pursuits such as bird watching, water sports, yachting and fishing, and simply being able to connect with the natural environment (Aquenal and DEPHA, 2008).

The Tasmanian State Policy on Water Quality Management developed in 1997 aims to achieve the sustainable management of Tasmania's surface water and groundwater resources by protecting or enhancing their qualities while allowing for sustainable development in accordance with the objectives of Tasmania's Resource Management and Planning System. The Tasmanian State Policy on Water Quality Management, 1997, outlines the minimum water quality management strategies to protect the environmental values (PEVs) identified, i.e., the current uses and values, in the estuary.

The strategies seek to provide water of a physical and chemical nature to:

- support modified but healthy aquatic ecosystems from which edible fish and crustacea may be harvested but not shellfish except where permitted by marine farming licences under the Living Marine Resources Management Act, 1995;
- allow people to safely engage in recreation activities such as swimming (where permitted), paddling and fishing in aesthetically pleasing waters and which is suitable to support aquaculture in marine farming zones and existing marine farming licences issued pursuant to the Living Marine Resources Management Act, 1995; and
- support the industrial use of the water for such uses as Gunns Ltd sawmill operations and cooling water for industrial activities.

The existing PEVs for estuarine waters in the Tamar catchment (excluding Deceitful Cove) are as follows (Department of Primary Industries, Water and Environment, 2005):

A: Protection of Aquatic Ecosystems
(i) Protection of modified (not pristine) ecosystems from which edible fish and crustacea are harvested but not shellfish except where permitted by Marine Farming Licences under the Living Marine Resources Management Act, 1995.

B: Recreational Water Quality and Aesthetics
(i) Primary contact water quality (where permitted).
(ii) Secondary contact water quality.
(iii) Aesthetic water quality.

C: Industrial Water Supply
(Aquaculture in marine farming zones and existing marine farming licences issued pursuant to the Living Marine Resources Management Act, 1995, Gunns Ltd and Bell Bay Power Station.)

For Deceitful Cove the PEVs are:

A: Protection of modified (not pristine) aquatic ecosystems from which edible fish, crustacea and shellfish are not harvested.

B: Recreational Water Quality and Aesthetics
(i) Secondary contact water quality.
(ii) Aesthetic water quality.

1.5 Environmental Issues

Sedimentation in the Tamar's upper reaches has been an issue of long-standing concern, both for reasons of amenity and environmental quality. The upper sections of drowned river estuaries like the Tamar receive sediments delivered from the upper catchments and from the redistribution of existing sediments circulating within the estuary. Sedimentation in the Home Reach section of the Tamar causes difficulties with navigation and is aesthetically unpleasing for many people in the community. The upper reaches have a long history of dredging to improve navigation, which disturbs the sediments that often accumulate or concentrate contaminants.

There are over 20 wastewater treatment plants (WWTPs) within the greater Tamar catchment which collect and treat sewage and other wastewater from surrounding townships. The level of treatment varies based on the type of wastewater, technologies available and environmental criteria. Many of these plants have associated water recycling schemes that reuse the effluent for pasture irrigation. However there are plants where the opportunity to recycle effluent is not possible and therefore effluent is discharged into waterways under conditions set out in environmental permits.

The older parts of Launceston were designed to have a combined sewerage and stormwater drainage system. Storages have been built in recent years to capture the first flush of stormwater for treatment at the Ti Tree Bend WWTP. However during periods of high run-off, overflows of untreated sewage combined with stormwater occasionally enter the estuary. Other sources of sewage entering the estuary can be leaching from poorly maintained septic systems and discharged directly from recreational vessels (Aquenal and DEPHA, 2008).

Stormwater and urban runoff represent a significant diffuse source of pollution to urban waterways. Contaminants are washed off roofs, streets, parks and gardens, eventually entering the river system. Urban stormwater is generally characterised by high levels of suspended solids, nutrients, bacteria and a range of metals and hydrocarbons, all of which can be detrimental to estuarine ecosystems and water quality. The suburbs surrounding Launceston do not operate a combined stormwater-sewer system; stormwater is not collected or treated but flows directly into the Tamar estuary (Aquenal and DEPHA, 2008). The TEER program operates a stormwater working group in partnership with local councils and water corporation stakeholders, which aims to develop projects to gauge and minimise the impact of stormwater in the Tamar estuary.

Heavy industry in the Tamar Valley catchment has existed for many years, and types of industrial discharges into the Tamar estuary have varied over time with upgrades of Environmental Protection Notices (EPNs) regulated by the Environmental Protection Agency (EPA). Industrial pollutants may enter the Tamar via a number of possible environmental pathways such as direct discharges of liquid processing wastes, stormwater run-off, groundwater seepage and spills. In some cases, mass emission from indirect and/or infrequent inputs may be greater than average end-of-pipe discharges (Aquenal and DEPHA, 2008). Advancing technologies in waste processes and treatment are driven by the tightening control measures imposed by the EPA, to reduce the impact on the Tamar estuary as the receiving body.

Introduced pest species within the Tamar estuary are also an environmental concern with several target pests identified; Pacific oyster (Crassostrea gigas), rice grass (Spartina anglica), mosquito fish

(Gambisia holbrooki), Asian bag mussel (Musculista senhousia) and the European green crab (Carcinus maenas) (Aquenal & DEPHA, 2008). Pest identification and surveys are beyond the scope of this TEER EHAP, for more information on these introduced pest species see the State of the Tamar Estuary 2008 (Aquenal & DEPHA, 2008).

2 Ambient Water Quality Monitoring Program

TEER coordinates a monthly ambient water quality monitoring program sampling along the length of the Tamar estuary in Northern Tasmania.

The Ecosystem Health Assessment Program (EHAP) aims to broadly gauge the ecological health of the estuary by collecting and analysing water quality indicators to gain an understanding and classify the status of the ecosystem. This inaugural EHAP report incorporates Tamar estuary data that has been collected in the first year of the monitoring program from October 2009 to September 2010.

Ecosystem health can be determined by the response of the ecosystem to natural and human inputs (EPA 2007).

1. Monitoring the ecological health serves four main purposes (Downes et al., 2002):
2. To assess the ecological state of ecosystems.
3. To assess whether performance criteria have been exceeded.
4. To detect and assess the impact(s) of human generated disturbances.
5. To assess the responses of the ecosystem to restoration efforts.

To allow the ecological assessment of the estuary, the Tamar has been divided into five functional zones (Figure 2, see section 2.3 for more detail.), the zones reflect the differences in critical habitats, key processes and anthropogenic impacts on the estuary and also provide a focus for management actions and future research (Pantus and Dennison, 2005). The EHAP aims to improve the scientific knowledge around the processes impacting on the health of the waterways. Reliable scientific data is collected to gain a greater understanding of the Tamar estuary with findings communicated to the community and estuary managers through reports, publications, targeted research projects and local media launches.

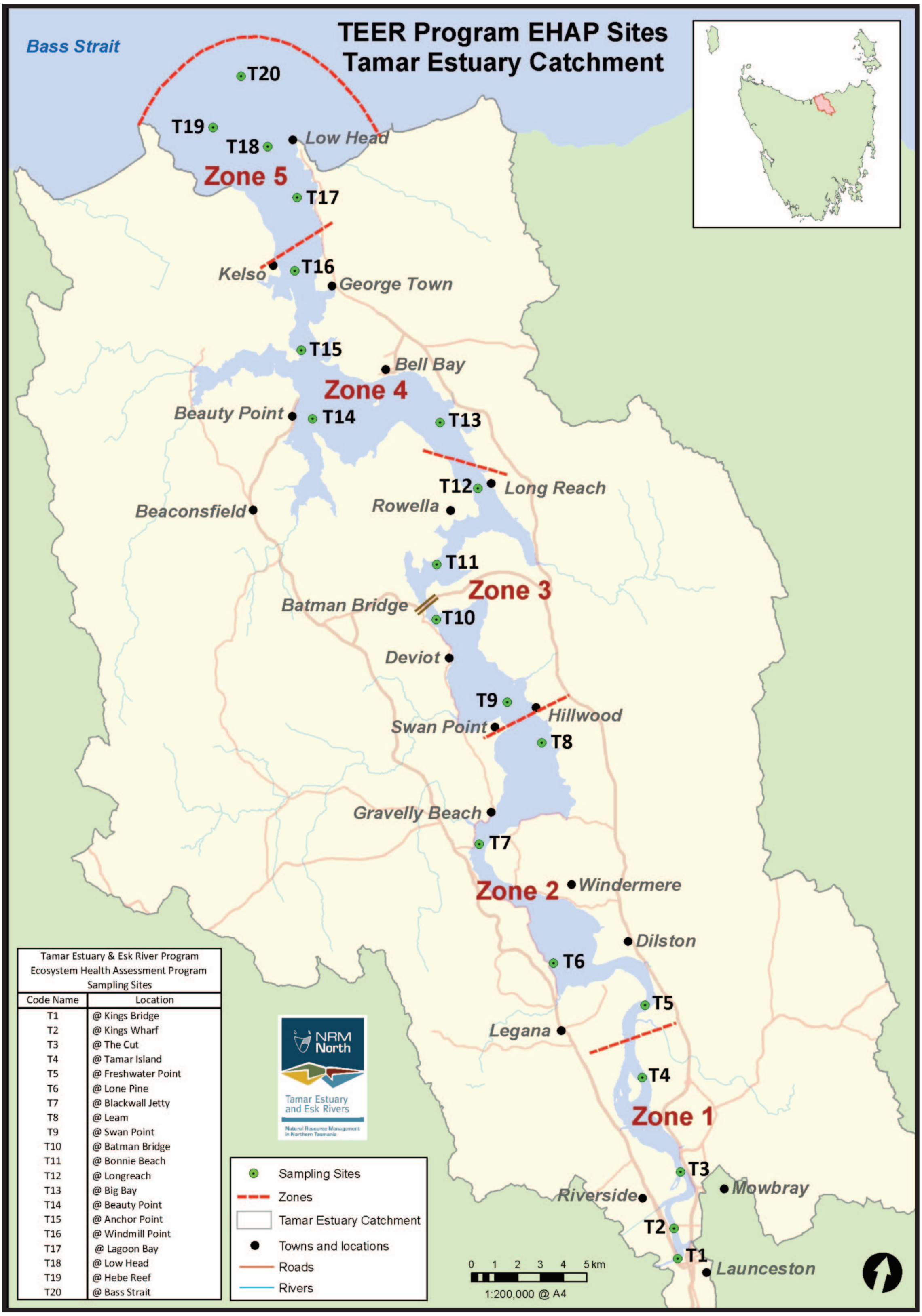
Monitoring methods

Water quality monitoring occurred monthly with samples taken at 20 sites along the Tamar estuary from Kings Bridge in Launceston in the upper reaches and extending out past Hebe Reef where the lower estuary discharges into Bass Strait. Each of the five functional zones incorporates four sampling sites (Figure 2). Sampling was generally conducted on a single day, but on two occasions sampling was split over two days to accommodate tide, weather and daylight.

At all sites, water quality parameters (Table 1) are measured at discrete depths throughout the water column by a calibrated multi-probe water quality meter which is lowered from the surface to the bottom of the water column. Water clarity and light penetration are measured by lowering a secchi disk from the surface of the water and recording the distance where the disk is no longer visible.

Surface and bottom water samples from each site are analysed for nutrients, metals, chlorophyll a and total suspended solids (TSS) at Analytical Services Tasmania (AST), a NATA-accredited laboratory (nutrient samples were filtered (0.45μm) on the boat to allow for total and dissolved nutrient samples to be analysed). Surface water samples are taken by grab sampling 10cm under the surface of the water and bottom samples are taken by using a Niskin bottle which captures water at depth (1one metre above bottom of estuary).

Bacteriological samples are taken for surface waters at each site and analysed for enterococci at Tasmanian Laboratory Services.



Tamar Estuary & Esk River Program
Ecosystem Health Assessment Program
Sampling Sites

Code Name	Location
T1	@ Kings Bridge
T2	@ Kings Wharf
T3	@ The Cut
T4	@ Tamar Island
T5	@ Freshwater Point
T6	@ Lone Pine
T7	@ Blackwall Jetty
T8	@ Leam
T9	@ Swan Point
T10	@ Batman Bridge
T11	@ Bonnie Beach
T12	@ Longreach
T13	@ Big Bay
T14	@ Beauty Point
T15	@ Anchor Point
T16	@ Windmill Point
T17	@ Lagoon Bay
T18	@ Low Head
T19	@ Hebe Reef
T20	@ Bass Strait

Figure 2. TEER EHAP zones and sampling sites.

Table 1: TEER EHAP sampled parameters

Physical Chemistry	Nutrient (µg/L)	Dissolved Metals (µg/L)
Temperature (°C)	Ammonia	Copper(Cu)
Salinity (ppt)	Total Phosphorus	Mercury(Hg)
Dissolved Oxygen (% Sat & mg/L)	Dissolved Reactive Phosphorus	Lead(Pb)
pH (Units)	Total Nitrogen	Zinc(Zn)
Turbidity (NTU)	Nitrite + Nitrate	Cadmium(Cd)
Chlorophyll a (µg/L)		Aluminium(Al)
Specific conductivity (mS/cm)		Iron(Fe)
Total Suspended Solids (0.45 micron filtered) (mg/L)		Manganese(Mn)
Secchi Disk (m)	Bacterial	Arsenic(As)
	Enterococci (/100ml)	Selenium(Se)

2.1 Quality Assurance & Quality Control (QAQC)

Quality assurance and quality control are a set of operating and sampling procedures carried out by the TEER EHAP team that help to ensure that calibration, sampling techniques, storage, transport and analysis of samples are as consistent as possible, reducing the variation in results due to incorrect procedures. The laboratory analysing the samples provides specific instructions to follow when sampling in the field. *Duplicate, *field and *trip blank samples are taken at a nominated sampling site allowing results to be compared and any inconsistencies to be brought to the attention of the program. The QAQC results are uploaded and stored in the database and compared to the results from the reference site for each monitoring date.

* Duplicates - double sampling to ascertain if there are any differences between the two results.

* Field samples – pre-prepared laboratory samples which are treated the same way as ambient samples.

* Laboratory prepared samples which remain unopened and are analysed when they arrive back at the laboratory to assess how samples are treated during transit.

2.2 Water Quality Guidelines

Where appropriate, data used in this EHAP report is considered alongside national water quality guidelines, in particular the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).

The ANZECC guidelines provide a framework to enable the assessment and management of environmental values including ambient water quality in relation to fresh, estuarine and marine environments. The guidelines provide guidance on assessing water quality and to identify if systems are functioning outside of normal or expected ranges. They are used as default triggers where site specific information is lacking, and may help identify management priorities.

The trigger values used for the Tamar estuary rely on the classification of the estuary as a ''slightly to moderately disturbed'' ecosystem, reflecting a range of historical and current land use that puts pressure on the aquatic environment. The ANZECC,2000, guidelines can be found at:

http://www.environment.gov.au/water/policy-programs/nwqms/index.html

It is important to note that the ANZECC default trigger values for south-eastern Australia have been adopted here (detailed in Table 2) even though they do not include any data from Tasmanian estuaries. The water quality “trigger values” produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) for some Tasmanian estuaries (Murphy et al., 2003) have not been used as they did not include data from the Tamar estuary in their assessment.

Ideally site specific derived water quality objectives (WQO) or trigger values would be developed for the Tamar estuary. Also, for the maintenance and progressive improvement of water quality in the estuary, water quality targets should be set for those water quality indicators affected by anthropogenic influence. As a priority TEER will use the EHAP data to facilitate the development of these site specific water quality targets over 2012-2013.

Table 2: ANZECC Estuarine Default trigger values for south-east Australia for slightly disturbed ecosystems

Parameter	Chl-a µg/L	TP µg P/L	FRP µg P/L	TN µg N/L	NH4+ µg N/L	NOx µg N/L	DO % Sat	pH units
ANZECC Trigger level	4	30	5	300	15	15	Lower 80 Upper110	Lower 7 Upper 8.5

Chl-a = chlorophyll a, TP= Total Phosphorus, FRP= Filterable Reactive Phosphorus,
TN = Total nitrogen, NH4+=ammonium, NOX= nitrate plus nitrite, D.O=Dissolved Oxygen

2.3 Identification of Tamar Estuary Functional Zones

For the development of the TEER EHAP, the Tamar estuary has been divided into five functional zones that reflect differences in critical habitats, key processes and anthropogenic impacts of the estuary (Figure 2). A functional zone is defined as a geographic entity with common structural and functional characteristics which can be defined in a conceptual model and quantified by measurement (Dennison et al., 1999). The zones provide a focus for management actions and future research (Pantus and Dennison, 2005). The five functional zones define clear boundaries through which change can be measured over time along the length of the estuary.

Table 3 shows the range of salinity, water temperature, pH and depth for the five functional zones.

Table 3: Zone 1-5 Salinity, Water Temperature, pH, and depth range

Zones	Sites	Salinity (ppt)	Water Temp (°C)	pH	Water sample depth (m)
Zone 1 upper estuary	T1-T4	0.01 – 13.0	5.6 – 23.5	6.8 – 7.9	5 – 8
Zone 2	T5-T9	0.04 – 28.5	6.4 – 24.5	7.0 – 8.1	11 – 20
Zone 3 mid estuary	T10-T11	18.0 – 32.0	8.7 – 21.8	7.8 – 8.1	17 – 33
Zone 4	T12-T13	21.7 – 35.3	9.8 – 21.2	8.0 – 8.2	4 – 42
Zone 5 lower estuary	T14-T20	29.5 – 35.4	10.6 –20.5	8.0 – 8.2	14 – 40

Proxy Sites for Zones 1-5

For the purposes of describing the differences between the zones in regard to water quality and physical characteristics, one proxy sampling site was chosen to represent each of the five zones. Salinity profiles were used to identify the five proxy sites that were representative of the sites grouped within each EHAP functional zone (1 to 5). When used in the results section of this report the values given are the average of all depths measured in that month's profile.

The sites chosen for each zones respectively were: T3 for zone 1; T7 for zone 2; T11 for zone 3; T15 for zone 4; and, T18 for zone 5 (Figure 3).

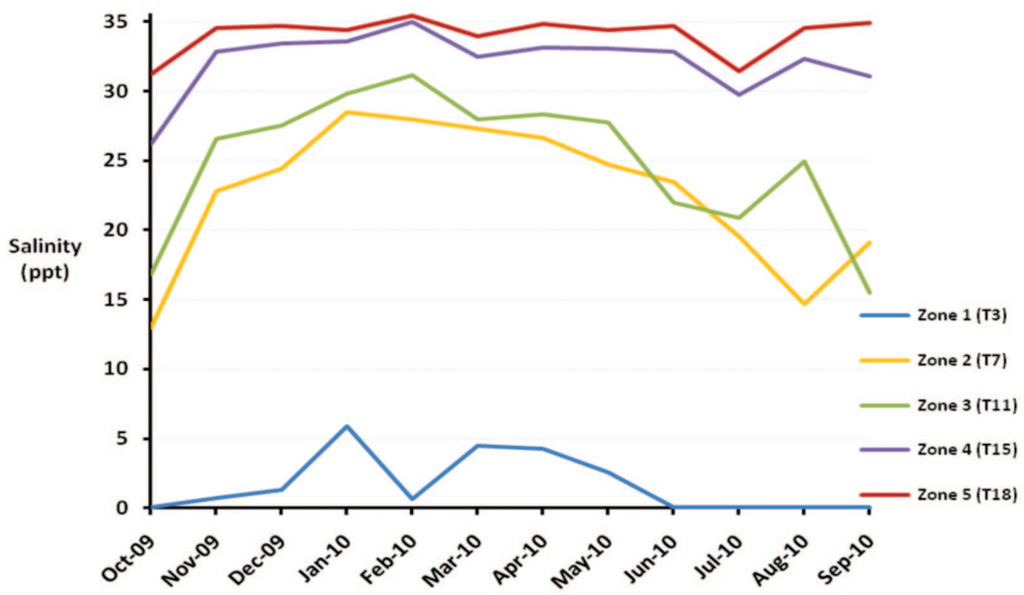


Figure 3: Zone 1-5 Proxy Sites Salinity

Zone 1 (sites 1-4)

Zone 1 extends from the town of Launceston to north of Tamar Island in the upper estuary. The foreshore of this zone is the most heavily urbanised of the estuary, supporting an urban population of around 100,000 (Figure 4). In the upper reaches of this zone there are direct freshwater inputs from the North Esk and South Esk rivers which drain the upper sections of the Tamar catchment (Figure 2). As a result, this zone has limited marine influence, with bottom waters only slightly more saline than surface waters there is also another freshwater input from the Lake Trevallyn Tail Race hydro-electric power scheme.

Zone 1 is the shallowest in the estuary with a depth ranging from 5–8 metres with broad shallow tidal flats. The benthic habitat, like much of the Tamar estuary is silt (Lucieer et al., 2009). Due to the urbanised nature of the Launceston city area, there are many diffuse and point source pollution inputs to this zone including stormwater runoff and effluent from wastewater treatment plants. There is also a historical legacy of metal contamination in sediments from mining and smelting activities in the catchment. The upper reaches of the estuary around sites T1 and T2 has a history of extensive dredging for navigational purposes and is also an area of sediment accumulation as sediments are delivered from the upper catchments and existing sediments are redistributed within the estuary. Figure 5 shows the salinity at zone 1 proxy site T3 over the sampling period ranging according to seasonal variation, in summer there is a clear difference in salinity between surface and bottom samples while in the wetter months freshwater dominates the surface and bottom sample.

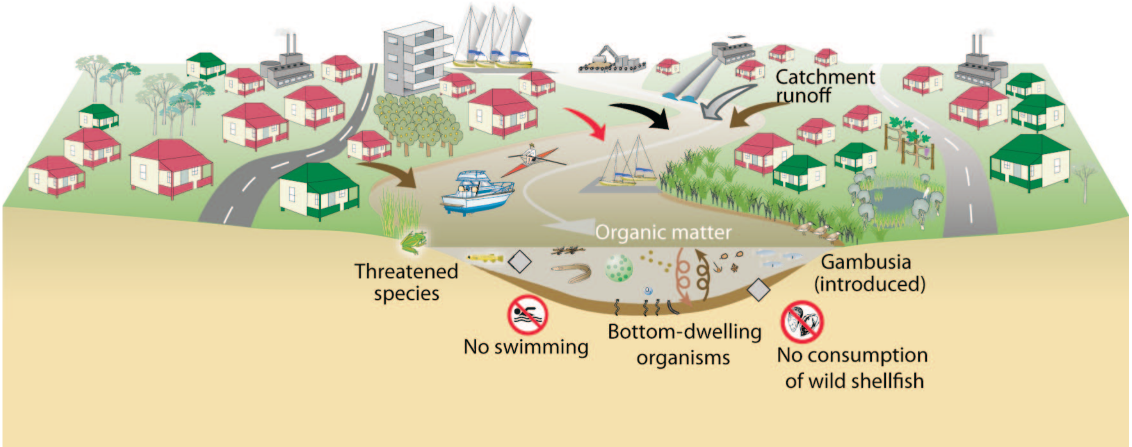


Figure 4. Zone 1 Conceptual diagram describing land use around upper Tamar Estuary

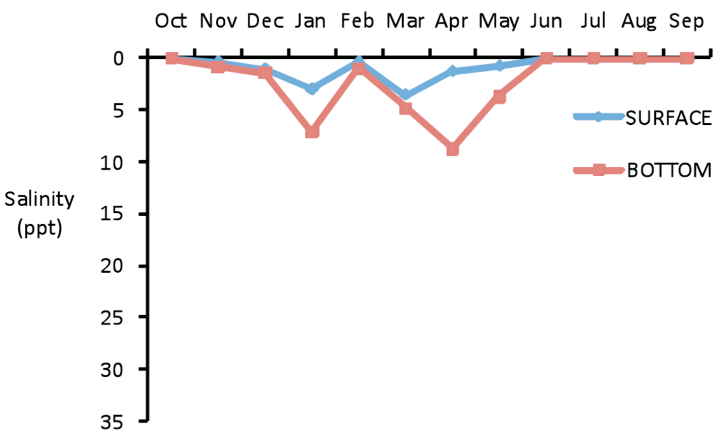


Figure 5. Salinity at Zone 1 proxy site T3 Oct 2009-Sep 2010

Zone 2 (Sites 5-8)

Zone 2 extends northwards from Tamar Island to Swan Point in the mid to upper estuary (Figure 2). The benthic habitat is predominately silt bottom (Lucieer et al., 2009) with the introduced species Spartina anglica (rice grass) occupying the margins of the banks, and introduced Gambusia holbrooki (mosquito fish) which inhabits the Tamar Island wetlands. The salinity and depth range increases along the length of the estuary travelling north. Zone 2 has a salinity range of 0.04-28.5 (Table 3 & Figure 7) and a sampling depth range of 11-20 metres during the sampling period from October 2009 to September 2010. There are smaller communities spread out along the eastern and western shores of this zone with the largest being Legana and Exeter. This area was where historically the dredge spoils from Launceston were deposited. Nelsons Shoal located on the eastern shore between Dilston and Windermere (Figure 2) is a vast mudflat where sediments in the estuary accumulate. There are also large sections of agricultural land along the eastern shore of this zone (Figure 6).

This part of the estuary experiences large and dynamic changes in salinity (0.04 ppt to 28.5ppt). The influence of freshwater inflows is reduced compared to zone 1, however the surface is always fresher than bottom (figure 7), and winter rains result in lower salinities than drier summer months.

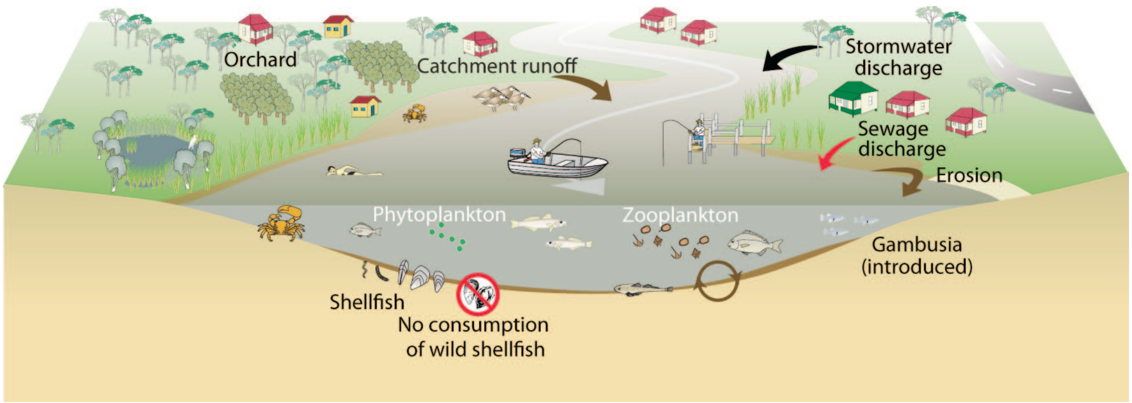


Figure 6. Zone 2 Conceptual Diagram describing land use in mid-upper Tamar Estuary

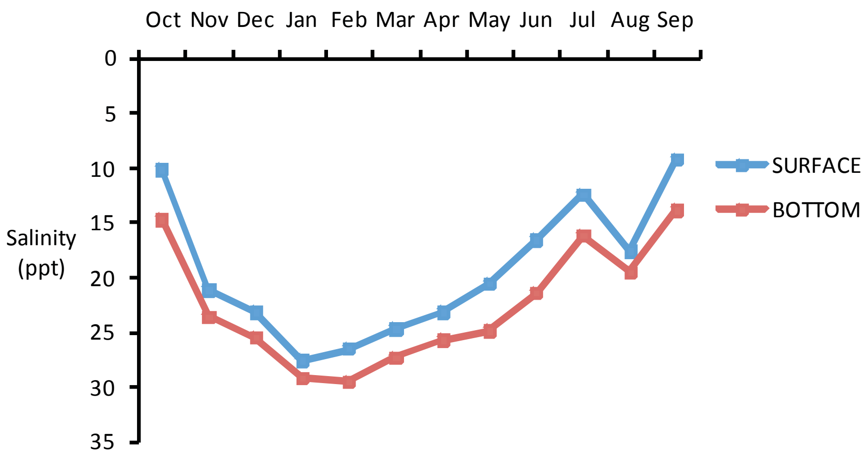


Figure 7. Salinity at Zone 2 proxy site T7 Oct 2009-Sep 2010

Zone 3 (Sites 9-12)

Zone 3 is located mid estuary between Swan Point and Rowella halfway along the Longreach section of the Tamar estuary (Figure 2). This area features large silt bays with smaller rocky channels, especially around the Batman Bridge where the substrate is mainly cobble and reef (Lucieer et al., 2009). The salinity range is 18.0-32.0 ppt (Table 3 & Figure 9) with the sampling depth ranging from 17-33 metres. There is less variation in salinity between surface and bottom samples, and a seasonal signal is still evident. Zone 3 has smaller rural communities along the shores of the Tamar with agriculture, wood and aquaculture industries operating close to the estuary's shore (Figure 8). Zone 3 is also used for recreational activities in the form of swimming, boating and fishing.

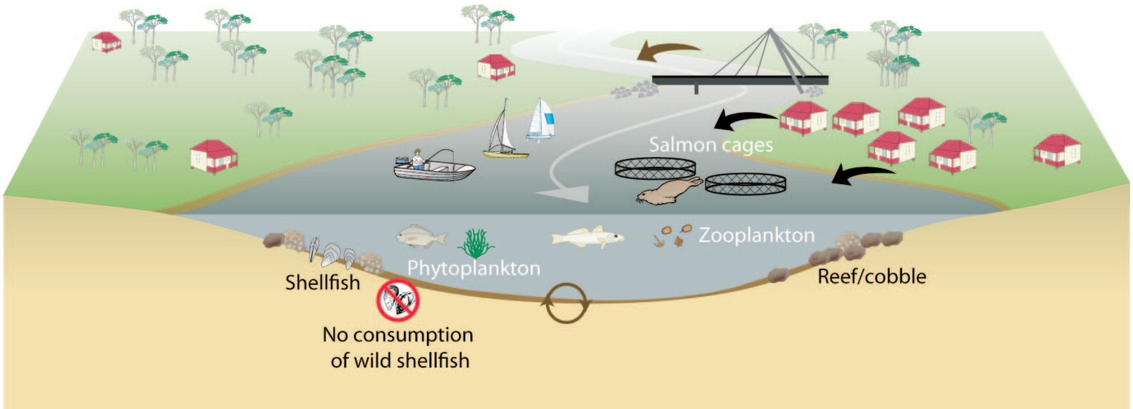


Figure 8. Zone 3 Conceptual diagram describing land use in mid Tamar Estuary

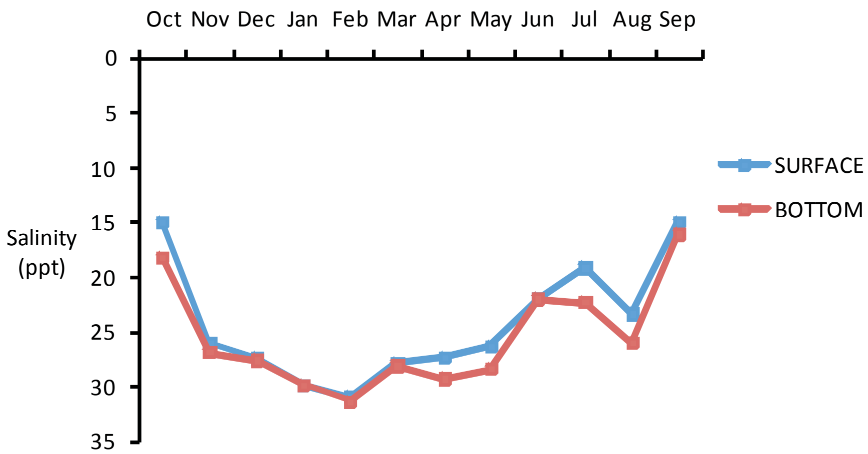


Figure 9. Salinity at Zone 3 proxy site T13 Oct 2009-Sep 2010

Zone 4 (Sites 13-16)

Zone 4 is situated in the lower estuary between Rowella and George Town. The estuary here is wide and deep with Middle Arm and West Arm joining the estuary on the western shore (Figure 2). The bottom habitat is mainly silt in the southern half of the zone with cobble and reef predominating in the northern section of the zone from Deceitful Cove to George Town (Lucieer et al., 2009). The sample salinity ranges from estuarine to full marine at 21.7-35.3 ppt with a sample depth range of 4-42 metres (Table 3 & Figure 11). There is a strong marine influence, and less stratification of the water column compared to zones upriver. There are a number of introduced pest species found in this area and the greater Tamar estuary including the Pacific oyster, Asian bag mussel, European green crab, rice grass and gambusia (Aquenal & DEPHA, 2008). The Bell Bay section is the most industrialised section of the estuary supporting mining, metal processing, timber and shipping industries (Figure 10) and has a history of elevated metal concentrations in sediments from historical practices of both mining and metal processing. The main population centres are Beauty Point on the western shore and George Town on the eastern shore. Zone 4 is also used for recreational activities such as skiing, swimming, fishing and boating.

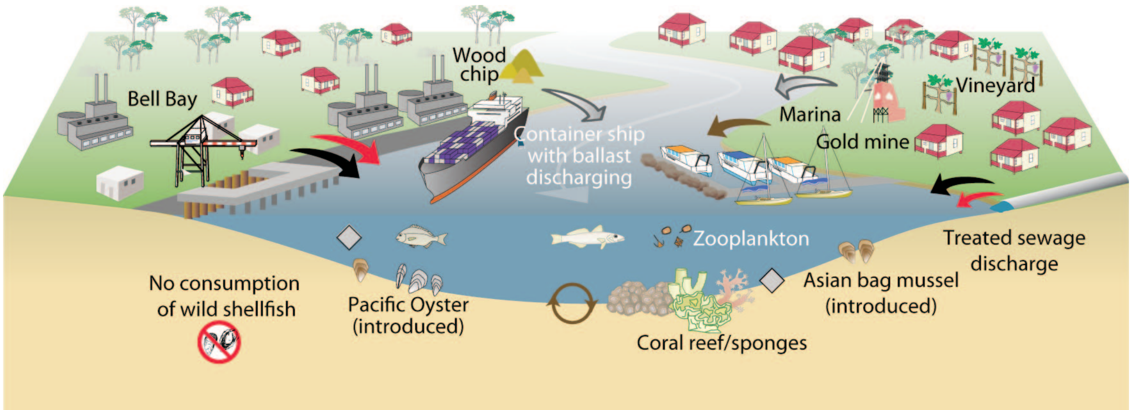


Figure 10. Zone 4 Conceptual diagram describing land use in mid- lower Tamar Estuary

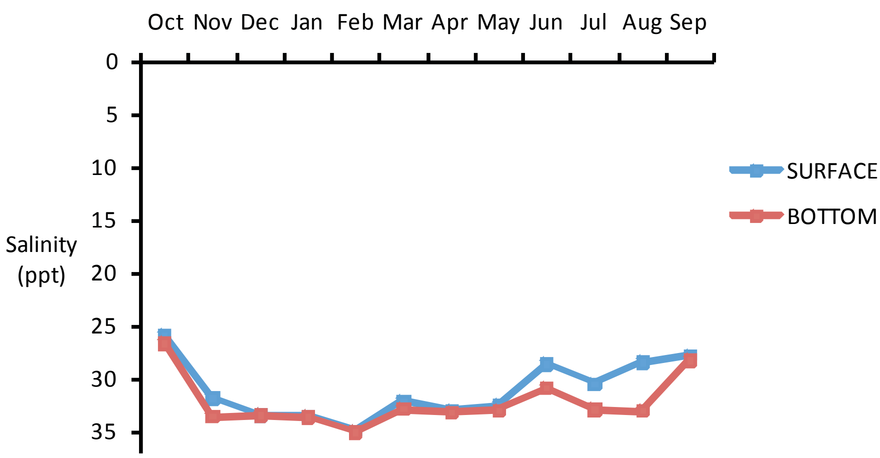


Figure 11. Salinity at Zone 4 proxy site T15 Oct 2009-Sep 2010

Zone 5 (Sites 17-20)

Zone 5 is located in the lower Tamar estuary and extends from George Town to Bass Strait, 3.5km past the river mouth (Figure 2). This is the zone where the estuary meets the ocean and as a result the salinity here is high and predominately marine (Figure 13) except in times of large floods moving down the estuary. The sample salinity in zone 5 ranges from 29.5-35.4 ppt with a sample depth range of 14-40 metres (Table 3 & Figure 12). The bottom habitat is a mixture of sand, seagrass, sponge garden, cobble and reef with sandy rocky shores and sandy beaches closer to the ocean (Lucieer et al., 2009). This zone is the entry to the Tamar estuary and is a shipping route to the industry ports of Bell Bay and Longreach (Figure 12). Zone 5 is also used for recreational activities such as swimming, boating, fishing and scuba diving.

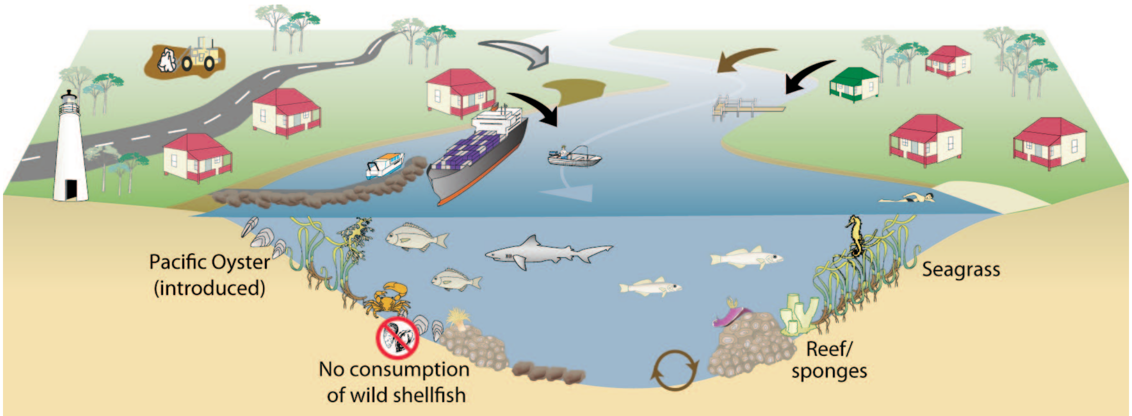


Figure 12. Zone 5 Conceptual diagram describing land use in lower Tamar Estuary

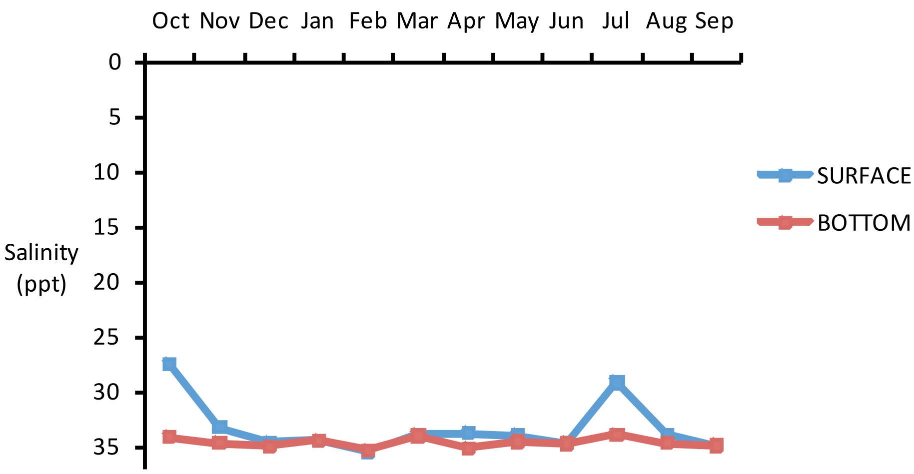


Figure 13. Salinity at Zone 5 proxy site T18 Oct 2009-Sep 2010

2.4 Northern Tasmania climate description (October 2009-Sept 2010)

Waterways are heavily influenced by climatic conditions. In wet years, high surface and river flows deliver increased pollutants via runoff from the upper catchments which ultimately end up in the estuary. During dry years and times of drought there are decreased flows in the catchment which can lead to increased summer temperatures and lower seasonal dissolved oxygen concentrations. This section describes the climate during the sampling period of October 2009 to September 2010 as background to the results shown later in the report.

Launceston has a temperate climate with average maximum air temperatures ranging from 13.1°C in the winter to 23.6°C in the summer (Table 4). The long-term average yearly rainfall for Launceston is 696.6mm (Bureau of Meteorology, 2011).

Table 4. Launceston climate averages. Source Australian Bureau of Meteorology. Launceston Climate (2011).

Climate Averages for Launceston				
	Spring	**Summer**	**Autumn**	**Winter**
Maximum Temperature (deg C)	17.9	23.6	19.0	13.1
Minimum Temperature (deg C)	7.0	11.5	7.5	2.8
Rainfall (mm)	172	122	153	230

The EHAP sampling period from October 2009 to September 2010 was characterised as receiving high rainfalls (Figure 14) with a number of floods occurring in the Tamar catchment.

After three relatively dry years, 2009 was wetter than usual across almost all of Tasmania. Months with above average rainfall were common throughout the year, but particularly between June and September (Bureau of Meteorology, 2011). August 2009 was one of the wettest on record and a record wet September in the east led to repeated flooding in many rivers in the north and east until early October 2009 (Bureau of Meteorology, 2011).

Overall, 2010 was wetter than usual in the north of Tasmania with major flooding occurring in the South Esk River. The first six months of the year were relatively dry and, similar to 2009, flooding occurred between June and September with Lake Trevallyn spilling for the majority of the time over these four months (Bureau of Meteorology, 2011).

There are six catchments that drain into the Tamar estuary; the North Esk, South Esk, Macquarie, Brumby's-Lake, Meander and Tamar catchments (see Figure 1). The majority of freshwater draining into the estuary is delivered by the South Esk River and to a lesser extent the North Esk River.

Flow data from the North Esk and South Esk is used below to describe the flows entering the Tamar estuary.

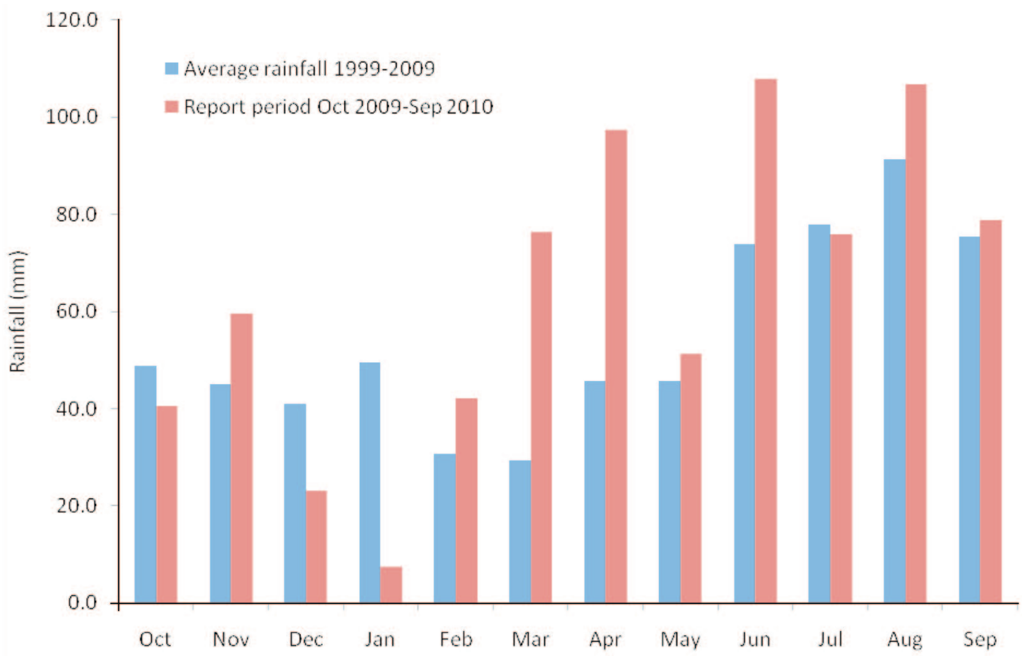


Figure 14. Launceston Rainfall. Ti Tree Bend Gauge (Data from Australian Bureau of Meteorology)

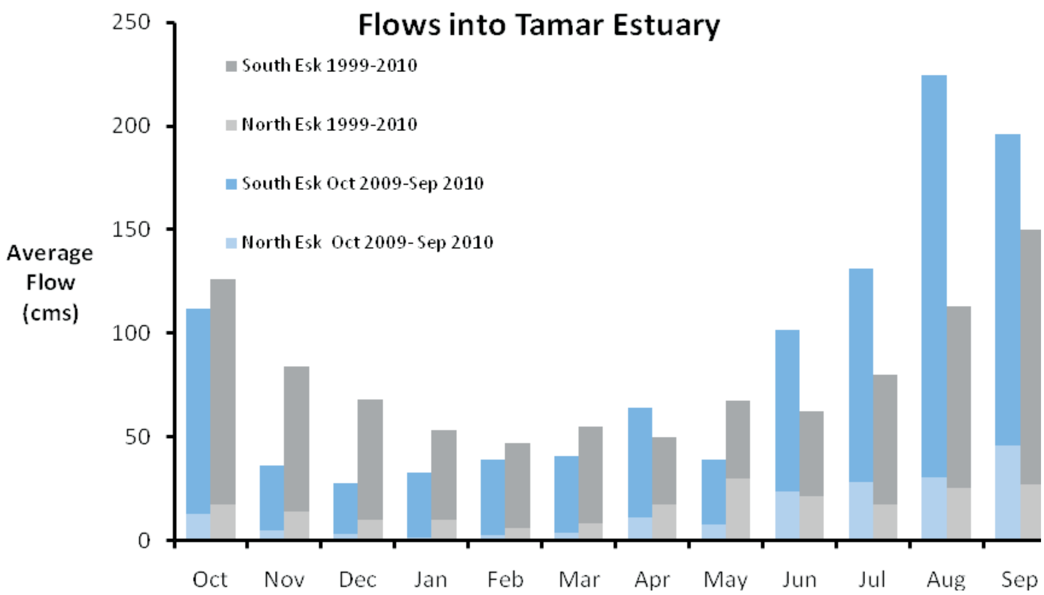


Figure 15. Average monthly flows into Tamar Estuary from the North Esk and South Esk rivers for Oct 2009-Sept 2010 and 10 yr average (1999-20010). Note: Flow data into the Tamar estuary is compiled from North Esk and South Esk flow data sourced from the Hobart Regional Office Bureau of Meteorology and Hydro Tasmania respectively.

Figure 15 shows average monthly flows for the EHAP sampling period reveal a similar seasonal pattern to the 10-year average with increased flows over winter and spring and lower flows over the summer months. The first half of the EHAP sampling period show flows lower than the 10-year average with an increase in flow from June 2010 to September 2010 exceeding the 10-year average flow due to high rainfall in the catchments.

3 Results of ambient water quality monitoring

This section describes results from the water quality sampling program for October 2009 to September 2010. ANZECC guidelines are shown, where available, for comparison. Appendix 2 provides a description of each of the data samples taken as part of the monitoring program.

3.1 EHAP data representation

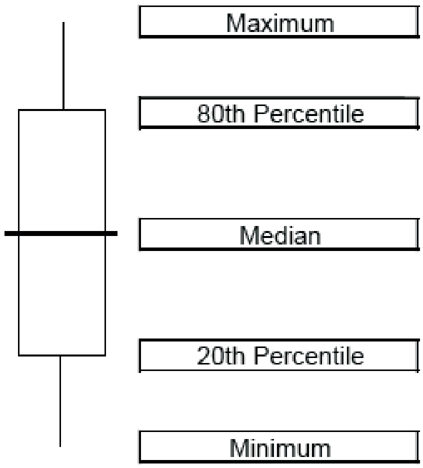


Figure 16. Key to data representation- 'Box-and-Whisker' plots

Much of the data in the following sections are presented as ''box-and-whisker'' diagrams (Figure 16). Box-and-whisker diagrams are a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower 20th percentile, median, upper 80th percentile and largest observation (sample maximum). A box plot may also indicate which observations, if any, might be considered outliers. These diagrams display the full spectrum of data collected, together with key statistical information. The 80th and 20th percentiles are used when representing physical parameters (such as salinity) and 95th and 5th percentiles are applied to toxicants (such as metals). The spacing between the different parts of the box helps to indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. The letter n and a number will be located above each box-and-whisker plots, i.e. (n=12), this indicates how many samples have been included in the box-and-whisker analysis.

3.2 Temperature, salinity and pH

Temperature, salinity and pH provide important contextual information about estuarine circulation. Both temperature and salinity provide important clues about water column structure and estuarine mixing, and are essential information for the development and calibration of hydrodynamic models (Aquenal and DEPHA, 2008). Temperature, salinity and pH influence the types and rates of biogeochemical processes and affect the distribution, diversity and abundance of aquatic species. Temperature is important in determining the rates of microbial, plant and animal growth. Temperature is also an important factor in the timing of fish, and other animal, migration and reproduction (Aquenal and DEPHA, 2008).

Most plant and animal species have very specific salinity tolerances, and the distribution and variability of salinity dictate to a large degree the types and distribution of estuarine biota within a system. Salinity also plays an important role in the flocculation and settling of particles. Where fresh, turbid river waters enter an estuary, dispersed particles tend to agglomerate at the interface between fresh and brackish water. Salinity levels within an estuary generally range from near fresh (<0.5 ppt) to near seawater (34 ppt) (Aquenal and DEPHA, 2008).

pH, a measure of the acid balance of water, influences many biological and chemical processes, and is an important control on the solubility of some metals, particularly iron and copper. If pH levels are lowered, metals bound in estuarine sediments can be released to the water column. Estuary pH levels generally average from 7 to 7.5 in fresher sections and between 8 and 8.6 in more saline areas (USEPA, 2002).

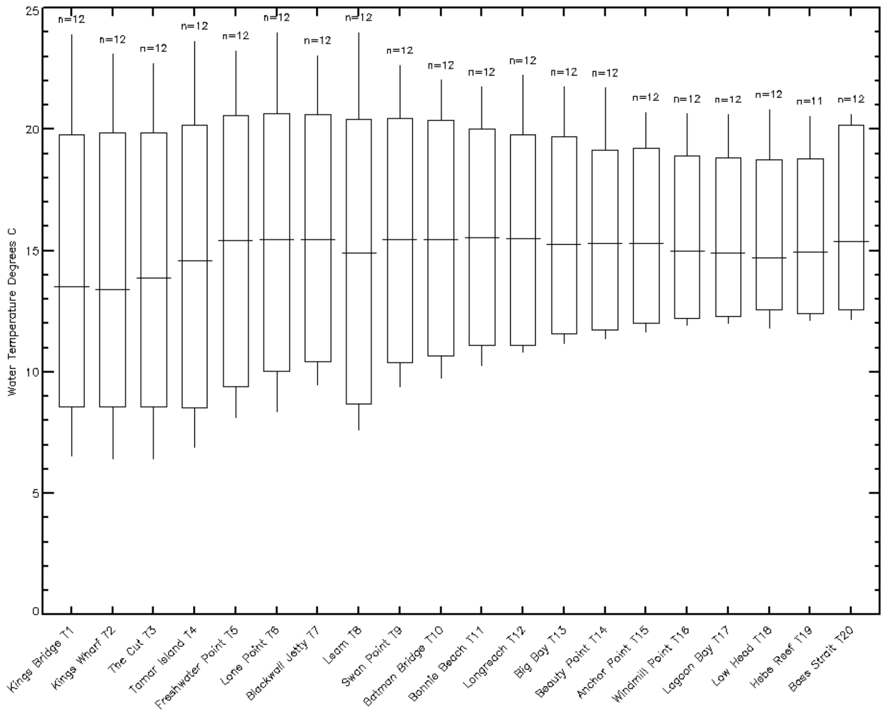


Figure 17. Water Temperature (°C) for TEER sites 1-20 at surface waters for the 2009-2010 study period

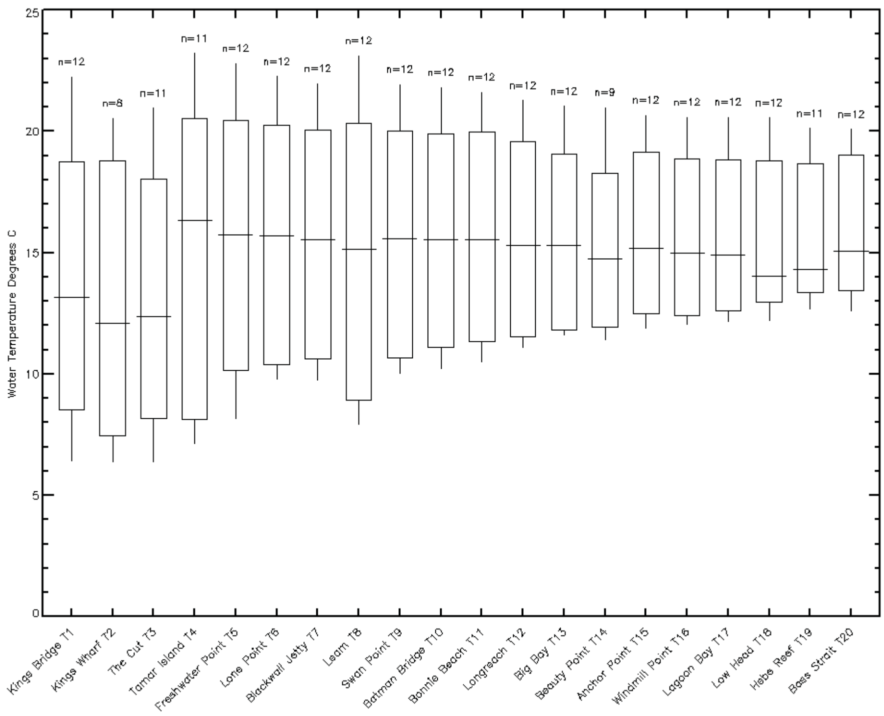


Figure 18.Water Temperature (°C) for TEER sites 1-20 at bottom waters for the 2009-2010 study period

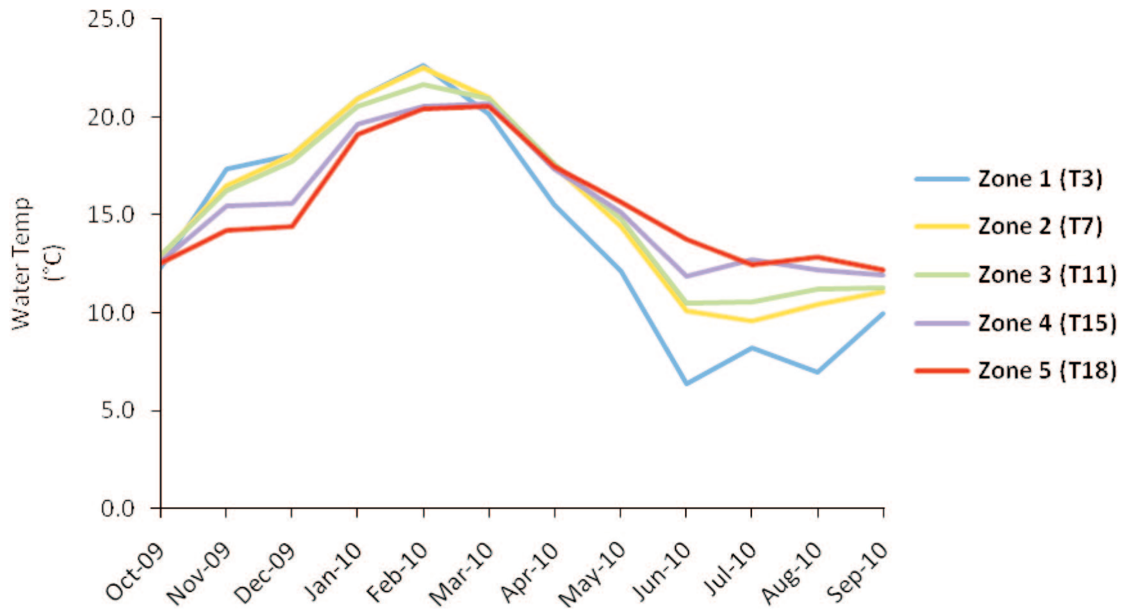


Figure 19.Water Temperature (°C) Zone 1-5 Proxy sites monthly profile averages

Figures 17 and 18 show the water temperature (ºC) for the 20 TEER sites between October 2009 and September 2010 at the surface and at the bottom respectively. Water temperature in the estuary varies according to season, ranging from around 7ºC to 10ºC in winter and 18ºC to 20ºC in summer. Temperature can also vary according to location in the estuary as well as depth of the water column. Temperature stratification can occur down the water column under different scenarios such as thermal heated surface layers from the sun, colder water at greater depths and haloclines where the denser saltwater lies beneath the less dense freshwater layer. Stratification is more pronounced in the upper part of the estuary.

The same seasonal patterns are evident across all zones; there are generally lower temperatures in zone 1 and higher temperatures in zone 5 from March to September. Conversely between October and February zone 1 experiences higher water temperature than zone 5(Figure 19). The range in water temperature during the EHAP monitoring period was greater in the upper estuary (5.6-23.5ºC) when compared to the water temperature range in the lower estuary (10.6-20.5ºC) (Table 3).

Key findings: Water temperature for the estuary follows seasonal influences and is highest in summer with the largest temperature range found in zone 1 in the upper estuary ranging from 5.6°C to 23.5°C compared to zone 5 in the lower estuary which showed a range of 10.6°C to 20.5°C. Bottom waters reflect marine influences which are cooler than surface waters in summer, and show less variability.

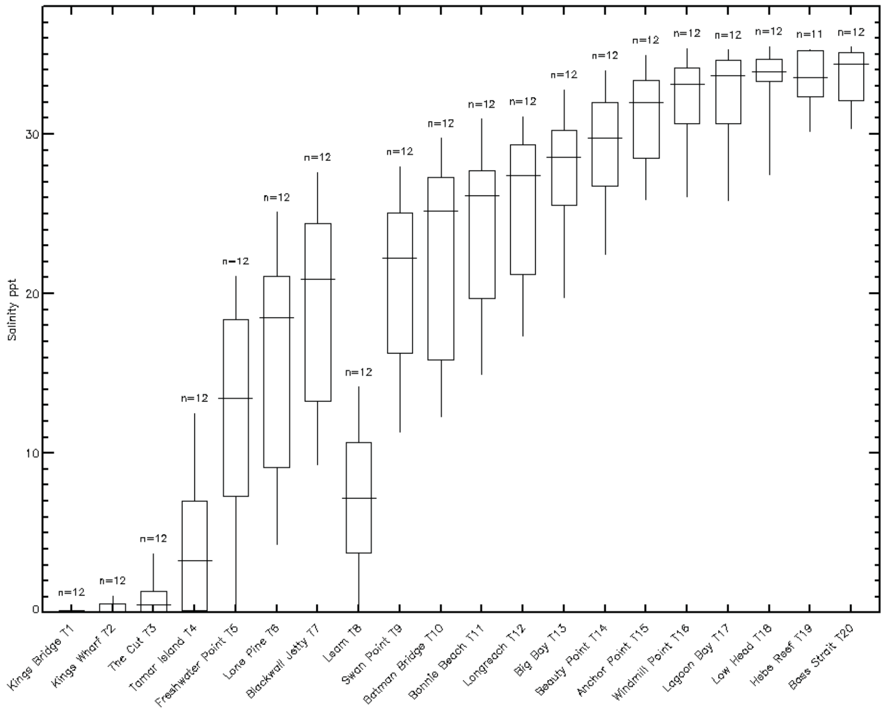


Figure 20. Salinity (ppt) for TEER 1-20 in surface waters for the 2009-2010 study period

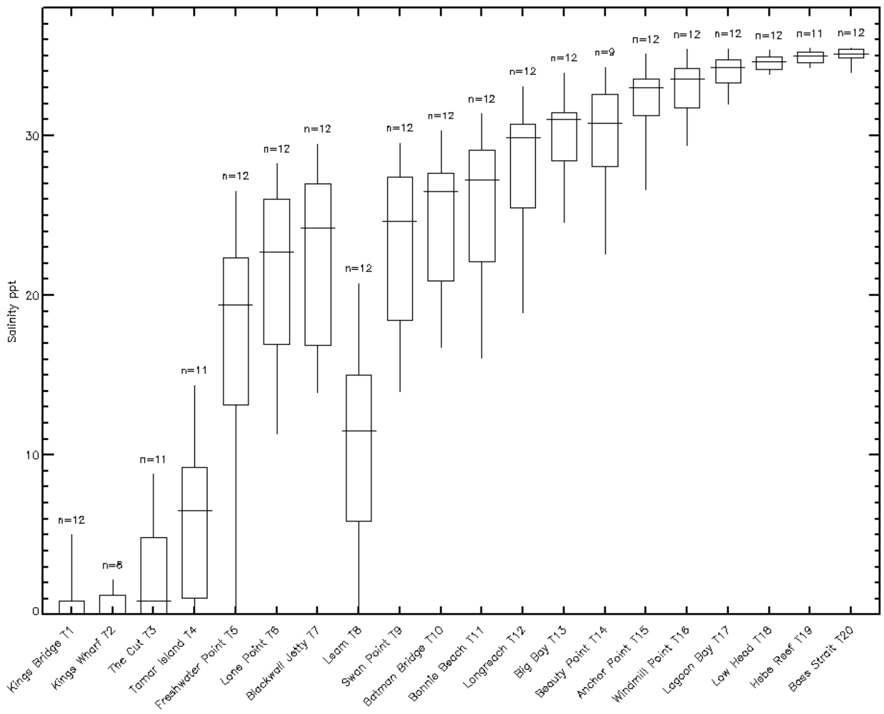


Figure 21.Salinity (ppt) for TEER 1-20 in bottom waters for the 2009-2010 study period

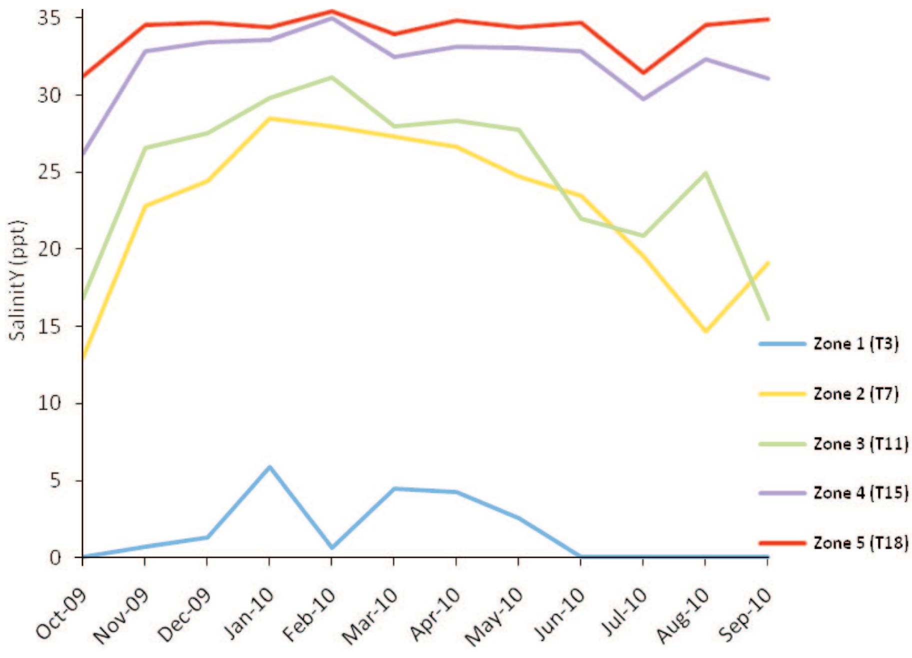


Figure 22: Salinity Zone 1-5 Proxy sites monthly profile averages

Salinity levels in the Tamar range from seawater at the mouth (35 ppt) and gradually become less saline (brackish) with distance upstream and at times may be entirely fresh in the upper reaches (Figures 20 & 21). Salinity varies seasonally in the estuary, with summer salinities being markedly higher than winter salinities due to lower freshwater catchment inflows during the summer months (Figure 22). This is most evident in zones 2 and 3. Salinity also varies with depth in the estuary and this is most marked in the middle estuary where incoming denser saline water is overlayed by a less dense fresher water layer, creating a salt wedge (Figure 23). The salt wedge will move and vary within an estuary depending on the interaction between freshwater seasonal flows and tidal influences. The stratification in the middle estuary is most pronounced during winter months when higher inflows of freshwater occur from the upper estuary.

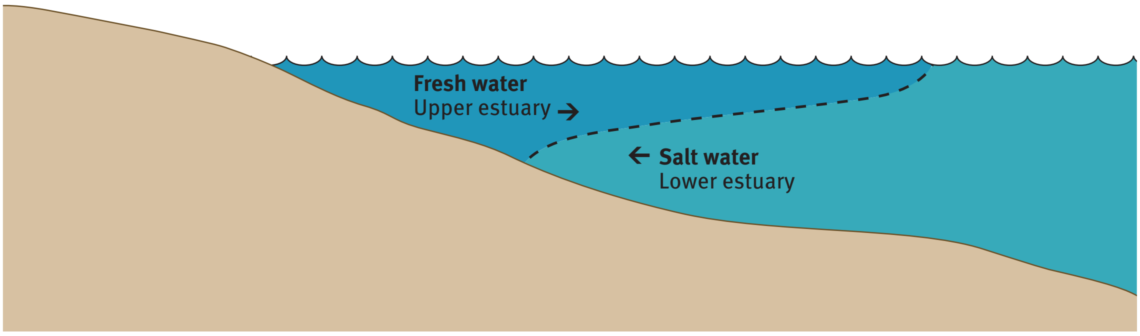
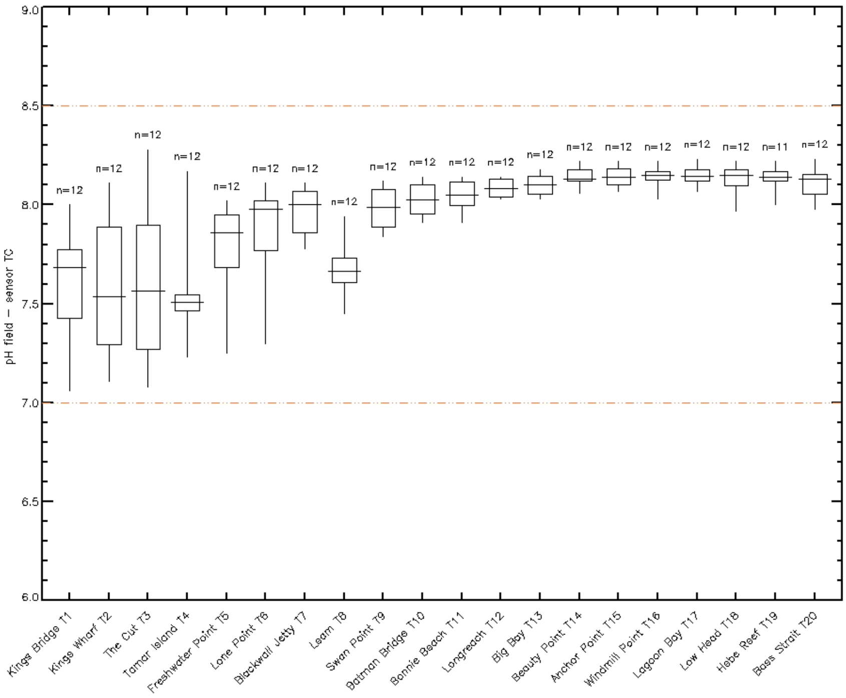


Figure 23: Estuary Salt wedge diagram

Both surface and bottom samples for salinity at site T8 (Leam) had distinctly lower salinity than either of the EHAP ambient sites on each side of it. This observation is repeated in other comparisons between water quality parameters and may be due to the unique mixing processes occurring at this site.

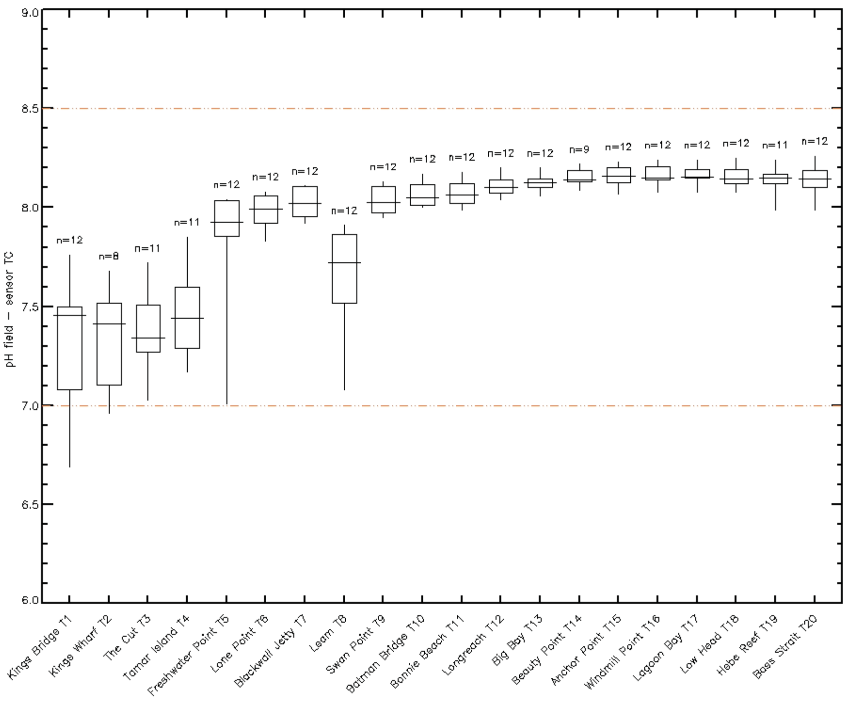
Figure 22 shows the trend of increasing salinity towards the ocean and the distinct differences in salinity between the zones.

Key findings: Tamar estuary salinity ranges from 0.01 ppt in zone 1 and increases to 35.4 ppt in the lower estuary in zone 5 closer to the estuary mouth. Salinity changes with depth, with less dense freshwater layering on top of denser saltier water. Floods can dilute salinity along the estuary, and push the salt wedge downstream.



ANZECC Upper and Lower limits

Figure 24: pH for TEER Sites 1-20 at Surface waters for the 2009-2010 study period



ANZECC Upper and Lower limits

Figure 25.pH field for TEER Sites 1-20 at Bottom waters for the 2009-2010 study period.

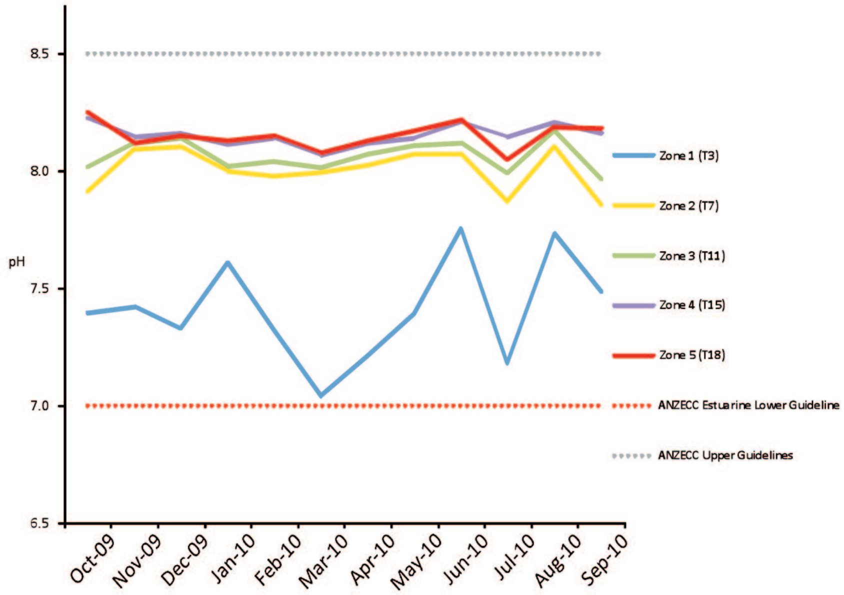


Figure 26: pH Zone 1-5 Proxy sites monthly profile averages.

The median pH in the estuary gradually increases downstream from 7 in the upper estuary and 8 in the lower estuary (Figures 24 & 25). The pH in the Tamar estuary sampled from October 2009 to September 2010 was within both the upper and lower ANZECC default guidelines. The pH default trigger values have lower and upper limits of 8.0 and 8.4 respectively for marine waters and lower and upper limits of 7.0 and 8.5 respectively for estuaries (Table 2).

Site T8 at Leam has lower pH values than adjoining sites (Figures 24 & 25), showing median values of pH 7.7 for surface and bottom samples whereas sites T7 and T9 show median pH values above 8.0.

Zone 1 has a lower and more variable pH compared to all other zones, which have a similar pH over time (Figure 26). The lower zones experience a greater marine influence, and pH is buffered to a higher degree than sites dominated by freshwater inputs. This has implications for biological processes, toxicant bioavailability and water chemistry. While zone 1 is within the ANZECC guidelines, results for March 2010 show a pH approaching the lower limit (pH 7.0). Zone 1 also shows high variation between sampling months when compared to zones 2-5 which show more uniform pH values (Figure 26).

Key findings: pH is generally within ANZECC guideline levels for all sites in the Tamar. As expected, pH increases towards the mouth of the estuary, with lower variability the result of the buffering capacity of seawater.

3.3 Dissolved Oxygen

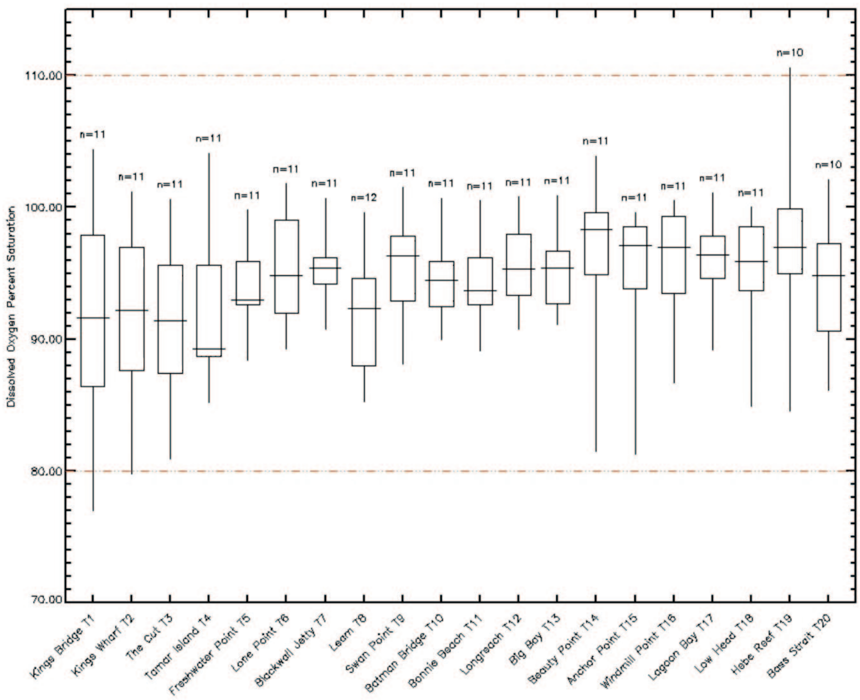
Oxygen is essential to nearly all forms of life and influences most chemical and biological processes in water bodies. Reduced dissolved oxygen (DO) levels can be stressful to fish and other aquatic organisms, particularly those living at the sediment-water interface, where low DO events tend to be most pronounced (ANZECC, 2000). Chronic or intermittently low DO levels can eliminate more sensitive organisms and significantly alter benthic community structure. Where oxygen levels are undetectable, types and rates of bacterial processes in sediments are altered, potentially resulting in the release of sediment-bound nutrients and toxic metals, and the production of methane and hydrogen sulphide gases (Aquenal & DEPHA, 2008). High levels of organic enrichment can trigger these anoxic benthic conditions.

Levels of DO in a healthy estuarine environment generally lie between 6.5 and 9.0 mg/L, or 80 90% saturation as measured over at least one daily cycle (ANZECC, 2000). Most organisms can grow and reproduce unimpaired when DO levels exceed 5mg/L (Aquenal & DEPHA 2008). However, when levels drop to 3 to 5 mg/L they become stressed, and below 3 mg/L (hypoxia) many species will move elsewhere and immobile species may die. Where anoxia occurs (<0.5 mg/L), organisms that require oxygen for survival will die (USEPA, 2002a).

Dissolved oxygen (DO) levels in estuarine waters are dependent on a number of factors, including temperature, salinity, biological activity, turbulence and mixing, and may fluctuate widely over a period of hours, weeks or months (Head , 1985).

Oxygen dissolves more readily at low temperatures and low salinity, thus DO levels tend to be significantly higher in cold freshwater than in warm seawater (Aquenal & DEPHA, 2008). Aquatic plants are net producers of oxygen during daylight hours (photosynthesis), but are net consumers at night (respiration); therefore, DO levels also vary over a 24-hour period, with the lowest concentrations occurring around sunrise (Aquenal and DEPHA, 2008).

The upper reaches of the Tamar estuary have historically shown low levels of DO, suggesting localised organic pollution (Pirzl and Coughanowr, 1997). Elevated water temperatures and stratified conditions (i.e. limited vertical mixing) may contribute to reduced DO, occurring during summer months when river flows are generally lower and water temperatures higher resulting in strong thermal and salinity stratification. Low dissolved oxygen levels in the estuary may also be exacerbated by re-suspension and oxygen demand of organic rich sediments (mud and silts) in the upper estuary, as well as by urban and agricultural run-off from the catchment (Aquenal and DEPHA, 2008).



ANZECC Upper and Lower limits

Figure 27: Dissolved Oxygen % Saturation for TEER sites 1-20 at surface waters for the 2009-2010 study period.

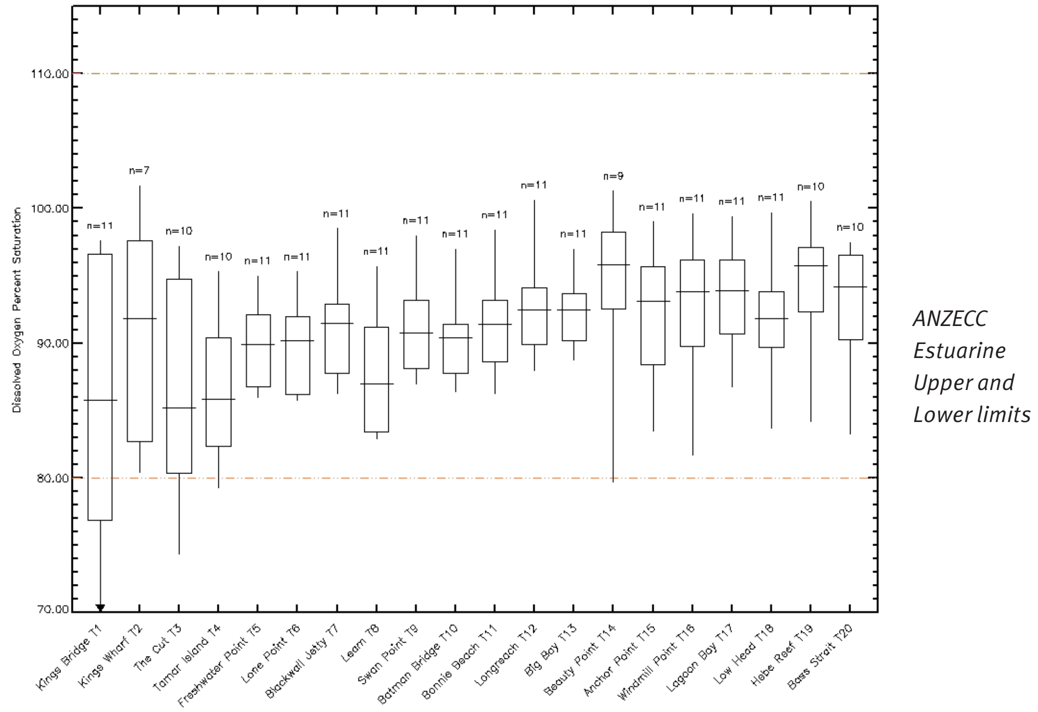


Figure 28: Dissolved Oxygen % Saturation for TEER sites 1-20 at bottom waters for the 2009-2010 study period.

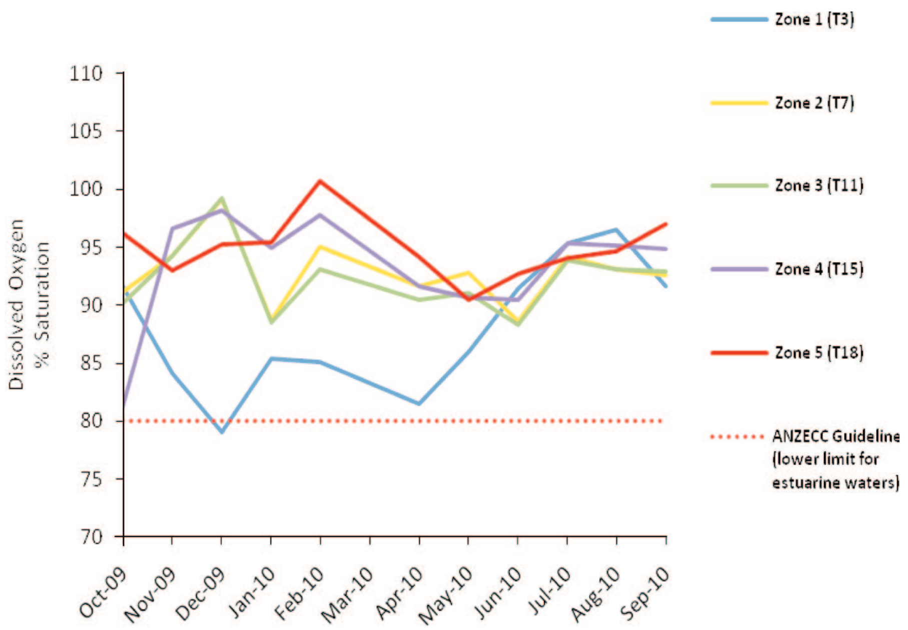


Figure 29: Dissolved Oxygen Zone 1-5 Proxy sites monthly profile averages.

Median dissolved oxygen concentrations were generally higher in the lower estuary, showing a declining trend moving up the estuary, while DO levels also tended to be higher in surface waters than bottom waters, particularly in the middle and upper estuary (Figures 27&28). Dissolved oxygen concentrations are most variable in the upper estuary in zone 1. Median values did not exceed the lower and upper ANZECC estuarine guidelines of 80% and 110% for estuaries categorised as slightly disturbed ecosystems. However 20% of the data collected for bottom samples at Kings Bridge

(Site T1 Figure 2) were below the ANZECC default trigger values for dissolved oxygen (80% saturation). Minimum recorded DO values also fell below recommended ANZECC guidelines in bottom waters at the Cut (T3) and Tamar Island (T4) in the upper estuary, and at Beauty Point (T14) which is a very shallow site in the lower estuary. EHAP data shows zone 1 in the upper estuary having lower DO concentrations during summer than for zones 2-5 (Figure 29).

Key findings: Dissolved oxygen is generally within ANZECC guideline levels for all sites in the estuary except zone 1. Dissolved oxygen is seasonally low in summer and fell below trigger levels in December in zone 1.

3.4 Nutrients

Nutrients, in particular nitrogen (N) and phosphorus (P), are essential for the metabolism of aquatic biota. Nitrogen is present in animal and plant tissues chiefly as proteins while phosphorus is contained in cell walls and energy transporting molecules (EHMP, 2008). Nitrogen and phosphorus levels in aquatic ecosystems can fluctuate due to natural processes such as current upwelling, weathering and the breakdown of naturally occurring organic matter (Aquenal & DEPHA, 2008). However large inputs of N and P in urbanised estuaries are more likely to be derived from anthropogenic sources such as wastewater treatment plants (WWTP), industry outfalls, stormwater and agricultural runoff.

Excess nutrification in waterways can stimulate growth of aquatic vegetation and algae to reach nuisance and in some cases bloom proportions. Algal blooms, in particular cyanobacteria (blue green algae), have the potential to be toxic and poisonous to humans and animals and have adverse effects on the surrounding aquatic environment. Algal blooms can also cause dissolved oxygen and pH levels to fluctuate and limit light penetration in the water column by dispersing locally resident organisms.

ANZECC guidelines recommend that site-specific nutrient guidelines be developed for estuaries using either local data or data from appropriate reference systems, and that these guidelines also be based on studies of ecological and biological effects. Where this information is not available, low-risk default values have been identified based on reference data collected from unmodified or slightly-modified estuaries within five geographical regions across Australia.

Table 5: ANZECC Estuarine nutrient default trigger guidelines for South Eastern Australia

Total Nitrogen TN	Nitrate + Nitrite	Ammonium NH4+	Total Phosphorus TP	Filterable Reactive Phosphorus FRP
300 µg/L	15 µg/L	15 µg/L	30 µg/L	5 µg/L

The ANZECC estuary guidelines used here do not incorporate any data from Tasmanian estuaries; a precautionary approach should be adopted when applying these default trigger values to Tasmanian systems (Aquenal and DEPHA, 2008). Developing Tamar specific nutrient water quality triggers and trigger values is a priority for TEER to better understand the impact of nutrients in the estuary, and is currently under way.

As trends for surface and bottom box-and-whisker plots are similar, plots for TEER EHAP bottom nutrients are presented in Appendix 3.

3.4.1 Total Phosphorus (TP)

The data collected for total phosphorus (TP) as part of the TEER EHAP show elevated levels of TP in the upper half of the estuary (sites 1-13) for both surface and bottom samples (Figure 30). The ANZECC default trigger of 30 µg/L of phosphorus was exceeded the majority of the time. Again site T8 at Leam does not follow the trend and is much higher in phosphorus than either of the adjoining sampling sites. Zone 1 shows significantly higher concentrations of TP (Figure 31). The catchment adjacent to zone 1 is the most urbanised and has inputs from stormwater and wastewater treatment plants; this is also the zone that receives the greatest amount of freshwater and in turn receives phosphorus loads from the North Esk and South Esk rivers draining the greater Tamar catchment especially during times of high flow. TP levels are elevated in zone 1 with a peak in the summer months which are typically characterised as periods of low flow (Figure 31).

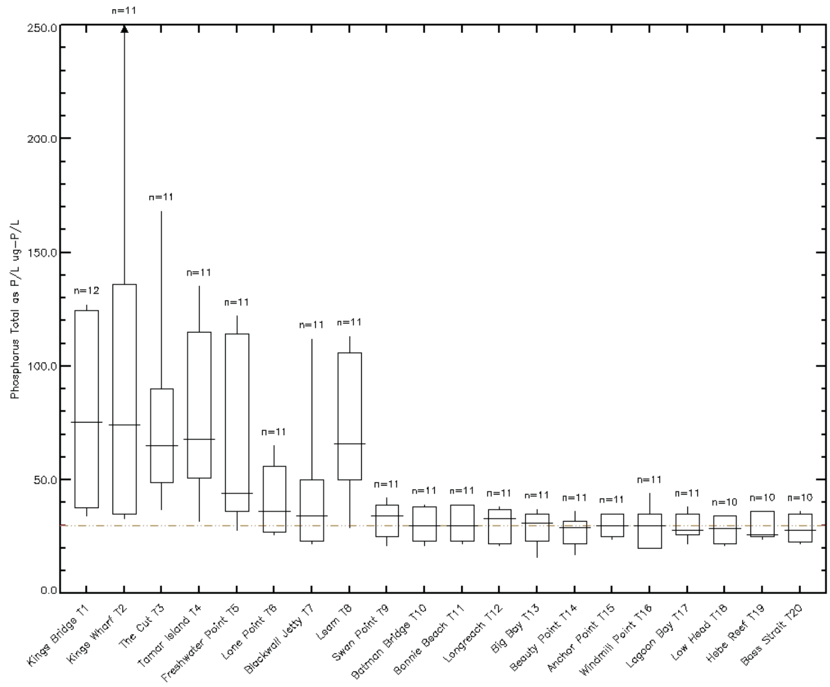


Figure 30: Total Phosphorus (µg/L) for TEER Sites 1-20 at Surface waters for the 2009-2010 study period.

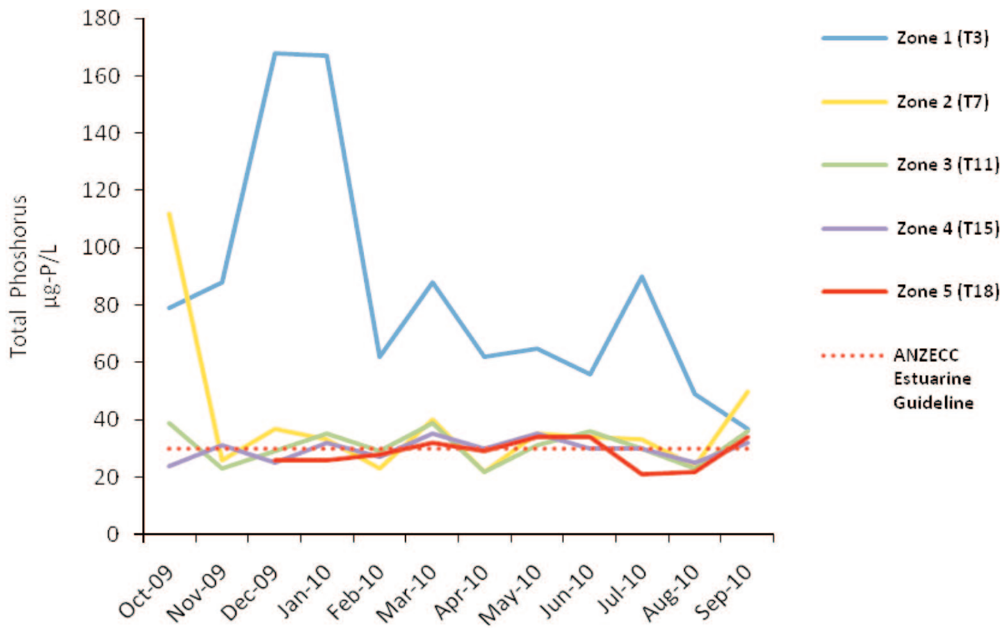
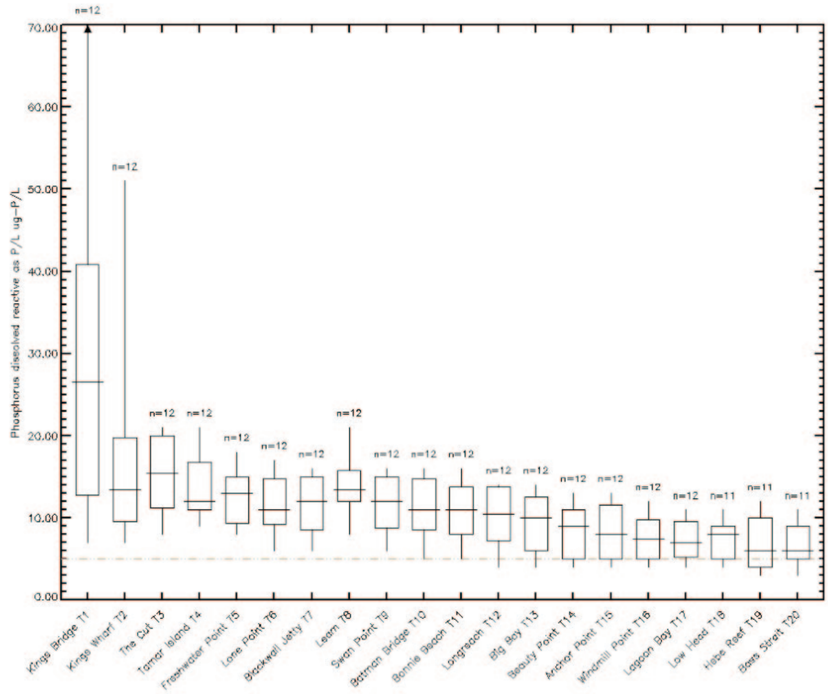


Figure 31: Total Phosphorus Zone 1-5 Proxy Sites monthly surface samples

Key findings: Total phosphorus levels were higher in the upper estuary around zones 1 and 2 with median values exceeding the ANZECC, 2000, default trigger guidelines at sites T1-T8. Phosphorus levels in Zone 1 peaked during early summer 2010.

3.4.2 Dissolved reactive phosphorus

Dissolved reactive phosphorous (DRP) consists of inorganic phosphate, largely made up of Orthophosphate (PO 3) (Whitehead et al., 2010). Median DRP concentrations in the Tamar estuary ranged from 7 to 27 µg/L at sites monitored along the length of the estuary (Figure 32). All median values for surface and bottom samples exceeded the ANZECC estuarine default trigger of 5 µg/L. There is a seasonal influence observed with elevated levels of DRP during high flow events associated with winter. However zone 1 shows higher concentrations even in summer periods. The DRP results show similar patterns to TP with the higher values concentrated in the upper reaches of the estuary and values decreasing further down the estuary. As with TP, sources of DRP are likely to be WWTP inputs, industry outfalls, stormwater and agricultural runoff. All zones exceed ANZECC default triggers for most of the year with the highest exceedance in most zones from March to September (Figure 33). Zone 1 is above the default trigger values for all 12 sampling events and shows the highest values from October to March.



ANZECC Estuarine triggers 5ug/L

Figure 32: Dissolved reactive phosphorus (µg/L) for TEER Sites 1-20 at surface waters for the 2009-2010 study period.

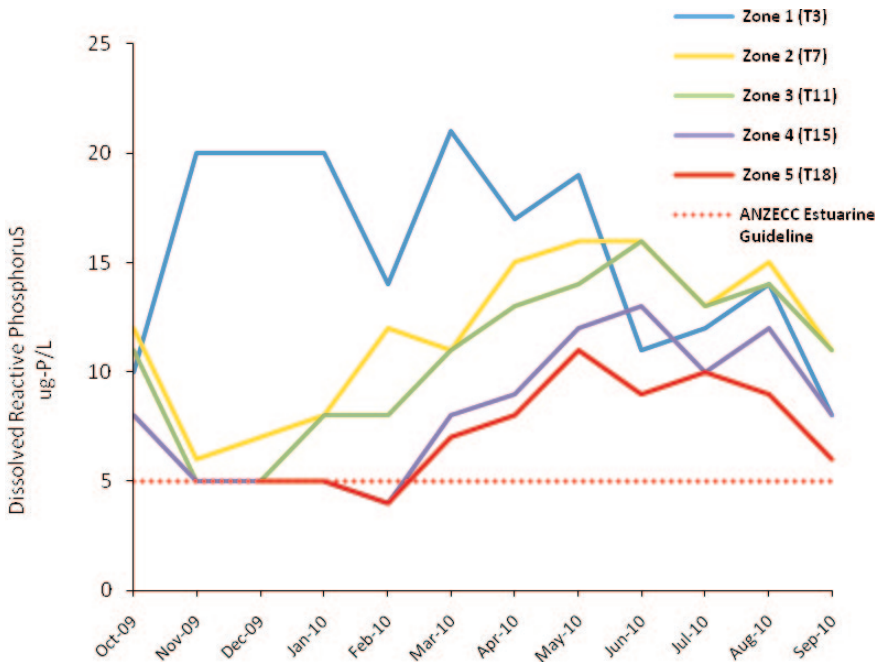
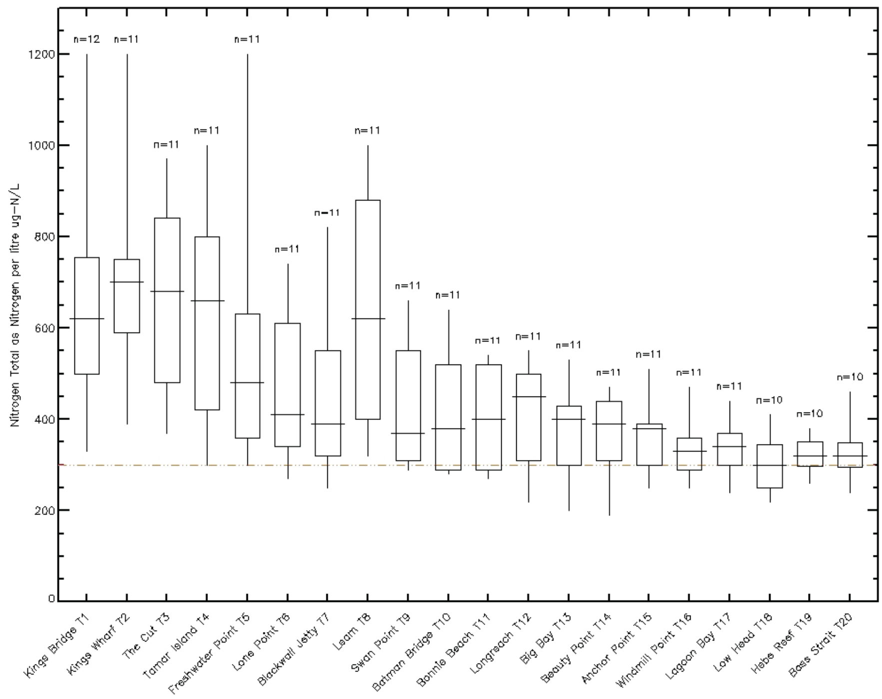


Figure 33: Phosphorus. Dissolved Reactive Zone 1-5 Proxy sites monthly surface samples

Key findings: Median Dissolved reactive phosphorus values exceed guidelines along the entire length of the estuary with higher levels occurring in the upper estuary in zone 1.

3.4.3 Nitrogen (N)

Median values for nitrogen at all sampling sites along the Tamar estuary exceed the ANZECC estuarine default trigger guidelines for both surface and bottom data (Figure 34). Higher levels of nitrogen were detected in the upper estuary with levels tending to decrease down the estuary. Zone 1 concentrations of nitrogen were elevated compared to all other zones in the estuary (Figure 35). Across all zones there is an increase in nitrogen during winter with increased rainfall. Leam (T8) has elevated values for nitrogen compared with adjoining sites. As with other nutrient loads, nitrogen sources were more concentrated in the upper estuary which may be due to the whole upper catchment discharging via freshwater tributaries the North Esk and South Esk rivers and the urbanised area around the city of Launceston.



ANZECC Estuarine triggers 300ug/L

Figure 34: Total Nitrogen (µg/L) for TEER sites 1-20 at Surface waters for the 2009-2010 study period.

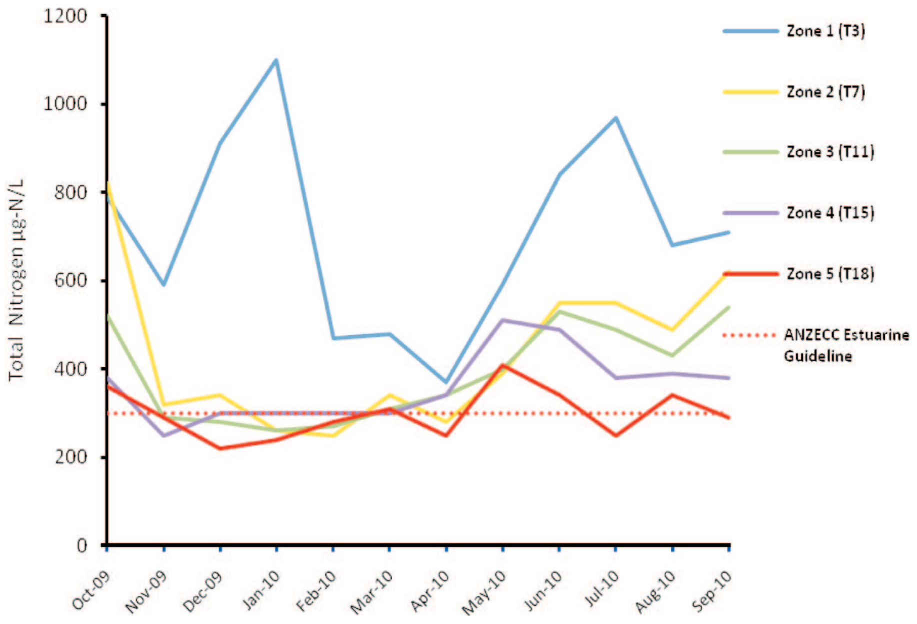


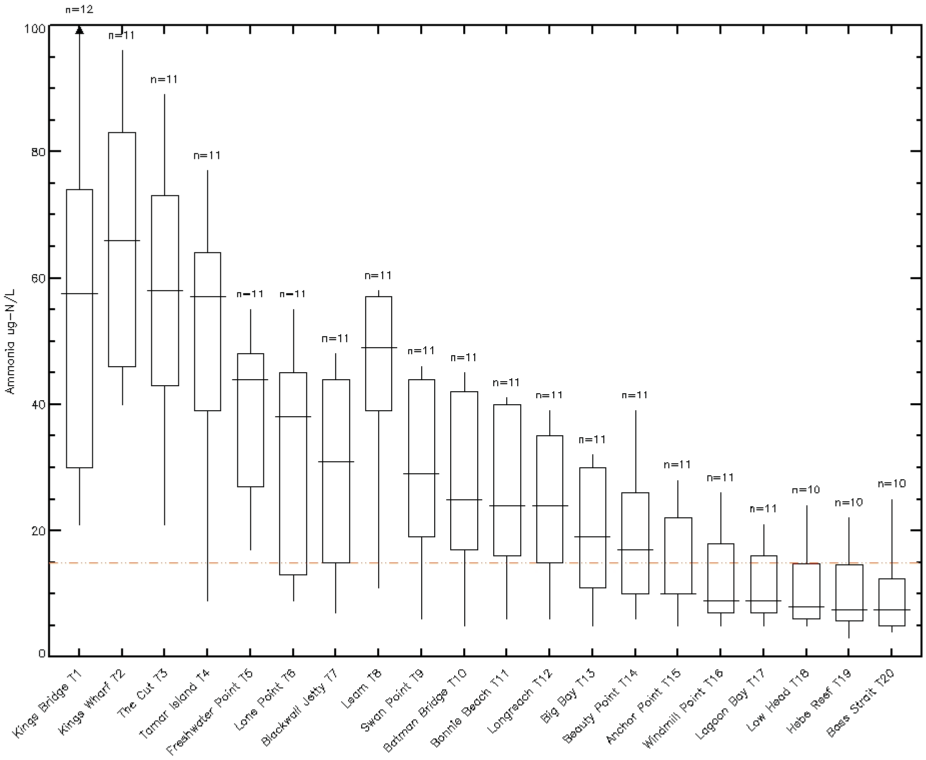
Figure 35. Total Nitrogen. Zones 1-5 Proxy sites monthly surface samples

Key findings: Median total nitrogen values exceed guidelines along the entire length of the estuary with higher levels occurring in the upper estuary in zone 1 and 2.

3.4.4 Ammonia + Ammonium (NH_4)

The majority of the sampling sites in the Tamar zones 1-4 have median values that are significantly above the ANZECC estuarine default trigger for ammonia + ammonium (15µg/L) (Figure 36).

In the upper estuary from Kings Bridge (T1) to Beauty Point (T14) the median values for each site exceed the default trigger. From Anchor Point (T15) out to Bass Strait (T20) the median values fall below the default trigger for ammonia + ammonium (Figure 36). Seasonal influences were observed in all zones, with increased ammonia + ammonium concentrations during winter months from June through to August (Figure 37). Conversely, during January 2010 all zones fall below the default ANZECC trigger for ammonia (Figure 37). Leam (T8) has elevated ammonia concentrations compared to adjoining sites.



ANZECC Estuarine triggers 15ug/L

Figure 36: Ammonia (µg/L) for TEER sites 1-20 at surface waters for the 2009-2010 study period.

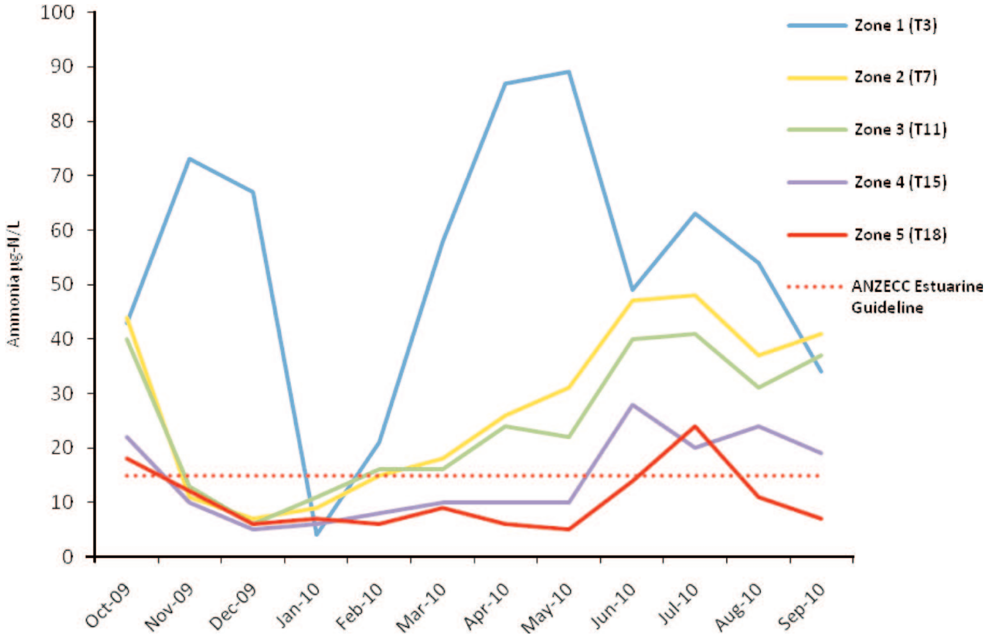
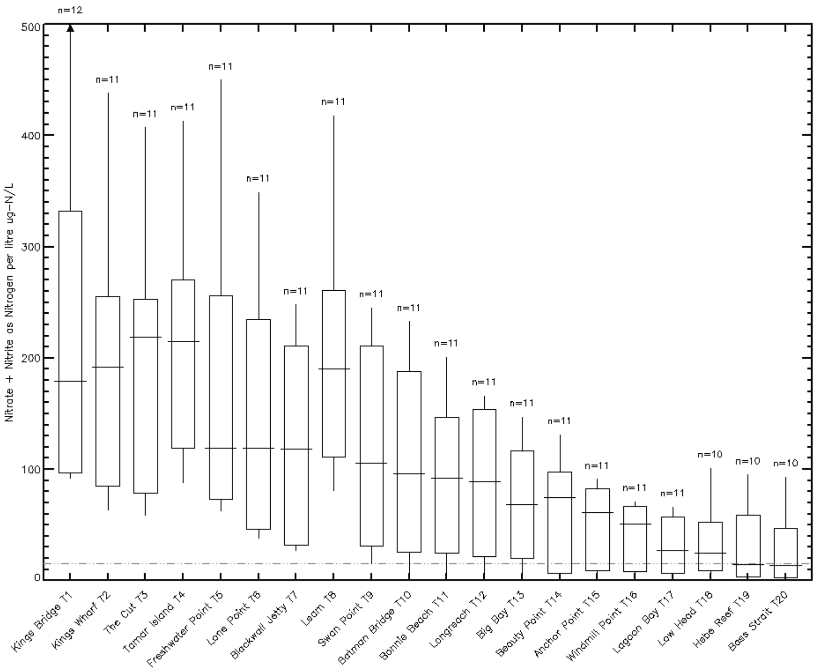


Figure 37: Ammonia Zone 1-5 Proxy sites monthly surface samples.

Key findings: Median ammonia values exceed the ANZECC 2000 guidelines for the majority of sites in the estuary with greater concentrations of ammonia occurring in the upper estuary. Values are higher during the winter months

3.4.5 Nitrate + Nitrite

Nitrate + nitrite levels for all 20 TEER sites exceed the ANZECC default triggers for the majority of the estuary for surface and bottom samples taken for the TEER EHAP (Figure 38). Only at sites T18-T20, in the more marine environment, did median values fall below the estuarine guideline level. In the upper estuary, all measured values were above the estuary guidelines, while further down the estuary only median and higher percentile values lie above the guideline. A seasonal influence is once again observed with increased concentrations of nitrate + nitrite during the winter months and decreasing concentrations during summer months. (Figure 39).



ANZECC Estuarine triggers 15ug/L

Figure 38: Nitrate + Nitrite (μg/L) for TEER sites 1-20 at surface waters for the 2009-2010 study period.

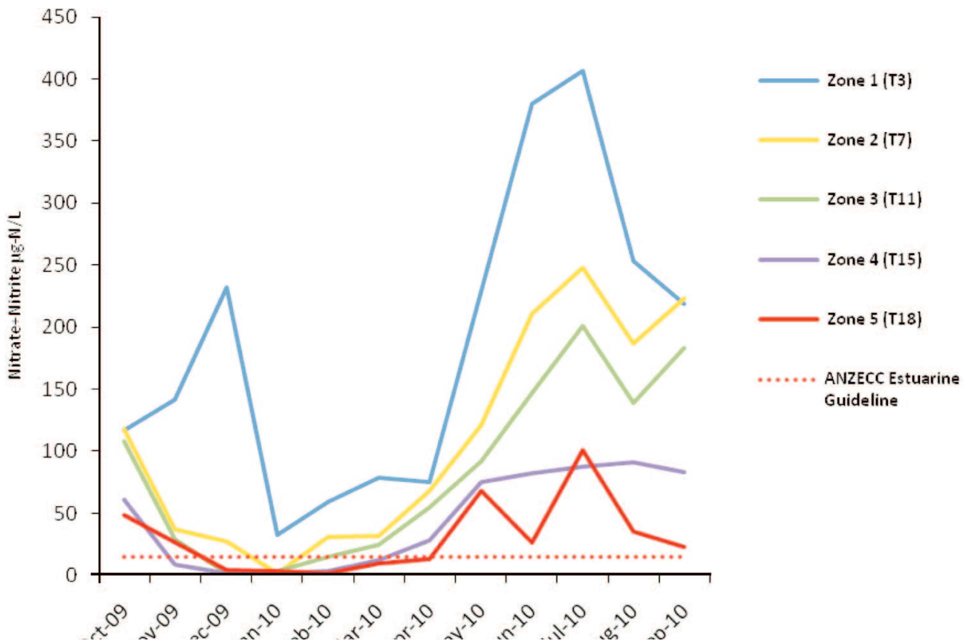


Figure 39: Nitrate + Nitrite Zones 1-5 Proxy sites monthly surface samples

Key findings: Nutrients exceed guideline levels in all zones of the estuary. Nutrients are generally highest in the upper estuary and decline closer to guideline levels in the lower estuary, with some measurements in the lower estuary within ANZECC default trigger values. Nutrient levels are generally highest in winter months and lowest during summer. Setting WQOs for nutrients is a priority, and will need to address seasonal variability in sources.

3.5 Chlorophyll *a*

The green pigment chlorophyll is present in most photosynthetic organisms and provides an indirect measure of algal biomass in a water body (Chapman, 1992).

The concentration of chlorophyll in water bodies is primarily dependent on the light input and the supply of biologically available nitrogen or phosphorus (EHMP, 2008). High levels of chlorophyll can be indicative of eutrophication. Algal blooms and high chlorophyll a in estuaries usually occur in middle and lower estuarine areas (Aquenal & DEPHA, 2008).

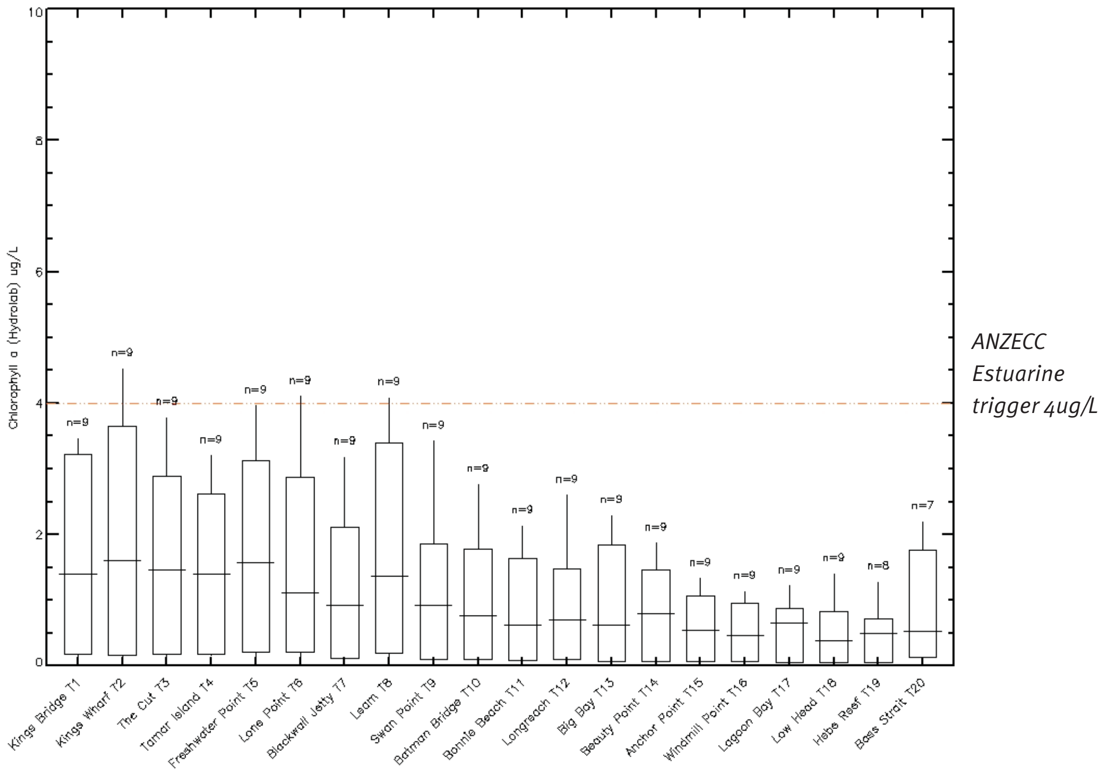


Figure 40: Chlorophyll a (Hydrolab) (µg/L) for sites 1-20 at surface waters for the 2009-2010 study period.

Figure 41: Chlorophyll a Zones 1-5 Proxy Sites. Monthly average of laboratory data.

As part of the TEER EHAP ambient water quality monitoring chlorophyll a was measured using an in situ Hydrolab 4 fluorescence probe. The Hydrolab in situ probe data (Figure 40) show that median chlorophyll a levels did not exceed the ANZECC default trigger guidelines during the 2009-2010 monitoring period. Chlorophyll levels are slightly decreased travelling down the estuary towards the mouth. The first State of the Tamar Report published in 1997 highlights that algal blooms have not historically been a problem in the Tamar estuary (Pirzl and Coughanowr, 1997). Figure 41 shows results for each zone, with no chlorophyll a data recorded between January and March 2010 due to suspect results recorded during this time. The incomplete graph still suggests that chlorophyll a levels are higher in summer and decrease in winter months when flows are higher and temperatures are lower.

Key findings: Based on field measurements chlorophyll a is generally within guideline levels for all zones with levels at or close to the default trigger occasionally being experienced in zone 1. Chlorophyll a declines as you travel down the estuary.

3.6 Total Suspended Solids, Turbidity and Secchi Disk

Total suspended solids

Total suspended solids (TSS) are the measure of particulate matter in water usually expressed as TSS (mg/L). Total suspended solids consist of silt and clay, phytoplankton, decaying organic matter and other particles derived from both natural and anthropogenic sources (Aquenal & DEPHA, 2008). Sediment levels in estuaries often vary widely in response to river discharges, wind and tidal mixing and phytoplankton blooms. Typically, TSS tend to accumulate at the interface between salt and freshwater, which in the Tamar is generally found at the toe of the salt wedge in the stratified section of the estuary around Freshwater Point (Aquenal and DEPHA, 2008).

The most significant external sources of suspended particulate matter to the Tamar estuary are the North Esk and South Esk rivers, particularly during heavy rainfall. Anthropogenic loads originate from urban runoff, stormwater, WWTPs and industry (Aquenal & DEPHA, 2008).

TSS are a major pollutant that significantly impact on water clarity and colour. TSS can originate from various land uses, including urban and rural uses, and can be a transfer mechanism for metals and organic pollutants in waterways (Sutherland, 2006).

Note: There are no specific ANZECC, 2000, guidelines for TSS; however site specific TSS water quality objectives can be developed for water bodies.

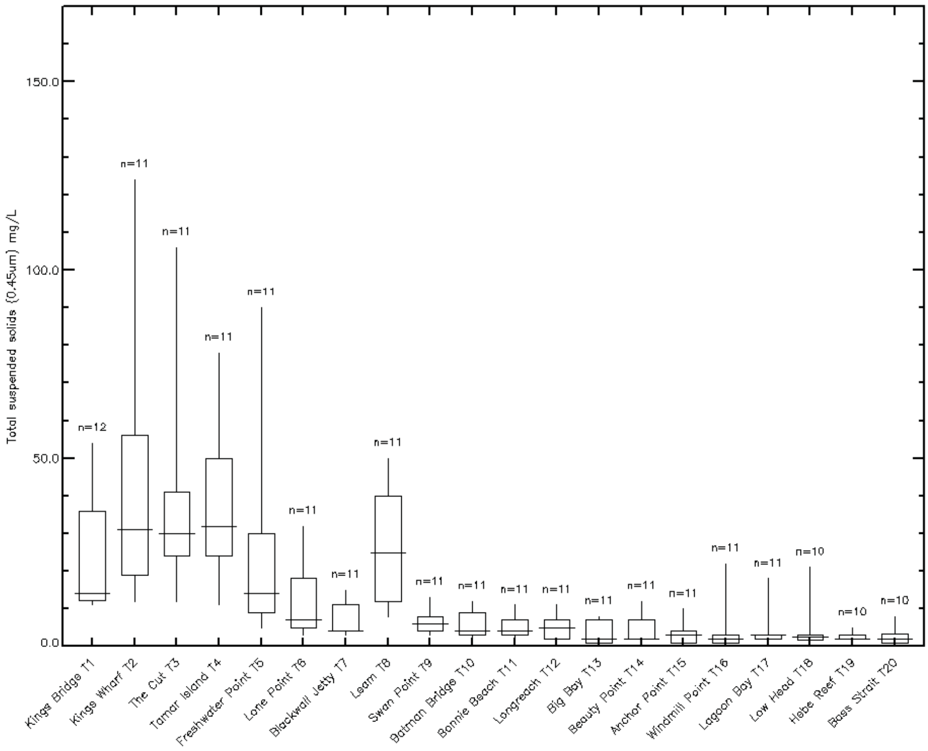


Figure 42: Total suspended solids (0.45μm) (mg/L) for T 1-20 at surface waters for the 2009-2010 study period.

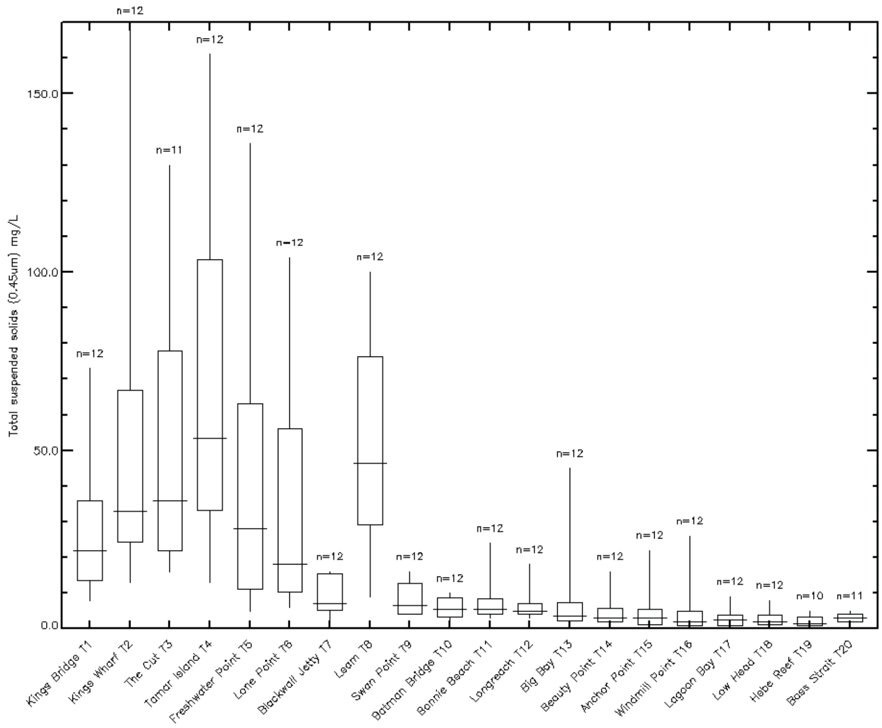


Figure 43: Total suspended solids (0.45μm) (mg/L) for T 1-20 at bottom waters for the 2009-2010 study period.

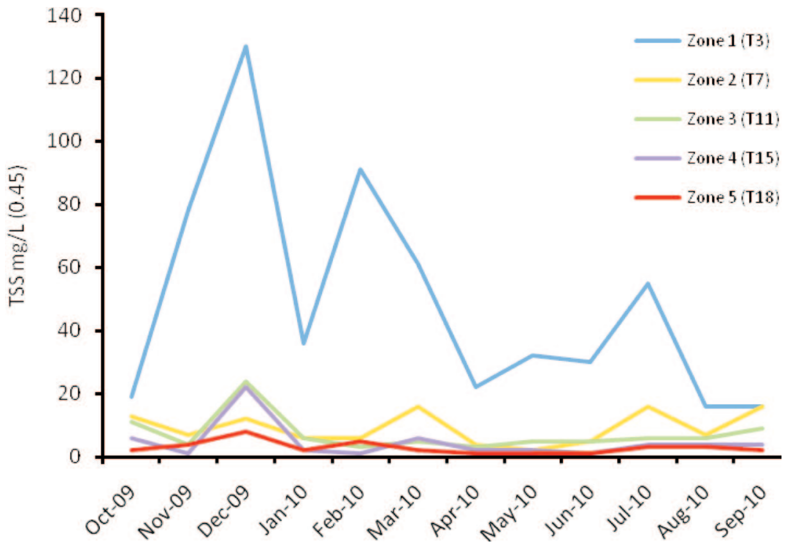


Figure 44: Total Suspended Solids Zone 1-5 Proxy Sites. Monthly samples.

Total suspended solids results for bottom and surface samples show increased levels in the upper estuary in particular from Kings Bridge (T1) to Leam (T8) (Figures 42 & 43). The highest median values for both surface and bottom TSS were recorded at Tamar Island (T4) (Figures 42 & 43). Bottom sample values for TSS are higher compared to the surface samples, probably due to tidal scouring of the bottom substrate. TSS values decrease dramatically north of Leam (T8); which may be due to tidal influence and clearer saline waters entering the system. Site T8 at Leam shows dramatic differences in TSS values to adjoining sampling sites, once more suggesting that there is some kind of unique mixing process occurring here that warrants further investigation in relation to this site's interaction with the estuary.

Zone 1 has higher TSS values than other zones in the estuary (Figure 44). This is a function of past and present processes occurring in the upper estuary. Suspended sediments are delivered to the estuary from the North Esk and South Esk rivers which carry sediment loads from the 10,000km   Tamar catchment, including urban areas on the foreshores of the estuary, and deposit sediments in zone 1. In addition existing estuary sediments are resuspended by tidal process and move dynamically around zone 1 (McAlister et al., 2009). There was extensive dredging of the areas around Launceston when it was an operating port, these dredge spoils deposited downstream resuspend and circulate around zone 1 before being deposited in different areas according to tide and flood energy. For more information on sediment quality, sedimentation and dredging refer to the State of the Tamar Estuary Report 2008 (Aquenal & DEPHA, 2008).

3.6.2 Turbidity

Turbidity is a measure of the scattering of light by suspended particulate and dissolved solids in water. It is measured by passing a beam of light through a water sample contained in a transparent cell. The measurement is made by detecting the amount of light scattered by a sample (infrared or visible) compared to a pure water solution.

Excess amounts of suspended particles can contribute to environmental damage, including reduced light penetration through the water column, smothering of benthic organisms, irritation to fish gills and the transportation of contaminants (SEQ Ecosystem Health Monitoring Program, 2008).

Changes in light penetration in the water column affect the ability of aquatic plants to utilise light for photosynthesis.

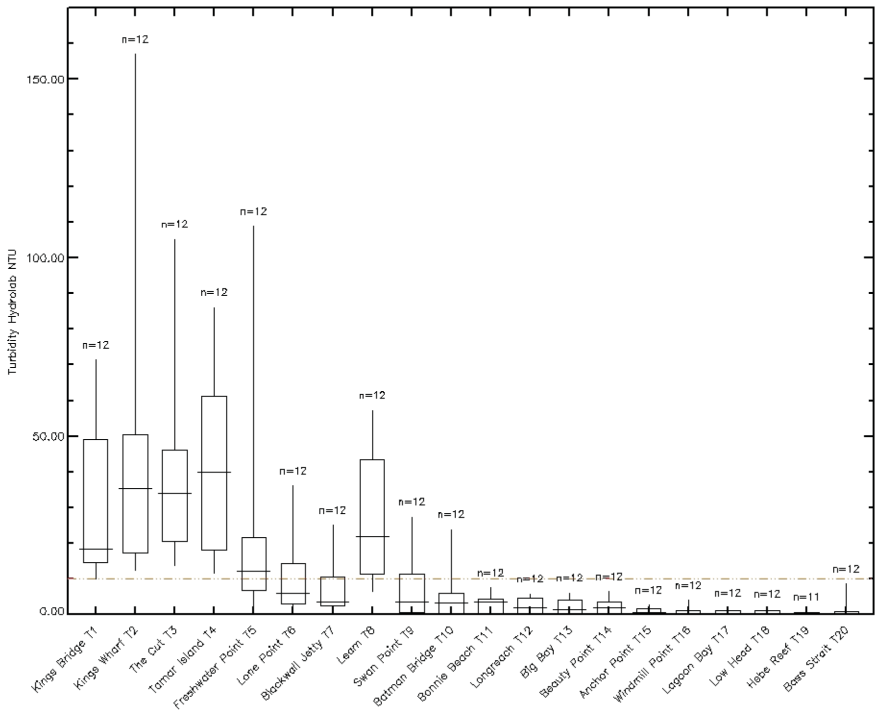


Figure 45: Turbidity Hydrolab (NTU) for sites T 1-20 at Surface waters for the 2009-2010 study period.

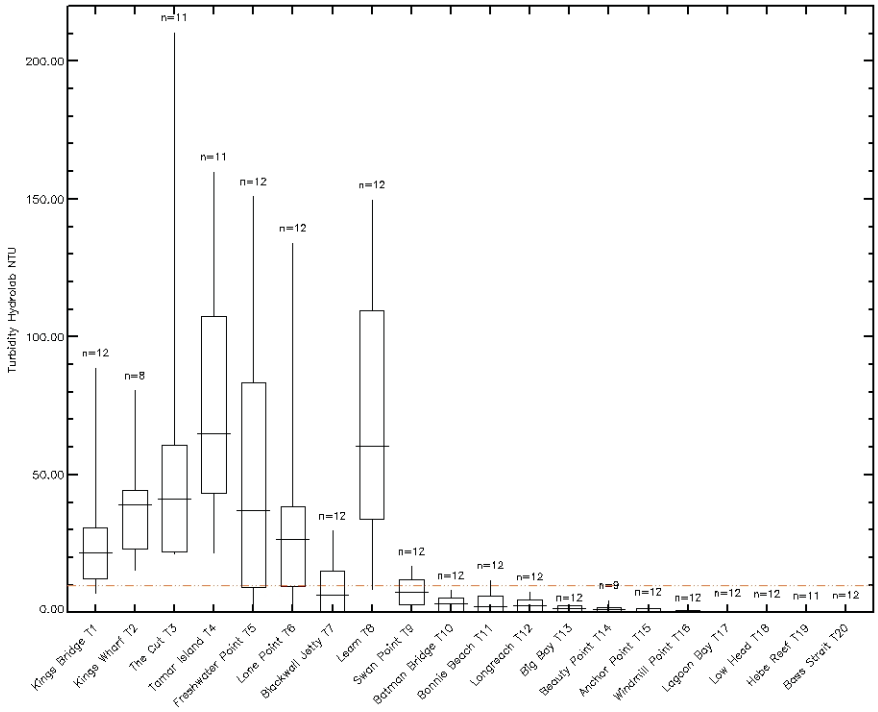
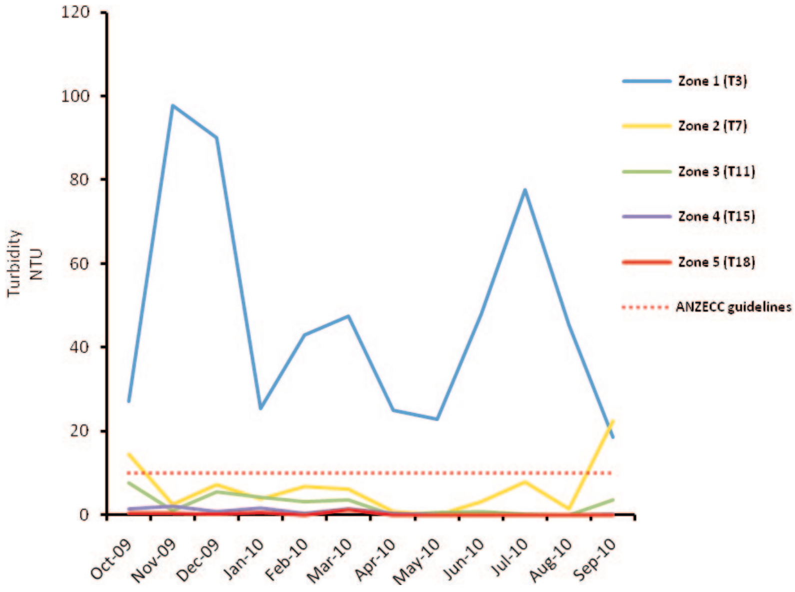


Figure 46: Turbidity Hydrolab (NTU) for TEER sites T 1-20 at bottom waters for the 2009-2010 study period.



ANZECC triggers 10 NTU

Figure 47: Turbidity Zone 1-5 Proxy Sites. Monthly profile average.

Turbidity results in the Tamar estuary display a similar pattern to that of the TSS results with elevated levels of turbidity occurring in the upper estuary (Figures 45, 46 and 47). Bottom values are greater than surface samples (Figure 46). This may be due to the tidal scouring of the bottom substrate transporting sediments. The highest median values for turbidity (similar to TSS results) were found in bottom samples at Tamar Island, site T4 (Figure 46), and, as shown with bottom TSS results, turbidity values tend to decrease either side of this sampling site with the exception of Leam (T8).

Figures 45 and 46 displays the ANZECC estuarine guidelines (10 NTU) for turbidity and show that in zone 1 guidelines are exceeded. The bottom samples for turbidity are higher than the surface turbidity samples and show guidelines being exceeded not only in zone 1 but also in the first two southern sites (T5 & T6) of zone 2. The upper Tamar estuary is high in turbidity due to the interactions between freshwater inputs delivered from the greater catchment via the North Esk and South Esk rivers and the more saline waters delivered by the estuary.

3.6.3 Secchi Disk

Water transparency, or light absorption, is affected both by dissolved and particulate material. An estimate of the transparency of the surface layer can be made using a secchi disk (Head et al., 1985).

Secchi depth is measured using a circular plate coloured in quarters of black and white, known as a secchi disk, which is lowered into the water until it is no longer visible. High secchi depths indicate clear water; whereas low secchi depths indicate cloudy or turbid water. This method gives an indication of the amount of light penetrating a water body, the euphotic depth (Aquenal & DEPHA, 2008). The euphotic depth dictates at what depth aquatic plants can manage to survive and photosynthesise. The secchi depth can be greatly influenced by weather, particulate and algal matter occurring in a water body. Generally, in estuaries, the closer the oceanic input, the greater the secchi depth.

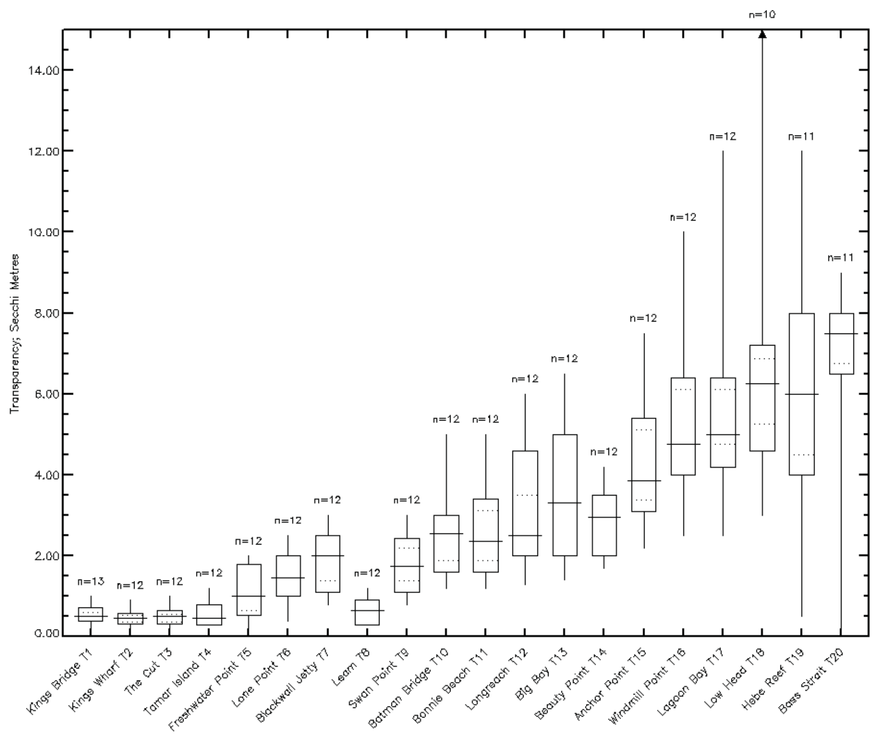


Figure 48: Transparency; Secchi disk (metres) for TEER sites 1-20 at surface waters for the 2009-2010 study period.

As expected, secchi depth results show an increasing trend towards the mouth of the estuary, where there are greater inputs of clear oceanic water (Figure 48). The upper estuary shows low secchi depths mainly due to the influence of high TSS and turbidity decreasing the ability of sunlight to penetrate the water column. Leam (T8) continues to show inconsistencies when compared with the whole data set, with a comparatively low secchi depth. Beauty Point (T14) is also lower than adjoining sites. This could be due to the very shallow nature of the T14 site, influencing the maximum reading attainable.

Key findings: Total suspended solids and turbidity are substantially higher in zone 1 than in other areas of the estuary, due to the interaction of salt and freshwater and tidal influences in this part of the estuary. Secchi depths reflect this with much higher depths in the clearer waters of the lower estuary. Site specific water quality objectives that recognise the natural processes occurring in the estuary need to be developed to gain a better understanding of trends in sediment measures.

Sedimentation in the Upper Tamar Estuary

The sedimentation of the upper Tamar estuary around Launceston is of considerable public concern to Launceston residents and businesses. In the below box section values and the process of sedimentation in the upper Tamar estuary are considered.

Box 1. Sedimentation in the upper estuary

The Tamar estuary is classified as a drowned river valley estuary. Characteristic of these types of estuaries is that in the upper reaches, as found around the city of Launceston, the main intertidal areas consist of extensive mud and sand flats (Underwood, 1995). These mudflats are highly productive areas and are important feeding grounds for many fishes and wading birds. Soft sediments represent one of the major types of habitats available for plants and animals in estuaries (Underwood, 1995).The upper Tamar estuary around Launceston provides habitat for a number of species of flora and fauna including threatened species such the white bellied sea eagle, Wedge Tailed eagle, grey goshawk, masked owl, swift parrot, Australian grayling, eastern dwarf galaxias, swan galaxias, green and golden frog and the glossy grass skink (Natural Values Atlas 2010). The estuary around Launceston has other seasonal visitors such as pelicans, grebes, herons and Australian fur seals from time to time. Mass fish aggregations have also been observed around Kings Bridge.

Estuaries are familiar habitats to most people because they are popular sites for development, urbanisation and recreation. As a result, estuaries and the surrounding foreshore are often subjected to human impacts. The city of Launceston is no exception and while it is a common perception that the upper section of the estuary around Launceston is continually silting up, this is in fact a natural process. The upper sections of drowned river estuaries receive sediments delivered from the upper catchments and from existing sediments already moving around within an estuary.

There are a number of natural processes that act on sedimentation in an estuary. Sediments entering an estuary are principally from rivers. The sediment is derived from the erosion of rock or previously deposited sediments and from the precipitation of dissolved material due to physical and chemical reactions as fresh and saltwater meets. During periods of slow flow, particles are able to settle out of the water column, but during faster flow they may be picked up again and moved elsewhere, a process known as scouring. The smallest particles of sediment take more than one tidal cycle to settle and consequently the water in upper estuaries is very turbid as the suspended material is carried back and forth with the tide until it settles out (Underwood, 1995).

Due to increased public concern and in a bid to better understand the sediment processes occurring in the Tamar estuary there have been a number of studies and reports completed: Foster et al. (1986) investigated Tamar River siltation; Launceston City Council undertook an investigation into the hydrodynamics of the Tamar estuary and how the sediment moves around the estuary (McAlister et al., 2009); and, NRM North, through TEER, has investigated the generation of sediments in the upper Tamar catchment (Stewart et al., 2010). All these studies have identified that increases in sedimentation observed in the Tamar estuary around Launceston are the result of the estuary trying to reach a state of equilibrium after being heavily dredged up until the 1960s.

Where the channel is out of equilibrium for some reason (e.g. due to dredging or change in tidal

dynamics), there will be a tendency to re-establish equilibrium through either deposition or erosion provided additional sediment is available and/or the bed is erodible. Thus (for example), previous extensive dredging of the upper Tamar estuary has been followed by subsequent siltation in order to restore regime equilibrium (McAlister et al., 2009; Foster et al., 1986).

The Foster report (see Patterson and Teakle, 2008) identified that siltation of the upper Tamar estuary occurred predominantly during dry weather periods through a process of upstream sediment movement due to tidal action.

The length and shape of the Tamar estuary also heavily influences sedimentation processes in the system. The Tamar is the longest estuary in Tasmania at approximately 70km. This coupled with physical landform features such as bottlenecks and 90° bends in the estuary make it very difficult for sediments to exit out into Bass Strait. As a result the sediments are resuspended and predominately circulate in and around the upper reaches of the estuary. In the Tamar estuary the incoming tide has the greatest energy as water from Bass Strait pushes in. A result of this is that sediments are constantly migrating in an upstream direction, (Foster et al., 1986).

3.7 Bacterial Pathogens-Enterococci

Water contaminated by sewage and animal faeces may contain pathogenic micro-organisms (bacteria, viruses, protozoa), which pose a health hazard when the water is used for recreational activities, particularly those involving total immersion. During these activities, there is a risk that water could be swallowed, inhaled or come into contact with ears, nasal passages, mucous membranes and cuts in the skin, allowing pathogens to enter the body (NZMFE, 2002).

The most common types of illnesses that have been associated with primary contact (i.e. full immersion) are gastrointestinal disorders, respiratory illnesses, eye, nose and throat infections and skin diseases. Consumption of shellfish collected from areas contaminated with pathogens may also pose a significant health risk (Aquenal and DEPHA, 2008).

The National Health and Medical Research Council (NHMRC) propose the sampling of enterococci bacteria as the indicator for bacteriological pathogens in marine and estuarine waters used for recreation. The enterococci group is a sub-group of the faecal streptococci found in the faeces of warm-blooded animals.

This report and both the 2010 and 2011 Tamar estuary report cards use the trigger value of 140 enterococci /100mL as the guideline to measure bacterial impacts and assess ecosystem health in the Tamar estuary.

While the TEER EHAP uses the Recreational Water Quality Guidelines (RWQG), Public Health Act, 2007, for the purpose of establishing a bacterial guideline to use in the Tamar estuary, it is in no way aligned to a regulatory requirement or an indication of sites suitability for recreational use.

Recreational water quality is currently monitored by local councils as a requirement of the RWQG. Councils are required to monitor the levels of bacteria (enterococci indicator) at swimming sites between the summer months of December through to March.

The guidelines state that where enterococci counts in a single water sample are greater than 140 enterococci/100mL a resample is required within 48 hours. Where two consecutive water sample results are greater than 280 enterococci/100mL, the public users of the water body are to be advised of the recreational health risk and that the water may be unsuitable for primary contact. This is usually achieved through appropriate signage. Home Reach in the upper estuary around the city of Launceston has permanent signage advising of the health risks associated with primary water contact even during the winter period.

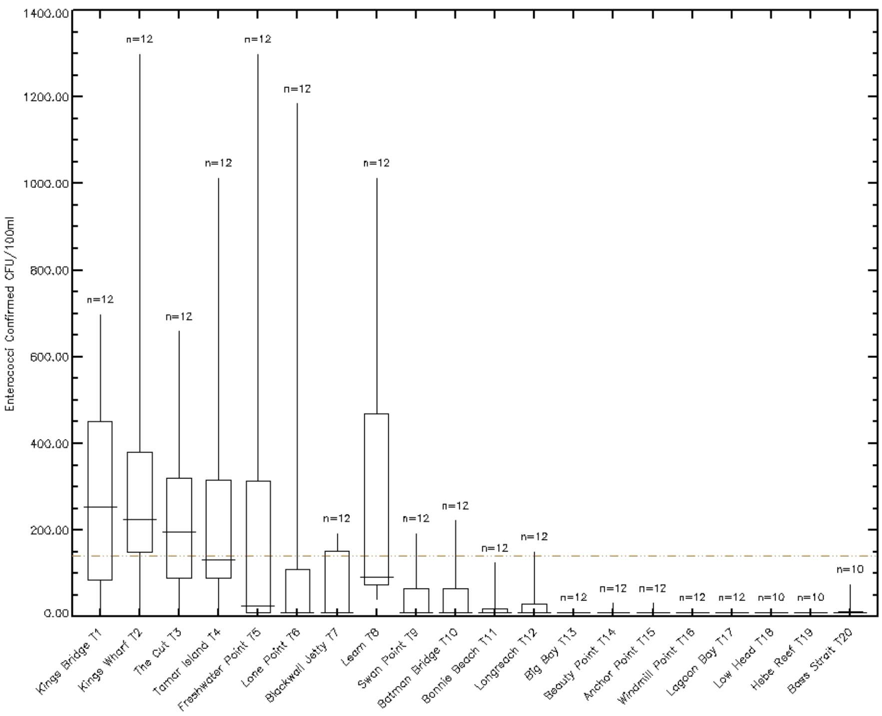
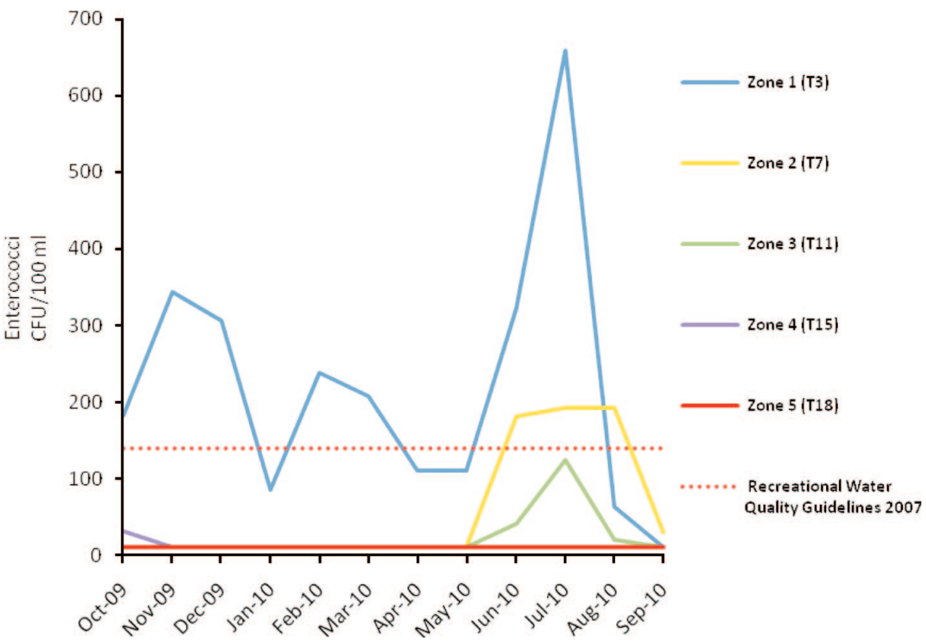


Figure 49: Enterococci Confirmed /100ml for TEER Sites 1-20 at Surface waters for the 2009-2010 study period.



Lower Limit 140 enterococci /100ml (RWQG 2007)

Figure 50: Enterococci Zone1-5 Proxy Sites Monthly surface samples

Enterococci results from sampling the Tamar estuary from 2009-2010 show that, in the upper estuary, median values at Kings Bridge (T1), Kings Wharf (T2) and The Cut (T3) are above the guideline for enterococci of 140/100ml (Figure 49). On some sampling occasions, enterococcus was detected in the thousands per 100mL. Enterococci numbers generally decrease further down the estuary and start to rapidly decline after Leam (T8).

Seasonality has a marked impact on bacterial levels in the estuary as in winter, with increased rainfall and flows; increased bacterial loads are delivered from tributaries, stormwater runoff and wastewater treatment plants. There are very high peaks in median enterococci in June to August in zone 1, well above the guidelines (Figure 50). Other zones are generally below guidelines, with the exception of zone 2 in winter, when the guidelines were exceeded.

The areas of the Tamar estuary that are more commonly used for recreational purposes are in the mid to lower estuary where the estuary is more suited to swimming, diving and skiing. In the upper estuary rowing is the most common activity where people may come into contact with the water.

The high levels of enterococci detected in the upper reaches of the estuary correspond with the highly urbanised and impacted areas in and around Launceston where there are a number of upper catchment, WWTPs and stormwater inputs. As much of Launceston's sewerage networks are combined with stormwater inflows, the largest WWTP at Ti Tree Bend sometimes becomes overloaded with increased volumes of incoming sewage and stormwater. In times of high rainfall, the Ti Tree Bend WWTP has the potential to discharge semi-treated effluent into the Tamar estuary.

Key findings: Median bacteria levels exceed guidelines for most of the time in the highly urbanised zone 1. Zone 2 also exceeds guidelines for wetter winter months. Bacteria levels generally decrease further down the estuary.

3.8 Metals

Metals in aquatic systems are derived from both natural and human sources. Natural sources include the weathering of rocks and leaching from soils, while anthropogenic sources include automobile emissions, power plants and mining and industrial wastes (particularly smelting, refining and electroplating) (Aquenal & DEPHA, 2008). As metals rapidly adsorb to particulate matter, they tend to accumulate in bottom sediments of estuaries and shallow coastal marine systems. Many estuarine organisms, particularly filter feeders such as mussels and oysters, accumulate metals from seawater, bottom sediments, interstitial waters and their food supply. The accumulation of metals by marine organisms is a function of many factors, such as temperature, salinity, diet, reproductive and life stages, with larval and juvenile stages more vulnerable to contaminants (Kennish, 1996).

Metals are persistent in the aquatic environment. If they are present above guideline concentrations, they pose potentially hazardous conditions due to their toxicity to estuarine and marine organisms. Metals may be subdivided into two categories: i) transitional metals (e.g. cobalt, copper, iron, manganese) which are essential to metabolism at low concentrations but may be toxic at high concentrations, and ii) metalloids (e.g. arsenic, cadmium, lead, mercury, selenium, tin) which are generally not required for metabolic function and are toxic at low concentrations (Kennish, 1996).

An approximate order of decreasing toxicity of common heavy metals is: mercury, cadmium, copper, zinc, nickel, lead, chromium, aluminium and cobalt, however toxicity can vary significantly between different organisms (Kennish, 1996).

Mercury and cadmium are highly toxic to aquatic organisms at very low concentrations, and also represent significant health hazards to humans. Inorganic forms of mercury have a relatively low toxicity to biota but are readily converted to more toxic organo-mercury forms (Aquenal & DEPHA 2008). The most toxic form of mercury is methyl-mercury which is highly toxic, resistant to environmental degradation and is rapidly taken up by aquatic organisms. Physio-chemical conditions in the water column and sediments influence the specific form or 'species' of metals, which in turn determines their potential to enter the ecosystem.

The main sources of metal contamination in the Tamar estuary include historic inputs from past mining activities (Aberfoyle and Storys Creek tin mines in the South Esk Basin and Beaconsfield on the West Tamar), anthropogenic inputs from past and present industrial activities, urban run-off and stormwater. Tin and tungsten mining in the upper South Esk catchment is probably the main source of cadmium in the Tamar (Pirzl and Coughanowr, 1997), whilst zinc present in the South Esk River is the likely result of mining activity in the catchment of a tributary (Norris et al., 1981). Current industrial activity in the Tamar estuary includes Rio Tinto Alcan aluminium smelter and the BHP Billiton TEMCO ferroalloy plant, both situated in the Bell Bay industrial zone on the lower estuary, and the Beaconsfield Gold Mine operated by BCD Resources situated on the West Tamar and re-opened in 1999. Historically, liquid emissions from the TEMCO and Rio Tinto Alcan sites were discharged at Deceitful Cove in the lower estuary. Rio Tinto Alcan (then Comalco) ceased discharge to Deceitful Cove in 1987 and BHP Billiton TEMCO ceased discharge in 1993, while Beaconsfield Gold Mine liquid emissions also discharge in the lower estuary at Middle Arm. Lead concentrations in mine discharge water have decreased significantly in recent years, compared to historic mining activities, to almost undetectable levels. Stormwater run-off from TEMCO still discharges into Deceitful Cove after passing through a wetland stormwater treatment system. In addition to point source discharges, diffuse sources such as industry-contaminated groundwater may also contribute to the metal load in the estuary (Aquenal and DEPHA, 2008).

3.9 National metal guidelines

The ANZECC guidelines for toxicants specify trigger levels for the protection of aquatic ecosystems at four different protection levels: 99%, 95%, 90% and 80%, whereby the protection level signifies the percentage of species expected to be protected. The highest protection level (99%) is chosen as the default value for ecosystems with high conservation value and the 95% trigger value could apply to ecosystems classified as slightly-moderately disturbed (ANZECC, 2000). For ecosystems that can be classified as highly disturbed it may be appropriate to apply a less stringent trigger value, such as 90%, or perhaps even 80%, depending upon the management goals for the particular ecosystem.

Table 6: ANZECC (2000) guideline trigger values for metals (µg/L) in marine systems (water column)

Metal (total) µg/L	ANZECC Marine Guidelines (2000) (Trigger levels)			
	99%	95%	90%	80%
Cadmium	0.7	5.5	14	36
Chromium	0.14	4.4	20	85
Copper	0.3	1.3	3	7
Lead	2.2	4.4	6.6	12
Mercury (inorganic)	0.1	0.4	0.7	1.4
Zinc	7	15	23	43

Table 7: Dissolved metal concentrations in Zones 1 and 4 from Sept 2009- Oct 2010. NA= insufficient information to determine high reliability trigger value. *Low reliability trigger.

RED = Above guidelines **GREEN = Below guidelines**

Dissolve Metal	Zone 1 Range (T1-T4) µg/L	Zone 4 Range (T13-T16) µg/L	ANZECC guideline µg/L 95 Level of protection	Detection limit µg/L
Copper	1-2	< 1	1.3	1.0
Lead	5-7	5	4.4	5.0
Mercury	< 0.05	< 0.05	0.4	0.0
Zinc	1-3	1-5	15	1.0
Cadmium	0.1	< 1	5.5	1.0
Iron	2-21	2-2	NA	20.0
Manganese	5-11	1-3	80*	1.0
Aluminium	2-5	2	NA	20.0
Arsenic	5-1	5	NA	5.0
Selenium	1-1	1	NA	10

Sampling metals for the TEER EHAP occurred bi-annually at sites T1-T4 in zone 1 and T13-T17 in zone 4. These zones were chosen as they are the most urbanised and industrialised zones in the Tamar estuary with documented elevated metal concentrations in sediments. The TEER EHAP collected water samples that were analysed for dissolved metal concentration. The samples are filtered down to 0.45µm to gain the fraction of metals that are soluble in water, as opposed to total metal analysis where no filtering is done and the water including particulate matter is analysed for metal concentrations. Both surface (0.1m below water surface) and bottom (1m above bottom of estuary) samples were taken at six-monthly intervals (two sampling events for metals from October 2009 to September 2010).

Dissolved metal concentrations did not vary for surface to bottom samples on the same sampling day and zone 1 in the upper reaches of the estuary show higher levels of dissolved metals than those observed in zone 4. This is consistent with results shown in the State of the Tamar Estuary Report 2008, where higher metal concentrations were found in the upper section of the estuary. This may be due to the high sediment levels and lower salinities in the upper section of the estuary and the tendency of metals to bind to particulate matter.

Table 7 shows the range in concentration of dissolved copper, lead, mercury, zinc and cadmium at zones 1 and 4 and compares them against the ANZECC guidelines for marine water. This comparison uses the 95% ANZECC trigger levels, which represent the percentage of marine species expected to be protected in a slightly to moderately disturbed ecosystem.

The laboratory, Analytical Services Tasmania, that undertook the metal analysis has conservatively applied minimum reporting limits for metals in saline waters by ICP-AES method (Table 7).

The range of dissolved copper concentrations in zone 1 of 1-2 µg/L exceeds the ANZECC guideline of 1.3 µg/L whereas dissolved copper concentration in zone 4 (<1µg/L) fell below the ANZECC trigger value.

Lead was the only other metal that exceeded guidelines, with results for zone 1 ranging from 5-7 µg/L compared to the ANZECC trigger guideline of 4.4 µg/L. Due to the detection limit of 5.0 µg/L from the analysing laboratory for lead, and the small number of samples, it is difficult to determine whether the results for dissolved lead in zone 4 are above or below the 4.4 µg/L guideline.

Dissolved mercury, cadmium and zinc ranges for both zones 1 and 4 were well below the ANZECC guideline concentrations (Table 7). Iron, manganese aluminium, arsenic and selenium have no recommended ANZECC guidelines for marine waters and show a similar trend to the previously described metals with higher levels in zone 1 than in zone 4. The upper Tamar estuary around zone 1 is influenced by freshwater inputs between sites T1-T3 in the form of the South Esk and North Esk rivers and the Lake Trevallyn Tail Race discharging into the estuary. During this sampling period, zone 1 had salinity ranges of 0.01-13 ppt and as such the marine ANZECC guidelines have been applied. However due to the complex mixing between fresh and marine waters, freshwater ANZECC guidelines could at times be considered for metals. The development of zone/site specific water quality objectives or triggers will aid in better describing the impacts of metals in zone 1.

Key findings: Metals were only tested in zones 1 and 4, where previous sampling had indicated impacts were likely to be found. Zone 1 was within guideline levels for all metals except copper and lead. Zone 4 exceeded ANZECC guidelines for lead only. Metal concentrations are likely to be due to historic use of the catchment and estuary (mining and other industries) as well as coming from the heavily urbanised areas of the upper estuary. TEER is currently conducting a study into seafood safety of the Tamar to investigate the levels of metals found in finfish and oysters and will communicate the results to the public including any health issues related to consumption of seafood.

4 Tamar Estuary Report Card

The Tamar estuary report card aims to report on the ecosystem health of the estuary and measure change by collecting relevant water quality and biological data to enable the assessment of the ecosystem. Ecosystem health is determined by the response of the environment to natural and human inputs and is defined as the degree to which the actual state of the ecosystem diverges from its ideal state (Pantus and Dennison, 2005). The report card uses a grading system of "A" through to "F" for the five zones within the estuary (Table 8). The range of the Ecosystem Health Index (EHI) used to define each letter score is also given. The method used to calculate these scores is discussed further below.

Table 8. Report card grade meanings

Letter	Grade	EHI range	Description
A	Excellent	0.86-1.00	Conditions meet all the ecosystem health values more than 85% of the time
B	Good	0.70-0.85	Conditions meet all set ecosystem health values in most of the reporting region
C	Fair	0.60-0.69	Conditions meet some of the set ecosystem health values in most of the reporting region
D	Poor	0.50-0.59	Conditions are unlikely to meet set ecosystem health values in most of the reporting region
F	Fail	‹ 0.50	Conditions meet set ecosystem health values less than 50% of the time

The first Tamar estuary report card published in 2010 used historical data dating back 10 years (1999-2009) to derive the grades; data from 2007 was also incorporated to give a standalone grade snapshot for one year. The 2011 report card differs from the 2010 report card as it incorporates the TEER EHAP data, described in this report, which has been collected monthly at 20 sites from September 2009- October 2010 to develop the grades for the functional zones in the estuary. The 2011 report card also incorporates the 10-year average (1999-2009) scores as a comparison between the two reports, although given the different basis on which these grades have been derived (i.e. 10 years of historical data versus a single year of monitoring) care must be taken in interpreting the meaning of such a comparison.

4.1 Methods for TEER Report Card grade determination

Report card grades have been calculated using the monitoring data described in the previous sections. The basic approach used to derive scores is given below. A more detailed description is given in Appendix 1.

1. Five functional zones were identified based on differences in critical habitats (e.g. seagrass, rocky reefs, wetlands), key processes (phytoplankton abundance; Chl a), human impacts, nutrient levels (e.g. total nitrogen), metals (e.g. zinc) and salinity within the estuary.
2. TEER EHAP monitoring data (October 2009-September 2010) was analysed. Indicator parameters were chosen and grouped into two categories: ambient water quality; and, recreational water quality.
   - Water quality indicators consist of dissolved oxygen, pH, total nitrogen, total phosphorus, turbidity, chlorophyll a and metals.
   - The recreational indicator is the bacteria Enterococci.
3. Data was spatially analysed and assessed against ANZECC (Australian and New Zealand Environment Conservation Council) guidelines for Fresh and Marine Water Quality and the Tasmanian Public Health Act Recreational Water Quality Guidelines.
4. Exceedance scores were calculated for each indicator from each category, for each of the five zones. These used a 1 to 4 categorisation of distance from the guideline value.

5. An Ecosystem Health Index (EHI) is calculated for each category in each zone by averaging indicator exceedance scores. EHI is then converted to a letter grade for each category in each zone.

The EHI range is used to generate a report card grade for each zone as given in Table 9 (note detailed values for +/- scores are given in Appendix 1). The letter grade represents the overall health of that zone.

Table 9: 2010 and 2011 Report Card Grades

Tamar Estuary Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
2010 Report Card Grades (Using historical data 1999-2009)	D	B -	B	B+	A-
2011 Report Card Grades (Using 2009-2010 EHAP data)	D+	B -	B+	B+	A-

The grades for 2011 have not changed markedly from the 2010 grades in the different functional zones of the estuary. However in zone 1 the grade has increased from D to a D+. Similarly in zone 3, which extends from Swan Point down to Rowella, the grade has increased from a B to B+. In zones 2, 4 and 5 grades have remained the same (Table 9). Poor grades in zone 1 are largely due to high levels of pathogens and nutrients, as well as metals exceeding guidelines. This poor water quality is likely due to the heavily urbanised nature of zone 1, unquantified major inputs from the North Esk and South Esk rivers and accumulated pollutants from historical land use practices, such as mining, in the catchment. Water quality generally improves as you move downstream, with greater flushing of the estuary, and reduced intensity of land use. Higher pollutant loads are frequently observed in the wetter winter months as inflows to the estuary increase during these periods.

Caution must be used when interpreting changes in grades between report cards. Small changes in grades can be driven by differences in the data collected or climate of the reporting period. The 2010 grades used historical data from 1999-2000 at different sites to the current TEER EHAP data set (October 2009-September 2010). There are differences in sites, collection methods, analysis and quality of the data between the two data sets used. Climate can also greatly influence observed water quality and is another factor that can affect report card grades. Regardless, it is promising that the grades have not declined between the two report cards.

5 Summary, key findings and future directions

This report has been developed to describe data produced by the TEER EHAP monitoring program used in the 2011 report card for the Tamar estuary. Methods used to generate the report card scores are described in more detail in Appendix 1. This is the first report card that has been produced using data collected as part of the TEER EHAP monitoring. The previous report card (2010) used historical data. As such, there are some differences between the data underlying the report cards, such as differences in sampling sites, indicators used in different zones (e.g. this report card does not use metals in zones 2, 3 and 5) and the period over which the data was collected. In addition, climate was different over the different monitoring periods. These factors do impact on scores and mean that caution must be used when interpreting changes in score between the two report cards. However it is possible to make conclusions from this analysis:

- Water quality improves as you travel along the Tamar estuary towards the ocean. This is partly due to the well flushed nature of the lower estuary, as well as because of the proximity of a major urban centre, Launceston, and significant tributary inputs to the upper estuary. Urban areas generate elevated loads of nutrients, sediments, pathogens and metals which are delivered to the estuary through stormwater systems and wastewater treatment plants. Tributaries bring pollutants such as sediments and nutrients generated across a large catchment area and deliver these to the estuary.
- The current status of the health of the estuary has been maintained compared with the 2010 report card even though the 2011 report card is based on data from a wetter period. Wetter periods, occurring during winter months, generally correspond to poorer water quality as pollutant loads to the estuary increase during these times. This is as expected given the higher flows and more erosive events during these times. Higher rainfall is also associated with more overflow events for wastewater treatment plants.
- Observations of bacteria levels, used to describe recreational water quality, are within guidelines in the lower estuary (zones 3, 4, 5) but are above guidelines some to most of the time in the upper estuary (zones 1, 2). This is because of high levels of bacteria in the upper catchment corresponding to urban areas, large tributary inputs and wastewater treatment plants which overflow into the estuary. It is also due to the poorly flushed nature of these parts of the estuary when compared with downstream zones.
- Elevated nutrient and bacteria levels are key drivers of poor grades in the upper estuary. These grades correspond to highly urbanised, poorly flushed areas of the estuary.
- Elevated copper and lead levels in zone 1 and lead levels in zone 4 are due to historic mining activities and other industry, as well as urban runoff. No data was collected in other zones given previous studies had not found significant problems with metals in these areas.

Several future directions and projects have been identified to improve current knowledge in the TEER. These are described below.

5.1 Zone 1 study

The TEER EHAP sampling will cease in September 2011, as 24 months of monitoring data will have been collected. A zone 1 study, conducted during the off-years, has been identified as beneficial to investigate the anthropogenic impacts in the upper-most reaches of the Tamar estuary. Sampling locations may be modified to capture the impact of acid sulphate soils, dredging, stormwater and WWTPs. The monitoring program will be designed to fulfil regulatory requirements for monthly ambient monitoring of WWTPs, and support any possible future infrastructure upgrades and decision-making in the upper reaches of the estuary around the city of Launceston. The proposed study will also allow for continued up-to-date information on the processors occurring in the upper Tamar estuary.

5.2 Mass Loads study

Due to the large catchment areas contributing flow to the Tamar estuary, the need for a mass loads study has been identified as beneficial and complementary to the TEER EHAP. The mass loads study will provide a much greater understanding of the link between the estuary and the freshwater tributaries that enter the system. Mass loads will be calculated using flow data obtained from Hydro Tasmania and Launceston City Council flow meters stationed on the North Esk and South Esk rivers. Flow data will be used in conjunction with water quality data to estimate the loads being delivered to the estuary. Mass loads monitoring collects monthly samples for the same parameters sampled for in the EHAP except for secchi disk and chlorophyll a at seven sites on the North Esk and South Esk rivers. The study will be conducted over six months with a review in November 2011 which will align with the beginning stages of the EHAP zone 1 study.

5.3 Seafood Safety

The Tamar estuary is a popular recreational fishing waterway in northern Tasmania. The target species are often taken for consumption which prompts an investigation to assess the levels of potential contaminants in the seafood from this estuary. In 1999 to 2002, investigations of metal contaminants of sediments, finfish and shellfish were undertaken on behalf of the Department of Health and Human Services (DHHS). Wood, 2002, found metal levels in finfish to be within the acceptable limits; however shellfish well exceeded these levels. The findings are in line with the DHHS ongoing recommendation that wild shellfish should not be harvested for consumption in northern Tasmania. General observations suggest long-term residents of the Tamar estuary realise the contamination of shellfish and do not harvest for consumption. However, due to the absence of signage and communications, visitors may unknowingly consume species which pose a health risk. The seafood safety investigation is designed to re-assess levels of metal contaminants in finfish and shellfish, and to create awareness within the community.

5.4 Freshwater Ecosystem Health Assessment Program (FEHAP)

The FEHAP will be designed to complement the estuarine EHAP and gain a catchment-to-coast understanding of the TEER region. A monitoring framework will be established that is reliant on the existing monitoring programs of the region's key organisations; NRM North, DPIPWE, UTAS, Hydro Tas, Forestry Tas, BLW, local councils and Inland Fisheries. These will be merged with snapshot monitoring from TEER to produce a catchment-based health report card complementary to the estuarine report card.

5.5 Developing Water Quality Objectives

In conjunction with the EPA and utilising the data gained from the TEER EHAP the program aims to develop Tamar estuary specific water quality guidelines to enable increased rigour when applying trigger levels and allow for more sensitive analysis and understanding of estuarine issues and processes. This process requires 24 months of monitoring data, which is now available.

5.6 Biological Indicator for the Tamar Estuary

TEER is exploring opportunities for a partnership with the University of Tasmania and Australian Maritime College for a post graduate study to identify a suitable biological indicator for the Tamar estuary for use in the EHAP monitoring program and report card. Possible indicators that could be suitable include oysters, rice grass, algae or fish.

5.7 Stormwater

Stormwater from urban areas typically contains a number of pollutants identified to impact upon the health of the TEER waterways. To better manage stormwater in this region, a stormwater officer position was created in partnership with local councils and water corporation stakeholders

for TEER in early 2011. The officer coordinates stormwater activities in the TEER region and provides expert technical advice to councils and other key stakeholders.

Future directions for stormwater management include the collation of all existing stormwater mapping data in the TEER region and stormwater monitoring. Both projects will help natural resource managers to better understand and evaluate the health and condition of waterways in the TEER region, and help direct future investment and on-ground works. Data collected during stormwater monitoring will also enable natural resource managers to better evaluate effectiveness of activities undertaken to improve waterway health. TEER will also be focusing on stormwater education for both councils and the community.

5.8 Application of TEER EHAP data

Information collected from the TEER EHAP and from current projects contributes to the future management, investment and development of the Tamar estuary and Esk rivers by providing up-to-date scientific data to partner and non-partner organisations which feeds into the development of many decision support tools such as:

1. TEER water quality triggers.
2. Model building such as hydrodynamic models, sediment and plume dilution models.
3. Environmental assessments.
4. Mass loads estimation to the estuary.
5. Nutrient source identification.
6. Reports and report cards.
7. Education and awareness, i.e. website, signage and media launches.
8. Research.

EHAP monitoring data and associated information also serves as a valuable time stamp allowing for the measurement of change over time in the TEER region.

Appendix 1. Method for calculating report card scores

The scores used in the report card are calculated using the general method described in the TEER Report Card Methodology (2010). This Appendix briefly describes the steps used to generate scores for this report card and any assumptions that were used in each step (Figure 51).

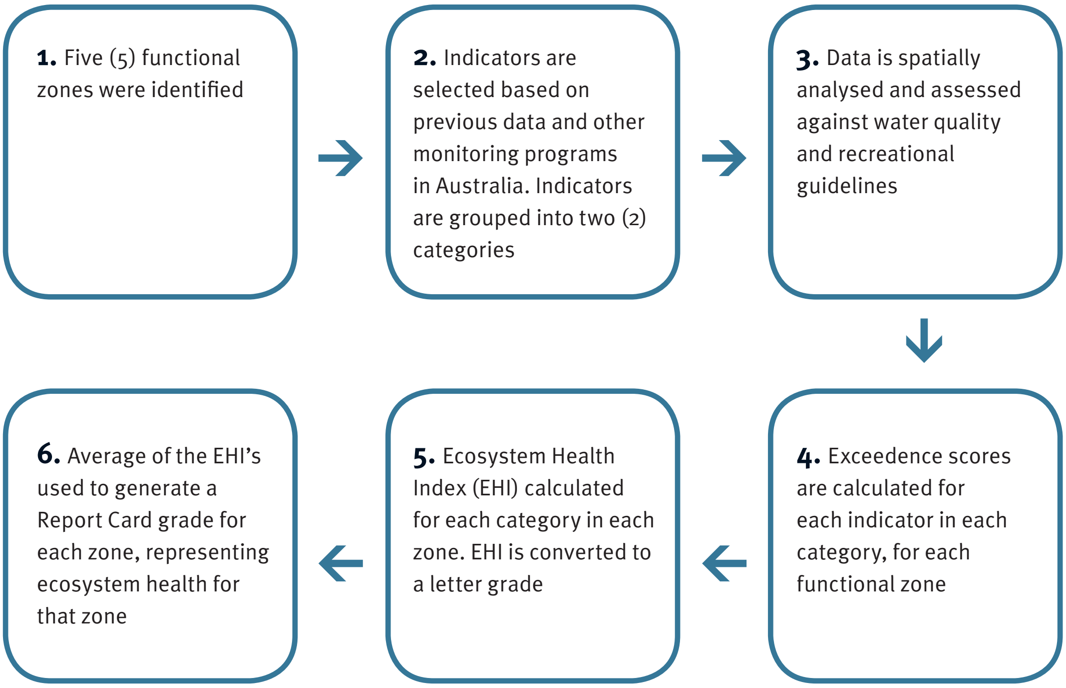


Figure 51: Steps used to generate report card scores (from AMC (2010))

Steps 1 & 2: Data used in generating the scores

Two different scores are generated: one for ambient water quality and the other for recreational water quality. The water quality score is based on a set of indicators: TN, Chl-a, mercury (Hg), TP, aluminium (Al), lead (Pb), pH, arsenic (As), zinc (Zn), turbidity, cadmium (Cd), dissolved oxygen (DO), copper (Cu). Recreational scores are based on bacterial counts of Enterococci.

All data has been checked for completeness and all values below the minimum detectable level (‹x) are replaced with the largest value below the minimum detectable level to the appropriate number of decimal places. For example, ‹4 is replaced with 3.9 if values are given to one decimal place or 3 if values given in integers.

Zones are the same as were defined for the 2010 report card. The analysis for water quality in this report card is not directly comparable to any of the previous years' analyses because of limited metal data and possible problems with chlorophyll a measurements. Datasets for all parameters other than chlorophyll a are largely complete for all months and river zones. Chlorophyll a data is missing for most zones in January to April.

Metal data is only available for April and October in river zones 1 and 4. Metal data is collected from surface and bottom water samples.

With the exception of metals, only surface data was used. Where multiple observations of a parameter were taken for a single time step at different water levels (i.e. a vertical profile of the water column is provided), the value used for that time step is the mean of the values over that part of the water column of interest at the site. For example where a 'surface value' is required, all observations in the top 25% of the water column at that site and time step are averaged to generate a single value. Apart from duplication through vertical profile measures, a single measurement for each parameter was available in each month.

A LOWESS regression was then fit to each parameter for each month to produce the data set used to calculate the final scores for each zone of the river.

Step 3: LOWESS regression

LOWESS is a data smoothing method in which a regression is performed in a moving range around each X value with the values in the range weighted according to their distance from the X value (see for example NIST/SEMATECH, 2006) This means that no explicit model equation is produced. Regressions can be either linear or higher order polynomials. Figure 52 shows an example of a point being estimated using LOWESS. A weighted linear regression is performed using values inside the marked range. Values closest to the point of interest are given the highest weighting. The estimated value is that predicted by the weighted linear regression for the specified X value. The range is then moved to the right and different observations and weights used for linear regressions to produce estimates across the full range of X values.

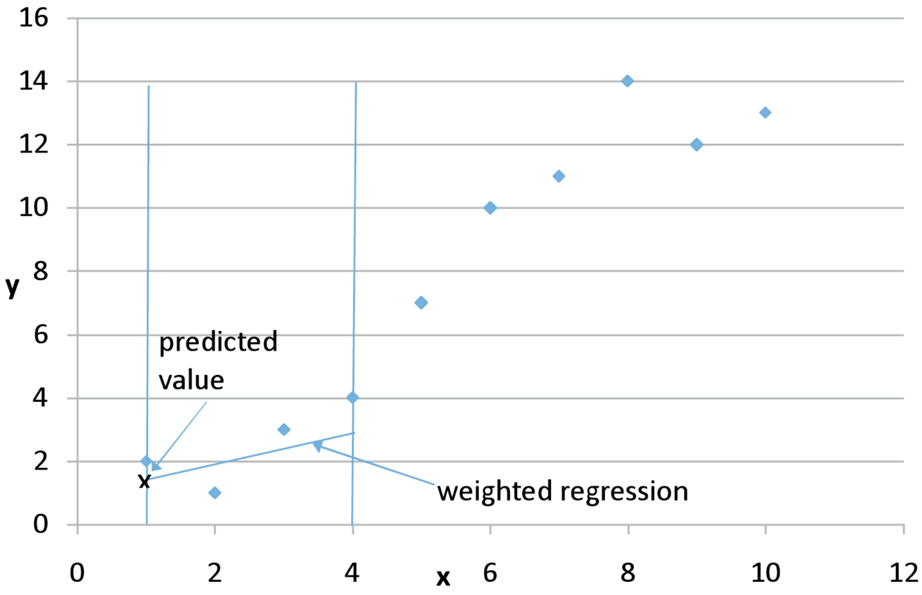


Figure 52: Example of a value fit by LOWESS regression (note a linear regression is used in this case)

For the estuary report card, LOWESS regression is used to create a smoothed data series along the length of the river. The X value in this case is the distance along the estuary. Each observation point is associated with a distance along the estuary. Lagoon Beach is the mouth of the Tamar estuary or zero distance. Seaward points are given a negative value (to -7) and points up the estuary are given positive values (to 67). The distance from the mouth of the estuary used to define the extent of each zone is given in Table 10.

Table 10: Distance from mouth of Tamar estuary for each zone

Zone	Distance from Mouth km
1	> 54
2	35 - 54
3	20 - 34
4	5 - 19
5	< 5

A smoothing weight of approximately 0.5 is used for all parameters, although this varies slightly depending on the parameter and month based on goodness of fit to the data. The LOWESS model provides a predicted value for each parameter for each kilometre of the estuary for each month. The LOWESS smoother is only used over the distance range of the data collected, so the start and end point of the estuary varies from parameter to parameter and month to month, depending on where on the estuary the data was collected (e.g. Figure 52).

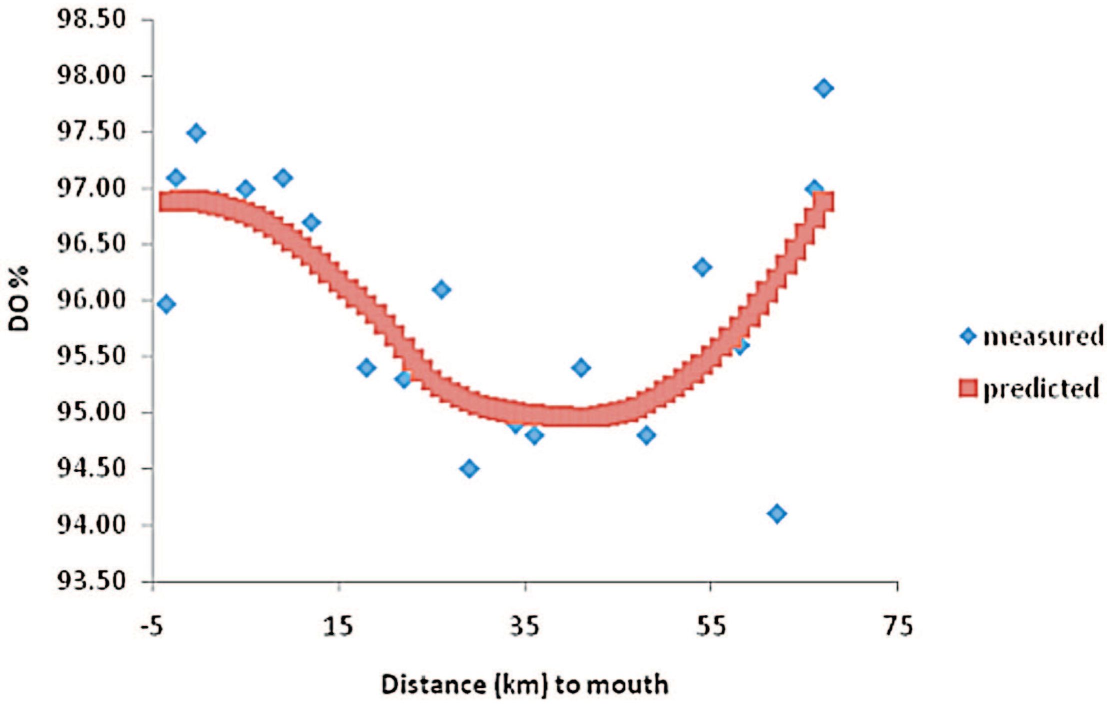


Figure 53: Dissolved oxygen in the month of August from the mouth (-3.5 km) to the head (67 km) of the Tamar Estuary, with a LOWESS smoothed function fitted

Step 4: Evaluating exceedance of the guideline values

A set of guideline values is used for each parameter (as described in the main body of this report) to decide whether or not the parameter value is indicative of a healthy estuary section. The LOWESS models are used to predict a value for each one kilometre section of the estuary. These points are then assigned a category value of 1 to 4 based on the distance of the smoothed LOWESS value of that point to the threshold value (Table 10).

Table 11. Rules used to assign category values to 1 km points along the estuary using LOWESS smoothed valued (parameters other than pH)

LOWESS smoothed value	Category value
› 50% above guideline value	1
0-50% above guideline value	2
0-50% below guideline value	3
› 50% below guideline value	4

For example, if the guideline value is 10 then a LOWESS smoothed value of 3.5 would be more than 50% below the guideline value (i.e. below 5) so would be given a category value of 4. This means that for this parameter the estuary can be considered to be in a very healthy condition. If instead the LOWESS smoothed value was 12 then this is less than 50% above the guideline value, so the category value of 2 is assigned, indicating a somewhat impaired condition.

Data for pH is managed differently as values both less than and greater than the exceedance value are viewed as detrimental to the ecosystem. In this case values within the range provided are given a score of 4, indicative of a value that is not detrimental to the ecosystem. So far, all pH data collected in the estuary has been within the range provided, and as a result no consideration has been given on how to allocate a score to values outside of the range. This may need to be done in the future.

Step 5: Calculating the EHI

For each parameter, a category value for each zone is then calculated as the mode of all relevant category values. A separate category value is calculated in this way for each month. For example, if the January observations were given category values such that 5 observations had a value of 1, 2 had a value of 2, 3 had a value of 3 and 1 had a value of 4, then the mode, or most frequent, category value is 1 so January is assigned a category value of 1 for this parameter (Figure 54).

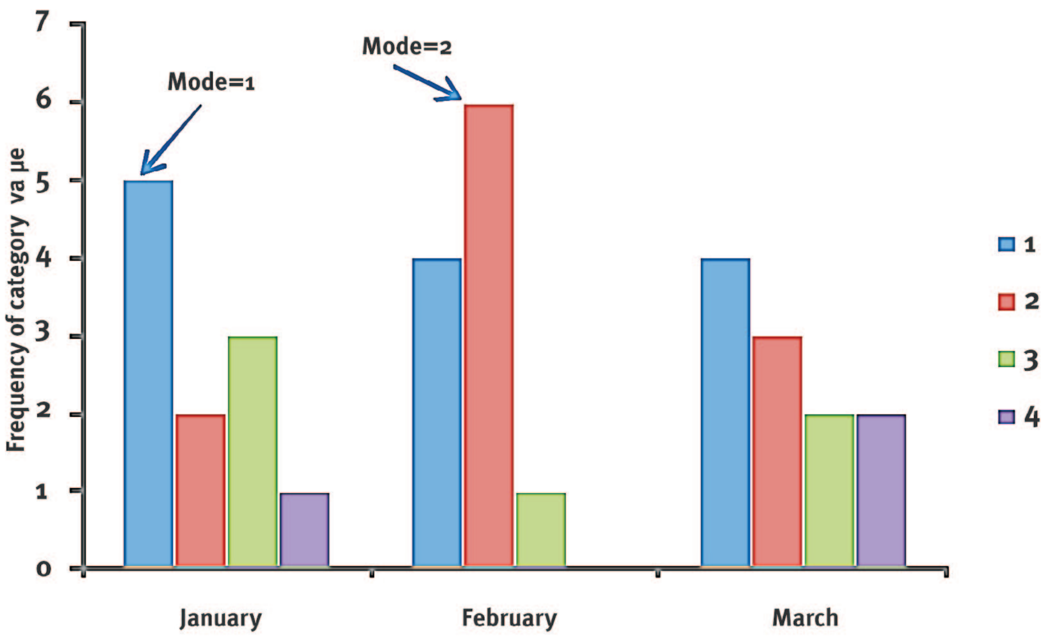


Figure 54: Example showing calculation of monthly category value for a parameter

The Ecosystem Health Index (EHI) is a measure of how much of a waterway's area complies with the defined water quality objectives (EHMP, 2008). The EHI for an indicator (water quality, recreation) in a zone is calculated by averaging the category values across all relevant parameters then converting this value to a proportion (by dividing by 4).The list of parameters used for water quality and recreational EHIs is given in the first section of this Appendix. Table 12 shows an example of how the EHI for a parameter is calculated using synthetic data for enterococci as an example.

Table 12.Calculation of the Ecosystem Health Index (EHI) for enterococci

		Zone				
Indicator	Month	1	2	3	4	5
Enteroccoci	Jan	1	3	3	1	1
	Feb	2	3	3	2	2
	Mar	2	2	3	1	1
	Apr	1	3	3	1	1
	May	1	2	3	1	2
	Jun	1	1	1	1	–
	Jul	1	2	2	1	3
	Aug	1	1	2	1	2
	Sep	2	3	3	3	3
	Oct	–	3	3	1	1
	Nov	1	2	3	2	2
	Dec	1	2	3	1	1
	Average	1.27	2.25	2.67	1.33	1.73
	EHI	0.32	0.56	0.67	0.33	0.43

Step 6: Report card grades

A letter grade is then assigned for each indicator based on these EHI values. The relationship between EHI values and letter grades is given in Table 13. For example an EHI of 0.51 would be given a letter grade of D- indicating a poor condition while a letter grade of 0.955 would get a letter grade of A+ indicating an excellent condition.

Table 13: Relationship between EHI and letter grade used in the report card

EHI	Letter Grade
0.950 - 1.000	A+
0.900 - 0.949	A
0.850 - 0.899	A-
0.800 - 0.849	B+
0.750 - 0.799	B
0.700 - 0.749	B-
0.675 - 0.699	C+
0.625 - 0.674	C
0.600 - 0.624	C-
0.575 - 0.599	D+
0.525 - 0.574	D
0.500 - 0.524	D-
‹ 0.500	F

The report card grade for each zone is generated using the average of the water quality and recreational EHIs.

Appendix 2. EHAP sampling data description

Table 14 gives a description of flow and rainfall conditions for each of the monthly sampling dates taken as part of the EHAP.

Table 14.EHAP sampling data description

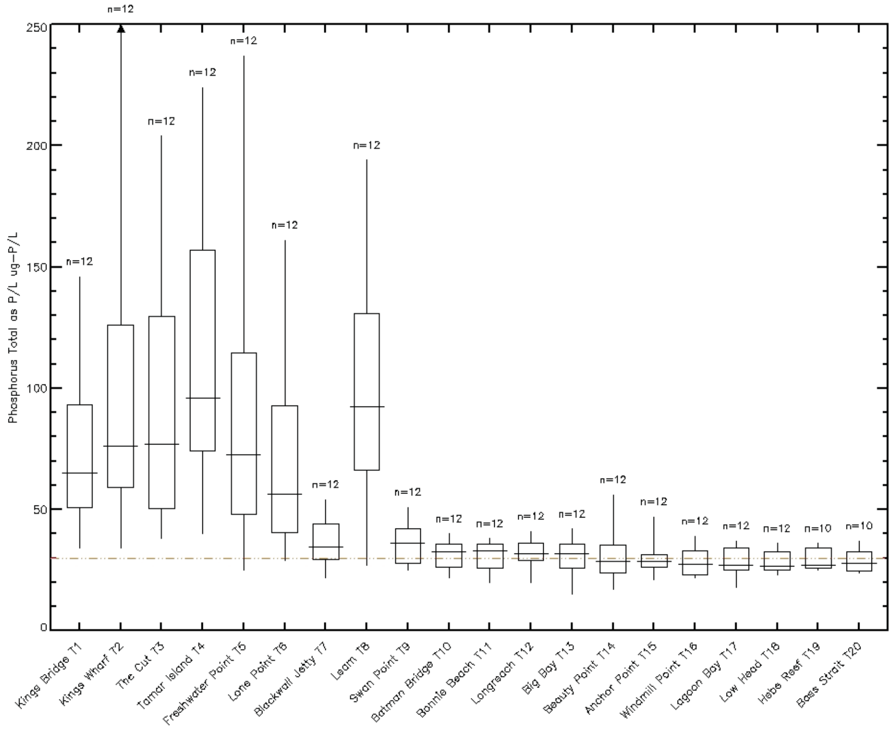
Sampling Date and commencement of sampling run time	Total flows into the Tamar estuary 7 days prior to sampling (cumecs)	Total monthly flows into Tamar estuary (cumecs)	Field Comments	Tidal stage at start of sampling run
6/10/2009 09:30	1935	3469	Heavy rain in catchment Lake Trevallyn spilling 10 days prior to sample date	09:30 LTN LOW TIDE
4/11/2009 09:15	322	1089	Mostly dry	09:15 LTN LOW TIDE
9/12/2009 09:20	276	853	Dryer than usual for this time of year	09:20 LTN LOW TIDE
28/01/2010 08:15	286	1021	Extremely dry month well below average	08:15 LTN LOW TIDE
10/02/2010 07:15	246	1090	Wetter than usual February	07:15 LOW HEAD HIGH TIDE
18/03/2010 07:30	320	1228	Wettest March in many years	07:30 LOW HEAD LOW TIDE
14/04/2010 08:30	338	1708	Rained most of the month Higher than average rainfall	08:30 LOW HEAD MID HIGH TIDE
12/05/2010 08:00	216	1217	Heavy rain in the North East some flooding in South Esk River	08:00 LOW HEAD HIGH TIDE
22/06/2010 09:55	753	3044	Very wet in the north with minor flooding and spills at Lake Trevallyn	09:55 LTN HIGH TIDE
14/07/2010 08:35	1002	4070	average rainfall for July	08:35 LTN LOW TIDE
11/08/2010 08:00	704	6968	Heavy rainfall in the east of the Tamar catchment lake Trevallyn spilling all month	08:00 LOW HEAD LOW TIDE
15/09/2010 09:15	1221	3653	Heavy rain periods with Lake Trevallyn spilling for majority of the month	09:15 LTN MID LOW TIDE

Australian Bureau of Meteorology 14/09/10

http://www.bom.gov.au/climate/current/month/tas/archive/index.shtml

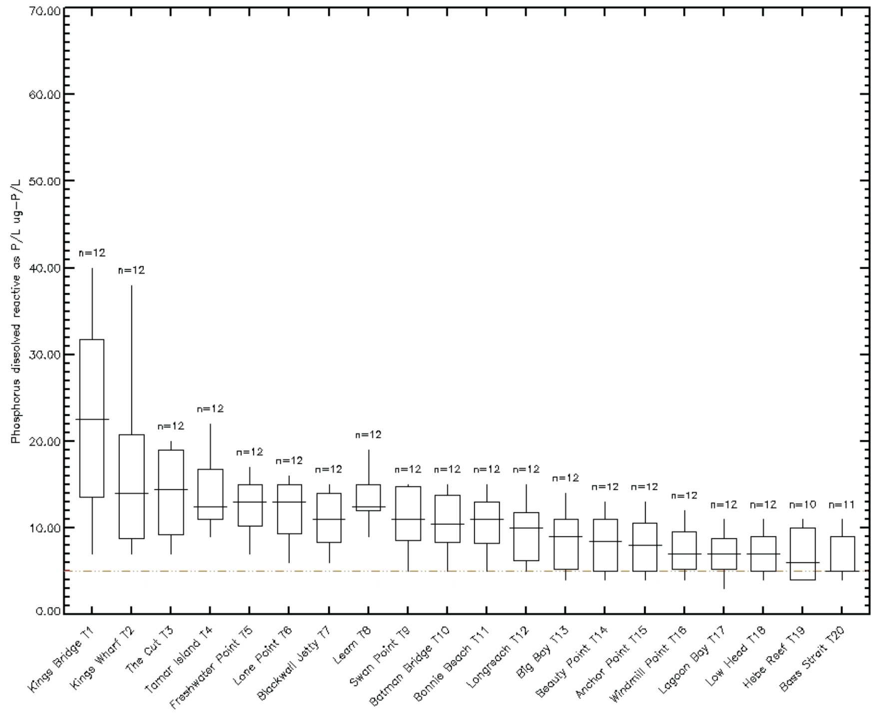
Appendix 3. Nutrient box-and-whisker plots

Appendix 3 provides the box-and-whisker plots for the bottom or deepest nutrient samples. These correspond closely to trends observed in surface samples shown in Section 3.3.



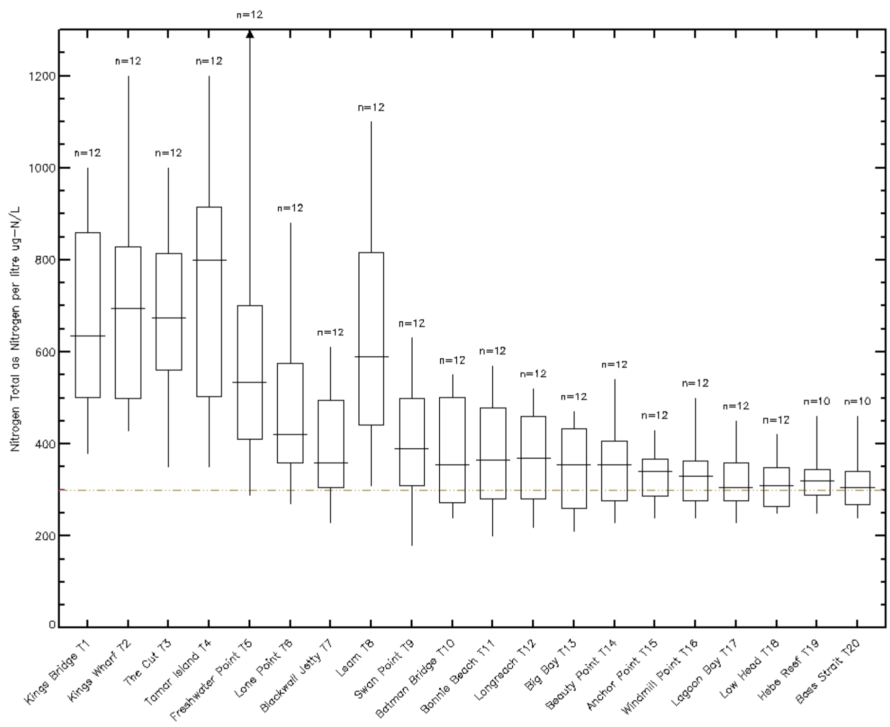
ANZECC Estuarine triggers 30ug/L

Phosphorus Total as P/L µg-P/L for TEER Sites 1-20 at bottom waters for the 2009-2010 study period.



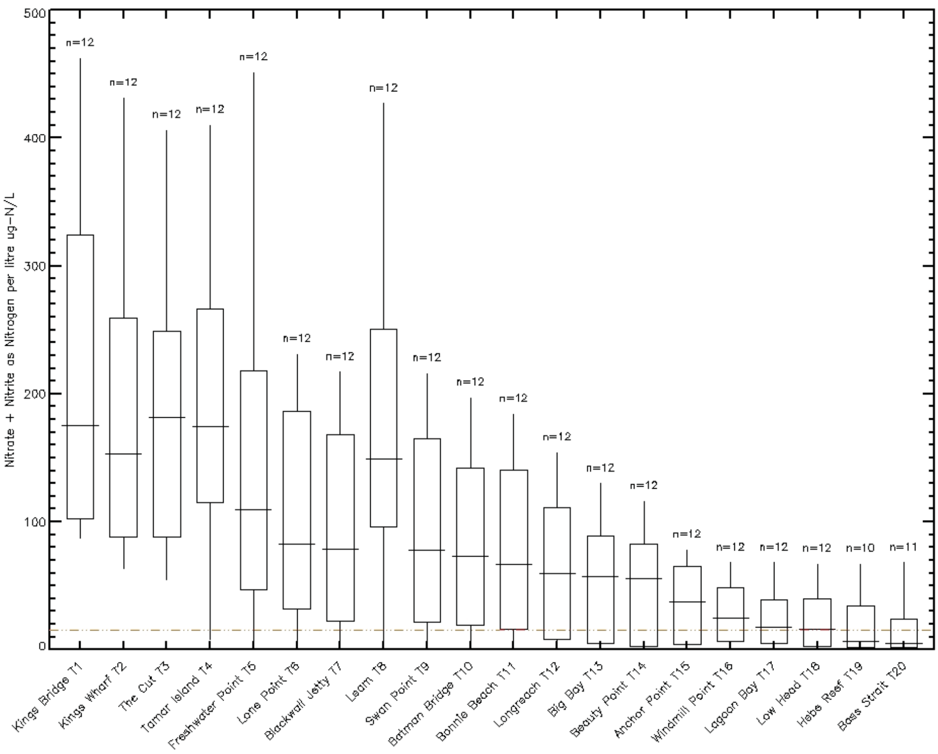
ANZECC Estuarine triggers 5ug/L

Phosphorus dissolved reactive as P/L µg-P/L for TEER Sites 1-20 at bottom waters for the 2009-2010 study period.



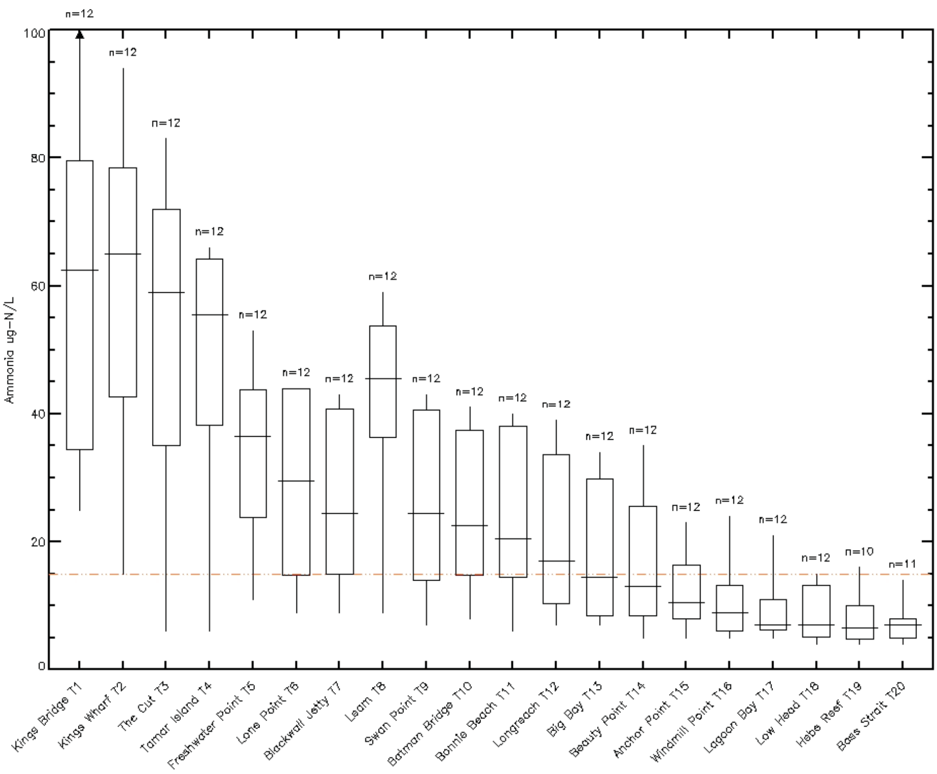
ANZECC Estuarine triggers 300ug/L

Nitrogen Total as Nitrogen per litre µg-N/L for TEER Sites 1-20 at bottom waters for the 2009-2010 study period.



ANZECC Estuarine triggers 15ug/L

Nitrate + Nitrite as Nitrogen per litre µg-N/L for TEER Sites 1-20 at bottom waters for the 2009-2010 study period.

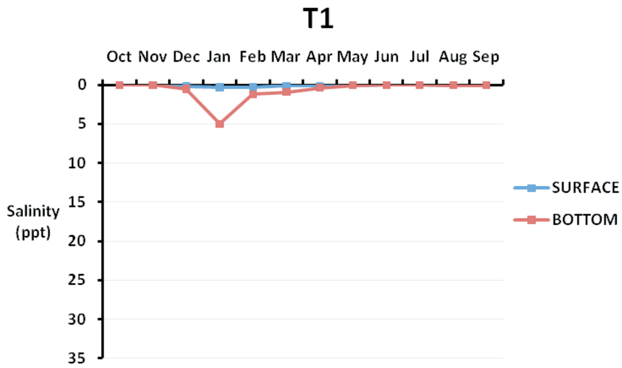


ANZECC Estuarine triggers 15ug/L

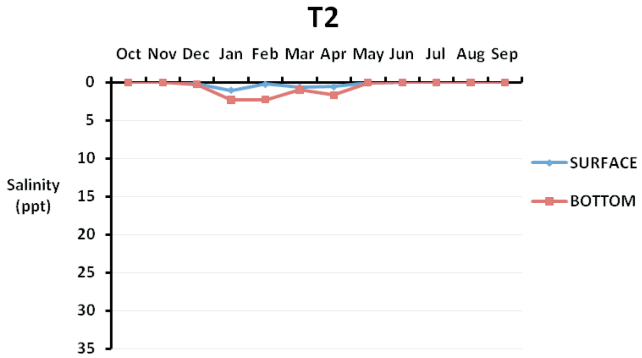
Ammonia µg-N/L for TEER Sites 1-20 at bottom waters for the 2009-2010 study period.

Appendix 4. Salinity at EHAP sites

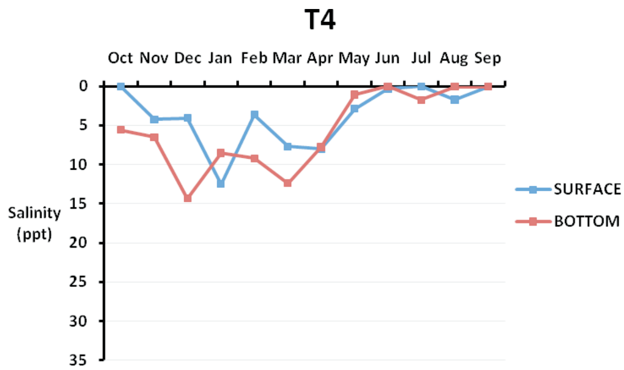
Appendix 4 shows monthly salinity observations for all EHAP sites that were used to choose proxy sites for each zone.



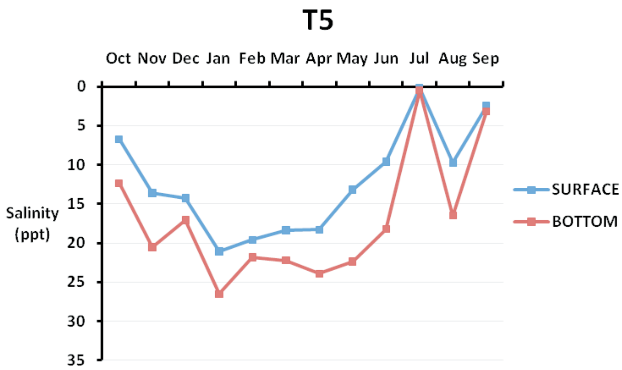
Zone 1 site T1 Salinity



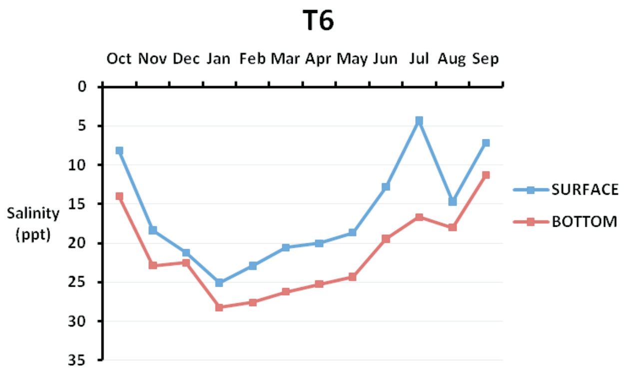
Zone 1 site T2 Salinity



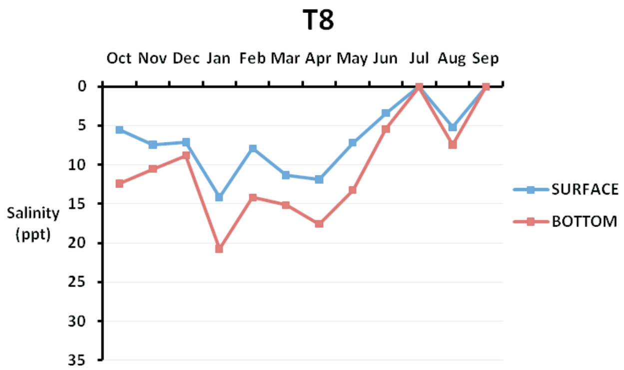
Zone 1 site T4 Salinity



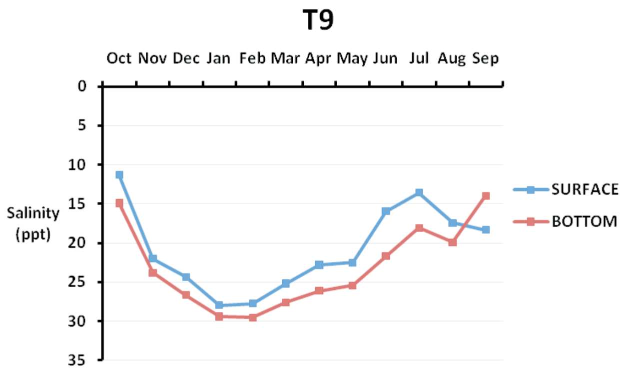
Zone 2 site T5 Salinity



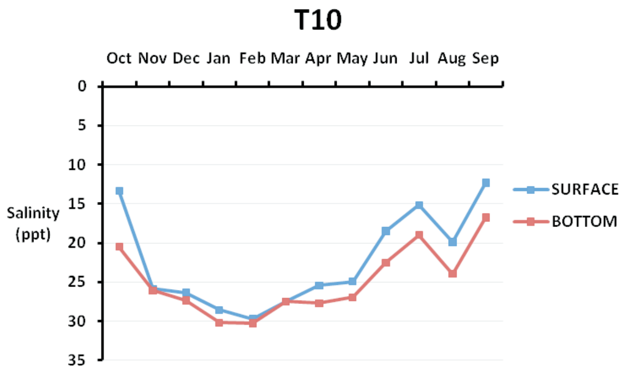
Zone 2 site T6 Salinity



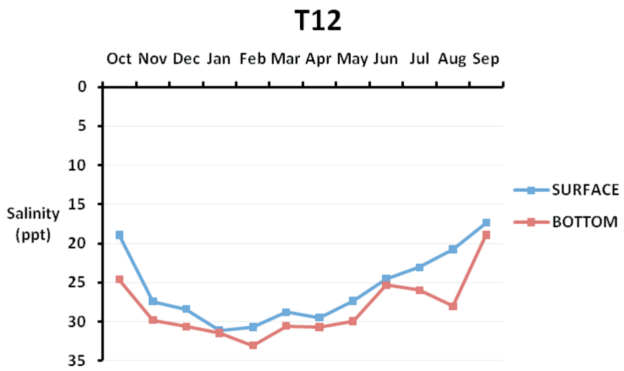
Zone 2 site T8 Salinity



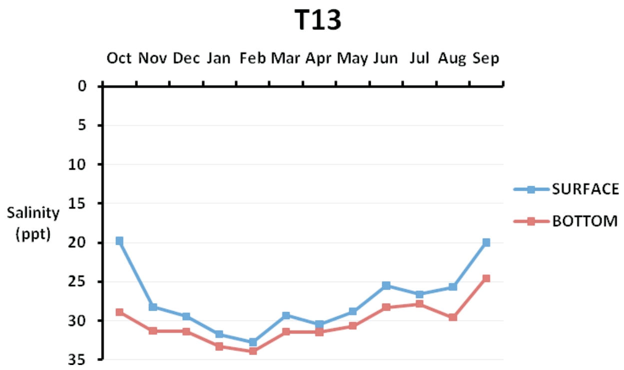
Zone 3 site T9 Salinity



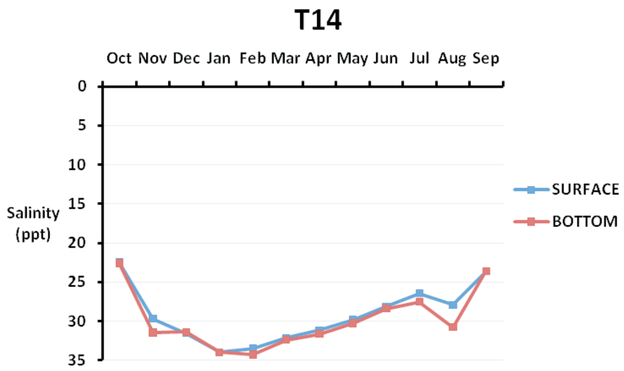
Zone 3 site T10 Salinity



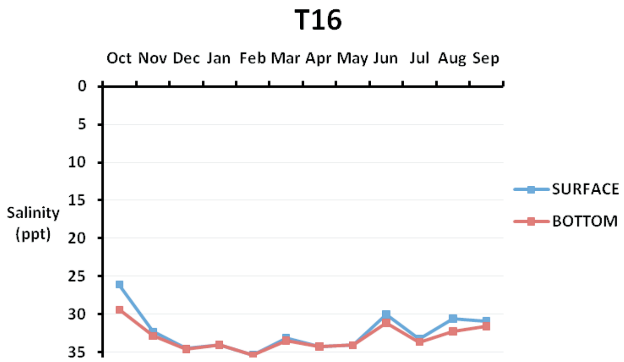
Zone 3 site T12 Salinity



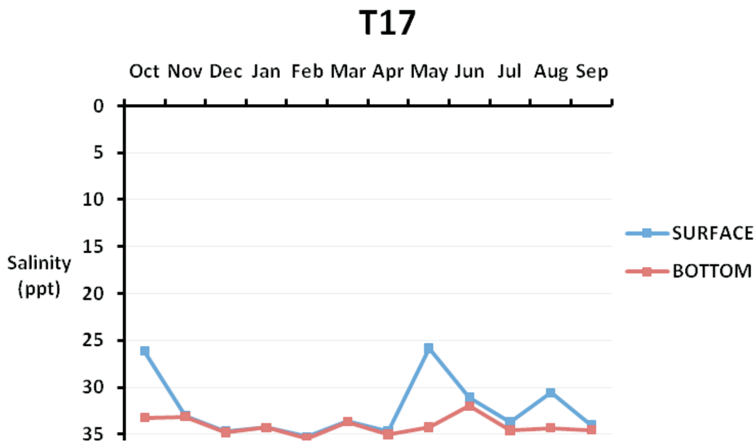
Zone 4 site T13 Salinity



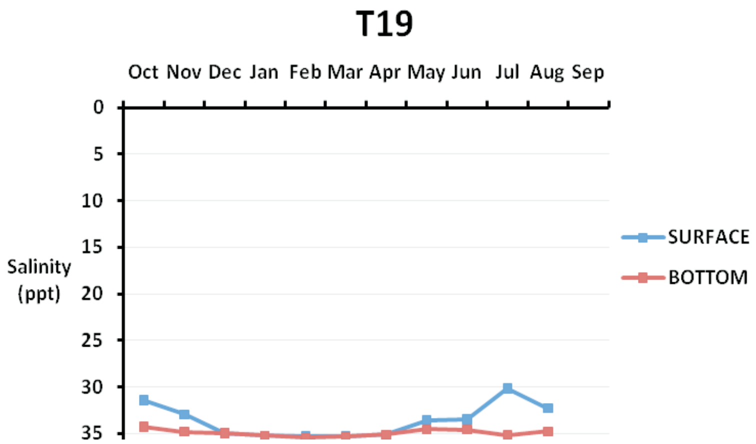
Zone 4 site T 14 Salinity



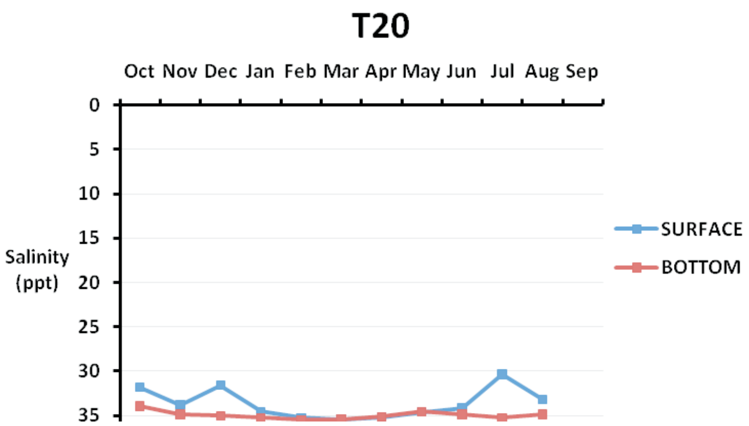
Zone 4 site T16 Salinity



Zone 5 site T17 Salinity



Zone 5 site T19 Salinity



Zone 5 site T20 Salinity

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