FINAL REPORT TO NHT

COASTAL & ESTUARINE RESOURCE CONDITION ASSESSMENT

A BASELINE SURVEY IN THE SOUTHERN NRM REGION, TASMANIA

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Coastal and Estuarine Resource Condition Assessment: A baseline survey in the Southern NRM Region, Tasmania

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Summary

This report presents data obtained as part of the trial implementation of the Coastal and Estuarine Resource Condition Assessment (CERCA) project. CERCA was established to address the widely-acknowledged need for a standardised means of collecting, analysing and presenting coastal and estuarine condition information.

NRM South, in partnership with the Tasmanian Aquaculture and Fisheries Institute (TAFI), has developed CERCA to improve availability of estuarine health data and access to information, as well as identifying the data and information needs of stakeholders.

A comprehensive review of condition assessment methodologies, followed by extensive consultation with resource managers (including state and local government, industry and community groups), resulted in the selection of baseline monitoring parameters and priority monitoring sites.

A 12-month program was developed and implemented in order to obtain baseline information on water quality (salinity, water temperature, dissolved oxygen, turbidity, pH, dissolved nutrients, silica), ecological condition as shown by Chlorophyll a, benthic macroinvertebrates, pathogens, and habitat extent determined from habitat mapping

While in some cases the program built on existing collection programs, in most locations this represented the first effort to obtain comprehensive quality assured/quality controlled data.

The CERCA trial has shown that the proposed framework can be successfully applied to collect, collate, analyse and present condition information that is useful to a variety of stakeholders. It has also yielded valuable baseline information that can be used to monitor changes to the health of coastal and estuarine ecosystems in Tasmania's southern NRM region.

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Acronyms and Abbreviations

AEST	Australian Eastern Standard Time
ANZECC	Australian and New Zealand Environment Conservation Council
AST	Analytical Services Tasmania
AusRivAS	Australian River Assessment System
BOM	Bureau of Meteorology
CERCA	Coastal and Estuarine Resource Condition Assessment
CFEV	Conservation of Freshwater Ecosystem Values
COAG	Council of Australian Governments
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEP	Derwent Estuary Program
DHHS	Department of Health and Human Services
DPIWE	Department of Primary Industries, Water and Environment
DPIW	Department of Primary Industries and Water
DEPHA	Department of Environment, Parks, Heritage and the Arts
ECA	Estuarine Catchment Area
EDA	Estuarine Drainage Area
EHO	Environmental Health Officer
GPS	Global Positioning System
HES	Huon Estuary Study
LGAT	Local Government Association of Tasmania
MPA	Marine Protected Area
MRL	Marine Research Laboratories
NATA	National Association of Testing Authorities
NLWRA	National Land & Water Resources Audit
NWQMS	National Water Quality Management Strategy
NHT	Natural Heritage Trust
NRM	Natural Resource Management
PEVs	Protected Environmental Values
Ramsar	Convention on Wetlands, signed in Ramsar, Iran, in 1971
SCAT	Southern Coastcare Association of Tasmania Inc.
STP	Sewage Treatment Plants
TAFI	Tasmanian Aquaculture and Fisheries Institute
TSGA	Tasmanian Salmon Growers Association
TSQAP	Tasmanian Shellfish Quality Assurance Program
WQGs	Water Quality Guidelines
WQOs	Water Quality Objectives

Introduction

Background

Classification of Estuaries in the Southern NRM Region

Estuaries are the link in catchments between the freshwater rivers and streams and the marine waters of the coast. Estuaries are generally highly productive systems, and are therefore a valued resource in Tasmania. Estuaries and coastal wetlands have long been recognised as essential nursery areas for many marine species. They provide a range of recreational and economic opportunities, and have commercial value for the local tourism and aquaculture industries. These systems are valued for many uses, such as marine farming, boating, fishing, hunting, swimming, bird watching and other recreational and tourism activities. However, some activities within these systems and their catchments can cause water quality degradation and therefore threaten the ecological health and productivity of these resources.

Salinity in estuaries is often stratified, with fresh or brackish water flowing from the streams and/or rivers on the surface of the water column, while denser saline water flows inward with the tides in the bottom waters. Estuaries are therefore quite variable environments, which are influenced by terrestrial runoff and oceanic circulation. Many of the smaller estuaries in Tasmania are under increasing pressure due to a variety of factors including urban and industrial expansion, increased agricultural and forestry activities in the catchment, climate change and introduced marine pests. However, information on the condition of these estuaries is patchy and in many cases extremely limited.

For this project, available literature on the values, threats, status and health of coastal ecosystems (estuaries and coastal waters) in the Southern NRM Region was reviewed and collated, including the identification of existing monitoring efforts (Temby and Crawford 2007). This was essential to devising ways in which resource condition assessment and monitoring could be coordinated and expanded. This process also identified data deficiencies that may need to be overcome.

The evaluation of existing monitoring highlighted that at any one time it is unlikely that there will be sufficient resources to monitor all waters in the Region. It was therefore necessary to determine which estuaries and coastal waters are the priority for monitoring and are representative of the Region. The CERCA Project Directions discussion paper (Temby and Crawford 2007) identified potential estuaries/coastal waters for monitoring and condition assessment.

A number of factors were considered to determine priorities. These included: (a) significance of the location; (b) practicality of monitoring; and (c) capacity for collaboration (see Temby and Crawford 2007). The considerations were quite broad and may be conflicting, reflecting the wide range of issues and potential uses of estuaries and coastal waters in the Region. In no way did this process seek to rank one location as being of more “value” than another, only as a process for considering potential locations for the initial stages of implementation (i.e. locations that have a high likelihood of successful implementation given resource constraints).

CERCA Objectives

The development of a standardised means of collecting, analysing and presenting coastal and estuarine condition information was identified as a key need for southern Tasmania (NRM South, 2005). NRM South, in partnership with the Tasmanian Aquaculture and Fisheries Institute (TAFI), aims to fulfil this goal by developing a Coastal and Estuarine Resource Condition Assessment (CERCA) framework in the Southern NRM Region of Tasmania (Temby and Crawford 2007).

This project proposes a resource condition framework for southern Tasmania by developing a baseline assessment and ongoing monitoring and evaluation program for key estuaries and coastal waters. This CERCA Program has been developed through extensive consultation with State Government, Local Governments, industries and community groups and by collating and assessing available information on water quality and condition of estuaries and coastal waters.

Rigorous field-testing involving potential partners was essential in evaluating the success of the CERCA Framework. The 12 month trial included collection and collation of baseline monitoring data, involving partners (see Temby and Crawford 2008), using a centralised database for water quality, and reporting information back to stakeholders (e.g. Report cards). The results of the baseline monitoring program are presented in this report.

Developing a CERCA Program

The first step in developing a monitoring program is to identify the purpose(s) for monitoring as this will determine what type of monitoring program and which indicators are appropriate. In the Southern NRM region, reliable information on the condition of coastal and estuarine resources is required to manage these systems effectively and to assess development (including onground/improvement work) proposals adequately. In order to overcome data deficiencies, monitoring methods need to provide spatial and temporal consistency (and be capable of replication in time and space), be robust and credible and they must also be cost-effective.

The monitoring methodologies described in this report are those considered to be most appropriate at the time of writing. These methodologies should be reviewed as more data become available and modified to incorporate new and improved methods. Monitoring methods have been selected using indicators developed and evaluated by the Tasmanian Coastal, Estuarine and Marine Indicators Working Group (Mount 2006), which are a sub-group of the National set of indicators. These indicators have been developed to assess the status and trends of Tasmanian estuarine and coastal resources.

It is important to remember that a baseline or benchmark of resource condition is required as a starting point against which changes in condition can be evaluated. Unfortunately, this information is generally not available for most estuaries and marine waters in Tasmania. Most estuaries in Tasmania have significant activity occurring in their catchments, and a number of estuaries are already obviously degraded and no data exist on their pristine condition, making it impossible to quantify the changes that have already occurred. Thus today's condition has to be the benchmark for assessing change in the future. However, we can sometimes make comparisons between relatively undisturbed estuaries ('reference estuaries') and those that have been modified as a means of evaluating the current condition of an estuary, for estuaries that are close geographically and have similar characteristics.

As a consequence, the first task in assessing the condition of estuaries will be to establish a comprehensive benchmark dataset. Future monitoring may not necessarily remeasure all variables from the benchmark dataset as monitoring programs are improved and refined, but it is very important to have a comprehensive baseline so that a variety of comparisons can be made as required in the future.

Coastal and Estuarine Water Quality Management

The Australian and New Zealand Environment Conservation Council (ANZECC) has provided a forum for member governments to develop coordinated policies about national and international environment and conservation issues. The ANZECC water quality guidelines (ANZECC 2000) were developed to provide managers and users with a framework for assessing water quality condition in our rivers, lakes, estuaries and marine waters. These guidelines are available online at www.deh.gov.au/water/quality/nwqms. The National Water Quality Management Strategy (NWQMS) was developed by ANZECC and introduced by the Australian, State and Territory Governments to sustainably manage the nation's water bodies. The main policy objective of the NWQMS is "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development". The ANZECC Water Quality Guidelines are national recommendations, which can be adapted and applied at a State and/or Regional level.

The *State Policy on Water Quality Management 1997* (the Water Policy) was introduced in response to the National Water Quality Management Strategy. The Water Policy sets a framework for:

- determining Protected Environmental Values (PEVs), which have been set for the majority of catchments in the Southern Region. The PEVs are used as a basis for setting Water Quality Objectives (WQOs)
- setting Water Quality Guidelines (WQGs) and WQOs. WQGs are estimated levels of indicators that should be met in order to protect certain environmental values, while WQOs require more precise information, are set for a specific body of water and should be met to achieve all PEVS (Environment Division, DTAE)

- establishing guidelines for the management of both point and diffuse sources of pollution (e.g. dairy effluent management, works in streams, road construction and maintenance, forestry management and soil management on agricultural land)

The ANZECC Water Quality Guidelines recommend a number of steps for assessing estuarine health (Dept Environment and Conservation 2006). These steps were an integral part to the development of CERCA in the Southern NRM Region in Tasmania. Some of these steps are fulfilled by existing organisations (e.g. State Government) – an objective of the development of the CERCA framework was to recommend a structure to address the gaps in this process.

Step 1: Environmental and resource values were determined by the local community for their local estuaries and waterways as part of the PEVs process implemented by the Tasmanian Government. Protected Environmental Values for all surface waters are available on the DPIW website at www.dpiw.tas.gov.au/inter.nsf/WebPages/EGIL-53L3KY?open. Although important in the process of determining water quality objectives and targets, the PEVs for coastal waters, estuaries and catchments in the NRM South Region are relatively uniform and thus have limited value for selecting key locations for monitoring. In general, the locations were considered to be modified (not pristine) ecosystems from which edible fish, crustacea and shellfish are harvested and were valued for their primary contact, secondary contact and aesthetic water quality. Some estuaries were valued for their water supply to industry (mostly aquaculture/marine farming zones).

Step 2: The setting of Water Quality Guidelines and Objectives is a State Government responsibility. WQGs may draw on the ANZECC Water Quality Guidelines and these are not necessarily a State defined level. WQOs however are set by the State using site specific information gathered through the PEV process.

Step 3: Determining protection levels was a key output of the Conservation of Freshwater Ecosystem Values (CFEV) Project, developed by the Department of Primary Industries and Water (DPIW) as part of the Water Development Plan for Tasmania. The CFEV Project produced a database based on Comprehensive, Adequate and Representative (CAR) reserve-design principles that can be used as a planning and information tool. The CFEV Project examined all freshwater-dependant ecosystems, including saltmarshes and estuaries. Across Tasmania, 113 estuaries were assessed according to their classification (biophysical classes), condition (Naturalness score), special values (e.g. important and/or threatened species, communities or habitats), land tenure security (National Park, Crown land, private land etc.) and conservation value. This information was used to produce a hierarchy of conservation management priorities using the criteria of Naturalness, Representativeness and Distinctiveness (pers. comm. Danielle Hardie, DPIW).The CFEV desktop analysis used existing data and/or modelled outputs to develop various data sets (CFEV 2006):

1. Using selected categories/values from already existing data sets (e.g. TasVeg, GTSpot/Natural Values Atlas);
2. Using point data collected through other programs (e.g. Edgar *et al.* 1999) and applying mapping rules or statistical modelling to attribute values to all spatial units; and
3. By modifying or updating existing data sets to suit the CFEV objectives (e.g. IBRA tree assemblage map).

However, the data available on estuaries were limited, and significantly less that that available for some of the other ecosystem themes (e.g. rivers). The information from the CFEV database for estuaries should be evaluated with this in mind until the database is updated with more recent estuarine information.

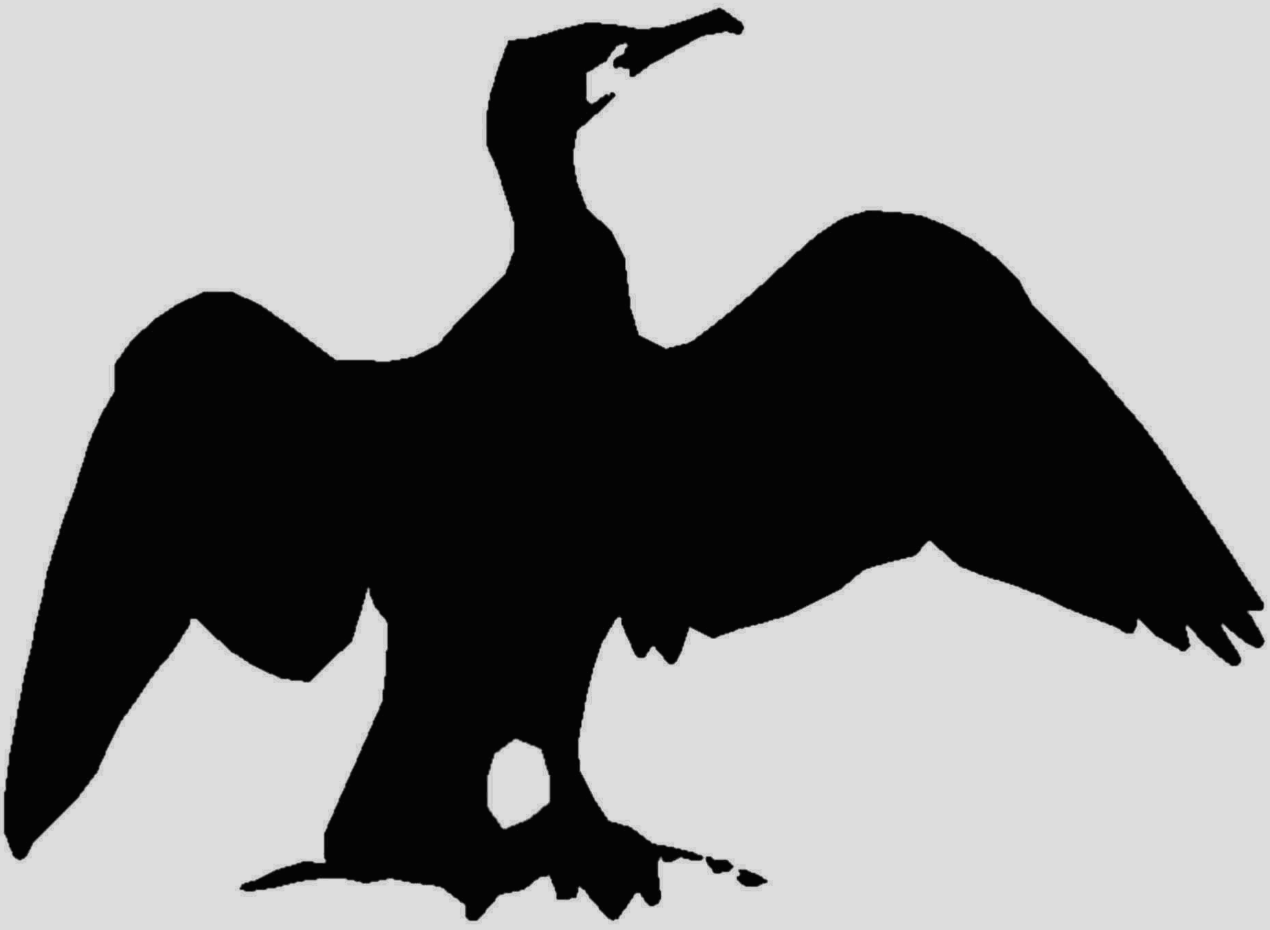
Step 4: Threatening processes and risks to estuaries have been examined through the Edgar *et al.* (1999) study and extended through CFEV. A discussion paper (Temby and Crawford 2007) was produced to summarise the available information on water quality and ecological condition in the catchments and marine and estuarine habitats of the Southern NRM Region (including threats and risks), and to recommend priority locations in which to initiate and trial a CERCA Program. In addition to the steps 1-4 above, a number of additional factors were considered to determine priorities: (a) significance of the location, (b) practicality of monitoring, and (c) capacity for collaboration. These considerations are quite broad and may be conflicting, reflecting the wide range of issues and potential uses of estuaries and coastal waters in the Region.

Step 5: The indicators chosen for the CERCA program were selected using indicators developed and evaluated by the Tasmanian Coastal, Estuarine and Marine Indicators Working Group (Tasmanian Indicator Compendium 2006), which are a sub-group of the National set of indicators. These indicators have been developed to assess the status and trends of Tasmanian estuarine and coastal resources. The methods for monitoring each indicator have been based on a report that has been prepared by Christine Crawford, which provides information from a user's perspective on monitoring each indicator in Tasmania (Crawford 2006). Additional information on the national indicator set is available online in the Coastal CRC Users Guide (Scheltinga *et al.* 2004) www.coastal.crc.org.au/Publications/Indicators.html. The Tasmanian Indicator Compendium is also available online at www.dpiw.tas.gov.au/inter.nsf/WebPages/LBUN-6N59JM?open. Additional information on monitoring methodology is available in the Waterwatch Australia National Technical Manual, which can be accessed online at www.waterwatch.org.au/publications/.

Step 6: The ANZECC Water Quality Guidelines (2000) outline National "default" trigger values and recommend a framework for setting more localised trigger values. Trigger levels are given as a threshold value or as a range of desirable values for different indicators above or below which there is a risk of adverse biological effects (i.e. within the trigger value range – low risk to the environment, outside the trigger value range – possible risk to environment and need for further action to investigate and/or fix the cause (Dept Environment and Conservation 2006). If the trigger level of a particular indicator is exceeded, it "triggers" further investigation to determine whether there is a problem and if so, the likely cause. This information should be used to investigate management options (e.g. onground action) to minimise the threat to the system. Local trigger values are important because estuaries vary substantially from location to location, and also within systems. The ANZECC 2000 guidelines and targets for estuaries were set without reference to Tasmanian data and thus should be used with caution. DPIW have recently adopted the ANZECC Water Quality Guidelines (2000) to develop trigger values at each of its freshwater baseline monitoring stations (Water Assessment Branch 2008).

The 12 month CERCA baseline monitoring program described in this report has allowed us to develop "draft" trigger values for some estuaries in the Southern NRM Region. These values are designed to be specific to local areas and should be updated as more data becomes available. The ANZECC Water Quality Guidelines (2000) recommend a minimum of 24 months baseline data are to be utilised for setting trigger values, so it is important that values be updated as more data become available.

Methodology



Monitoring Locations

Forty-three key estuaries and coastal waters were assessed in the Southern NRM Region with regards to geomorphology, condition, usage (recreation, tourism, fishing, rafting, bushwalking, hunting, swimming), agriculture, forestry and hydro-power generation), conservation significance and tenure (see Temby and Crawford 2007). The aim was to select a representative range of coastal areas and estuaries, spread across the municipalities as much as possible. It was also crucial that estuaries and coastal waters selected for monitoring had interested, informed and committed stakeholder groups that could form linkages within an integrated monitoring program.

The locations selected as priorities to were Port Cygnet, North West Bay, Pitt Water / Orielton Lagoon, Little Swanport and Moulting Lagoon / Great Swanport (Fig 1).

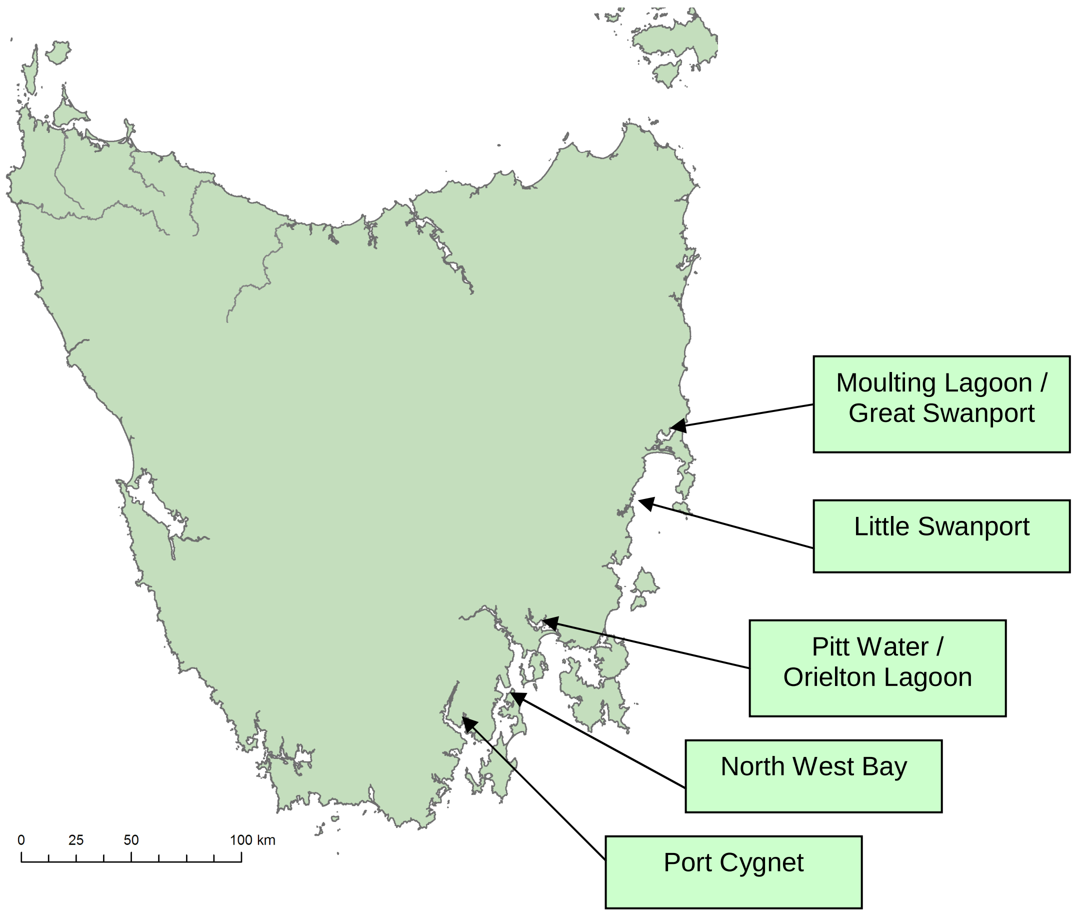


Figure 1. The five priority estuaries monitored in the Southern NRM Region.

A minimum of 5 sites at key locations in each estuary or coastal waters were selected for monitoring over a 12 month period. Due to the availability of longer-term data, Little Swanport was an exception to this, with only 1 site selected for water quality monitoring over the 12 month period. It was important that each site was revisited using coordinates stored on a GPS and that monitoring methodology remained consistent over time so that any changes could be clearly identified. GPS co-ordinates (decimal latitude/longitude) for the 24 sites sampled in this study are provided in Table 1.

Table 1. GPS co-ordinates (decimal latitude/longitude) for the 24 sites sampled in the Southern NRM Region of Tasmania.

Estuary	Site Label	Hydstra Site Number	S	E
Moulting Lagoon / Great Swanport	MLAG1	8045	42.0037	148.16016
	MLAG2	8046	41.99498	148.24567
	MLAG3	8047	42.04905	148.17033
	MLAG4	8048	42.06414	148.15302
	MLAG5	8049	42.08025	148.18363
	MLAG6	8050	42.08197	148.20758
Pitt Water / Orielton Lagoon	PWO1	8040	42.79652	147.54655
	PWO2	8041	42.8039	147.48845
	PWO3	8042	42.80665	147.52641
	PWO4	8043	42.81633	147.55109
	PWO5	8044	42.83075	147.60329
North West Bay	NWB1	8033	43.02388	147.27094
	NWB2	8034	43.02594	147.28079
	NWB3	8035	43.01976	147.28443
	NWB4	8036	43.05108	147.30623
	NWB5	8037	43.05129	147.28551
	NWB6	8038	43.03934	147.27582
	NWB7	8039	43.05485	147.27002
Port Cygnet	PC1	8027	43.16302	147.08235
	PC2	8028	43.16421	147.08315
	PC3	8029	43.16465	147.08029
	PC4	8030	43.17827	147.08626
	PC5	8031	43.19081	147.08986
	PC6	8032	43.19997	147.08479
Little Swanport	LSP1		42.3112205	148.023749
	LSP2		42.310352	147.993781
	RackC2/C4		42.317106	147.984829
	LSP3		42.324127	147.978189
	LSP4		42.335331	147.963120
	LSP5		42.334346	147.937931

Indicators

The indicators we have selected aim to assess the condition and trends in estuarine and coastal waters, meet NRM reporting requirements in Tasmania and contribute towards developing trigger levels for estuarine condition parameters specific to Tasmania. The methodology for monitoring each indicator has been described in a report (Crawford 2006, available at http://eprints.utas.edu.au/view/authors/Crawford,_C.html) that provides information from a user's perspective on monitoring each indicator in Tasmania. The monitoring methods were selected using indicators developed and evaluated by the Tasmanian Coastal, Estuarine and Marine Indicators Working Group (Mount 2006), which examined the nationally agreed coastal, estuarine and marine condition indicators (Scheltinga *et al.* 2004) for their suitability for monitoring the condition of representative coastal, estuarine and marine environments in Tasmania.

The indicators examined for this study were:

- Salinity (ppt)
- Water temperature (^{o}C)
- Dissolved Oxygen (DO) (% Saturation)
- Turbidity (NTU)
- pH
- Dissolved nutrients – ammonia (NH_4 mg/L), nitrate and nitrite (NOx mg/L), and reactive phosphorus (P mg/L), silica, molybdate reactive (mg/L)
- Chlorophyll a
- Animal/plant species abundance - Benthic macroinvertebrates
- Extent/distribution of key habitat types
- Pathogens

Equipment

The indicators outlined above were examined between April 2007 and April 2008 at monthly intervals. The time of sampling (AEST) was recorded at each site. Meters (Table 2) were calibrated at least once in the month prior to sampling.

Table 2. Equipment (field probes) used to monitor water quality in this baseline study.

Indicator	Equipment
Turbidity (NTU)	HACH 2100P Turbidimeter
Salinity (ppt)	WTW Cond 315i
Temperature (^{o}C)	WTW Cond 315i
Dissolved oxygen (% Saturation)	TPS WP-82Y
pH	pHep Hanna waterproof HI98128

Salinity, temperature and dissolved oxygen profiles

The combination of tidal effects and inflow of freshwater can lead to stratification in estuaries and coastal water bodies. Stratification occurs when freshwater, which is less dense than seawater, flows seaward over a layer of salt or brackish water, which moves up and down the estuary with the tides (i.e. a salt wedge). In these cases, surface waters have quite different properties from deeper waters because they come from different sources and it is therefore important to take samples at multiple depths. In addition, point source discharges (industrial or municipal) often occur at depth, and may not be fully quantified in surface samples.

Stratification can cause underlying waters to become isolated from oxygenation processes such as surface water exchange or photosynthesis. They can become very low in dissolved oxygen (hypoxic) and therefore harmful to many organisms. However, many shallow estuaries are well mixed by tidal currents and wind resulting in uniform salinity through the water column. This uniformity tends to decrease near the source of freshwater.

Temperature, salinity and dissolved oxygen were measured monthly at every site (see Fig 2-6) at 1 m intervals from the surface (0 m) to the bottom of the water column, allowing the construction of vertical profiles. The exact depth of each profile was recorded where the bottom did not fall exactly on a 1 m interval.

Salinity is a measure of the proportion of salt present in the water. Seawater is measured as parts per thousand (ppt). It is an indicator used to understand the hydrodynamics and mixing processes occurring in an estuary as freshwater mixes with seawater. Salinity is also an important factor in the ecology of an estuary as many organisms can only survive within a limited salinity range. It is a key indicator affected by environmental flows into estuaries. Salinity varies considerably within and between estuaries due to climate (rainfall), tides and freshwater flow regimes. Monitoring baseline salinity profiles can help us to understand the hydrodynamics of an estuary. In the longer term, changes in salinity profiles can be associated with climate change (e.g. rainfall/ocean circulation), changes to environmental flows (e.g. floods, barriers/dams, water extraction), groundwater flow or artificial freshwater input (e.g. stormwater/industrial discharge) (Mount 2006).

Water temperature (^{o}C) within an estuary is strongly influenced by the natural climatic influence of the seasons. A baseline of temperature data is required so long-term changes can be detected, and because water temperature is a key factor controlling the rate of biological processes. Water temperature may respond to changing freshwater flow regimes and hydrodynamics, climate change and/or changed industrial/municipal discharge (e.g. discharge of heated or cooled effluent) (Mount 2006).

Dissolved Oxygen (DO) is a useful measure of ecosystem health, as it refers to the amount of soluble oxygen contained in water that is available to aerobic (oxygen-requiring) organisms. It can be measured as mg/L or %Saturation. Oxygen is exchanged between the atmosphere and the surface waters through degassing and aeration. Photosynthesis will also increase DO levels in the water column. Photosynthesis and atmospheric exchange occurs mostly at the surface, so bottom waters are often depleted in oxygen. This can be intensified by stratification of the water column, which is common in estuaries and which can isolate bottom waters from oxygen-rich surface waters, resulting in anoxic or hypoxic conditions. DO is removed from the system by aquatic animals through aerobic respiration, abiotic oxidation and nitrification processes. Natural processes such as climate, tides and decomposition of organic matter can result in decreased DO levels, but decreased DO can also be caused by pollution from increased organic load and bacterial activity (Mount 2006). Increased organic load may be a result of pollution from sewage treatment plants (STPs), industry, organic runoff and/or dumping of organic matter.

Turbidity and pH

Turbidity is a measure of the amount of suspended material in the water column, or water clarity/murkiness. This can be caused by particulate matter, such as silt, and biological matter, suspended in the water column. The ANZECC Water Quality Guidelines (2000) and the Tasmanian Indicator Compendium (Mount 2006) recommend monitoring turbidity because increased turbidity levels can indicate changing hydrodynamics, removal/disturbance of habitat, algal blooms, erosion, wastewater discharge or changed freshwater flow regimes (Mount 2006). In addition, turbidity is a relatively inexpensive and simple indicator to monitor. Increased turbidity may be a symptom of siltation and/or increased contaminant loads. It can affect productivity in an estuary due to the reduction of available light for photosynthesis, and, potentially, the depletion of DO.

pH is a measure of acidity or alkalinity of water on a log scale from 0 (acidic) through 7 (neutral) to 14 (alkaline). Most coastal, estuarine and marine organisms prefer a pH in the range of 7-8.5. pH is generally relatively stable in estuarine and marine waters because of carbonate buffering. Changes in pH levels within an estuary can be caused by changed hydrodynamics (freshwater flow, tides and/or oceanic circulation), disturbance of acid sulphate soils, industrial discharge (e.g. mining) or agricultural inputs (fertilisers, lime etc). pH levels outside the natural range can cause harm to fish and shell-forming organisms, and can alter the biological availability of metals and toxicants.

pH has not been commonly measured in Tasmanian estuarine and coastal waters, and although recommended, is not considered as essential as the other physical-chemical indicators. Although pH has some limitations as an indicator of environmental health, it can provide insights into estuarine processes when supplemented with other measures (Mount 2006). Any major or sustained change to pH can be indicative of a very serious system change that requires further investigation (Mount 2006). If monitoring in relation to acid-sulphate soils it is important to measure pH immediately after rainfall events, especially the first run-off of water from likely affected acid-sulphate areas. If there is evidence of urban or industrial impacts, pH can be used successfully as a tracer of plumes or point sources.

Turbidity (NTU) and pH of surface waters were tested at every site. Three replicate samples at every site each month were taken for turbidity measurements and then averaged for graphing purposes.

Dissolved nutrients and silica

Nutrients in the water column include both organic and inorganic forms, and can be either dissolved or particulate. Dissolved inorganic nutrients (NH_4, NOx, P) are the most biologically available and thus in excess are likely to impact on estuarine and marine systems, particularly through excessive plant growth leading to eutrophication. Nitrogen and phosphorus are cycled through the environment through chemical and biological processes and are essential for plant and animal growth. Nutrient concentrations can be influenced by freshwater flow or tidal flushing, increased runoff and increased pollution from terrestrial sources or aquaculture (Mount 2006). Nutrients can also be introduced to a system from influxes of nutrient-rich waters from the continental shelf and the Southern Ocean. Ammonia (NH_4) and nitrate plus nitrite (NOx) are generally naturally higher in Tasmanian estuaries than those in mainland Australia.

Although silica is a mineral, it is often considered to be a dissolved nutrient in estuarine monitoring due to its biological importance in some marine organisms (diatoms). This often results in low concentrations occurring in surface waters. Due to weathering of silicate minerals, freshwater/riverine concentrations of silica are often much higher than oceanic concentrations.

Dissolved nutrients (ammonia, nitrate plus nitrite (NOx) and soluble reactive phosphorous) and silica were sampled monthly from surface waters at key sites within each estuary (see Sampling Regime, page 18). Bottles, syringes and filters were supplied by Analytical Services Tasmania (AST). Samples were kept on ice until returning to the Marine Research Laboratories (MRL) where the silica samples were refrigerated and the dissolved nutrient samples were frozen until they were transferred to AST for analysis within a week of collection. Ammonia, nitrate plus nitrite, dissolved reactive phosphorous and silica were quantified by AST at their NATA-accredited laboratory using the APHA Method 4500.

If sufficient funding is available in the future, and information is required on nutrient loads from rivers into estuaries, total nitrogen (TN) and total phosphorous (TP) should also be monitored.

Chlorophyll a

Chlorophyll a is the green pigment found in plants, which absorbs sunlight and converts it to sugar during photosynthesis (OzEstuaries 2003). Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomasss in coastal and estuarine waters (OzEstuaries 2003). Long-term persistence of high chlorophyll a levels indicates a problem in the system such as high nutrient loading and eutrophication. Chlorophyll a concentrations are often higher after rainfall (due to increased runoff and availability of nutrients) and during summer when the water is warmer and there is more light availability (OzEstuaries 2003). Tidal flushing is an important control on algal blooms, as strong mixing decreases the residence time in the system (OzEstuaries 2003).

One litre of water was taken from just below the surface at key sites within each estuary (see Sampling Regime, page 18) for chlorophyll a analysis at the Marine Research Laboratories (MRL), TAFI. Samples were transported to the MRL on ice where the sample was filtered through Whatman GF/C glass microfibre filters, recording the total volume of water filtered. The filters were folded, wrapped carefully in aluminium foil and frozen until analysis could be completed.

Frozen filters were cut into small pieces and added to 10 mL of 90% acetone solution. The filter papers were then macerated in solution for approximately 10 seconds each using a cell disruptor. Tubes were then covered in aluminium foil to block out light and placed in a refrigerator for 12 hours. Tubes were then centrifuged for 15 minutes at 4 500 rpm. Extract was transferred into a glass 1 cm cuvet cell and placed into a Cintra 10 e spectrophotometer.

Absorbance readings were taken at 630 nm, 647 nm, 664 nm and 750 nm with three replicate readings for every sample. These replicates were averaged to give the sample reading and the % standard deviation using the Cintra software package. Chlorophyll a levels were then determined using the Golterman and Clymo equation – see http://dipin.kent.edu/chlorophyll.htm.

Benthic macroinvertebrates

Animal and plant species abundance is an important measure of estuarine health and water quality. This is because physical and chemical measures of water quality can vary rapidly (within 24 hours) by an order of magnitude or more due to changing environmental conditions, such as tidal fluctuations, climate or flooding into an estuary. By contrast, animal and plant species abundance generally does not change so rapidly and is therefore a better indicator of environmental conditions over time.

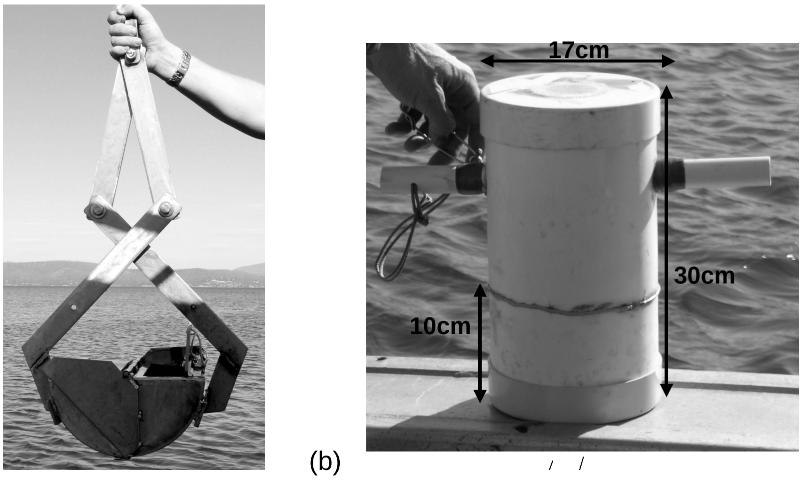
Benthic macroinvertebrates are typically the preferred biological community to monitor because they are:

- relatively sedentary and therefore exposed to pollution (e.g. organic and chemical contaminants) and other adverse conditions (e.g. low dissolved oxygen concentrations) in their immediate environment,
- widespread, occurring in all soft sediment environments,
- relatively long-lived (months-years) and therefore reflect longer-term conditions in an estuary (rather than only reflecting the conditions at the time of sampling), and
- relatively easy to sample (Hirst and Kilpatrick 2007).

Many water quality parameters, such as temperature, salinity, nutrients, chlorophyll-a, dissolved oxygen, turbidity, pH and pathogens can change rapidly (e.g. within minutes during and after a flash flood), seasonally due to seasonal changes in climate, annually due to climate change, and over decades due to changes in land use patterns. Changes to benthic macroinvertebrate communities can therefore be an important indicator of ecosystem degradation. However, they are time consuming to process and require specific expertise; therefore are a relatively expensive indicator to monitor.

Standard methodology has been developed by TAFI for the assessment of estuarine invertebrate fauna, which has been used in numerous studies on the impacts of salmon and shellfish farms on the environment and the condition and conservation status of Tasmanian estuaries (e.g. Edgar *et al.* 1999, Crawford *et al.* 2005, Macleod *et al.* 2004, Hirst *et al.* 2005, Macleod and Forbes 2006).

Sediment samples for assessment of invertebrate fauna are collected in shallow water using a hand-held 150 mm diameter PVC pipe corer (sediment depth 100 mm; sample area 0.0177 m^2) (Fig 2). In deeper water sediment samples are collected either by a diver using the PVC pipe corer or from a boat using a Van Veen Grab (sampling area 0.05 – 0.1 m^2).



(a) (b)

Figure 2. Sediment sampling equipment a) Van Veen grab in closed position, b) PVC pipe corer showing dimensions. From Macleod and Forbes (2006).

Five replicate cores were taken from each of the key sites within each estuary during Spring 2007 (see Sampling Regime, page 18). Two methods were utilised for sampling benthic macroinvertebrates. At shallow sites, five sediment cores were collected from 0.5 m depth using a benthic corer (150 mm diameter, 100 mm deep), whereas at the deeper sites, five benthic grab samples were collected using a Van Veen grab. Sediment samples were washed through a 1 mm mesh sieve and the material retained was collected and stored in 10% formalin/seawater solution for a minimum of 48 hours to ensure complete fixation. It was then stored in 70% alcohol.

Invertebrates were sorted and identified to the lowest possible taxonomic level and each taxa counted by staff at the MRL, TAFI. Results of the benthic macroinvertebrate survey completed during Spring 2007 will be released in a supplementary report in late 2008.

Extent/distribution of key habitat types

The health of estuaries and coastal waters depends on the maintenance of a diverse range of habitats. Healthy habitats promote biodiversity and improve the recreational, commercial, tourism and conservation value of an estuary. Habitat loss is caused by a variety of human activities including construction of marine facilities (roads, jetties etc), reclamation, urbanisation, dredging, trawling, aquaculture, tourism and unregulated recreational activities.

The Tasmanian Aquaculture and Fisheries Institute (TAFI) has developed the SEAMAP Tasmania Program to map coastal waters to 40 m depth, and is progressively mapping estuaries and inshore waters around Tasmania. Habitats mapped by SEAMAP Tasmania include different sediment types of sand, mud, reef, gravel and seagrass, and macroalgal beds. The method used by TAFI includes aerial photography (including purpose-flown aerial surveys if necessary), satellite imagery and acoustic surveys using a single beam echo sounder or sidescan sonar, and ground-truthing using video photography. Details of the TAFI SEAMAP Tasmania project and the habitat maps prepared by TAFI are available at http://thelist.tas.gov.au/asdd/ANZTA0025000006.html.

It is recommended that habitat types be mapped and updated every 5 years.

Pathogens

Pathogens are organisms such as bacteria, viruses, protozoans or fungi that cause disease in human and estuarine/marine organisms. Exposure to pathogens can occur in several ways, either directly through physical contact or indirectly through consumption of contaminated organisms such as shellfish. Total coliforms, themotolerant coliform bacteria, *E. coli*, and enterococci are used as indicators of pathogens. The main sources of pathogens are warm-blooded animals, including humans. These pathogens can be concentrated in sewage and storm water overflows, and in areas receiving animal wastes, such as downstream of intensive dairy farming.

There are two main sources of pathogen data in Tasmania:

- the Tasmanian Shellfish Quality Assurance Program (TSQAP), which has been monitoring thermotolerant coliforms in shellfish-growing waters for many years to assess whether the shellfish are safe for human consumption, and
- local councils who monitor recreational waterways to assess safety for primary contact, especially over the warmer months.

Additional indicators

There are some data gaps that remain in this monitoring program and it is recommended that these be addressed in the future if resources become available. Additional indicators could include:

- Invasive species
- Algal blooms/biomass
- Mass mortalities
- Toxicants
- Shoreline position
- Litter

Methodology and descriptions for these indicators is described in the Tasmanian Indicator Compendium (Mount 2006), and in the user guides by Scheltinga *et al.* (2004) and Crawford (2006).

Sampling Regime

All five locations were monitored monthly from April 2007-April 2008. However, in the future, water quality should also be monitored during and after flood events as this is now recognised as being increasingly important to understanding how an estuary functions and the impact of land use patterns on estuarine health. More robust indicators are generally monitored less frequently (e.g. animal and plant species abundance are often monitored in Spring and Autumn, while habitat extent is recommended to be mapped every 5 years).

Some estuarine environmental variables vary significantly according to the stage of the tide. It is therefore important to monitor at the same stage of the tide each time. A commonly accepted practice is to monitor water column variables during the outgoing tide and preferably as close to slack low tide as possible. Any nutrients or contaminants entering an estuary in inflowing freshwater are likely to be most concentrated at low tide and thus more readily detected. However, to better understand how estuaries are functioning, it is important to have some data collected over a full tidal cycle. This should be a component of the baseline assessment and should be repeated occasionally during ongoing monitoring.

Sampling for this study was conducted on an outgoing tide, wherever feasible. Tidal phase and time were recorded as recommended by the Derwent Estuary Program and TSQAP (pers comm. Christine Coughanowr and Alison Turnbull). The systems monitored in the Southern NRM Region were microtidal. Sampling on an outgoing low tide is especially important for macrotidal systems.

Safe monitoring methods are of utmost importance as the estuarine and inshore water environments are renowned for their unpredictability and rapidly changing conditions. Rogue waves, rapidly changing tides, changes in sea condition from calm to crashing waves, partially submerged floating objects and sudden changes in water depth are not uncommon in estuaries. Thus it is essential that monitoring in estuaries is never conducted alone and a constant eye is kept on the weather and surrounding conditions. Personal flotation devices must also be worn at all times when sampling from a boat or in streams. Sampling for this study was conducted from a small boat or by wading if sites were inaccessible by boat. Some sites (within North West Bay and Moulting Lagoon) were inaccessible during months of rough weather.

Moulting Lagoon / Great Swanport

Six sites were monitored at Great Swanport and Moulting Lagoon (Fig 3). At least four of these are accessible from the shore (with care due to strong currents at Swanwick, and deep silt in the Lagoon itself) and therefore have the potential to be monitored during flood events. The remaining two sites are based adjacent to the Swan River entrance and Long Point (possible access via 4WD on Swanwick site). Three of these sites correspond with the sites examined by Murphy *et al.* (2003).

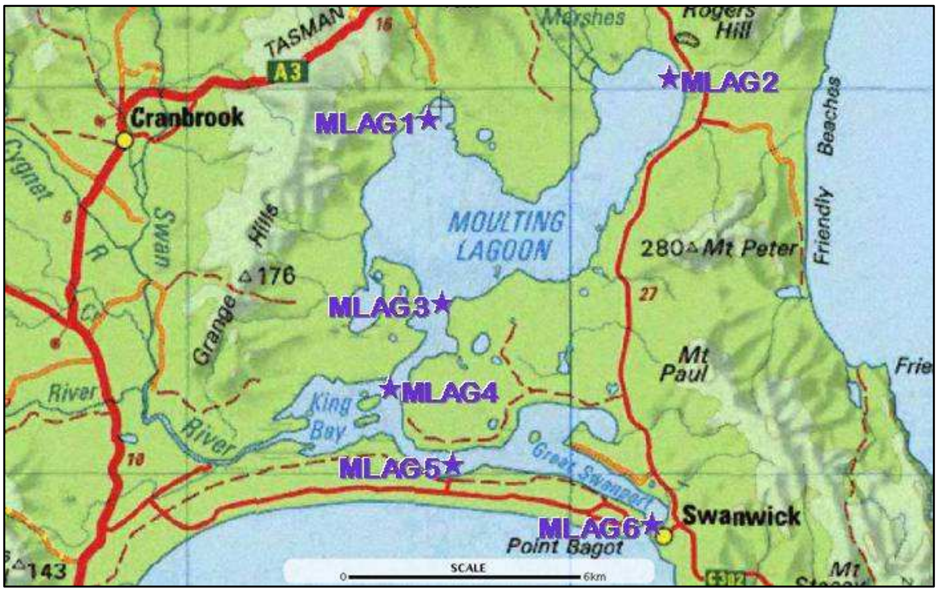


Figure 3. The monitoring sites in Moulting Lagoon and Great Swanport.

Access to sites in Moulting Lagoon is difficult – regular boat access is not possible due to the shallow nature of the Lagoon and the presence of *Ruppia* sp. Access via the shore is also difficult due to the size of the lagoon (large distances between access points), silty sediment (dangerous in parts for wading) and sensitive habitats (e.g. Apsley Marshes). Sites can be accessed via the shore, but due care must be taken at all times.

The sampling regime trialled was:

- Monitor monthly at outgoing low tide where feasible; where not feasible, record tidal phase
- Temperature, pH, DO, salinity, and turbidity were monitored monthly at all five sites (MLAG1-MLG6)
- Dissolved nitrate+nitrite, dissolved ammonia, dissolved, reactive phosphorous, silica and chlorophyll a were monitored monthly at four of these sites (MLAG1-2, MLAG4, and MLAG6).
- Macroinvertebrates were monitored during spring at four of these sites (MLAG1-2, MLAG4, and MLAG6).

Little Swanport

Little Swanport is unique in that some baseline water quality information is already available and monitoring is ongoing (e.g. TSQAP, TAFI, DPIW). Since very little (if any) additional monitoring was required, the CERCA baseline study focused on the collation of information (Fig 4a and 4b). The water quality information recorded during 2007-2008 includes salinity (ppt), temperature (^{o}C), pH, turbidity (NTU), dissolved nitrate+nitrite, dissolved ammonia, dissolved, reactive phosphorous, silica and chlorophyll a, which were measured at site “Rack C2/C4”. Past data is available for sites LSP1-5 (Fig 4). TSQAP also record temperature, salinity and thermotolerant coliforms at 6 sites (L.Swan1-2, L.Swan7-10).

DPIW monitor stream-flow and water quality information at 4-6 weekly intervals at two stations within the Little Swanport catchment. Data were collated for the site 3 km upstream from the tasman highway bridge and approximately 150 m downstream from the old Little Swanport River weir (Station 2235) for comparison with the sites within the estuary (Fig 16).

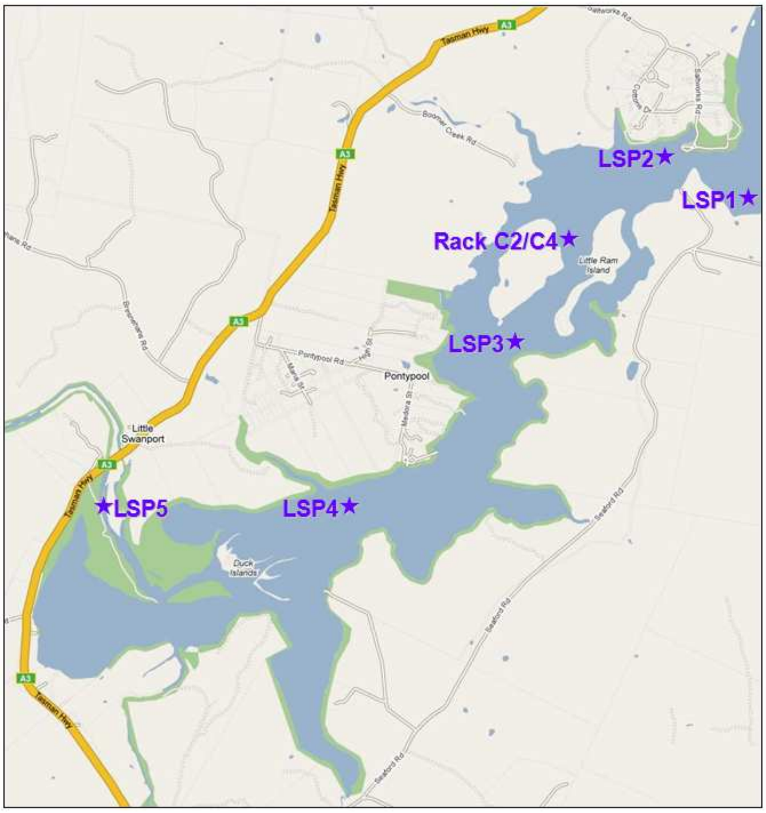


Figure 4a. The TAFI/DPIW long-term monitoring sites at Little Swanport.

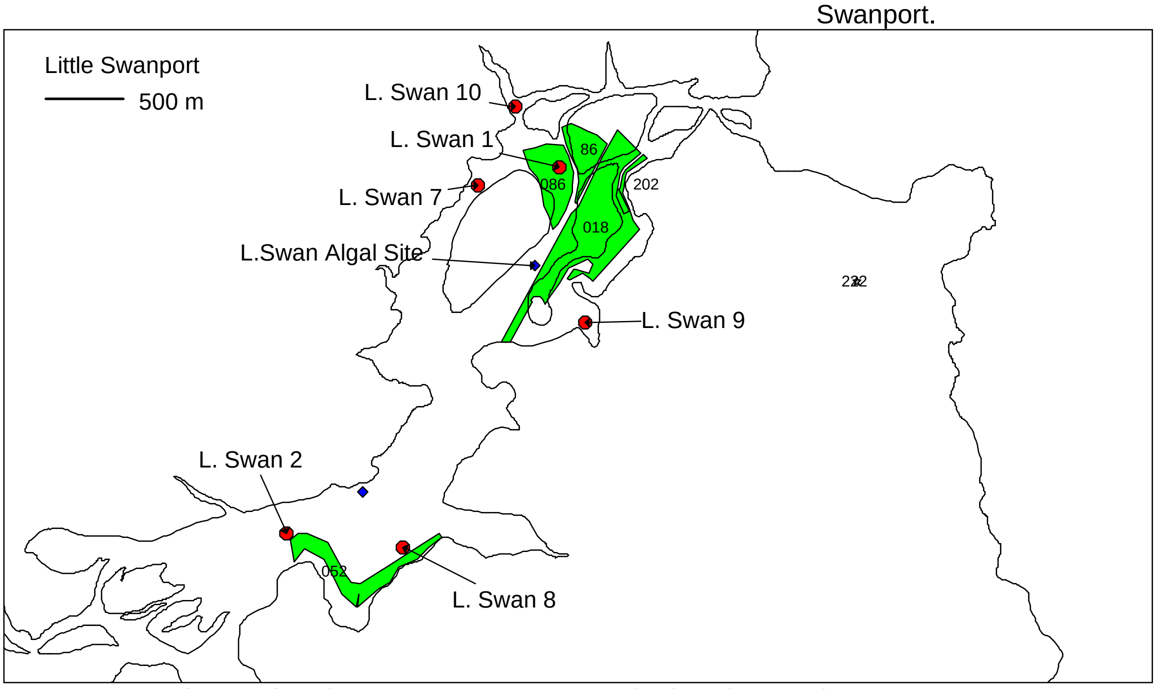


Figure 4b. The TSQAP long-term monitoring sites at Little Swanport.

Pitt Water / Orielton

Five sites were monitored at Pitt Water and Orielton Lagoon (Fig 5). Three of these are accessible from the shore (bridges/causeway/jetty) and therefore have the potential to be monitored safely during flood events. The remaining two sites are based adjacent to Barilla Bay and Woody Island. Three of these sites correspond well with the sites examined by Crawford and Mitchell (1999).

The sampling regime was:

- Monitor monthly at outgoing low tide where feasible; where not feasible, record tidal phase
- Temperature, pH, DO, salinity, and turbidity were monitored monthly at all five sites (PWO1-PWO5)
- Dissolved nitrate+nitrite, dissolved ammonia, dissolved, reactive phosphorous, silica and chlorophyll a were monitored monthly at three of these sites (PWO1-3).
- Macroinvertebrates were monitored during spring at three of these sites (PWO1-3).

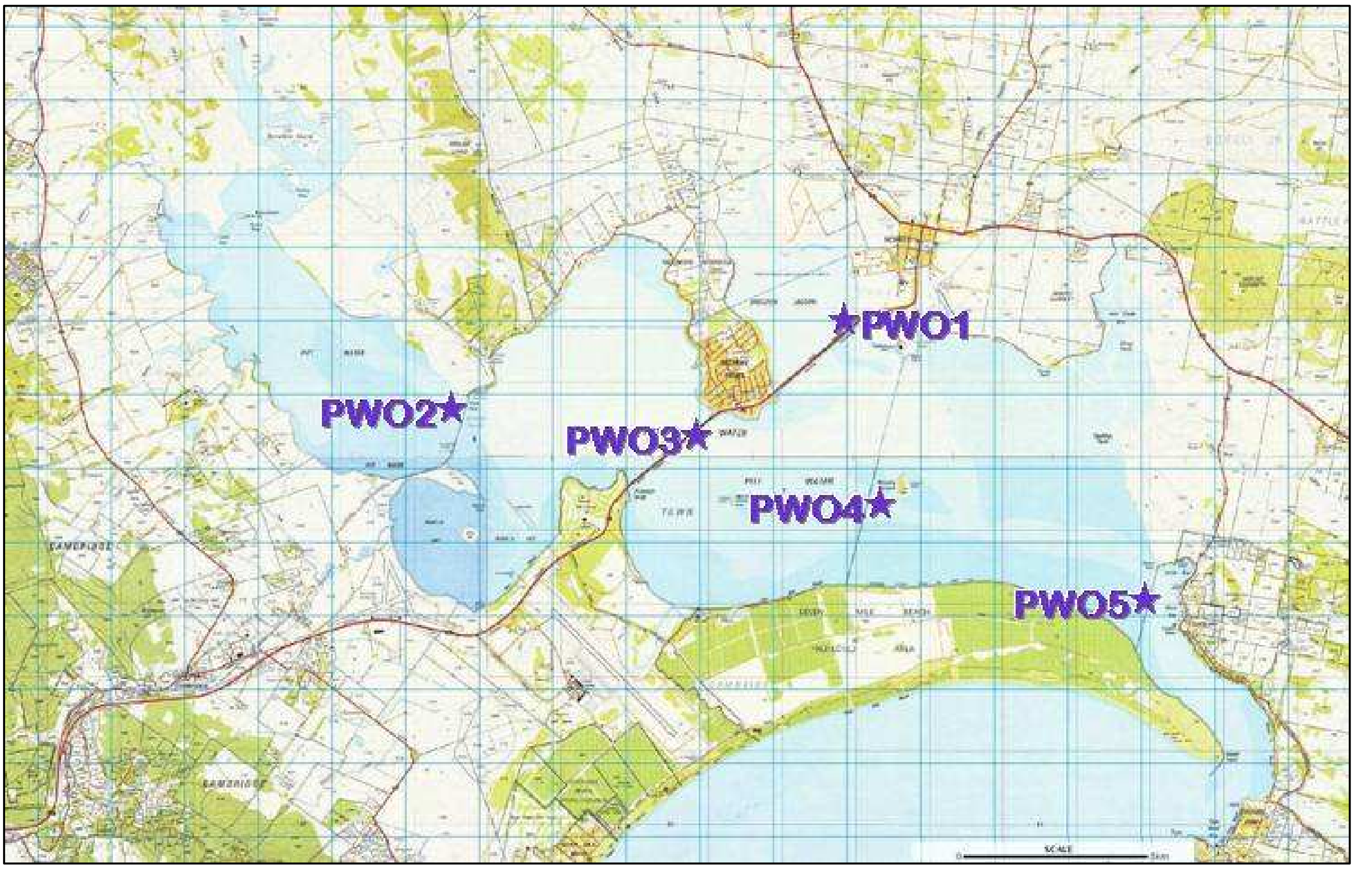


Figure 5. The monitoring sites in Pitt Water and Orielton Lagoon.

North West Bay

Seven sites were monitored at North West Bay (Fig 6), four of which correspond with the nutrient and water quality sites selected by Jordan *et al.* (2002) (Jordan *et al.*'s sites 1, 5, 6, and 7). A site at the mouth of the North West Bay River was also selected, as there is much community interest in the water quality and environmental flows in this river and would be a useful resource in the future. As a part of the trial, the Kingborough Council sponsored the analysis of water samples from three sites adjacent to the STP outfalls at Dru Point and Electrona as well as near the industrial premises at Barretta.

Two sites are accessible from the shore (mouth of North West Bay River and Barretta Jetty) and therefore have the potential to be monitored safely during bad weather or flood events.

Monitoring dates were coordinated with the Derwent Estuary Program (DEP) where possible.

The sampling regime was:

- Monitor monthly at outgoing low tide where feasible; where not feasible, record tidal phase
- Temperature, pH, DO, salinity, and turbidity were monitored monthly at all seven sites (NWB1-NWB7)
- Dissolved nitrate+nitrite, dissolved ammonia, dissolved, reactive phosphorous, silica and chlorophyll a were monitored monthly at six of these sites (NWB1-3, NWB5-7). Three of these were sponsored by Kingborough Council.
- Macroinvertebrates were monitored during spring at four of these sites (NWB1, NWB3, NWB5, and NWB6).

Figure 6. The monitoring sites in North West Bay.

Port Cygnet

Six sites were monitored at Port Cygnet (Fig 7). Three of these are accessible from the shore (bridges/walkways) and therefore have the potential to be monitored safely during flood events (PC1-PC3). The remaining three sites (PC4-PC6) were selected to correspond with the CSIRO HES sites in the Port (CSIRO Huon Estuary Study Team 2000) and the proximity to marker buoys used by the Port Cygnet Sailing Club (PCSC).

The sampling regime was:

- Monitor monthly at outgoing low tide where feasible
- Record tidal phase and time (AEST)
- Temperature, pH, DO, salinity, and turbidity were monitored monthly at all six sites (PC1-PC6)
- Dissolved nitrate+nitrite, dissolved ammonia, dissolved, reactive phosphorous, silica and chlorophyll a were monitored monthly at four of these sites (PC2, PC4, PC5 and PC6)
- Macroinvertebrates were monitored during spring at four of these sites (PC2, PC4, PC5 and PC6).

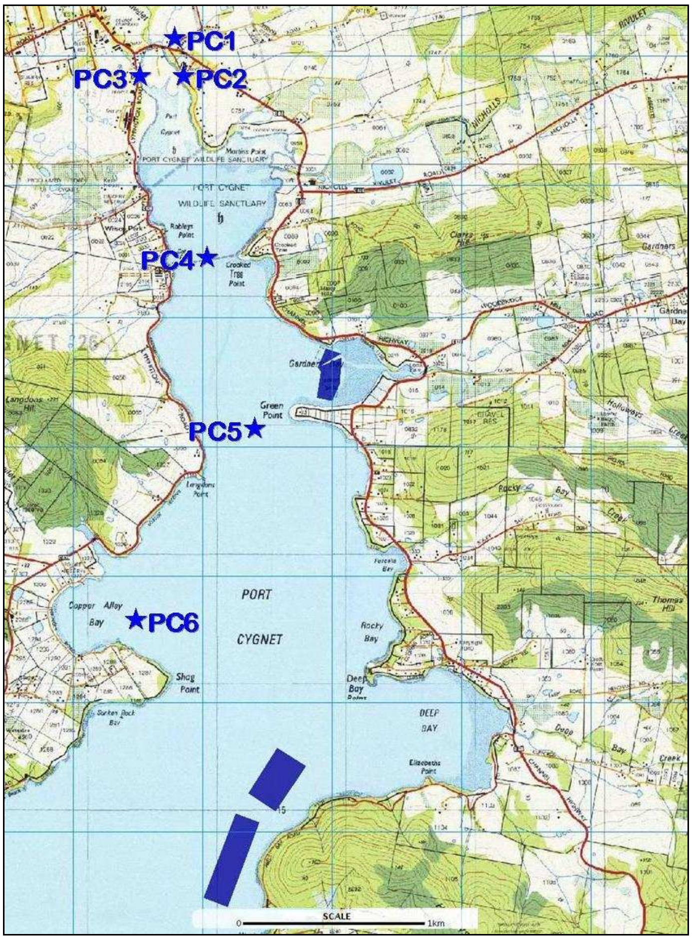
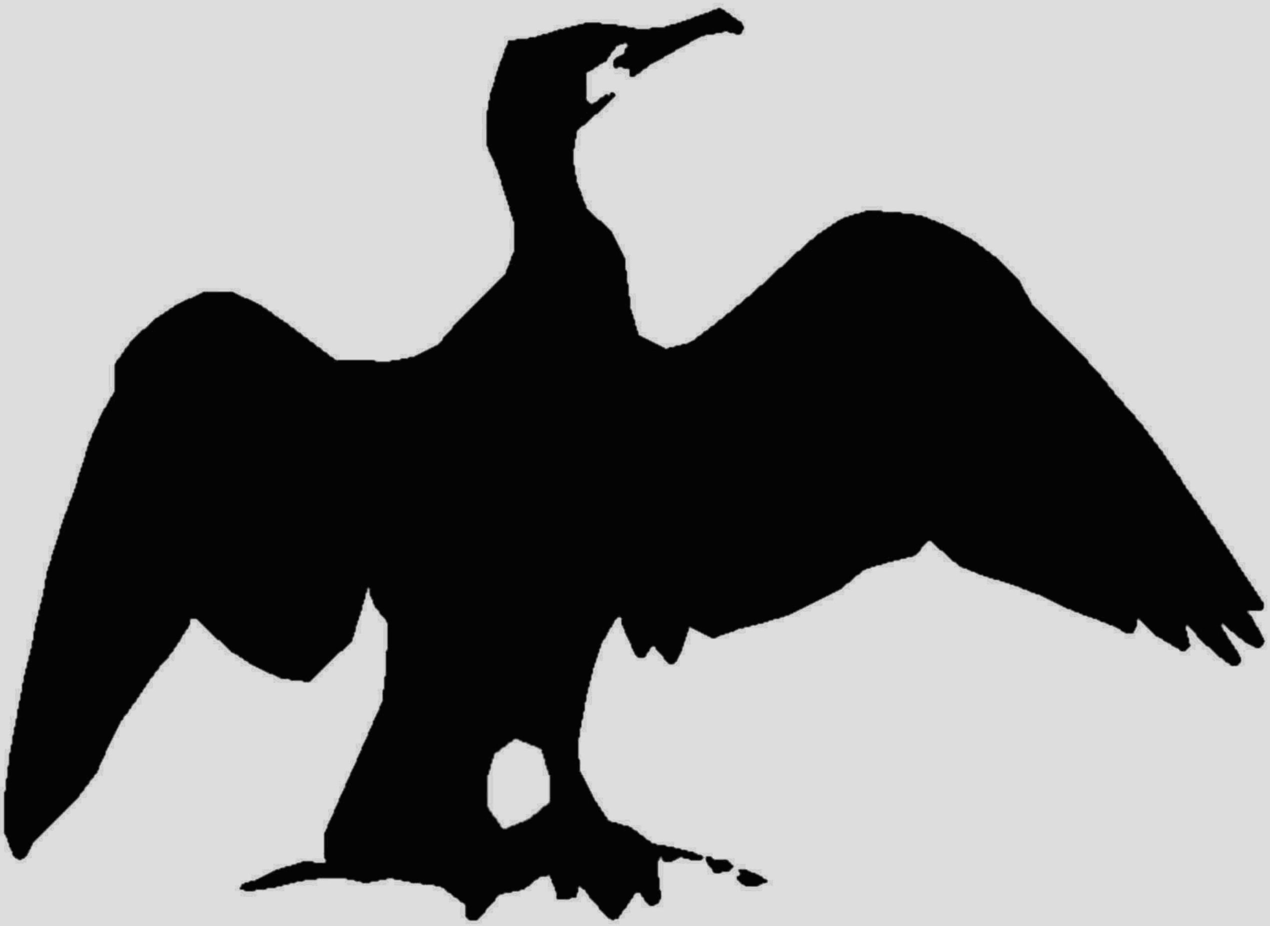


Figure 7. The monitoring sites in Port Cygnet.

Details of water quality and some biological data are provided separately for each of the 5 estuaries sampled in the following pages. This is followed by a summary of the macroinvertebrate data from each estuary and the differences between estuaries. The results are summarised and compared between estuaries in the section entitled “Management of Coastal and Estuarine Condition”.

Moulting Lagoon and Great Swanport



Location Description

The two subsystems of Moulting Lagoon and Great Swanport combine to form a large estuarine system at the base of the Swan-Apsley catchment. The Apsley River originates within the Douglas-Apsley National Park (west of Bicheno), while the headwaters of the Swan River lie within State Forest, where timber harvesting is the main activity (DPIWE 2005).

The Apsley River enters Moulting Lagoon from the North, while the Swan River enters Great Swanport from the West. Great Swanport is a very long, narrow estuary running behind a land barrier (Nine Mile Beach) and originating at the entrance of Moulting Lagoon and the mouth of the Swan River. Moulting Lagoon is a large, shallow lagoon, which was formed by the Apsley River and the inundation of the low-lying land behind Great Swanport.

The land in the lower catchment is used for sheep grazing, irrigated cropping, walnut farming and grape production. There is oyster farming in the Great Swanport area. Water for the Bicheno and Coles Bay domestic supplies is drawn from the Apsley River. The townships in this catchment are popular holiday destinations in the summer months, and water supply is a major issue due to low rainfall. The lagoon's continued conservation contributes to the economic and social wellbeing of the local community (PWS 2003). Hunting (ducks) and fishing (bream) are popular recreational pursuits in the area (PWS 2003).

Climate and tides

Moulting Lagoon / Great Swanport is located on the mid-east coast of Tasmania, which is known for its warm temperate climate and low rainfall. Rain that does fall is fairly evenly spread over the year with slight peaks in autumn and spring (Fig 8). Large volumes of freshwater episodically pass through the system, which is consistent with east coast rainfall patterns (Mount *et al.* 2005). The estuary has a very large catchment (1 031 km^2)

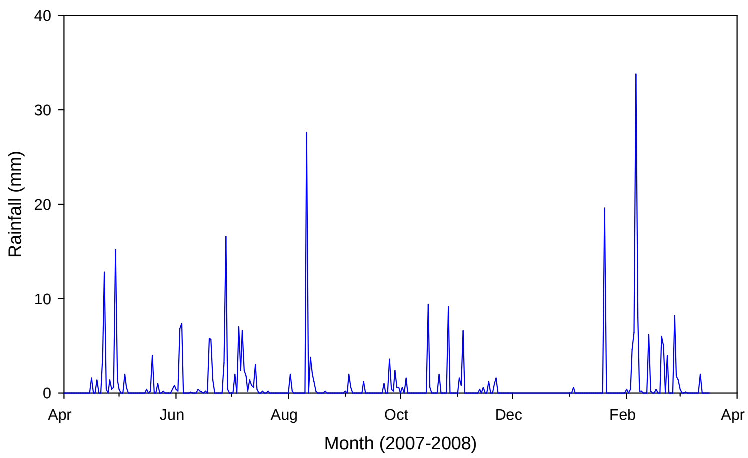


Figure 8. Rainfall recorded at Swansea during 2007-2008

The nearest meteorological station is located at Swansea, approximately 10 km south-west of the centre of the Lagoon. Bureau of Meteorology records from Swansea for the period 1957 to 2008 show that the temperature in January and February, the warmest months, range from a mean daily maximum of 22.2℃ to a mean daily minimu m of 11.7℃. In July, the coldest month, temperatur es range from a mean daily maximum of 13.3℃ to a mean daily minimum of 3.6℃ (BoM 2008).

Moulting Lagoon is a large body of shallow water, which contributes to the tidal flows through much of Great Swanport. The tidal range of the lagoon varies from 0.8 m at the mouth to 0.3 m in its upper reaches but is also dependent on wind strength and direction and barometric pressure at the time (PWS 2003).

Conservation value

Moulting Lagoon Game Reserve is one of 10 Tasmanian Ramsar sites (wetlands of international importance. Moulting Lagoon is on this list because it supports a large number of waterbirds, particularly black swans and Australian shelducks, at key stages of their lifecycles. It is a complex habitat of fragile, low-lying saltmarshes, coastal grasslands and ancient sand dunes supporting coastal woodlands. Seagrass beds cover extensive areas in the Lagoon.

Thirteen plant species found in the Moulting Lagoon area are of particular importance for conservation because of their threatened status (PWS 2003). Moulting Lagoon/Great Oyster Bay is a site of geoconservation significance, and the spit at Nine Mile Beach is one of only two mid-bay spits in Tasmania (PWS 2003).

Edgar *et al.* (1999) identified Great Swanport as being of Class B conservation significance. Class B estuaries are defined as high conservation significance, where the estuary and associated catchment area remain relatively pristine or contain an unusual range of species (Edgar *et al.* 1999). Edgar *et al.* (1999) recommends that Class B estuaries and associated catchments should be quarantined from future developments, and existing human impacts reduced wherever possible, and that aquatic biota should be protected other than from anglers using hook and line or exploitation within existing marine farm lease boundaries. The National Land and Water Resources Audit identified Great Swanport as being a near pristine, wave dominated estuary (subclass: wave estuary) (NLWRA 2002).

Extent/distribution of key habitat types

Habitat areas were surveyed in Great Swanport in 2005 and in Moulting Lagoon in 2006 by SEAMAP Tasmania (TAFI). Moulting Lagoon / Great Swanport is well covered with aquatic macrophytes including dense seagrass (Mount *et al.* 2005). Great Swanport is an open estuary (Edgar *et al.* 1999) with a distinct channel of 2-3 m depth occurring towards the mouth at Swanwick (Murphy *et al.* 2003). Within Moulting Lagoon, the upper reaches of Great Swanport and on either side of the main channel, the estuary is relatively shallow, being less than 1 m at low tide. In Great Swanport, *Heterozostera tasmanica*, *Zostera muelleri* and *Ruppia megacarpa* are common (Mount *et al.* 2005), while Moulting Lagoon is dominated almost exclusively by *Ruppia megacarpa* (Fig 9).

There is anecdotal evidence that habitats in Moulting Lagoon have changed over time due to siltation. It is reported that Sherbourne Bay was once deeper, dominated by hard sand and supported a recreational flounder fishery. Moulting Lagoon’s sensitivity to sedimentation requires further investigation and changes to seagrass distribution require ongoing monitoring.

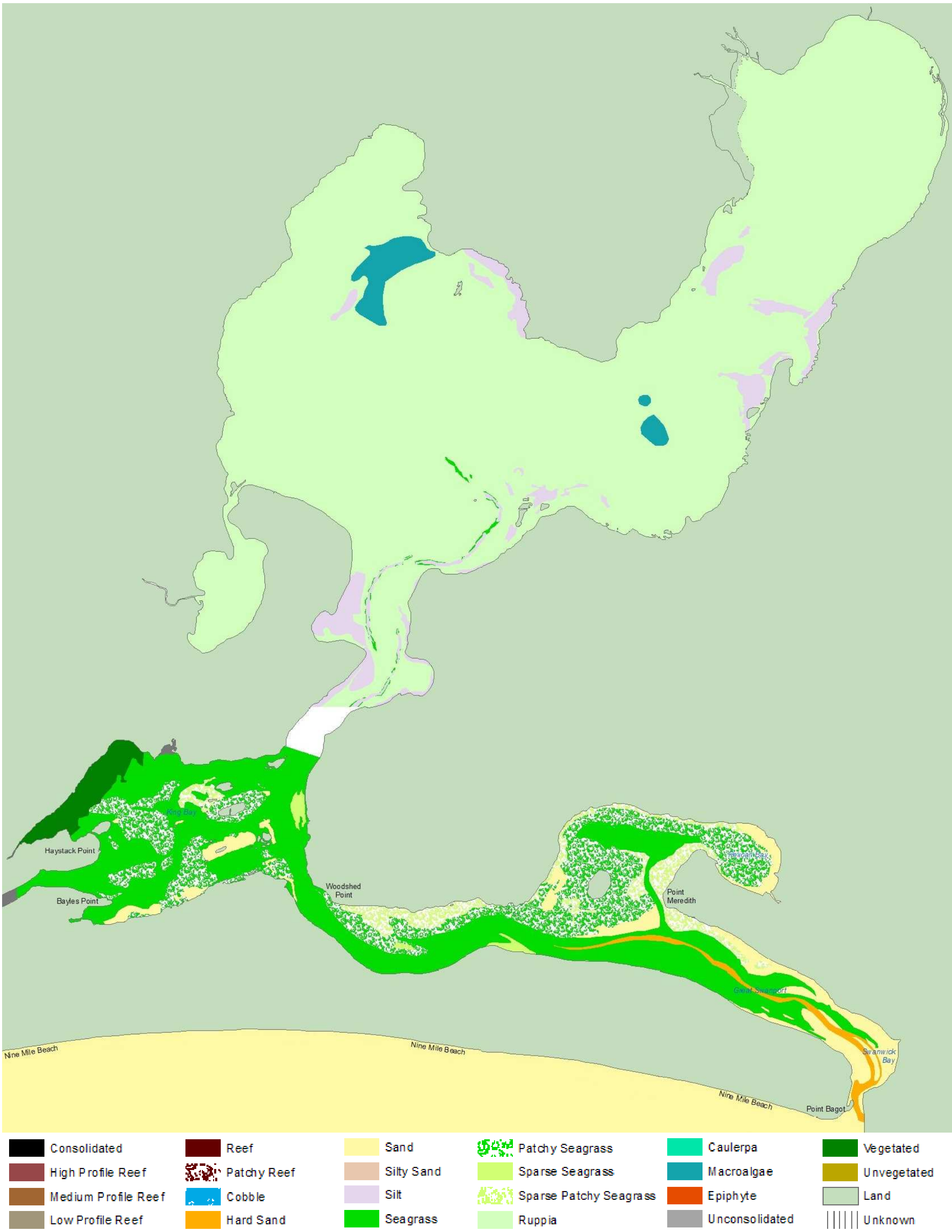


Figure 9. The habitat types in Moulting Lagoon and Great Swanport (SEAMAP Tasmania, TAFI).

Freshwater flows and water allocation

The Water Assessment Branch of DPIW has river flow gauges upstream of the Moulting Lagoon and Great Swanport estuary in the Swan/Apsley catchment. Stream flow (Cumecs) at the gauge furthest downstream (towards the estuary) was graphed for both the Swan and the Apsley Rivers, alongside the salinity graphs for comparison (Fig 10).

The majority of the water allocation is for irrigation (10 835 ML), with the remainder used for stock and domestic water supply (1 669 ML) (DPIW 2007). Water is drawn from the Apsley River for the domestic supply of Bicheno and Coles Bay.

Salinity, temperature and dissolved oxygen profiles

Plots of salinity, temperature and dissolved oxygen are provided for each site over the 12 month study period (Fig 10-12).

Salinity in Moulting Lagoon and Great Swanport varied considerably over the year and was strongly influenced by river flow and climate (rainfall and temperature). Moulting Lagoon was found to be well mixed, with few occurrences of stratification in salinity (Fig 10). This is probably due to the shallow-pan nature of the lagoon (~1 m deep), allowing wind forces to drive mixing. Tides appeared very weak within Moulting Lagoon, and water levels were driven mostly by increased or reduced freshwater flow from the Apsley River (i.e. water levels higher in winter, lower in summer).

During hot and dry weather, evaporation can create salinity levels more than twice that of seawater in some areas (Blackhall 1986. Hypersaline (elevated salinity, greater than seawater) conditions were observed in Moulting Lagoon for extended periods during summer and autumn, where salinity peaked at 45.8 ppt at Sherbourne Bay (MLAG1) during January 2008.

Conversely, during periods of higher flow from the Apsley and Swan Rivers, waters in Moulting Lagoon and parts of Great Swanport became brackish and almost fresh at times. The lowest readings were recorded during July at the Apsley Marshes (MLAG2), where salinity decreased to 4.9 ppt (Fig 10). Within Great Swanport, flow events were reflected in the salinity readings, but became less of an influence for sites closer to the mouth of the estuary (MLAG6), where salinity was relatively stable (~35 ppt) throughout the year. The exception to this resulted from a high flow event from the Swan River in July 2007, which resulted in stratification of the water column. Although salinity dropped in some parts of Great Swanport during the wetter months, prominent stratification did not persist outside the high flow events of July 2007 and February 2008.

Similarly, water temperatures were generally weakly stratified across all sites, but showed a distinct seasonal trend (cooler in winter, peaking in late summer) (Fig 11). There are greater extremes of temperature observed in the upper sites due to their shallow nature and the effect of solar warming and cooling. Seasonally, temperatures in Moulting Lagoon were much higher in summer, reaching 26.3^{o}C at Sherbourne Bay (MLAG1), while the winter minimum was 4.9^{o}C at Apsley Marshes (MLAG2). In comparison, temperature variability was more moderate at the mouth of Great Swanport (MLAG6), with the summer maximum reaching 23.5^{o}C and the winter minimum falling to 9.4^{o}C.

Dissolved oxygen levels were highly variable during spring and summer at the Apsley Marshes (MLAG2), especially in bottom waters, and to a lesser extent, Sherbourne Bay (MLAG1) (Fig 12). Anoxic conditions were observed at Apsley Marshes during the summer months and coincided with a large amount of decaying organic matter (*Ruppia* and cygnet carcasses) at the site. In contrast, dissolved oxygen levels at the sites with better/higher flushing capability (i.e. Great Swanport and lower Moulting Lagoon) were relatively stable and generally remained higher than 80% Saturation, which in conjunction with healthy seagrass habitats (Fig 9) indicates good ecosystem health in the lower estuary. Further investigation into the anoxic conditions observed in Moulting Lagoon is required, but in this case, these conditions are probably a natural occurrence and a result of the annual breakdown if *Ruppia* in the Lagoon (i.e. increasing organic load and therefore bacterial activity leading to oxygen depletion). Cygnet mortality on the other hand was probably caused by the hypersaline conditions occurring in the lagoon at this time (unlike adult swans, cygnets cannot excrete excess salt) (pers comm. Blackhall 2008). This requires further investigation.

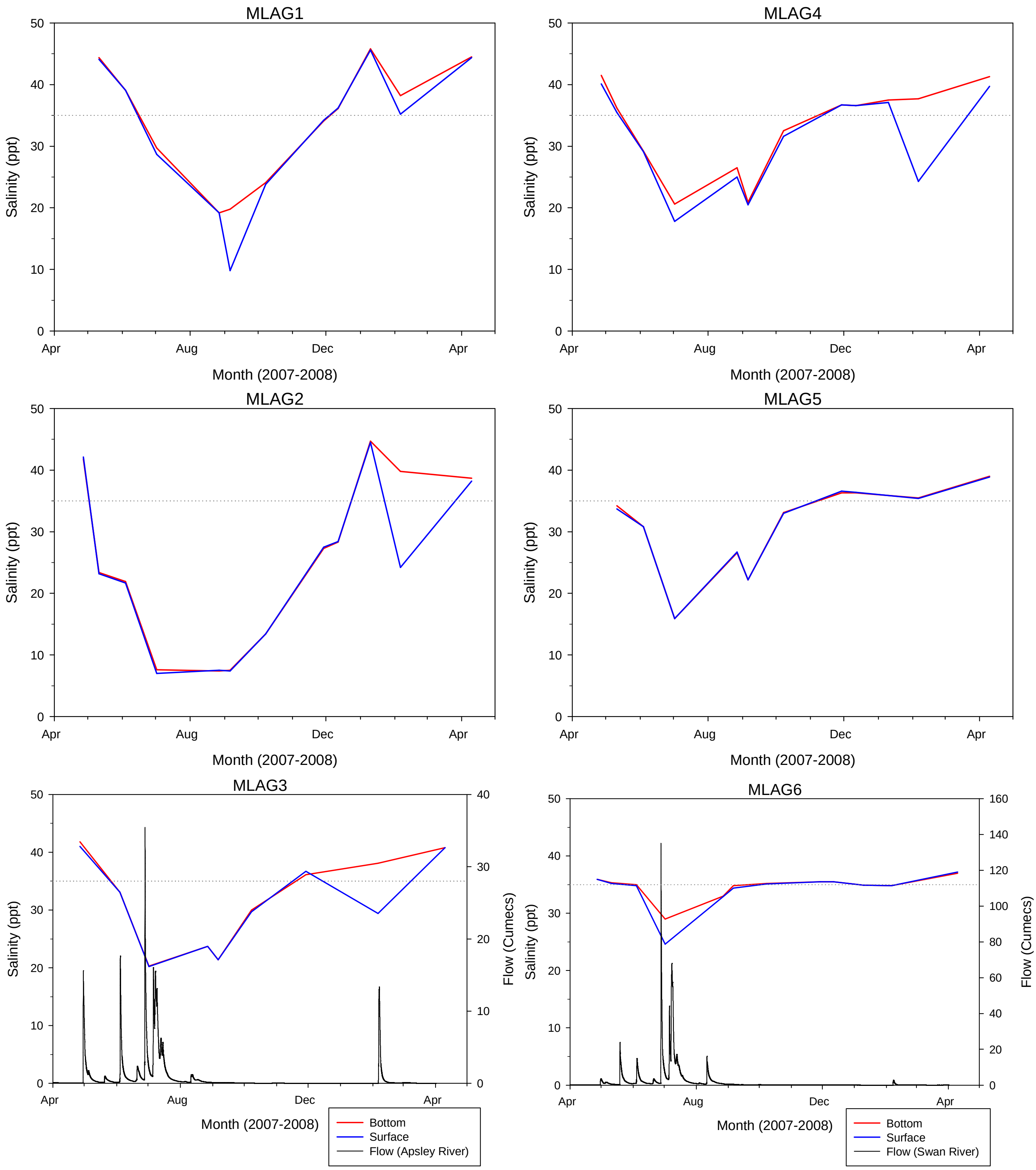


Figure 10. Annual salinity profiles in Moulting Lagoon and Great Swanport and flows from Apsley and Swan Rivers into the Lagoon.

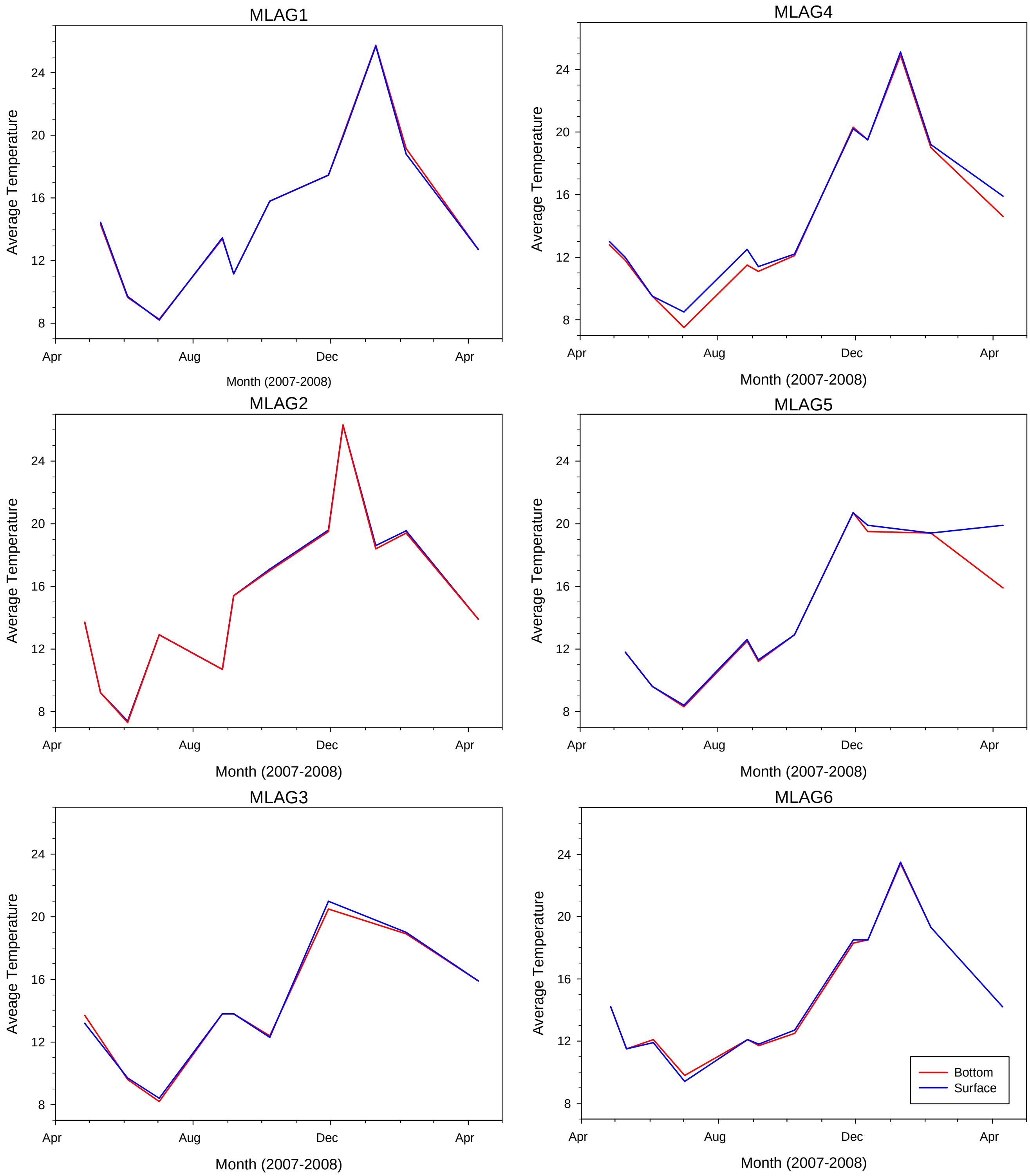


Figure 11. Annual temperature profiles in Moulting Lagoon and Great Swanport.

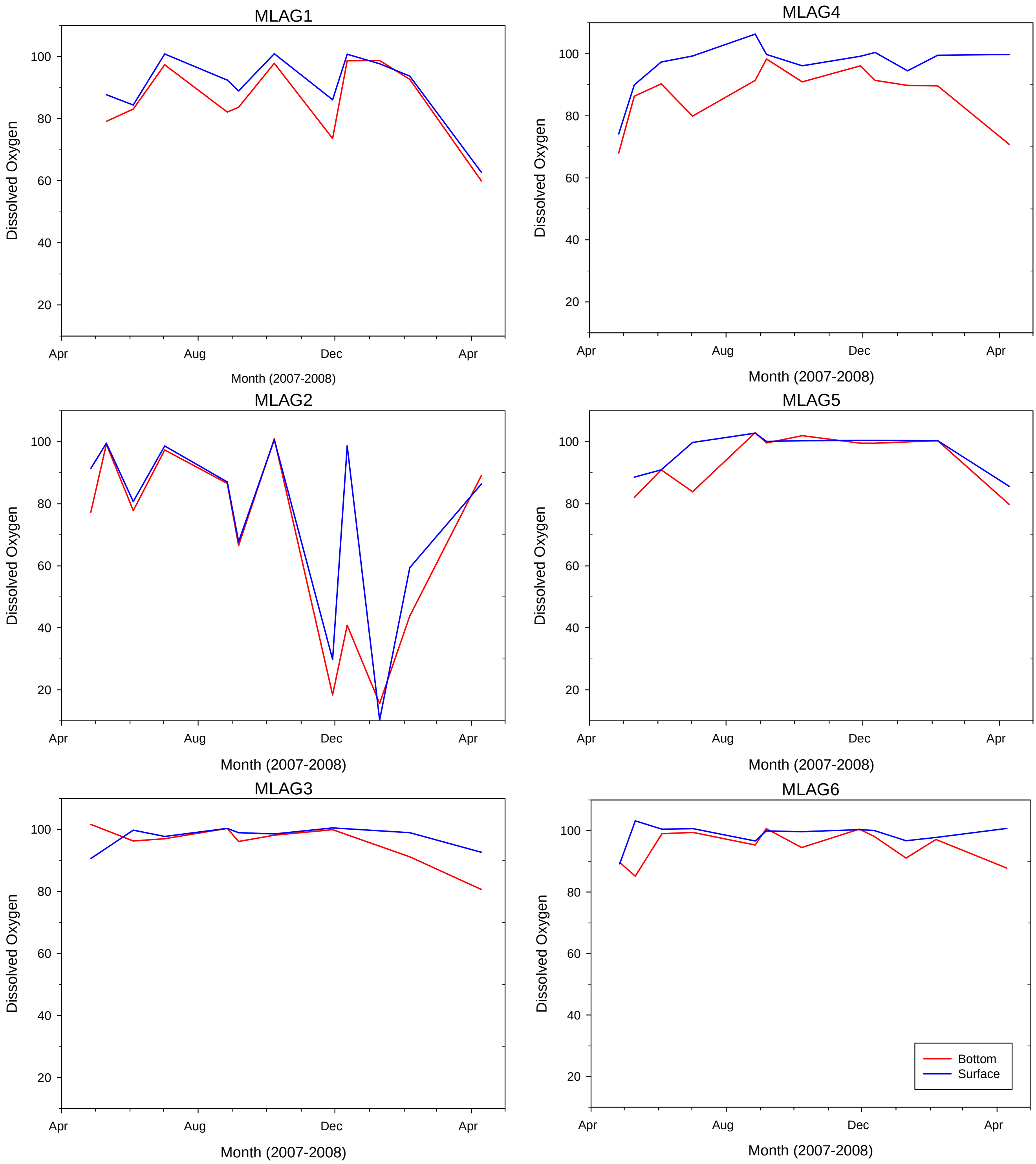


Figure 12. Annual dissolved oxygen profiles in Moulting Lagoon and Great Swanport.

Turbidity and pH

Turbidity levels at sites in Moulting Lagoon and Great Swanport were generally low (most values were <5 NTU), with the exception of the Apsley Marshes (MLAG 2) (Fig 13). Here, turbidity was considerably higher for most of the year, peaking in summer at 22.2 NTU. As discussed previously, the Apsley Marshes accumulated substantial amounts of decaying organic matter (*Ruppia* and cygnet carcasses) during the spring and summer months and this most likely had the largest influence on turbidity at this time. Along with increased organic loads and high temperatures, elevated turbidity can exacerbate dissolved oxygen depletion by reducing light availability (for photosynthesis), which is consistent with the dissolved oxygen results recorded at this site during summer. Elevated turbidity was also observed at this site during July/August, when turbidity peaked at 9.9 NTU. This was probably a result of increased suspended matter in the water column due to increased freshwater input from the Apsley River at this time.

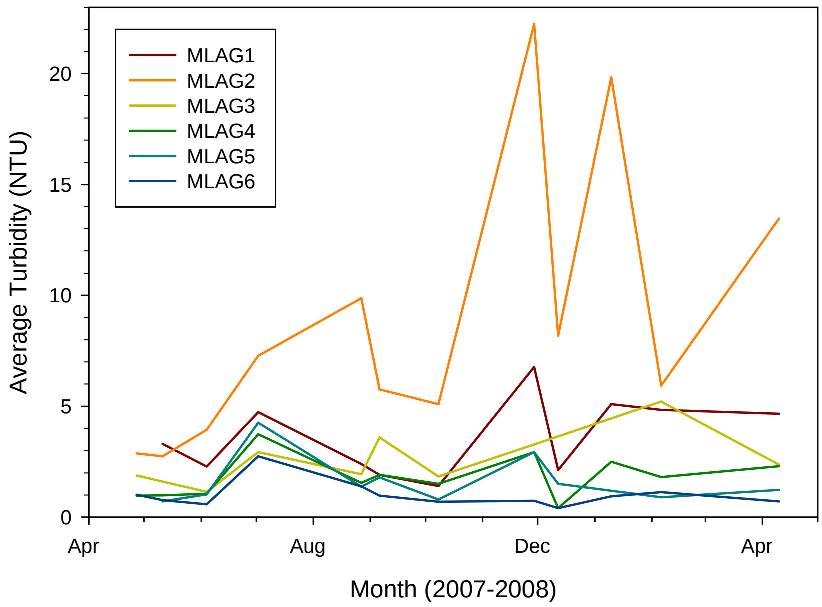


Figure 13. Annual turbidity levels in Moulting Lagoon and Great Swanport.

The pH readings in Moulting Lagoon and Great Swanport were elevated during late winter – early summer (8.2-9.5), especially at MLAG 1, and dropped to more typical seawater ranges during autumn (7.5-8.3) (Fig 14). The cause of the elevated pH levels (particularly in Moulting Lagoon) is unknown. It could be caused by fertiliser runoff (e.g. application of lime or other alkaline soil conditioners) or be due to unusual (but natural) evaporative processes.

It is important to continue monitoring pH in Moulting Lagoon as the area is known to be dominated by acid sulphate soils. If the soils are disturbed (through development, flooding or drought/extended exposure to air), this could be a significant source of pollution in the Moulting Lagoon and Great Swanport estuary (causing acidification of the water).

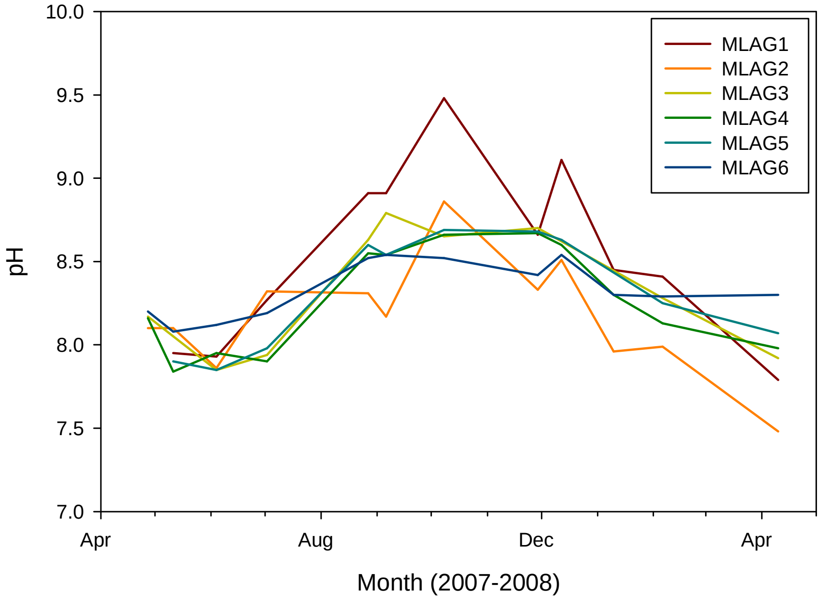


Figure 14. Annual pH readings in Moulting Lagoon and Great Swanport.

Nutrients, silica and chlorophyll a

Nitrate plus nitrite (NOx) levels were relatively stable through out the year, increasing in the Lagoon during high flow events observed in the Apsley River in July (Fig 15, but see also Fig 10 for flow information). The highest increase in NOx levels was seen at Sherbourne Bay (MLAG1), where NOx levels reached 327 µg/L, and not at the Apsley River mouth (MLAG2), where NOx levels peaked at 29 µg/L, perhaps as a result of agricultural runoff (probably in ground water as creek beds remained dry). The relationship between freshwater runoff and nutrient cycling in Moulting Lagoon is poorly understood and requires longer term investigation. Hydrodynamics may be playing a part in local concentration of nutrients, but flushing/residence of time of water within Moulting Lagoon will require further research. Water in Sherbourne Bay probably has a high residence time due to extremely low (direct) freshwater input and weak tidal exchange.

Increased freshwater flow also influenced NOx levels in Great Swanport, where elevated NOx levels were observed during high flow events at the mouth of the Swan River (MLAG4), peaking at 71 µg/L, and even at Swanwick, where tidal flushing is stronger (MLAG6) NOx levels peaked at 41 µg/L.

Ammonia levels were relatively high throughout the system, but especially in the Lagoon sites during winter (peaking at 366 µg/L at Sherbourne Bay). Although the highest peaks in ammonia levels occurred during times of high freshwater flow, reasonably high peaks were observed outside these events, but within times of low salinity. These results further support the notion that Moulting Lagoon has poor flushing capabilities. Ammonia levels did drop off in summer at all sites, but they remained high in comparison to other estuaries in the Region (again, probably due to the enclosed nature of the Lagoon and weak tidal flushing).

Soluble reactive phosphorus (SRP) levels were relatively stable throughout the year, with the exception of a substantial peak extending over summer at the Apsley Marshes (MLAG2), maximum 51 µg/L and a peak at MLAG in April. Elevated phosphorus levels can result in excessive aquatic plant growth and may have caused the peak in chlorophyll a (130.5 µg/L) at the same site. The elevated SRP levels at the Apsley Marshes appear to be related to low freshwater flow, and are perhaps a result of undiluted wastes concentrating at the site (e.g. human and animal wastes, soil erosion, detergents, septic systems or runoff from farmland).

Seasonally, chlorophyll a levels were relatively stable, however they varied substantially between sites – the highest readings were observed at the Apsley Marshes (130.5 µg/L). However, elevated chlorophyll a levels did not persist (possibly due to turbidity reducing light availability rather than availability of SRP, as SRP levels remained relatively high during summer). The next highest peak was at Sherbourne Bay (12.9 µg/L). Low readings were observed throughout Great Swanport, where chlorophyll a peaked at 1.7 µg/L at the mouth of the Swan River.

These high values for ammonia, phosphorous and chlorophyll a in the upper reaches of the lagoon are exceptionally high for estuarine systems and are probably reflective of a wetland marsh environment.

Silica levels were relatively high; particularly in Lagoon sites and at the mouth of the Swan River, indicating a relatively strong relationship with freshwater input. Silica levels were higher and persisted for longer than in other estuaries within the Southern NRM Region.

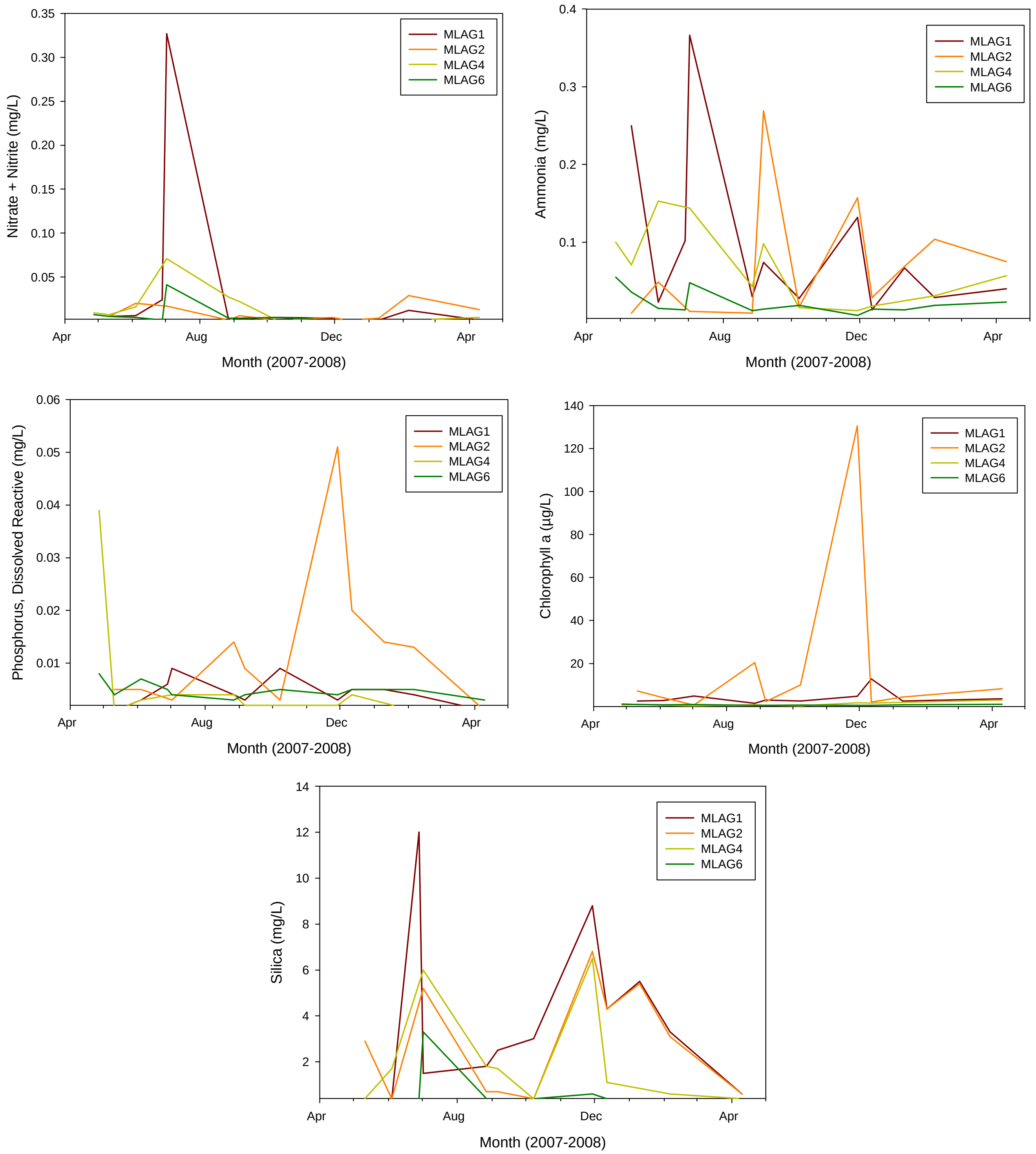


Figure 15. Nutrients, Chlorophyll a and Silica levels in Moulting Lagoon and Great Swanport.

Pathogens

Themotolerant coliform bacteria were monitored by the Tasmanian Shellfish Quality Assurance Program (TSQAP) during 2007-2008 at Great Swanport (sites GSP2-5, GSP7-10). The main sources of pathogens are warm-blooded animals, including humans. These pathogens can be concentrated in sewage and storm water overflows, and in areas receiving animal wastes, such as downstream of intensive dairy farming. Salinities of less than 12 ppt at Site 7 prompts a closure of the harvest area (Site 7 is at the uppermost lease, adjacent to Woolshed Point). TSQAP consider Site 7 to be the most sensitive area for salinity changes as it is furthest upstream. This is consistent with the results graphed in Fig 16, where site 7 was the only site to peak throughout the year, although the concentration of thermotolerant coliforms was still very low.

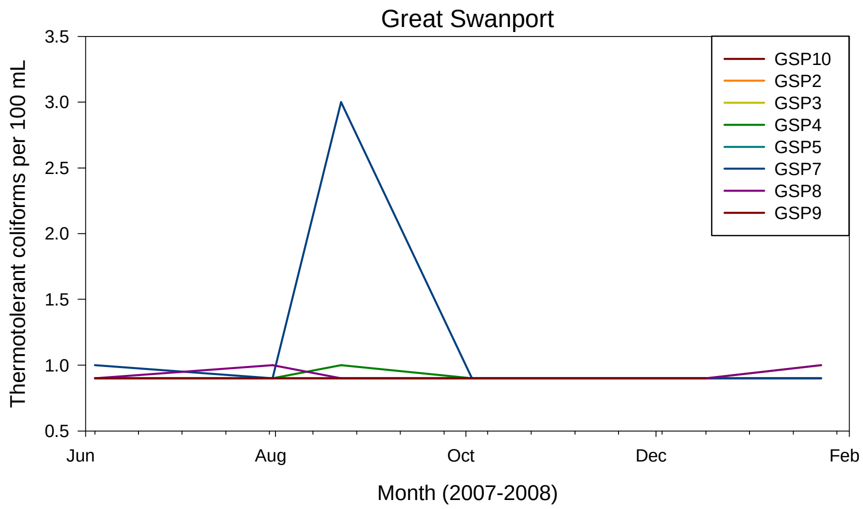


Figure 16. Thermotolerant coliform bacteria levels in Great Swanport.

Little Swanport

Location Description

Little Swanport estuary is an important, medium sized (~608 Ha), wave dominated Group II (open) estuary located on the mid-east coast of Tasmania (Edgar *et al.* 1999). The Little Swanport Catchment is drained by Little Swanport River (~60 km), which discharges into Great Oyster Bay via the Little Swanport estuary. The estuary receives significant freshwater inputs from the Little Swanport River and a number of smaller creeks along the west and south of the upper estuary (Mount *et al.* 2005). The estuary is relatively shallow, with an average depth of 2 to 4 m in the lower estuary and 1-2 m in the upper estuary (Murphy *et al.* 2003).

The majority of the Little Swanport catchment is utilised for agriculture and production forestry, but approximately 35% of the catchment is protected by reserves or National Park. The middle catchment is relatively un-developed, while the lower catchment has areas of smaller rural landholdings with extensive sheep grazing (Edgar *et al.* 1999). The estuary supports substantial oyster production and provides habitat for many plants and animals, including a large number of black swans (Mount *et al.* 2005).

A detailed study of the physical, chemical and biological aspects of the Little Swanport estuary has been produced by TAFI and there is ongoing research on physical, chemical and biological aspects of the estuary (Crawford *et al.* 2005).

Climate and tides

The Little Swanport catchment area is generally quite dry, with an average of 600-800 mm rainfall per annum and sporadic flooding. There are no Bureau of Meteorology stations located within a 25 km radius of Little Swanport; the nearest are at Swansea and Orford. In the past, climate data had been collated from three weather stations belonging to the Bureau of Meteorology positioned alongside the estuary at Lisdillon (Station 2896.1), Wine Glass Cottage (Station 2896.2) and Ravensdale (Station 2896.3) (see Crawford *et al.* 2005).

The flushing time of Little Swanport is calculated to be approximately 2.3 tidal cycles or just over a day (Crawford and Mitchell 1999). Streamlines in Little Swanport indicated good movement of water around the estuary on each tidal cycle with some circulation of water around Ram Island (Crawford and Mitchell 1999).

Conservation value

Edgar *et al.* (1999) identified Great Swanport as being of Class C conservation significance. Class C estuaries are defined as of moderate conservation significance, where the estuary and associated catchment area are affected by human habitation and land clearance, but have not been badly degraded (Edgar *et al.* 1999). Edgar *et al.* (1999) recommend that Class C estuaries and associated catchments should be made available for a variety of recreational and commercial purposes. The National Land and Water Resources Audit (NLWRA) identified Little Swanport as being a modified, wave dominated estuary (subclass: wave estuary) (NLWRA 2002).

Extent/distribution of key habitat types

The habitat types in Little Swanport were mapped by Mount *et al.* (2005) (Fig 17). The Little Swanport estuary is made up of a complex flood tide delta with many braided channels and a large island dividing the main channel that contains thick dense beds of aquatic macrophytes (*Zostera muelleri* and *Heterozostera tasmanica* are the dominant species in the lower estuary and *Ruppia* sp.,in the upper) (Mount *et al.* 2005). Unvegetated unconsolidated sediments form the primary habitat type on the bottom of the main central basin. In the lower reaches, native flat oysters (*Ostrea angasi*), and the associated filamentous macroalgae and other filter feeders cover large areas, especially in and along the sides of the braided tidal channels (Mount *et al.* 2005). In the upper reaches of the estuary, fluvial discharge of the Little Swanport River has created multiple short, deep, discontinuous channels and deposited a very large fluvial delta, including the Duck Island formations, which are all indications of a strong discharge rate. Ram Island dominates much of the estuary where the main central basin meets the flood tide delta (Mount *et al.* 2005).

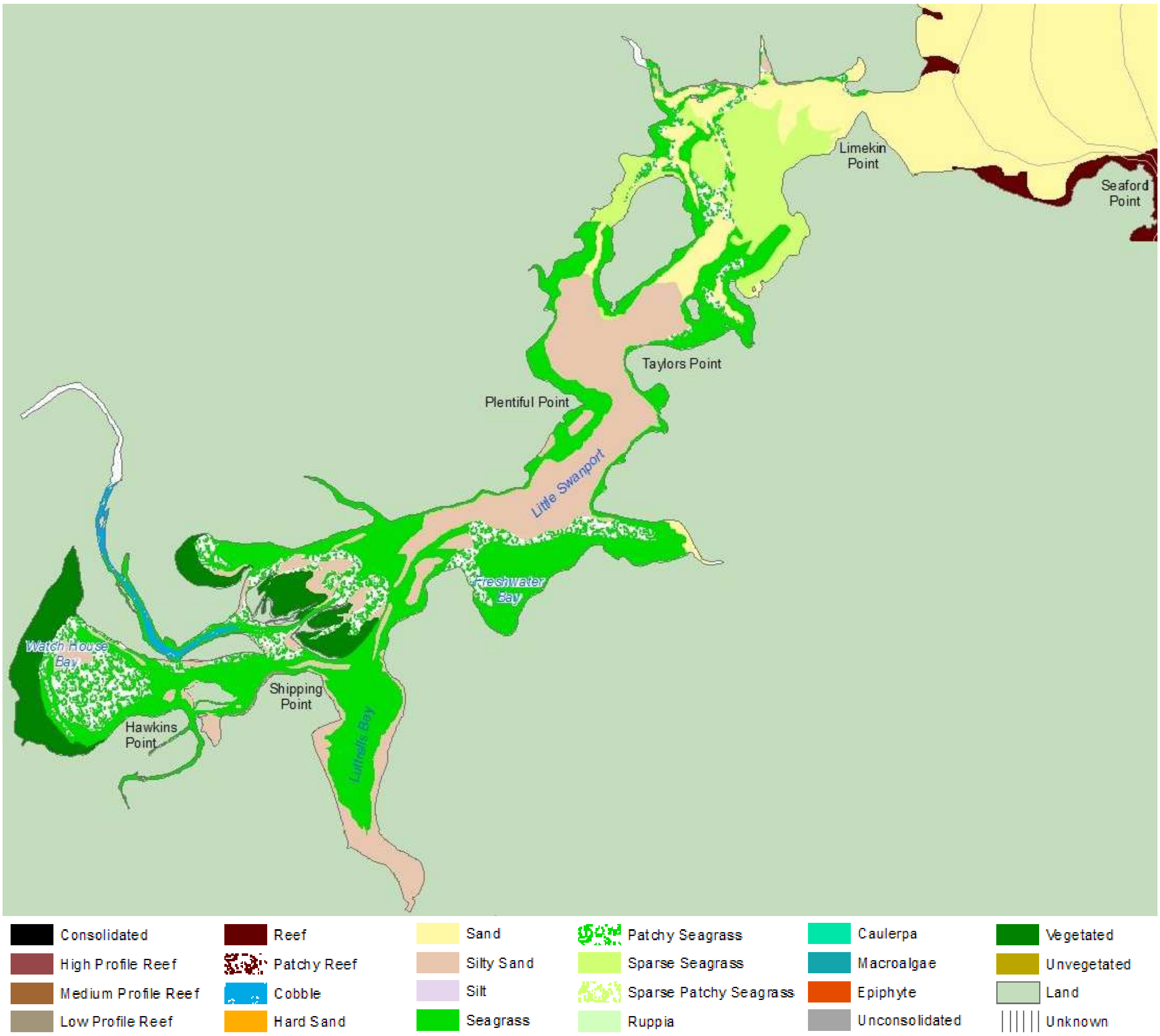


Figure 17. The habitat types in Little Swanport (SEAMAP Tasmania, TAFI).

Water quality data for the 2007-2008 period was collated from sources including TSQAP (salinity, temperature and coliform data for 6 sites), TAFI (salinity, temperature, dissolved oxygen, turbidity, pH, dissolved nutrients, silica and chlorophyll a data for 1 site) and DPIW (flow, temperature, dissolved oxygen, turbidity, pH and dissolved nutrients for 1 site).

Freshwater flows and water allocation

Water is mostly allocated for irrigation (3 230 ML), and stock and domestic use (264 ML) (DPIW 2007). Stream-flow gauges are present on the Little Swanport River and water quality information is sampled at 4-6 weekly intervals at two stations within the catchment: Little Swanport River 800 m downstream of Eastern Marshes Rivulet (Station 2212) and the Little Swanport River weir, 3 km upstream of Tasman Highway (Station 2207) which recorded data from 1971 until 1990, but was replaced by a new station approximately 150 m downstream from the old weir and has records from March 2004 to the present (Station 2235) (DPIW 2007). AusRivAS assessments are conducted at one site in the Little Swanport Catchment (Station 2212) and have described the riparian zone as highly modified and dominated by gorse (DPIWE 2005). Macroinvertebrate fauna in the riffle habitat is significantly impaired (Band B), but for the edgewater habitat, it is slightly better, ranging from impaired (Band B) to similar to reference condition (Band A) (DPIWE 2007).

The Water Assessment Branch of DPIW has river flow gauges upstream of the Little Swanport estuary in the Little Swanport River. Stream flow (Cumecs) at the gauge furthest downstream (towards the estuary) was graphed for the Little Swanport River, and compared with salinity data (Fig 18).

Salinity, temperature and dissolved oxygen profiles

Salinity in Little Swanport has been examined by Mount *et al.* (2005), Murphy *et al.* (2003) and Crawford *et al.* (2005). Little Swanport generally displays a slight salt wedge in the salinity profiles, with the first half of the estuary dominated by seawater to approximately 3.5-4 km from the mouth, above which the salinity values drop (Mount *et al.*2005). Murphy *et al.* (2003) also found that salinity dropped in the upper estuary and varied at different times during the year. However, no significant relationship between depth and salinity was observed (that is, there was no significant stratification).

During 2007-2008, salinity was monitored by TAFI and TSQAP at 7 sites. Salinity remained relatively stable with little stratification observed in the water column. Increased flow from the Little Swanport River did not seem to influence salinity at this site (Fig 18).

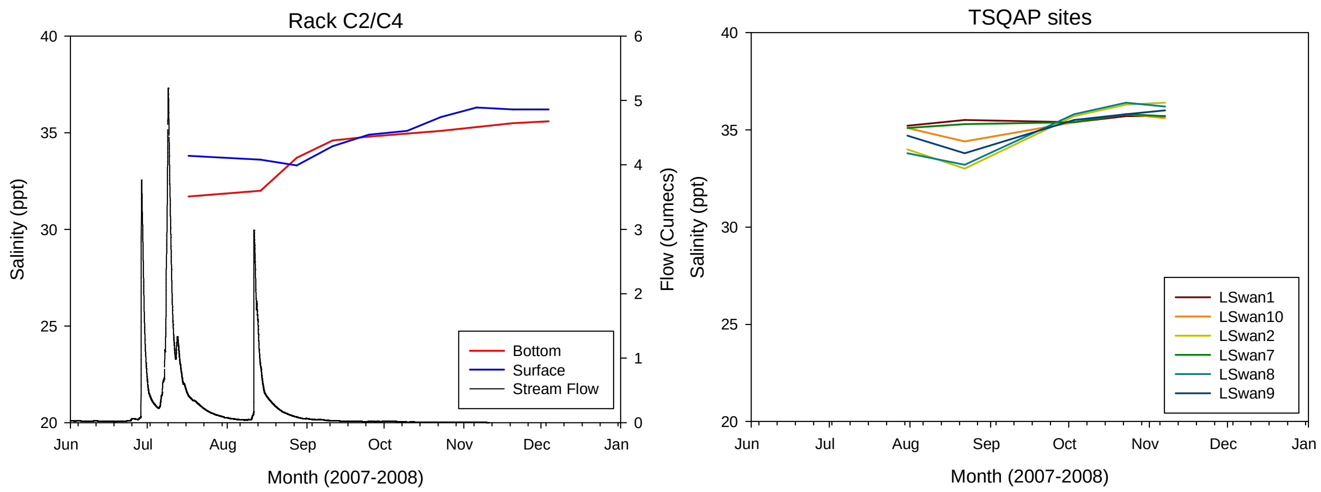


Figure 18. Annual salinity profiles in Little Swanport

During 2007-2008, temperature was recorded for surface waters at Station 2235 (freshwater site) and the 6 TSQAP sites. Surface and bottom water temperatures were recorded at Rack C2/C3 (Fig 19). Water temperatures were weakly stratified at Rack C2/C3, but all sites showed a distinct seasonal trend (cooler in winter, warmer in summer).

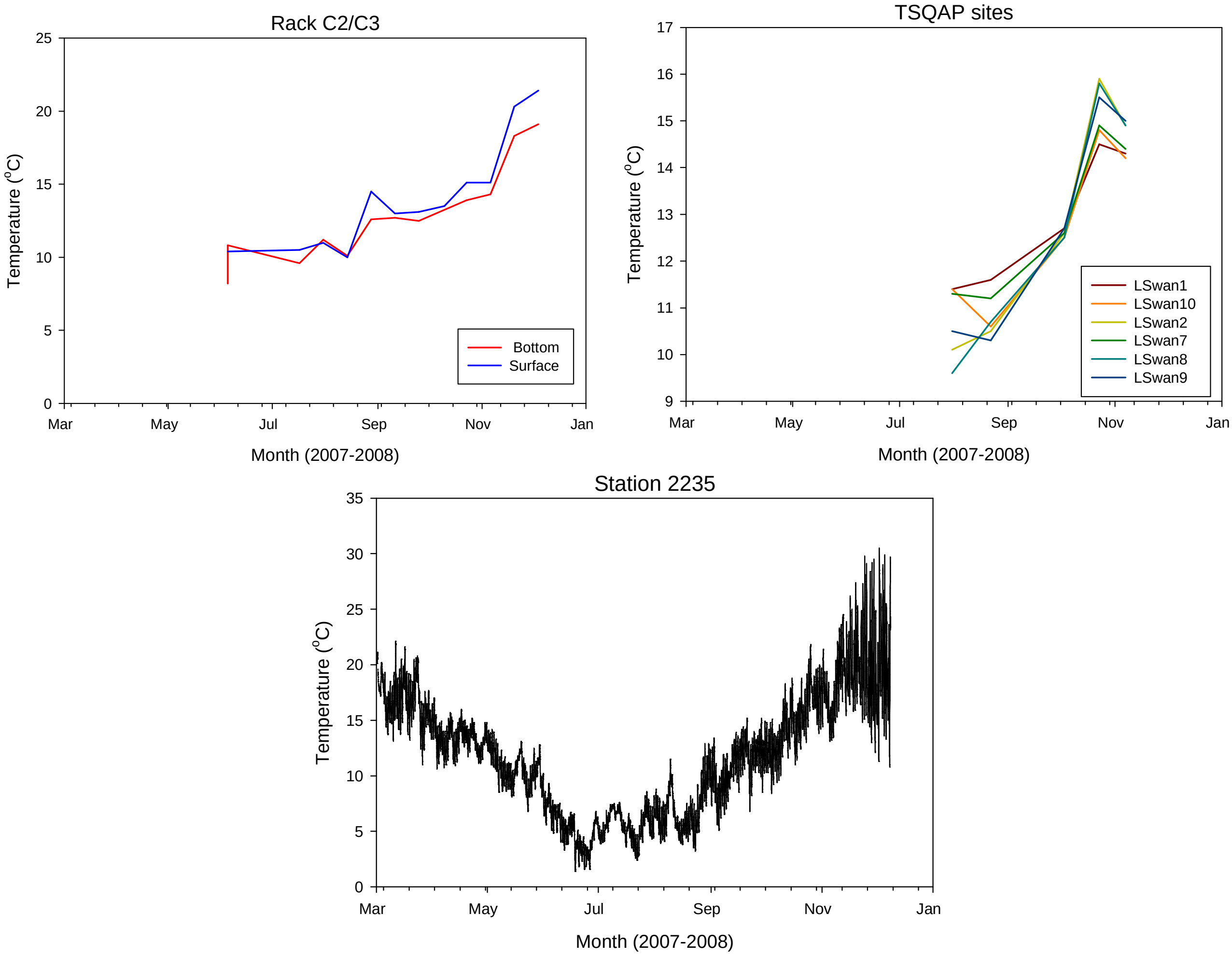


Figure 19. Annual temperature profiles in Little Swanport.

Stratification of DO in the water column has been found to be weak and not consistent over time ((Murphy *et al.* 2003). During 2007-2008, DO (mg/L) was recorded for surface waters at Station 2235. DO levels were highest (max 13.3 mg/L) during winter and dropped to 7.1 mg/L during summer (Fig 20). At the Rack C2/C3, DO was recorded for surface and bottom waters. DO levels in both the surface and bottom waters remained relatively stable throughout the year (>80% Sat).

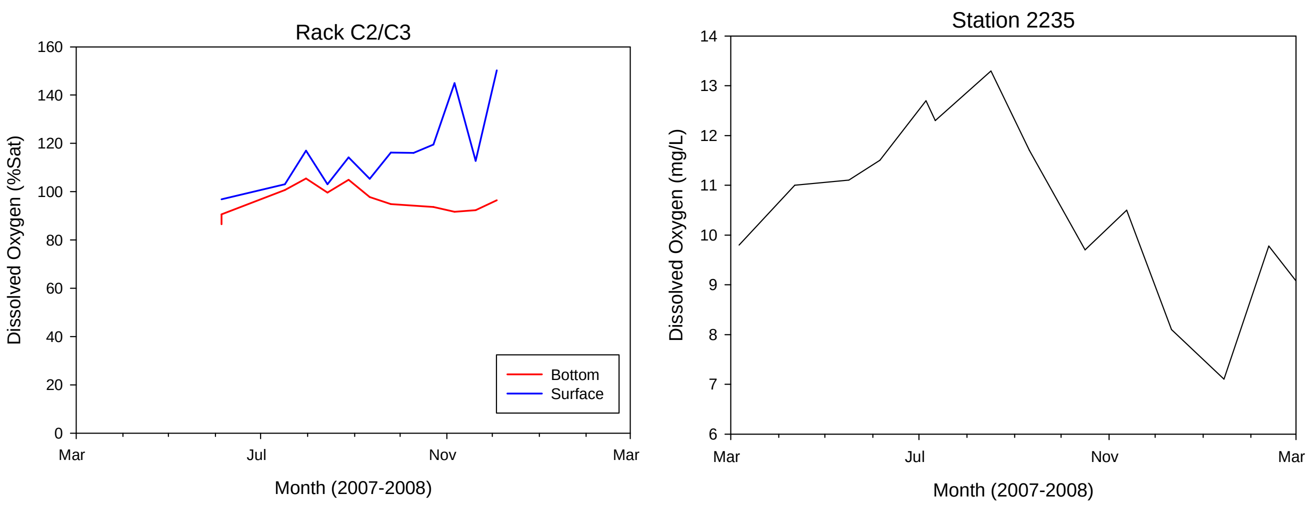


Figure 20. Annual dissolved oxygen profiles in Little Swanport.

Turbidity and pH

Turbidity levels were monitored for surface waters at Station 2235 and Rack C2/C3 during 2007-2008 (Fig 21). Turbidity increased during high flow events in the Little Swanport River, especially during July through to September (max 20.5 NTU). Turbidity levels within the estuary were relatively low, with a slight increase over summer. While there were minor variations over time, these variations did not appear to correspond with flow events. One possible explanation is the impact of wind/wave action resulting in disturbed sediments.

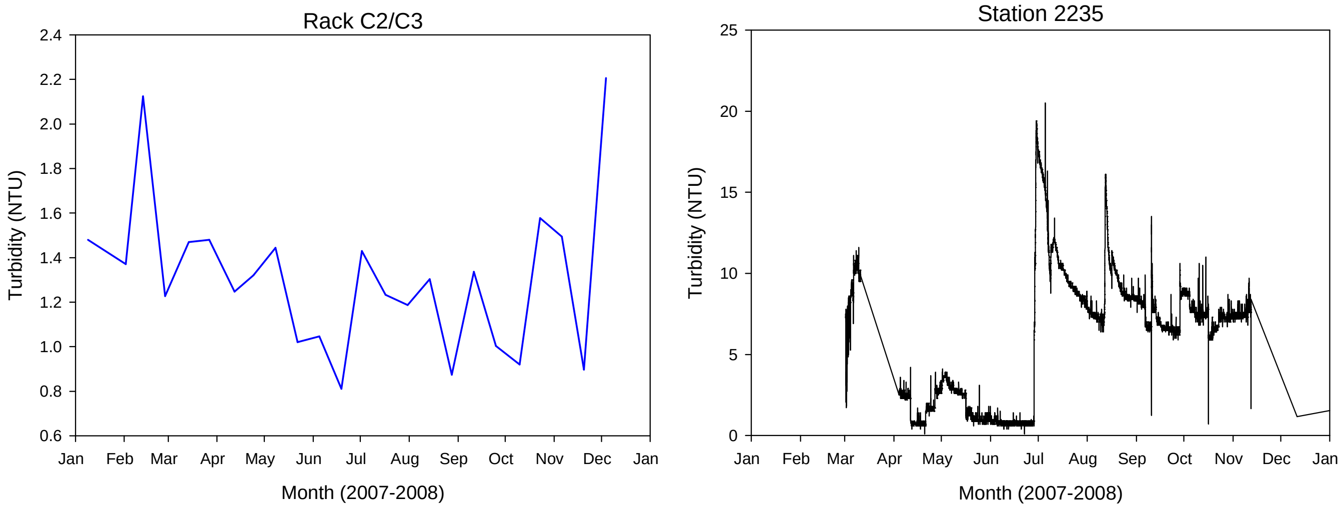


Figure 21. Annual turbidity levels in Little Swanport.

pH levels were monitored for surface waters at Station 2235 and Rack C2/C3 during 2007-2008 (Fig 22). pH levels in the river were much more variable over time when compared with the estuarine site. pH at Station 2235 decreased in winter (min pH 7.2), and increased during summer (max pH = 8.4). This is consistent with the impact of winter flows. In comparison, pH levels at Rack C2/C3 were very stable throughout the year (range 8.33-8.71).

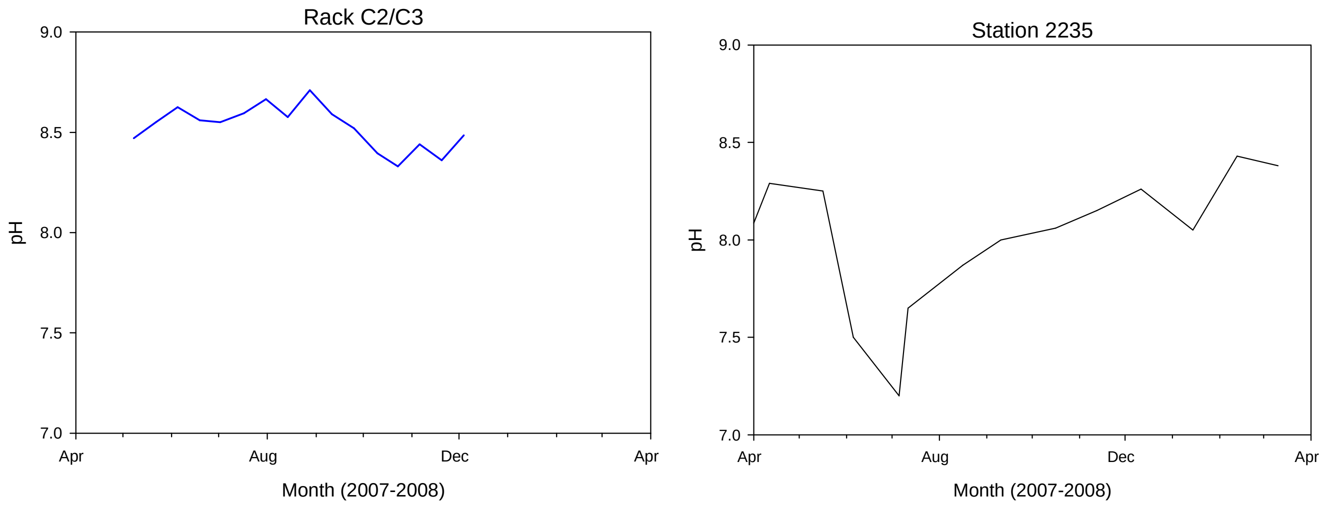


Figure 22. Annual pH readings in Little Swanport.

Nutrients, silica and chlorophyll a

Nitrate plus nitrite (NOx) levels were recorded at similar levels at the freshwater and estuarine sites throughout the year (Fig 23a). At Station 2235, nitrate peaked during March (174 µg/L) and winter (143 µg/L), while nitrite levels mostly remained below detection limits. At Rack C2/C3, NOx also peaked during winter (22 µg/L) but this is a relatively low peak value compared to other estuaries. The maximum ammonia concentration recorded at Station 2235 was 12 µg/L during summer, while at Rack C2/C3, ammonia peaked in late autumn/winter at 57 µg/L (Fig 23a). This high value during a low rainfall period suggests ammonia levels in the estuary do not originate entirely from catchment sources.

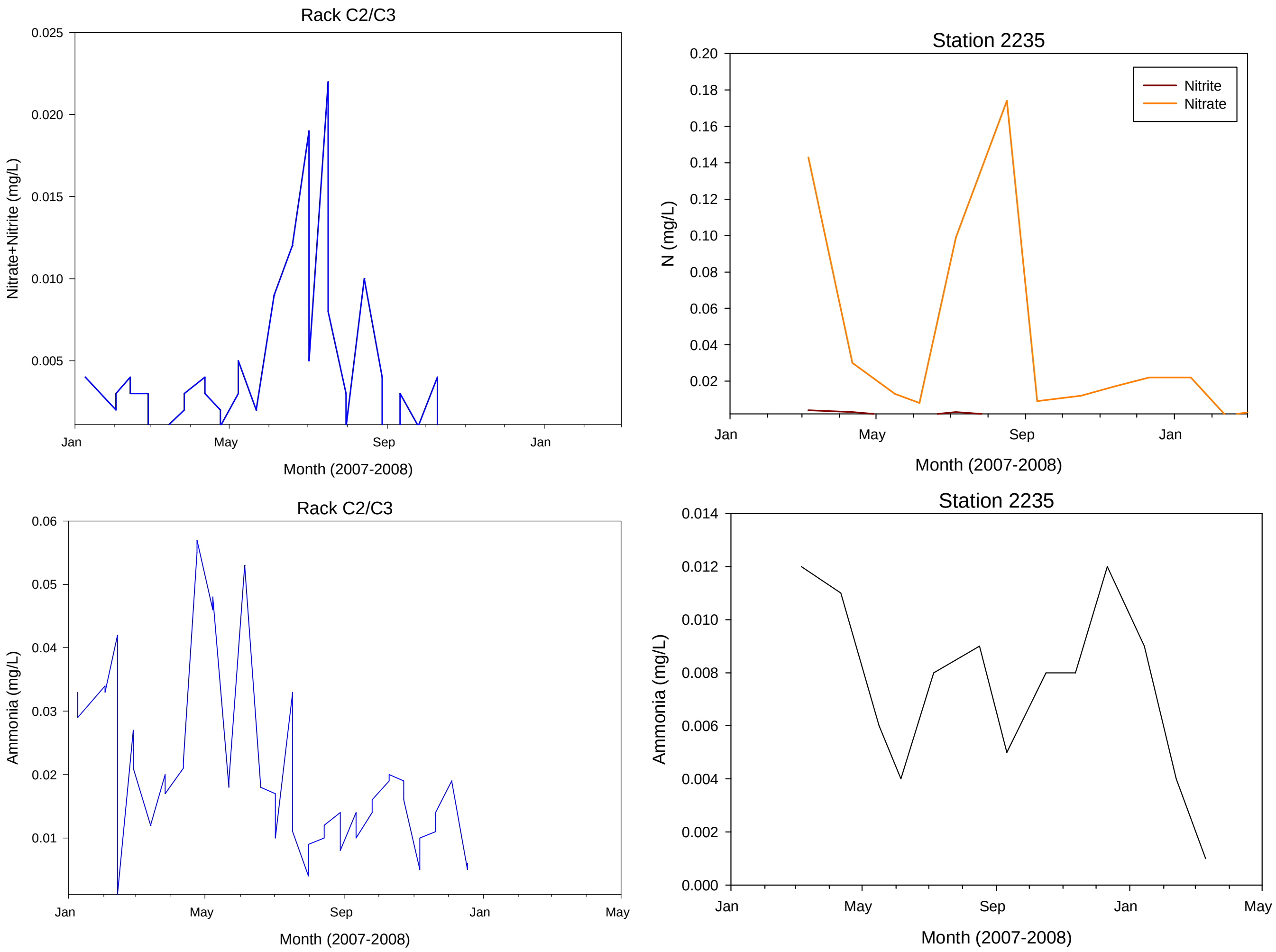


Figure 23a. Nitrate, nitrite and ammonia levels in Little Swanport.

Soluble Reactive Phosphorus (SRP) levels were low throughout the year, but peaked on occasions in the estuary (maximum 9 µg/L during May 2007) and in the river (maximum 7 µg/L during February 2008) (Fig 23b).

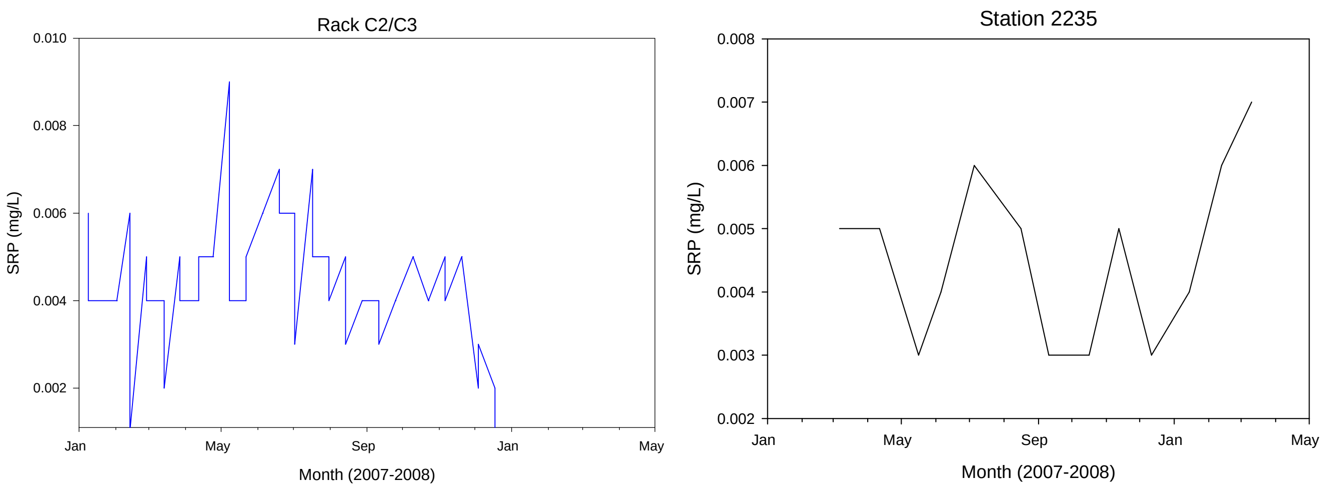


Figure 23b. Soluble Reactive Phosphorus levels in Little Swanport.

Although silicate levels were monitored at Rack C2/C3, levels were mostly below detection limits. Two small peaks occurred, one in August (1.1 mg/L) and September (0.8 mg/L) (Fig 23c). These low levels reflect the low freshwater flows into the estuary.

Chlorophyll a levels were variable throughout the year (range 0.41–4.18 µg/L) (Fig 23d). Despite this variation, the range is consistent with other estuarine Chlorophyll a levels monitored on the East Coast.

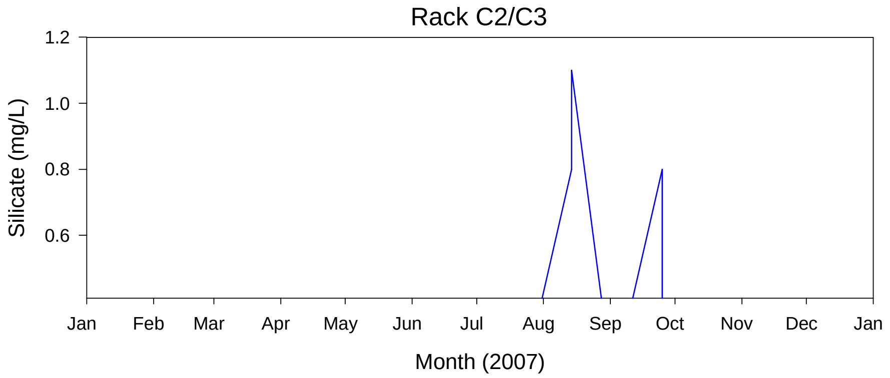


Figure 23c. Silicate levels in Little Swanport.

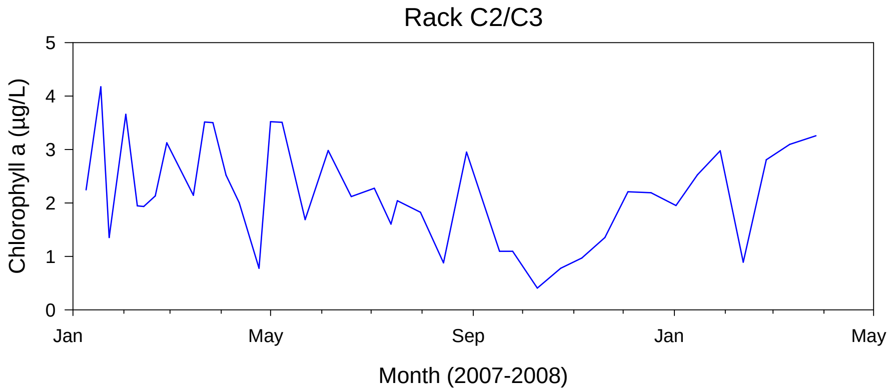


Figure 23d. Chlorophyll a levels in Little Swanport.

Pathogens

Themotolerant coliform bacteria were monitored by the Tasmanian Shellfish Quality Assurance Program (TSQAP) during 2007-2008 at Little Swanport (sites LSP1-2, LSP7-10) (Fig 24). Salinity readings of less than or equal to 15 ppt at any of the sample sites will cause a closure of the growing area to harvesting because of a previously desribed relationshop between salinity and coliform concentrations. The very low bacterial levels recorded during the sampling period are most likely because of very low rainfall and freshwater flows.

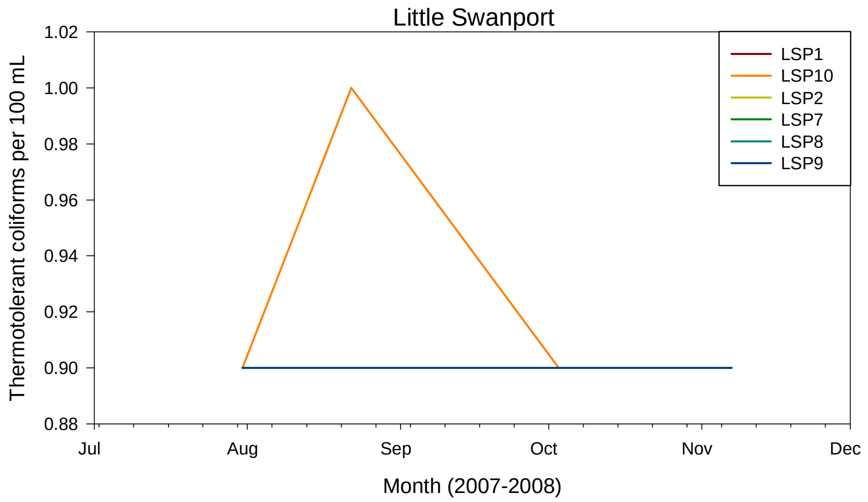
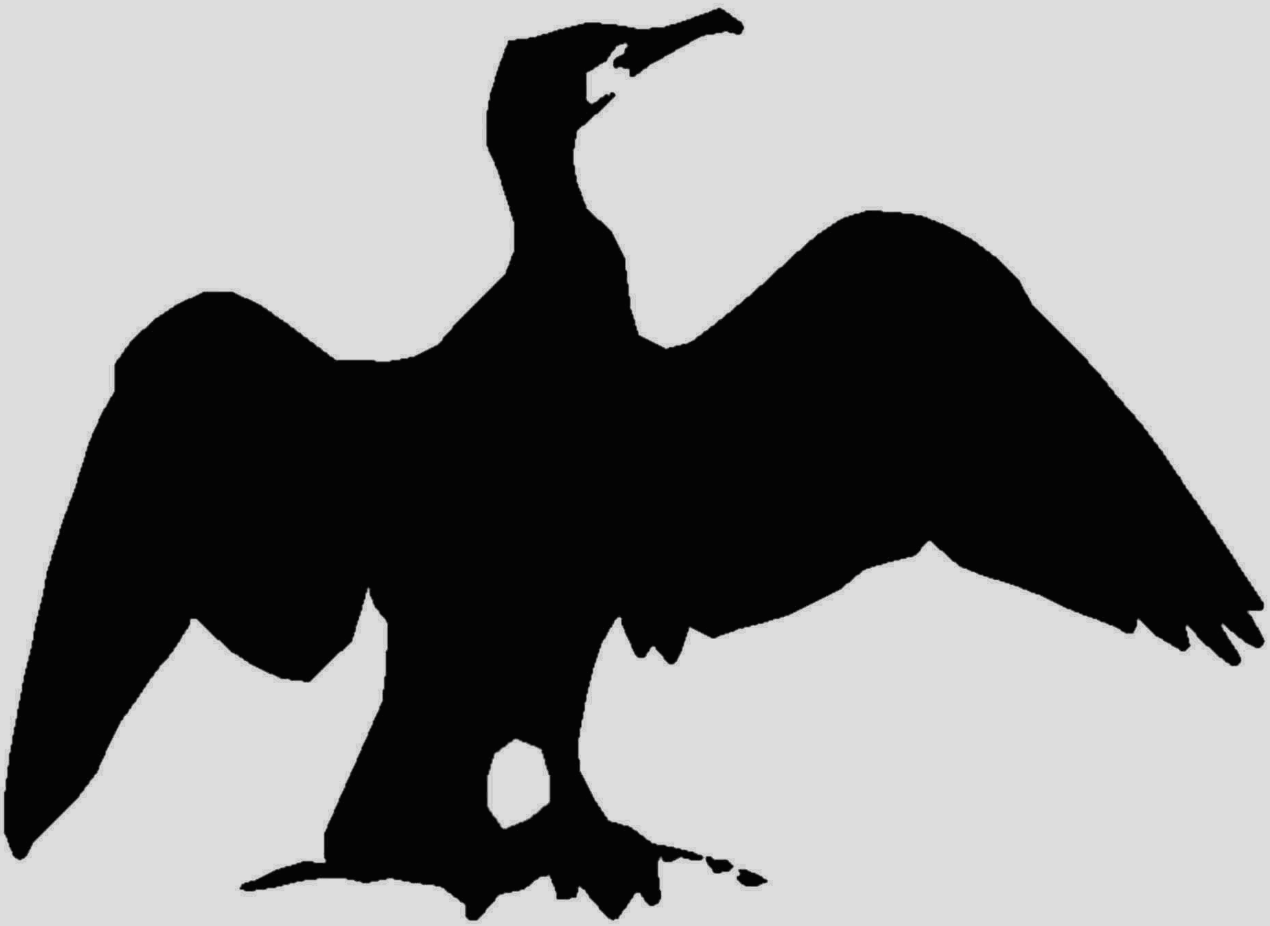


Figure 24. Thermotolerant coliform bacteria levels in Little Swanport.

Pitt Water and Orielton Lagoon



Location Description

Pitt Water is a very large (4 314 Ha), shallow (majority 1-3 m), Group II estuary (open estuaries) (Edgar *et al.* 1999). Orielton lagoon is a small (~265 Ha), shallow (~1.3 m) lagoon, separated from Pitt Water by a causeway. Pitt Water and Orielton Lagoon form a complex estuarine system that is extensively modified; there are two causeways across the centre of the estuary, flow-modifying structures (1 dam; 2 barrages) and areas of dense residential population around its shores (Midway Point and Sorell). Some light industrial and intensive agricultural and horticultural activities occur in the catchments of Pitt Water and Orielton Lagoon.

Intensive agriculture is limited mainly to the area within the South East Irrigation Scheme, where vegetable crops, stone fruits, turf and vineyard enterprises operate (DPIW 2007). There has been gradual removal of native vegetation since European settlement and increasing level of agriculture has seen salinity become a significant issue within the catchment (DPIW 2007). There is one significant river in the catchment – the Coal River – and a number of small ephemeral streams (e.g. White Kangaroo, Orielton and Sorell Rivulets and Iron Creek). These waterways contribute to the South East Irrigation Scheme, which supplies water to farmers in the valley for irrigation. The majority of the water allocation is for irrigation (29 523 ML), with the remainder, (1 189 ML) for other uses, including stock and domestic supply (DPIW 2007).

Aquaculture is present within the estuary (oysters) and commercial fishing (<5 operators). Recreational fishing (flathead, flounder) and other recreational activities (e.g. windsurfing, boating, sailing, swimming) are popular.

Although native woody vegetation comprises the majority (69.5%) of the catchment and crops, pasture and plantations comprise little over a quarter of the catchment (26.8%), most of the catchment is privately owned (823.3 km^2). Some of the Crown Land in the estuarine catchment area is exploited (64.2 km^2), however there is some land that is protected in Crown Reserve (32.1 km^2). The population density of this estuarine drainage area is 44.05 km^2 and the population density of the estuarine catchment area is 8.9 km^2 (Edgar *et al.* 1999).

There are four sewage treatment plants in the Pitt Water/Orielton area: Cambridge (permitted flow 125 kL/day, secondary treatment), Orielton (permitted flow 810 kL/day, secondary treatment, chlorination), Sorell (permitted flow 810 kL/day, primary treatment, chlorination) and Hobart Airport (permitted flow 350 kL/day, secondary treatment, UV). The urban area of the estuarine drainage area is 4.1 km^2 (3.75% of EDA) and the total urban area of the catchment is 8.5 km^2 (0.92% of ECA) (Edgar *et al.* 1999).

The causeway located in the middle of the estuary restricts the water flow to and from the upper estuary through a narrow channel (Crawford and Mitchell 1999). Pitt Water also underwent a change in freshwater flow patterns when the Craigbourne dam was built on the Coal River, upstream of the oyster growing area, in 1986, which resulted in previous sporadic flooding of the area being replaced by a constant and reduced flow into the estuary, except for rare large flood events (Crawford and Mitchell 1999). The second causeway also restricts flow between lower Pitt Water and Orielton Lagoon, which previously was a problem because of nutrient influx from wastewater disposal at Midway Point, leading to eutrophication and blue green algal blooms causing scums, odours and public health and aesthetic concerns (Davies *et al.* 2006). This causeway was recently (1998) modified to improve flow and flushing capability and to therefore decrease the number of eutrophication events. The Sorell Council has also diverted suburban wastewater disposal from the Lagoon to land disposal/irrigation.

The estuary's main central basin is associated with the Coal River. The next smallest basin, in Orielton Lagoon, is associated with Orielton Rivulet and a small sub-basin of Iron Creek Bay is associated with Iron Creek (Mount *et al.* 2005). Poor water quality has resulted in the short term closure to harvest of shellfish aquaculture due to high pathogen levels (Crawford and Mitchell 1999).

Climate and tides

Pitt Water-Coal Catchment is located on the border between the Sorell and Clarence municipalities and lies within the driest region of Tasmania – an average rainfall of only 500-600 mm pa (DPIWE 2005). The small amount of rain that does fall is fairly evenly spread over the year (Fig 25).

The nearest meteorological station is located at Hobart Airport, approximately 3 km south-west of the Sorell Causeway. Bureau of Meteorology records from Hobart Airport for the period 1958 to 2008 show that the mean daily temperature in January, the warmest month, range from a maximum of 22.4℃ to a minimum of 12.0℃. In July, the coldest month, mean daily temperatures range from a maximum of 12.4℃ to a minimum of 4.1℃ (BoM 2008).

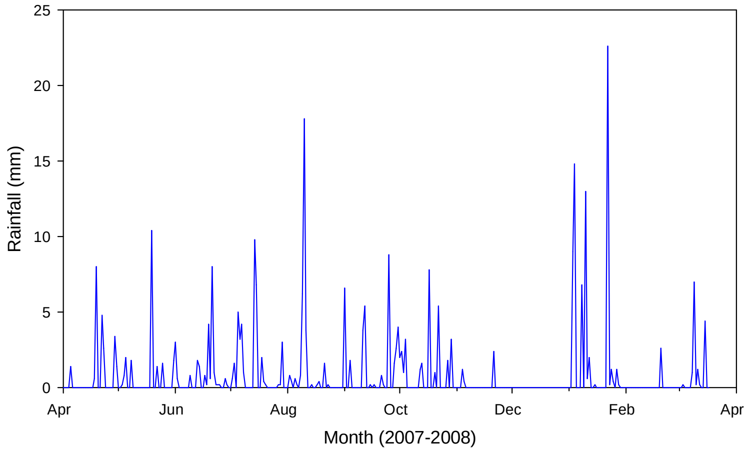


Figure 25. Rainfall recorded at Hobart Airport during 2007-2008

Conservation value

Edgar *et al.* (1999) identified Pitt Water as being of Class D conservation significance. Class D estuaries are defined as low conservation significance and moderately degraded, where the estuary and associated catchment have been moderately degraded by human impacts. Edgar *et al.* (1999) recommends that Class D estuaries should be made available for a variety of recreational and commercial purposes and remediation processes should be assisted where practical.

Pitt Water estuary contains a shark nursery area, the Orielton Ramsar site and one foreshore conservation area: Pitt Water Nature Reserve. Orielton Lagoon is a listed Ramsar site (wetland of international significance) because of its significance as a major summer feeding ground for migratory birds and local water birds. It also provides habitat for rare and threatened species such as the chequered blue butterfly (*Thedinesthes serpentata*), various rare saltmarsh plants (e.g. *Lawrencia spicata, Limonium australe, Wilsonia humilis*) and the largest known concentration of the endemic seastar *Patiriella vivipara.*

The area draining directly into this estuary has been severely impacted by human activities and the catchment has a high level of impact from human activities (Edgar *et al.* 1999). The Pitt Water/Coal catchment is rated as "substantially modified" on the Environmental Index and "significantly impaired" on the Biota Index (Norris *et al.* 2001).

Extent/distribution of key habitat types

Habitat areas were surveyed in lower Pitt Water in 2005 by Mount *et al.* (Fig 26), and Orielton Lagoon will be mapped by SEAMAP Tasmania during 2008. The lower Pitt Water estuary contains seagrass beds clustered around the well-formed parabolic flood tide delta near Woody Island, extensive intertidal flats and subtidal shallows, including sparse ascidian habitat (~350 Ha) (Mount *et al.* 2005). The causeway affects distribution of sediments and the main entrance channel has deep "holes" up to 20 m deep formed by strong scouring flows (Mount *et al.* 2005). There is a small area of saltmarsh (0.31 km²). Seagrass species present include *Heterozostera tasmanica, Zostera muelleri,* and *Ruppia* sp. (84 Ha) (Mount *et al.* 2005).

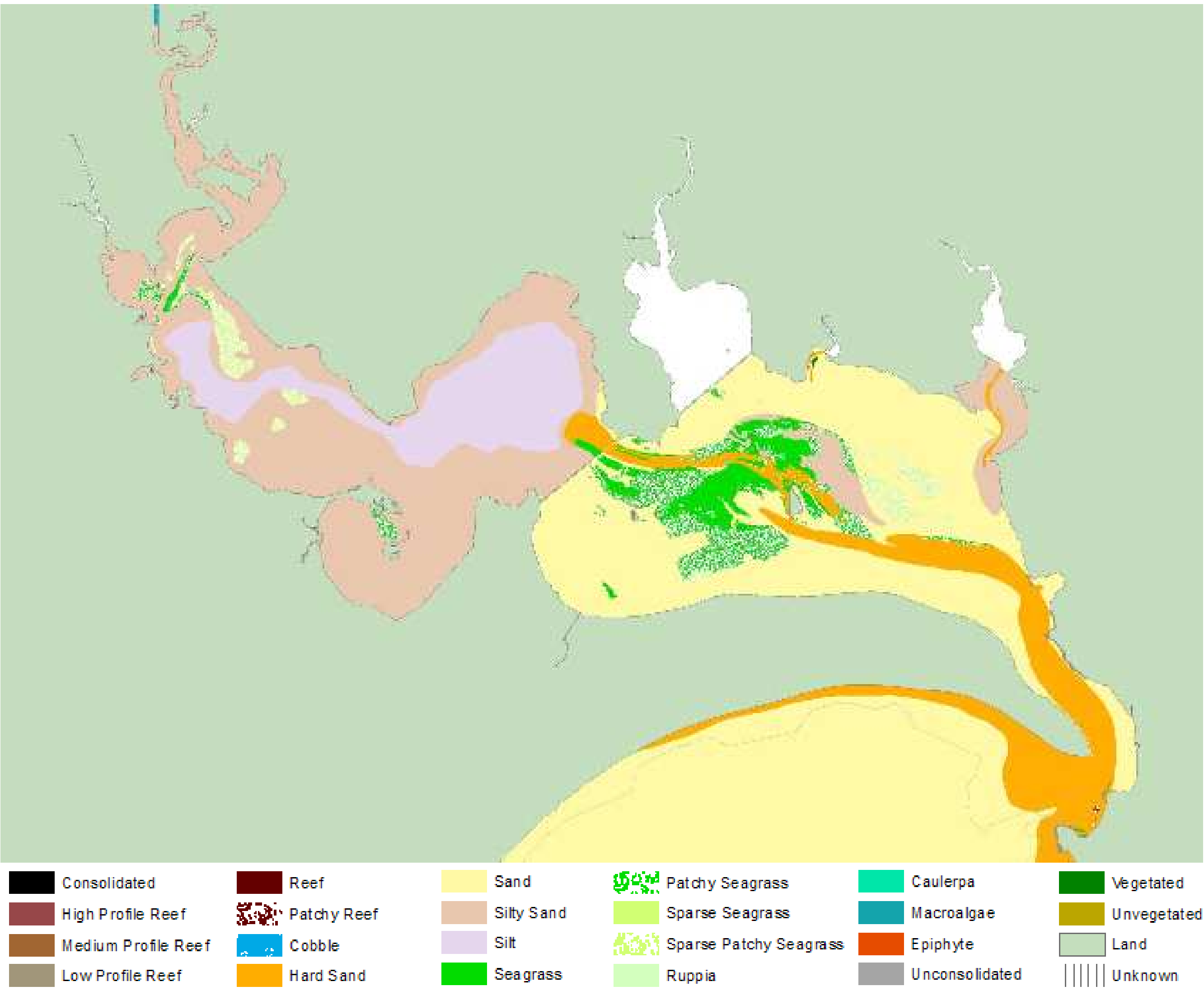


Figure 26. The habitat types in Pitt Water (SEAMAP Tasmania, TAFI).

Water Quality

Freshwater flows and water allocation

The Coal River catchment is the driest catchment on mainland Tasmania and the Coal River and its tributaries are regularly completely dry due to irrigation and low rainfall. As a result, the estuary receives very little freshwater input. However, there are tidal flows in the estuary and the estuary has a Fluvial Flow Rating of 6 (Freshwater Flow Per Unit Estuary Area) (DPIW 2007).

Water is mostly allocated for irrigation (17 219 ML), and stock and domestic use (928 ML) (DPIW 2007). Stream-flow information is collected from four stations within the catchment: White Kangaroo Rivulet (Station 3309), Coal River at Baden (Station 3203), Coal River downstream of Craigbourne Dam (Station 3206) and Coal River at Richmond (Station 3208) (DPIW 2007). Water quality information using instream sensors is collected and periodic water sampling at 4-6 weekly intervals is conducted at three of these stations (Stations 3309, 3206 and 3208) (DPIWE 2005). AusRivAS assessments are conducted at one site in the Pitt Water-Coal Catchment: Coal River above Richmond. This site has shallow riffles and pools, some native riparian vegetation (wattles and black gum), but it is dominated by exotic species such as willow, gorse and blackberries. There has been some active revegetation downstream. The water quality of the river is generally poor due to elevated nutrient concentrations and high conductivity. The riffle habitat has been classed as significantly impaired (Band B).

The Water Assessment Branch of DPIW has river flow gauges upstream of the Pitt Water estuary in the Pitt Water/Coal catchment. Stream flow (Cumecs) at the gauge furthest downstream (towards the estuary) was graphed for the Coal River, and compared with salinity data in the estuary (Fig 27).

Salinity, temperature and dissolved oxygen profiles

Plots of salinity, temperature and dissolved oxygen are provided for each site over the 12 month study period (Fig 27-29).

Due to low freshwater inputs, salinity in Pitt Water and Orielton lagoon was hypersaline at all sites, especially in the upper estuary in bottom waters over summer-autumn, dipping only slightly during the winter months. Orielton Lagoon (PWO1) and Pitt Water (PWO2-5) were found to be well mixed and a salt wedge was generally not present, or very weak, throughout. The exception to this occurred in the upper sites (PWO1 and 2) during January and March 2008 (Fig 27). In these situations, surface salinity decreased substantially, but this decrease was unrelated to elevated flow events in the Coal River (see Fig 27) and more likely due to localised rainfall and stormwater runoff.

Water temperatures were also weakly stratified across all sites, but showed a distinct seasonal trend (cooler in winter, peaking in late summer) (Fig 28). Generally, there was little variation in temperature between sites, but greater variability between seasons was observed in the upper estuary. The highest water temperature (22.5^{o}C) was recorded during summer at Orielton Lagoon, where the water is very shallow (~1 m) and tidal exchange is highly modified. The lowest winter temperature (7.6^{o}C) was recorded at PWO2 (upper Pitt Water site near Barilla Bay oyster farm), which is the site closest to the mouth of the Coal River and where tidal exchange is influenced by the Sorell Causeway.

Dissolved oxygen levels were also relatively stable and generally remained higher than 80% Sat across all sites in Orielton Lagoon and Pitt Water (Fig 29). Despite significant modification of the estuary (causeway), a degraded catchment and low freshwater inputs, the weak stratification and low variation of salinity, temperature and dissolved oxygen levels across sites indicates that Pitt Water is well mixed and water is flushed well by the tides.

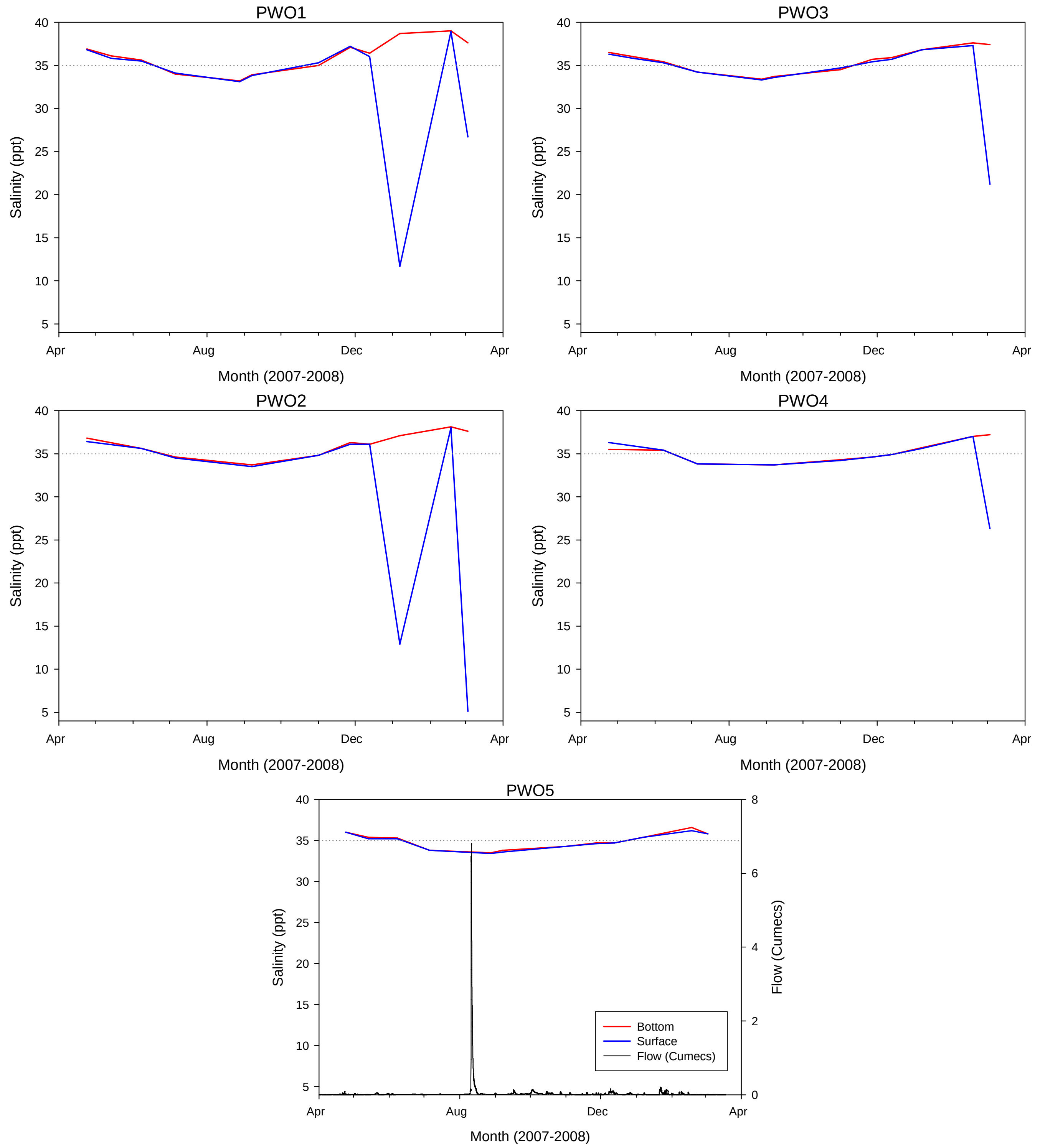


Figure 27. Annual salinity profiles in Pitt Water and Orielton Lagoon showing deviations from typical marine conditions (35 ppt).

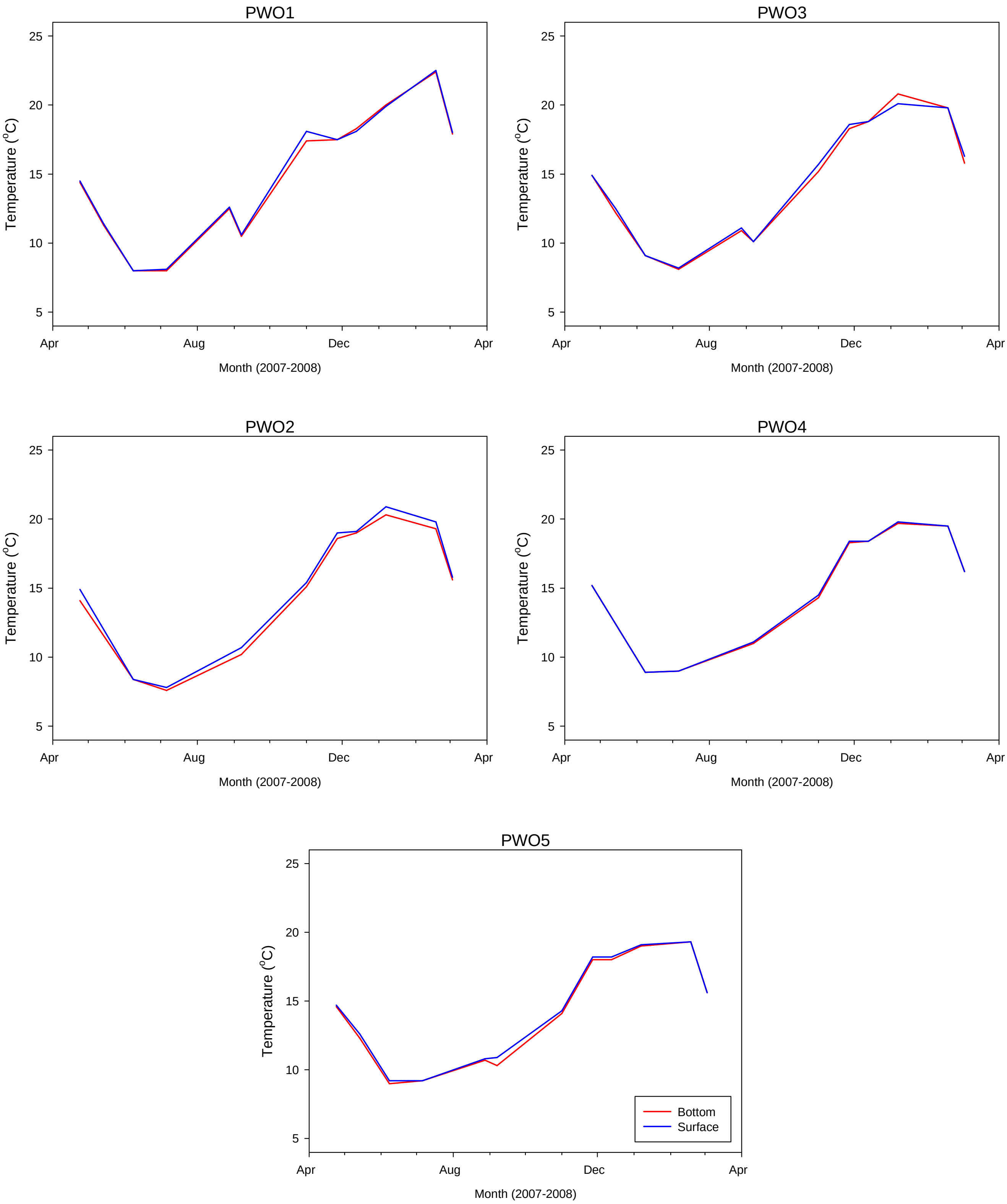


Figure 28. Annual temperature profiles in Pitt Water and Orielton Lagoon.

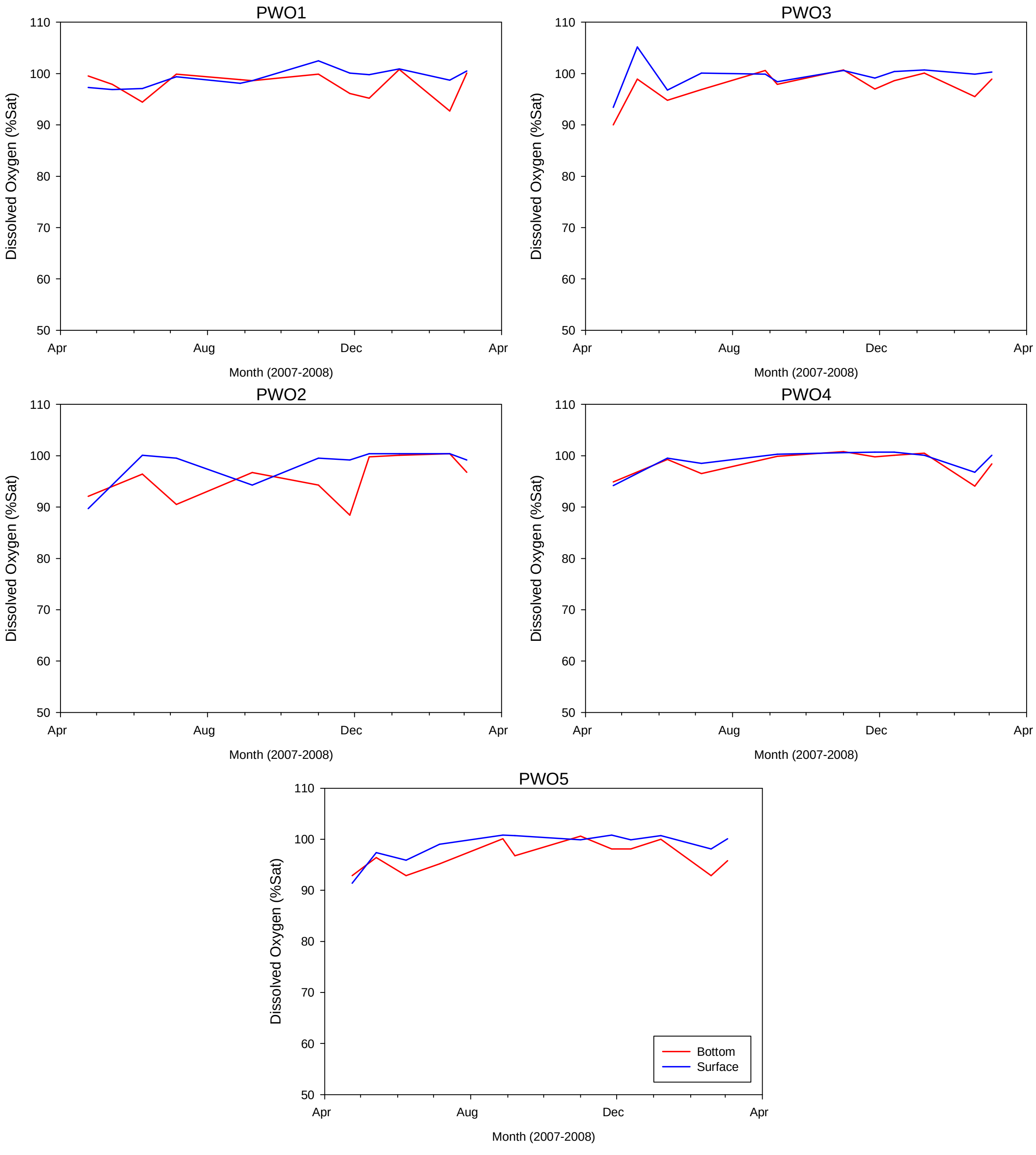


Figure 29. Annual dissolved oxygen profiles in Pitt Water and Orielton Lagoon.

Turbidity and pH

Turbidity levels in Pitt Water were generally quite low (<5 NTU) for most of the year, with the exception of occasional peaks at the upper sites (Fig 30). Turbidity in the upper sites (PWO2 and PWO1 (Orielton Lagoon)) was generally higher than the sites at and below the causeway (PWO3-5). The highest peak in turbidity occurred at Orielton Lagoon during August 2008 (14.7 NTU), which coincided with a high flow event in the Coal River (although the Coal River does not flow into Orielton Lagoon, Orielton Rivulet is part of the same catchment). Although other significant peaks in turbidity occurred on occasion (e.g. 10.3 NTU at PWO1 during March 2008), these elevations were unrelated to freshwater flow events (but did correspond with a brackish surface layer as discussed previously).

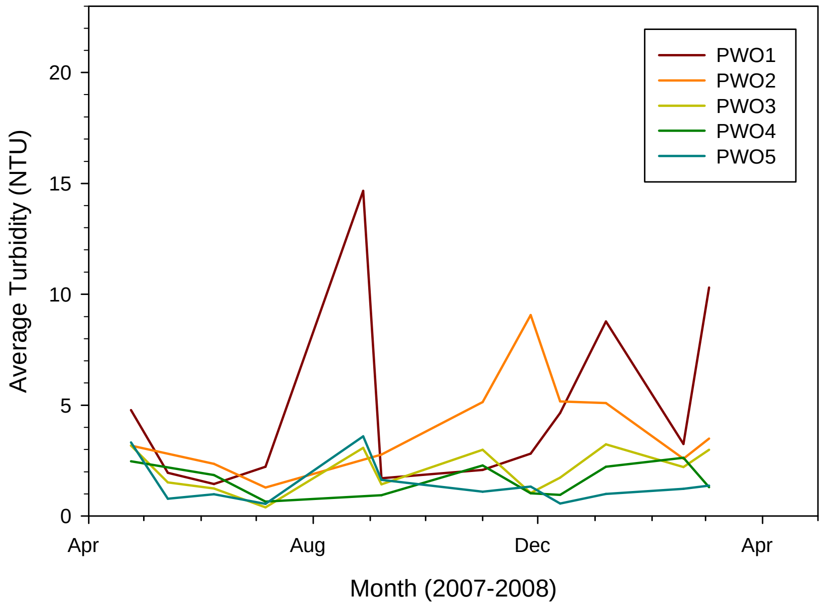


Figure 30. Annual turbidity levels in Pitt Water and Orielton Lagoon.

The pH of Pitt Water and Orielton Lagoon remained fairly stable throughout the year, with little seasonal variation or difference between the upper and lower estuary. The pH ranged from 8.08-8.55 across all sites for 2007-2008 (Fig 31). This is consistent with the degree of mixing indicated in the salinity data.

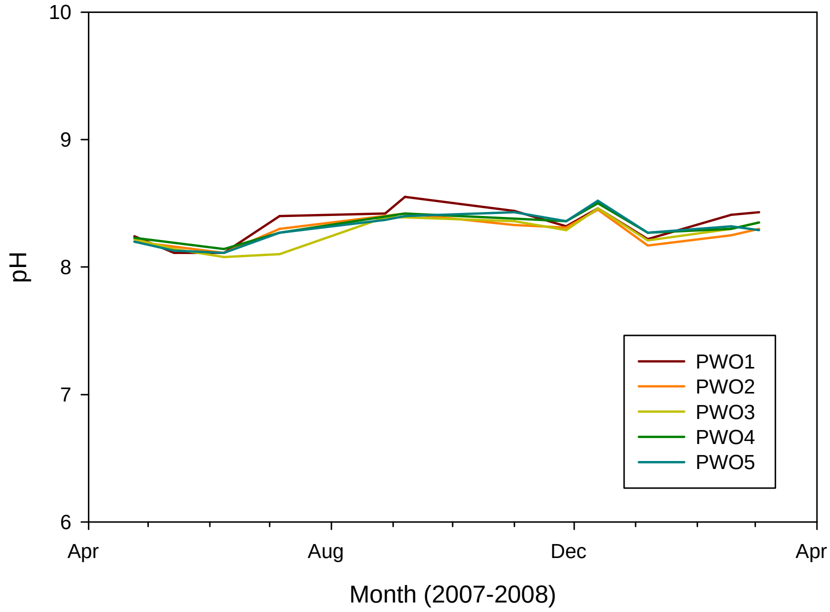


Figure 31. Annual pH readings Pitt Water and Orielton Lagoon.

Nutrients, silica and chlorophyll a

Nitrate plus nitrite (NOx) levels were low throughout the year, and mostly below detection limits. However, NOx did peak at the causeway (PWO3) during July 2007 (137 µg/L) and again in November 2007 (28 µg/L) (Fig 32). These peaks appear to be unrelated to freshwater flow from the Coal River (Fig 27) or to local rainfall events (Fig 25). Soluble reactive phosphorus (SRP) and silica levels also peaked at this site on these dates. It is possible that these occurrences of elevated nutrients are a result of stormwater and/or municipal runoff (e.g. human and animal wastes, soil erosion, detergents, septic systems or runoff from gardens).

Soluble reactive phosphorus (SRP) concentrations were generally in the range 3-10 µg/L, but peaked at the causeway (PWO3) at 21 µg/L. Silicate concentrations were below detection levels at Orielton Lagoon (PWO1), but very low peaks were recorded at the causeway in July (1.8 mg/L) and at the causeway and PWO2 in November 2007 (both 2.3 mg/L).

Ammonia levels were relatively stable for most of the year, peaking at all three sites during April 2007 (maximum 91 µg/L at Orielton Lagoon (PWO1)) (Fig 32). Again, these peaks appear to be unrelated to freshwater flow from the Coal River (Fig 27) or to local rainfall events (Fig 25).

Seasonally, chlorophyll a remained relatively low and stable across all sites, peaking at all sites during January 2008 (maximum 2.6 µg/L at PWO2).

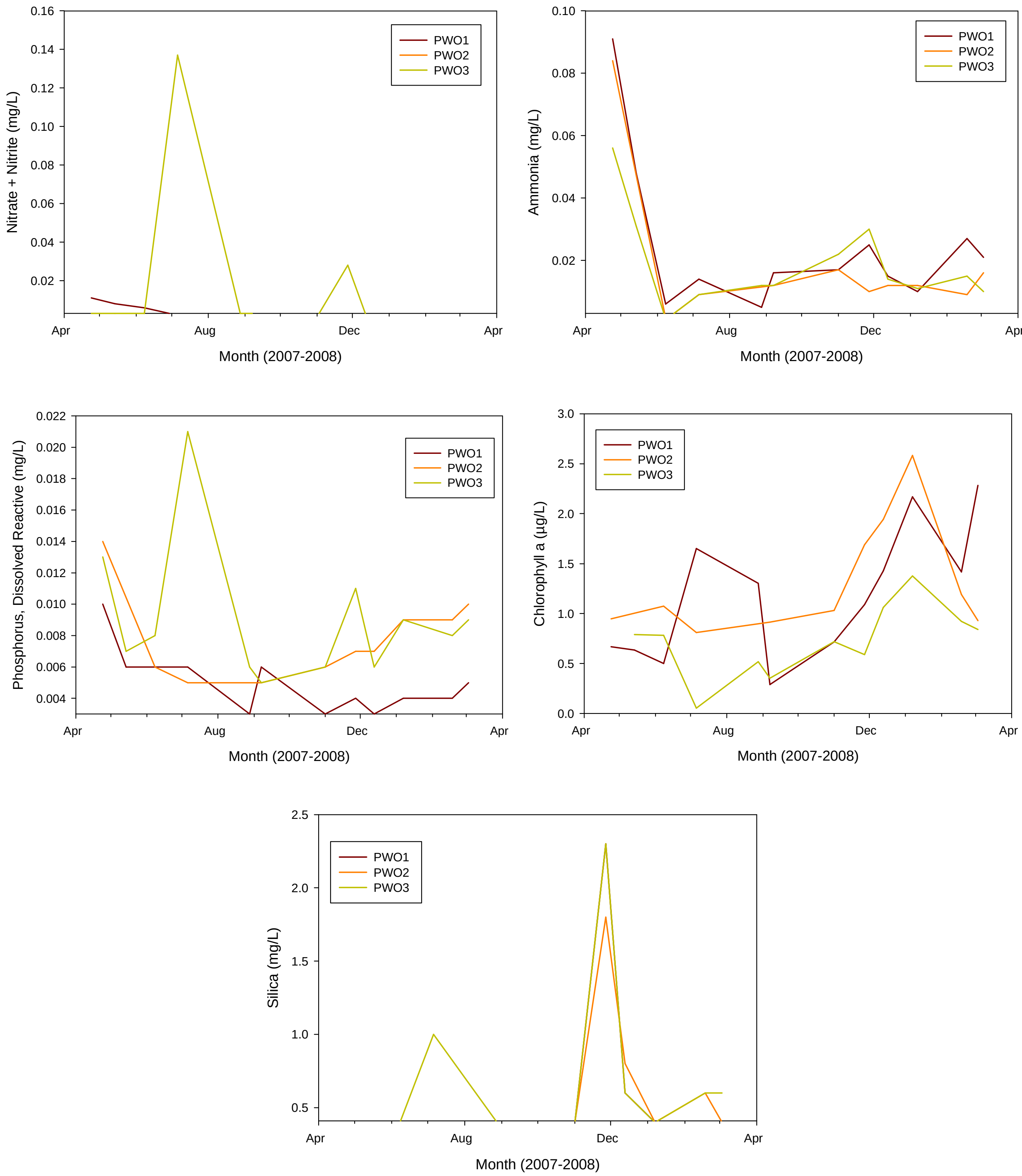


Figure 32. Nutrients, Chlorophyll a and Silica levels in Pitt Water and Orielton Lagoon.

Pathogens

Themotolerant coliform bacteria were monitored by the Tasmanian Shellfish Quality Assurance Program (TSQAP) during 2007-2008 at Pitt Water (sites PWO4-5, PWO5, PWO7, PWO9-10, PWO20-22) (Fig 33). Salinity readings and/or freshwater events are used as triggers for the closure of shellfish production areas as they pre-empt possible increases in pathogen levels. In Pitt Water, salinity readings of less than or equal to 30 ppt in Zone 1 will cause a closure of the growing area. The low levels of coliforms during the sampling period correspond to the low flows of freshwater into the estuary.

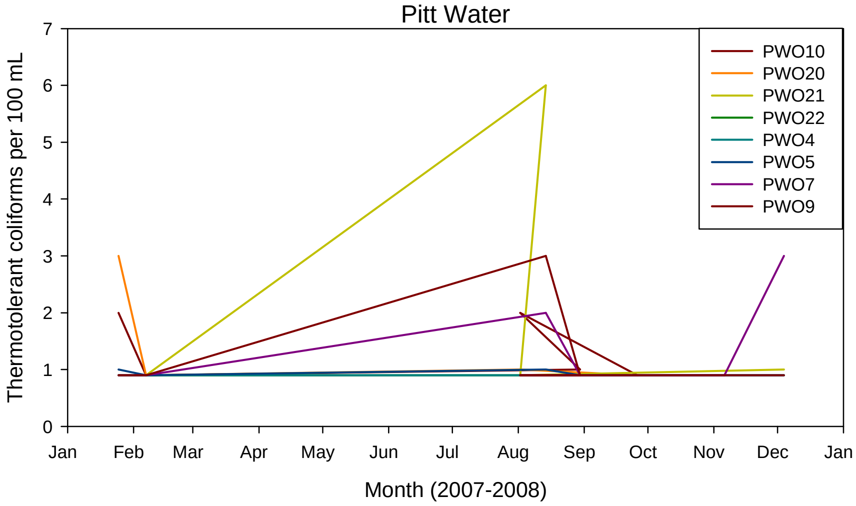
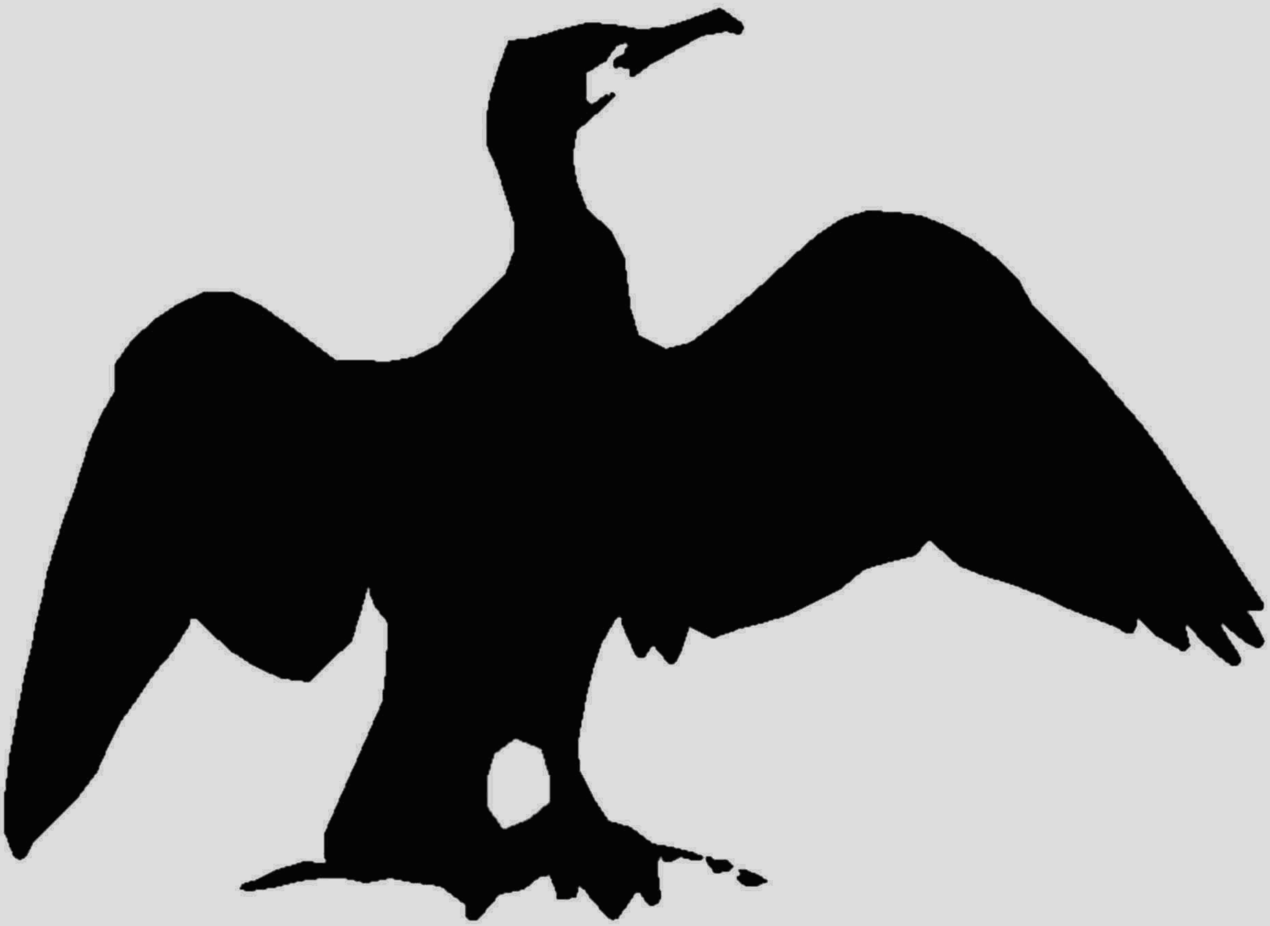


Figure 33. Thermotolerant coliform bacteria levels in Pitt Water and Orielton Lagoon.

North West Bay



Location Description

North West Bay is a relatively sheltered, but deep (max ~35 m) embayment that has been classed as a Group II estuary (open estuaries) (Edgar *et al.* 1999). North West Bay has a wide entrance, which opens at the northern end of the D'Entrecasteaux Channel, but is sheltered from the open ocean by Bruny Island. Its catchment area is about 176 km^2, dominated by the North West Bay River, which delivers around 79% of freshwater input into the Bay (Jordan *et al.* 2002). North West River flows from the southern side of Mount Wellington into North West Bay at Margate. Water from the upper reaches of this river and other smaller rivulets and creeks on the mountain have been dammed or diverted for irrigation and domestic water supply for Hobart and the surrounding suburbs and townships. There are extensive shallow subtidal and intertidal flats at the mouth of the North West Bay River (Jordan *et al.* 2002).

There have been numerous studies based in North West Bay, which have been summarised by Jordan *et al.* (2002). Jordan *et al.* (2002) also conducted a baseline water quality assessment of the estuary.

Climate and tides

North West Bay broadly experiences a temperate maritime climate. However the most relevant BoM station is situated in the upper catchment at Mount Wellington (thus relevant temperature data is not available, but rainfall data is relevant to flow in the North West Bay River). Rainfall patterns in the catchment show few consistent annual trends and rainfall events can occur anytime of year (Fig 34).

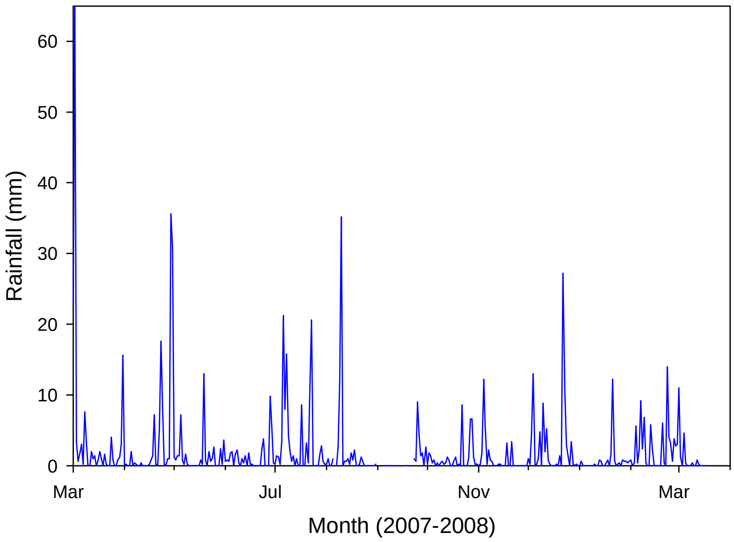


Figure 34. Rainfall recorded at Mt Wellington during 2007-2008

Tides are the main influence on water level in North West Bay, but in comparison to many other coastal regions of Australia the tides have a small range (average 0.5 m) (Jordan *et al.* 2002). Small variations in tidal height across the Bay occur infrequently due to the effect of wind and variations in atmospheric pressure (e.g. low pressure systems with associated strong westerly winds will tend to raise the sea level in North West Bay) (Jordan *et al.* 2002).

Conservation value

Edgar *et al.* (1999) identified North West Bay as being of Class E conservation significance. Class E estuaries are defined as low conservation significance, where the estuary and associated catchment area are severely degraded by human impacts (Edgar *et al.* 1999). Edgar *et al.* (1999) recommends that Class E estuaries and associated catchments be made available for a variety of recreational and commercial purposes, except where threats to public health exist, and to implement remediation processes where practical. Jordan *et al.* (2002) suggested the key threats to the fauna of unvegetated habitats in North West Bay are introduced pests, increased siltation from catchment runoff and organic enrichment from sewage and fish farming activities.

However, North West Bay is an area that is highly valued by the community (e.g. boat launch site, park, memorial, sports ground, saltmarsh, real estate, rural developments). Industrially, North West Bay is used for boat construction, and marine farming, as well as acting as a source to assimilate sewage, processing waste and various forms of catchment and stormwater runoff (Jordan *et al.* 2002). There is a significant finfish (salmon) farm in North West Bay, with on-shore marine farm facilities (TASSAL).

Extent/distribution of key habitat types

Habitat areas in North West Bay were surveyed as part of the Jordan *et al.* (2002) study (Fig 35). North West Bay is dominated by intertidal and subtidal unvegetated areas (over 95% area), which are a key habitat for many fish and macroinvertebrate species, several of which are introduced (Jordan *et al.* 2002). The sediment becomes more silty with increasing depth, reflecting depositional patterns from catchment and marine sources (Jordan *et al.* 2002). Seagrass beds are extensive around much of the shoreline and are dominated by *Heterozostera tasmanica. Halophila australis* and *Zostera muelleri* are found in smaller quantities (Jordan *et al.* 2002).

The wetland area adjacent to the mouth of the North West Bay River and the Margate Rivulet has not been mapped. It is recommended that the habitats in this area of the upper estuary be mapped in the future if possible. The mapping of wetland vegetation may also be a good indicator for ecosystem health and climate change, and North West Bay would appear to be an ideal location to trial this.

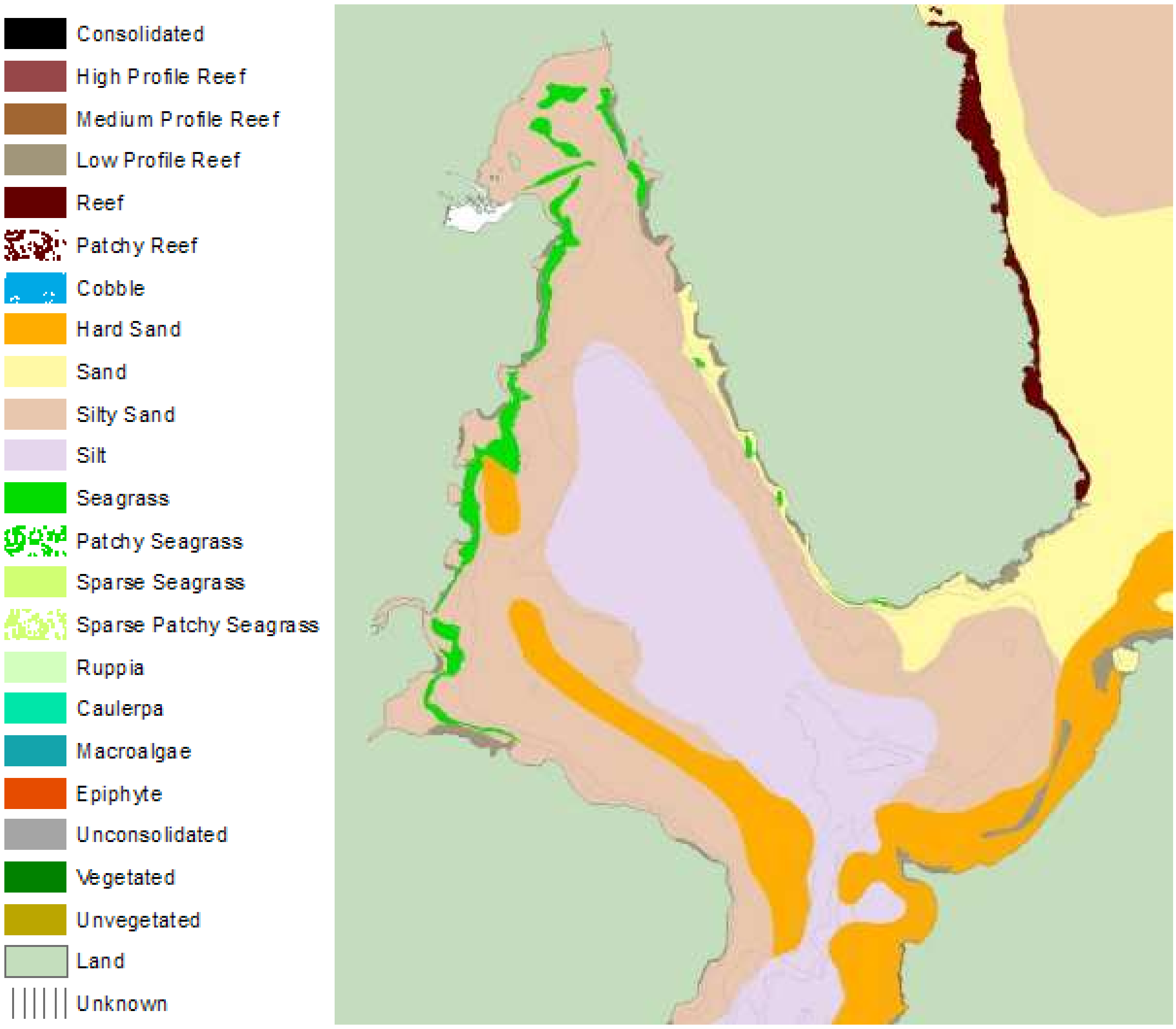


Figure 35. The habitat types in Pitt Water (SEAMAP Tasmania, TAFI).

Water Quality

Freshwater flows and water allocation

The majority of the water allocation in the Derwent Estuary-Bruny Catchment is for Water Supply (33 280 ML) and the remainder (12 698 ML) is used for activities such as stock watering and irrigation (DPIWE 2005. The Water Assessment Branch of DPIW has river flow gauges upstream of North West Bay, on the Snug Rivulet in the Derwent/Bruny catchment. Stream flow (Cumecs) at the gauge furthest downstream (towards the estuary) was graphed for the Snug Rivulet, alongside the salinity graphs for comparison (Fig 36). Water restriction triggers of 2 ML/day have been developed for the North West Bay River, which indicate flows when water restrictions are normally considered (DPIW 2007).

Salinity, temperature and dissolved oxygen profiles

Plots of salinity, temperature and dissolved oxygen are provided for each site over the 12 month study period (Fig 36-38).

The area of North West Bay that was studied for this project can be broken into two main parts: the upper estuary (NWB1-3), which is influenced strongly by the North West Bay River, and the Bay itself (NWB 4-7), which is marine dominated. The upper estuary receives input from North West Bay River, Margate Rivulet and the Dru Point sewage treatment plant (STP).

Waters were strongly stratified at the mouth of the North West Bay River (NWB1), where a distinct freshwater or brackish layer was observed year-round over the marine dominated bottom waters (~30-35 ppt) (Fig 36). Stratification of the water column was less frequent at the sites adjacent to the STP outflow (NWB2) and Stinkpot Bay (NWB3). The marine dominated Bay sites (NWB4-7) are less strongly influenced by freshwater flow from the rivers and creeks flowing into it – particularly towards the middle of the Bay (NWB5). Occasionally, salinity in North West Bay can be influenced by very high flow events in the Derwent and/or Huon Rivers. However during this study period, the sites closest to the D'Entrecasteaux Channel remained marine dominated. Brackish surface waters were only observed at sites that were closest to the shore, indicating it was a result of localised runoff rather than large-scale flood events (e.g. NWB6 and NWB 7 in December 2007). Salinity at the most central site (NWB5) remained constant throughout the year.

Although NWB1 (the mouth of the North West Bay River) was very shallow (~1 m), some stratification in water temperature was observed throughout the year (generally a difference of 1-3^{o}C). Other sites were weakly stratified in temperature during winter, but more distinct differences were observed during summer (warmer on the surface, cooler on the bottom). All sites showed a distinct seasonal trend (cooler in winter, warmer in summer) (Fig 37). Greater extremes in temperature were observed in the upper sites (especially NWB1) due to cold freshwater input in winter (including snow melt) and the effect of solar warming of shallow waters in summer.

Similarly, Dissolved Oxygen levels were variable within the upper sites of North West Bay (Fig 38), falling to as low as 58.2% Sat in bottom waters at NWB1 during January 2008. Although DO levels were weakly stratified at the lower North West Bay sites (NWB4-7), DO mostly remained higher than 85% Sat (even in the bottom waters), which means bottom waters are not depleted in oxygen and have the potential to maintain healthy biological life. Values <60% at NWBI in February 08, however, are possibly cause for concern.

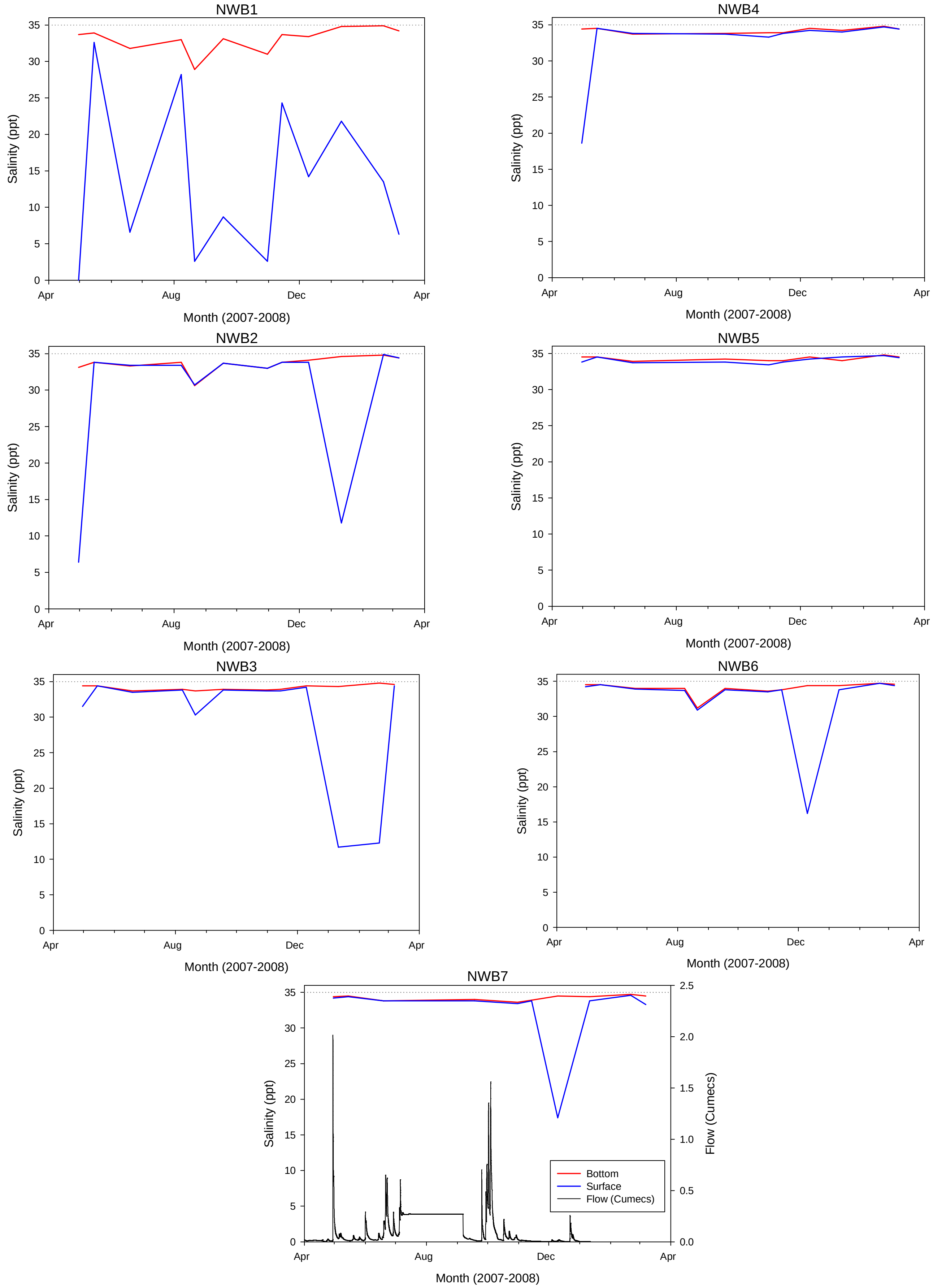


Figure 36. Annual salinity profiles in North West Bay showing deviations from typical marine conditions (35 ppt).

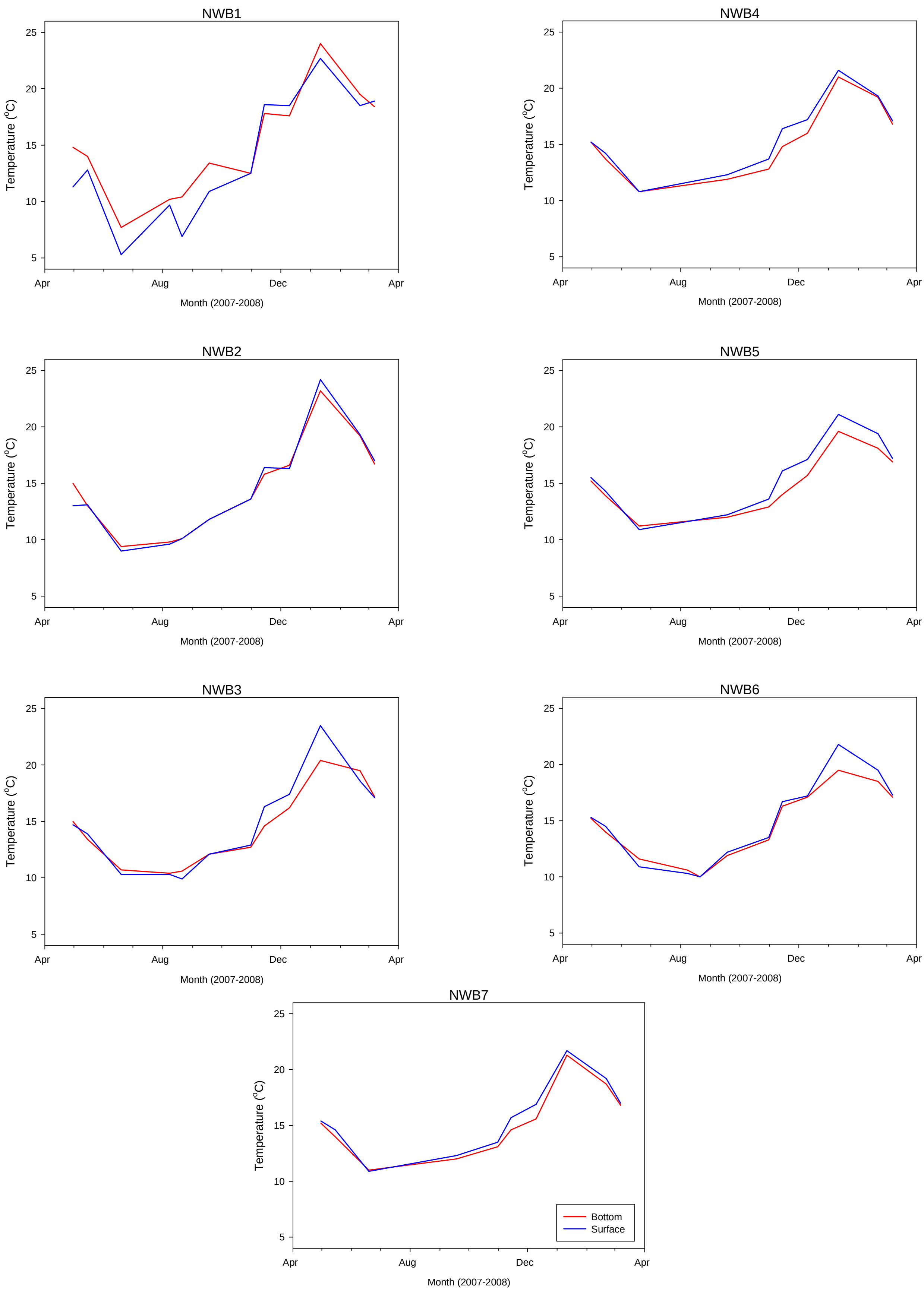


Figure 37. Annual temperature profiles in North West Bay.

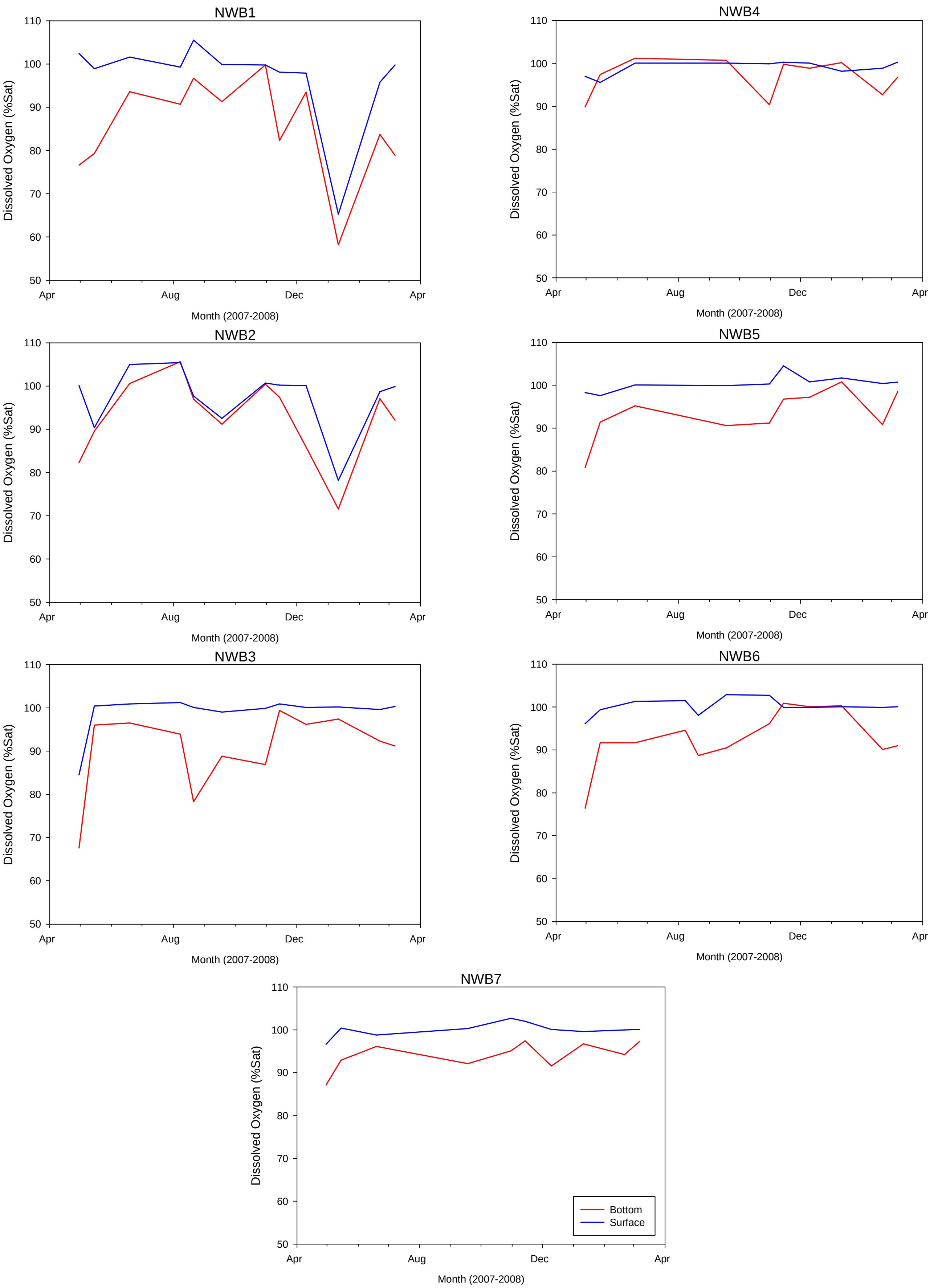


Figure 38. Annual dissolved oxygen profiles in North West Bay.

Turbidity and pH

Turbidity increases during rainfall and high flow events, which results in suspended solids (clays, silts, soils and organic matter) from road runoff, river bank erosion, and land use practices entering the North West Bay River through creeks and rivulets downstream of Longley (Green 1999). The delivery of suspended solids from the catchment also results in an influx of nutrients with areas of high turbidity generally linked to high nutrient levels (Jordan *et al.* 2002).

Turbidity levels throughout North West Bay were generally quite low (<4 NTU all year) (Fig 39). As expected, turbidity levels at the Bay sites (NWB4-7) were lower than the sites in the upper estuary (NWB1-3), reflecting the dominant input of the North West Bay River. Turbidity levels were relatively low at all sites; the highest reading was recorded at the site adjacent to the STP outflow (NWB2), which peaked at 4.94 NTU.

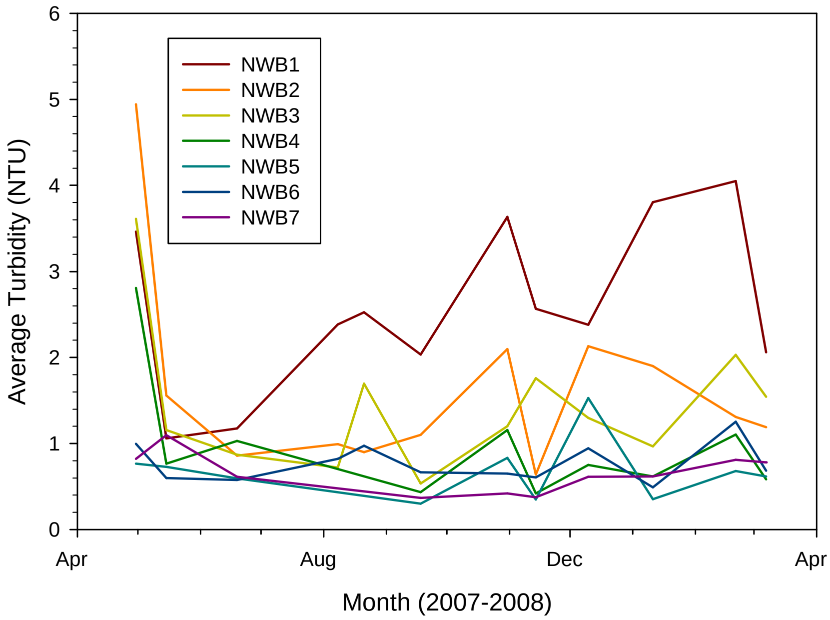


Figure 39. Annual turbidity levels in North West Bay.

As expected for a marine-dominated system, the pH of North West Bay remained fairly stable all year (pH ranged from 7.71-8.59), with little seasonal variation (Fig 40). NWB1 showed the greatest variance in pH, decreasing during summer due to increased freshwater input. This corresponds with low salinity in the surface waters and high turbidity at this site during this time.

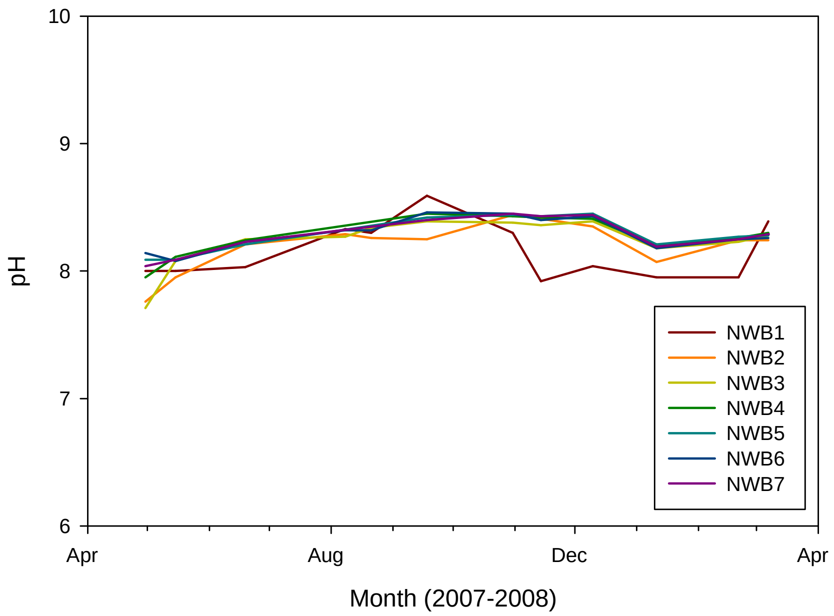


Figure 40. Annual pH readings in North West Bay.

Nutrients, silica and chlorophyll a

Nitrate plus nitrite (NOx) levels at North West Bay were relatively stable throughout the year (Fig 41). All sites were at or below detection limits during late summer/early autumn, and increased during winter. This winter increase in NOx has been recorded at many sites in the D'Entrecasteaux Channel and is due to the influx of nutrient-rich Southern Ocean waters. The exception to this trend occurred at NWB1, where NOx peaked at 180 µg/L during late August. This event corresponds with a distinct freshwater layer (2.6 ppt) (Fig 36), indicating that the influx of NOx originated from runoff in the catchment.

Ammonia levels were relatively stable throughout the system, but peaked on three occasions during summer (highest reading 61 µg/L at NWB1). Ammonia is a product of microbiological activity or an end-product of protein metabolism in animals, and is therefore an indicator of sanitary pollution. High levels are toxic to marine organisms, particularly in stressed systems. The ANZECC Water Quality Guidelines for estuaries suggest a 15 µg/L trigger for both NOx and ammonia, keeping in mind the limitations of these guidelines (see page 76). The cause of high nutrient input from the North West Bay River requires further investigation.

Soluble Reactive Phosphorus (SRP) levels were relatively stable across sites, peaking on occasions during summer, but the most pronounced and sustained peak at the majority of sites occurred during winter 2007 (maximum 17 µg/L). Interestingly, these peaks in SRP levels did not result in increased chlorophyll a, indicating another factor was limiting for plant growth (probably low water temperatures). Chlorophyll a levels were low throughout winter (average 0.61 µg/L), increasing during spring (median 1.51 µg/L) and highly variable during summer. Chlorophyll a peaked during December 2007 at NWB1, where levels reached 8.67 µg/L.

Silica levels were below detection limits (5 µg/L) during most of the year. The exception to this was at the mouth of the North West Bay River, where silica levels were quite high (maximum 11.0 µg/L), and correlates with low salinity in surface waters (i.e. silica originating from weathering of silicate minerals in the catchment).

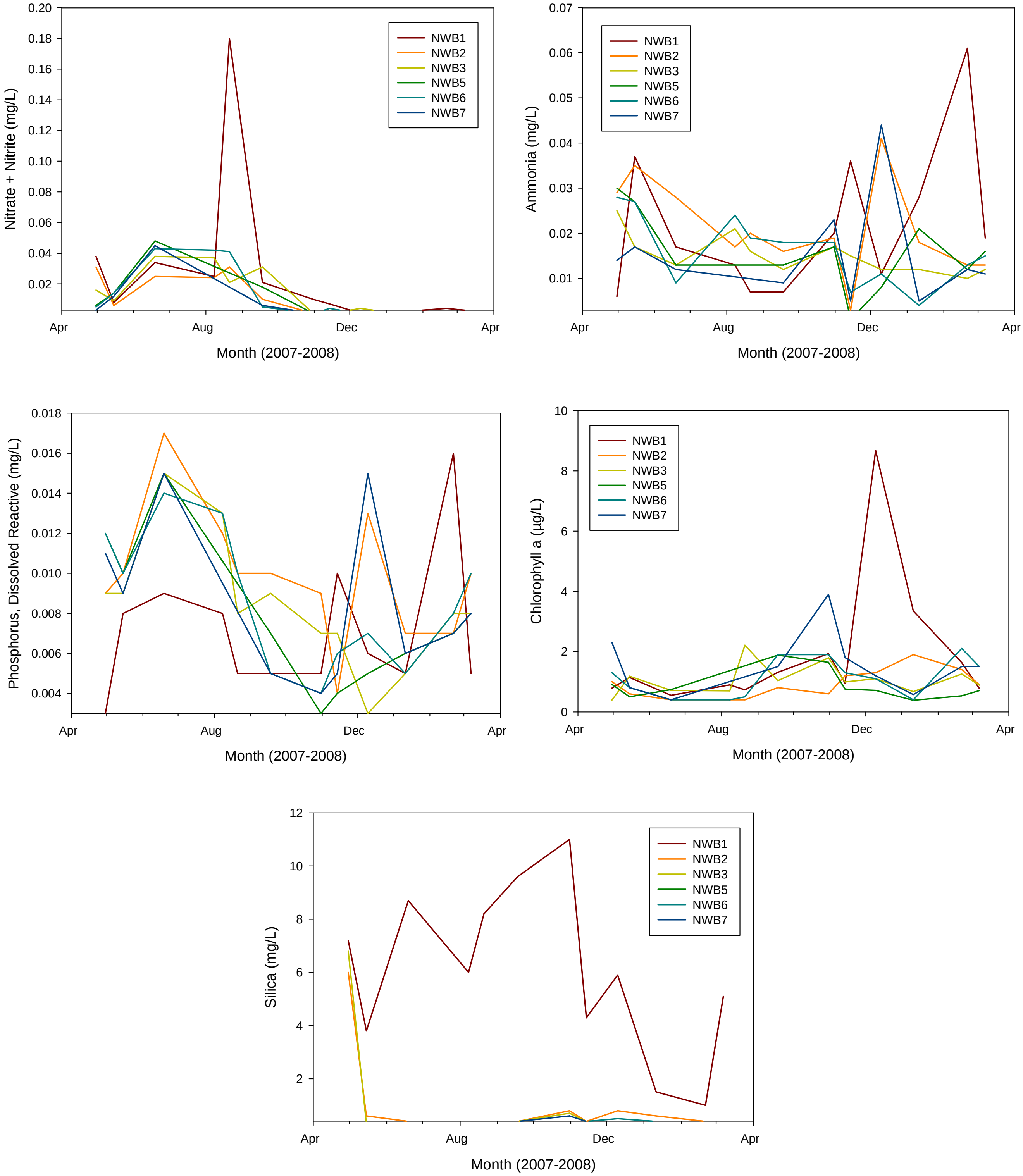
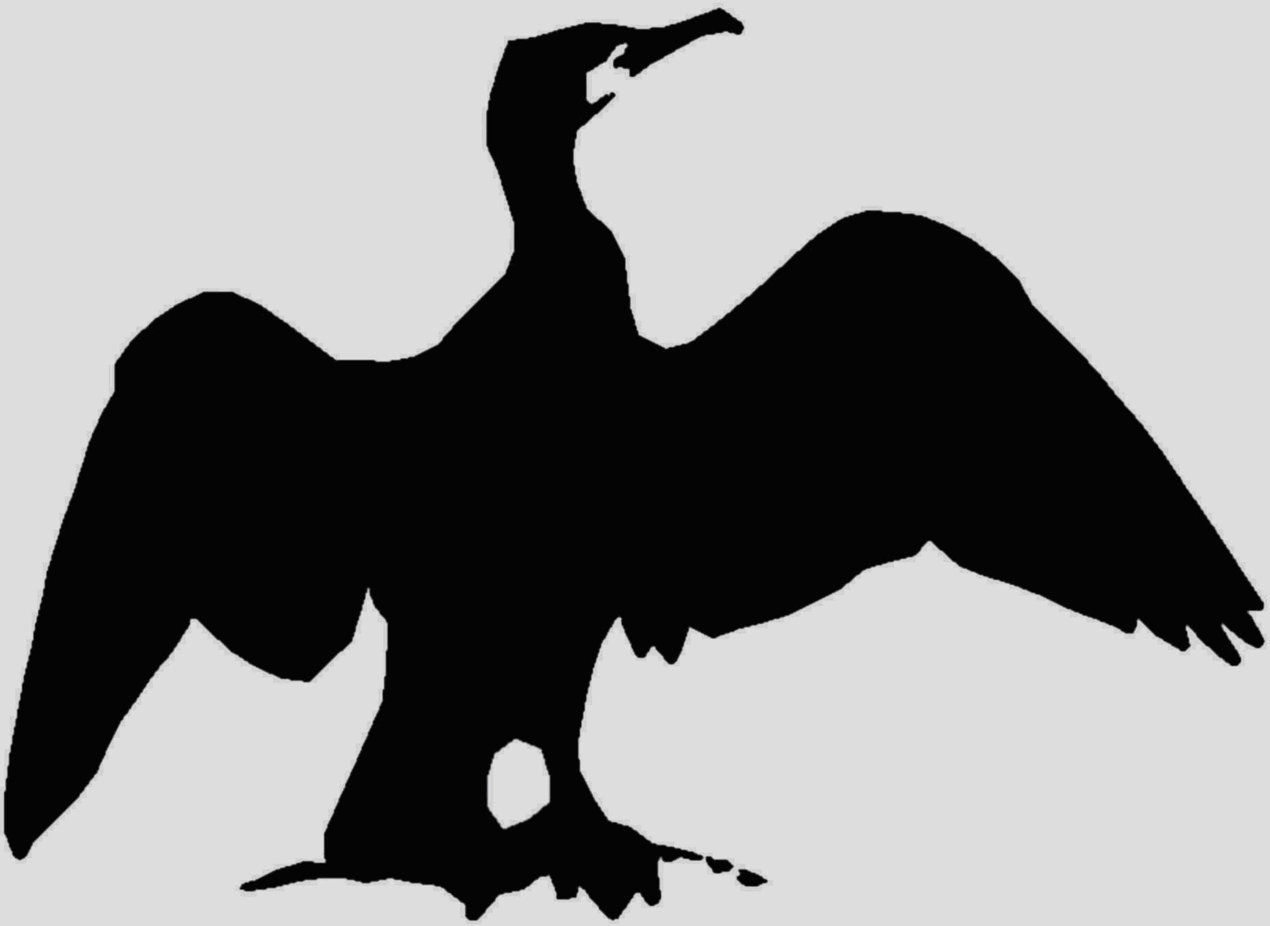


Figure 41. Nutrients, Chlorophyll a and Silica levels in North West Bay.

Port Cygnet



Location Description

Port Cygnet is a Group II estuary (open estuaries; Edgar *et al.* 1999) that is often considered part of the Huon Estuary (e.g. Huon Estuary Study, CSIRO). It is marine-dominated, with very little freshwater input from the Agnes and Nicholls Rivulets. Port Cygnet has three main freshwater inputs – Agnes Rivulet, Nicholls Rivulet and the Huon River. Port Cygnet Estuary is tide dominated and in a modified condition (Heap *et al.* 2001).

The area is very important to the local community as a port and for its recreation and tourism values. Port Cygnet is utilised for salmon and shellfish (oysters and mussels) aquaculture. The shellfish aquaculture businesses operate under a restricted lease whereby they can only sell juvenille shellfish for on-growing or harvest due to blooms of the introduced toxic dinoflagellate (*Gymnodinium catenatum*) during summer.

The estuarine drainage area has been moderately impacted by human activities (Edgar *et al.* 1999). The majority of the land in the estuarine catchment area is privately owned (126.4 km^2) with a small amount protected in Crown Reserves (4.3 km^2). The majority of the catchment is rural land with a sparse population; the urban/residential centre is based on the foreshore of Port Cygnet at the township of Cygnet. The population density of this estuarine drainage area was 19.22 km^{-2} and the population density of the estuarine catchment area was 14.71 km^{-2} in 1998 (Edgar *et al.* 1999). The urban area of the estuarine drainage area was 0.2 km^2 (0.55% of EDA); the total urban area of the catchment was 0.5 km^2 (0.36% of ECA) (Edgar *et al.* 1999). Cygnet has one Sewage Treatment Plant (permitted flow 400 kL/day, secondary treatment, chlorination) (Edgar *et al.* 1999).

Climate and tides

The nearest meteorological station is located at Geeveston, which is on the same latitude as Port Cygnet and is part of the Huon catchment (Fig 42).

Bureau of Meteorology records from Geeveston for the period 1958 to 2008 show that the mean daily temperature in February, the warmest month, ranges from a maximum of 22.2°C to a minimum of 9.9°C. In July, the coldest month, mean daily temperatures range from a maximum of 12.1°C to a minimum of 2.3°C (BoM 2008).

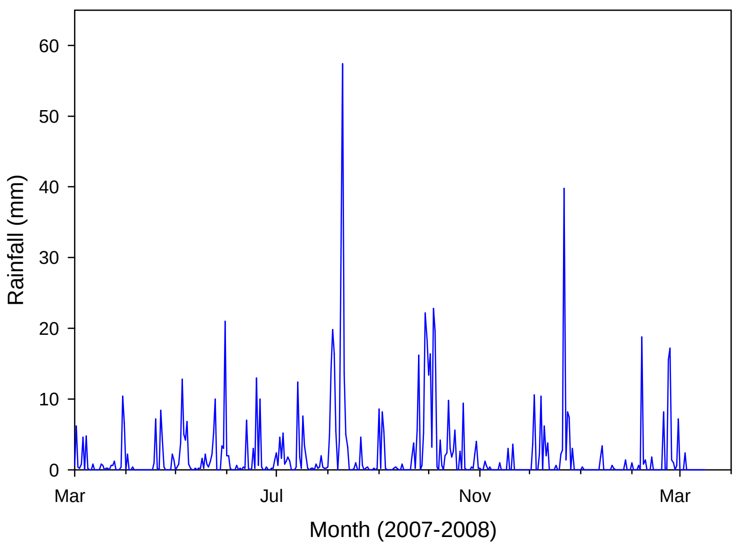


Figure 42. Rainfall recorded in Geeveston during 2007-2008

Conservation value

Edgar *et al.* (1999) identified Port Cygnet as being of Class D conservation significance. Class D estuaries are defined as low conservation significance, where the estuary and associated catchment area are moderately degraded by human impacts (Edgar *et al.* 1999). Edgar *et al.* (1999) recommend that Class D estuaries and associated catchments be made available for a variety of recreational and commercial purposes, except where threats to public health exist, and to implement remediation processes where practical.

Port Cygnet contains an estuarine wetland (107.8 Ha) on the southern boundary of Cygnet, which is nationally recognised as a Conservation Area and is listed on the Register of the National Estate for its importance as a refuge for over 70 bird species. Port Cygnet contains a shark nursery area and two foreshore reserves: Port Cygnet Conservation Area and Randalls Bay Conservation Area.

Extent/distribution of key habitat types

There are no habitat maps available for Port Cygnet. It is recommended that a baseline of habitat types be mapped as soon as possible and updated every 5 years.

Water Quality

Freshwater flows and water allocation

The Water Assessment Branch of DPIW has river flow gauges upstream of the Port Cygnet estuary in the Huon River. Stream flow (Cumecs) at the gauge furthest downstream (towards the estuary) was graphed for Huon River, and compared with salinity data (Fig 43).

Salinity, temperature and dissolved oxygen profiles

Plots of salinity, temperature and dissolved oxygen are provided for each site over the 12 month study period (Fig 43-45). The sites studied at Port Cygnet can be broken into two main zones – the wetland (PC1-3) and the Port (PC4-6).

Surface salinity in Port Cygnet is strongly related to freshwater inputs from Agnes Rivulet at the northern (wetland) end of the estuary, and the Huon River at the southern end of the estuary (Fig 43). Salinity profiles were stratified throughout the year, including within the shallow wetland. The exception to this was at PC2, where strong mixing occurs due to strong tidal flow over a shallow weir. Although flows in the Agnes Rivulet are low, the Agnes does influence salinity levels in the wetland area and as far out as PC4. Surface salinity dropped to 0.6 ppt in the wetland during spring. In contrast, the surface salinity in the Port sites (especially PC5 and PC6) was strongly influenced by increased flow in the Huon River, while bottom waters remained marine dominated (~35 ppt) throughout the year).

A distinct seasonal trend in water temperature variation was observed at all sites (cooler in winter, warmer in summer) (Fig 44). Water temperatures were not as clearly stratified within the wetland (PC1-3), due to the very shallow nature of these waters (~0.5 m). On the other hand, clear temperature stratification was observed in the Port sites (PC4-6). Brackish surface waters were cooler than the marine dominated bottom waters during autumn/winter, and warmer in spring-summer.

Clear groupings between the wetland sites and the Port sites were also observed with regards to dissolved oxygen (Fig 45). DO levels were highly variable within the upper estuary (wetland area), but not often highly stratified. DO levels at these sites dropped to low levels (min 9.2% Sat) during summer and autumn, but remained fairly high during winter and spring. Low DO levels during summer/autumn were probably caused by warm temperatures and reduced flow and therefore reduced flushing of the wetland. Low flushing results in a build up of organic matter and in conjunction with warm temperatures, promotes bacterial activity and therefore a drop in DO. Although DO levels at the Port sites remained fairly stable throughout the year (especially at the outer sites e.g. PC6), bottom waters were comparatively depleted of oxygen. The low values of <40% at PC4 in autumn and <60% at PC5 in autumn and spring are cause for concern. Low DO in Port Cygnet compared with the Huon estuary have previously been recorded (TAFI, unpublished data).

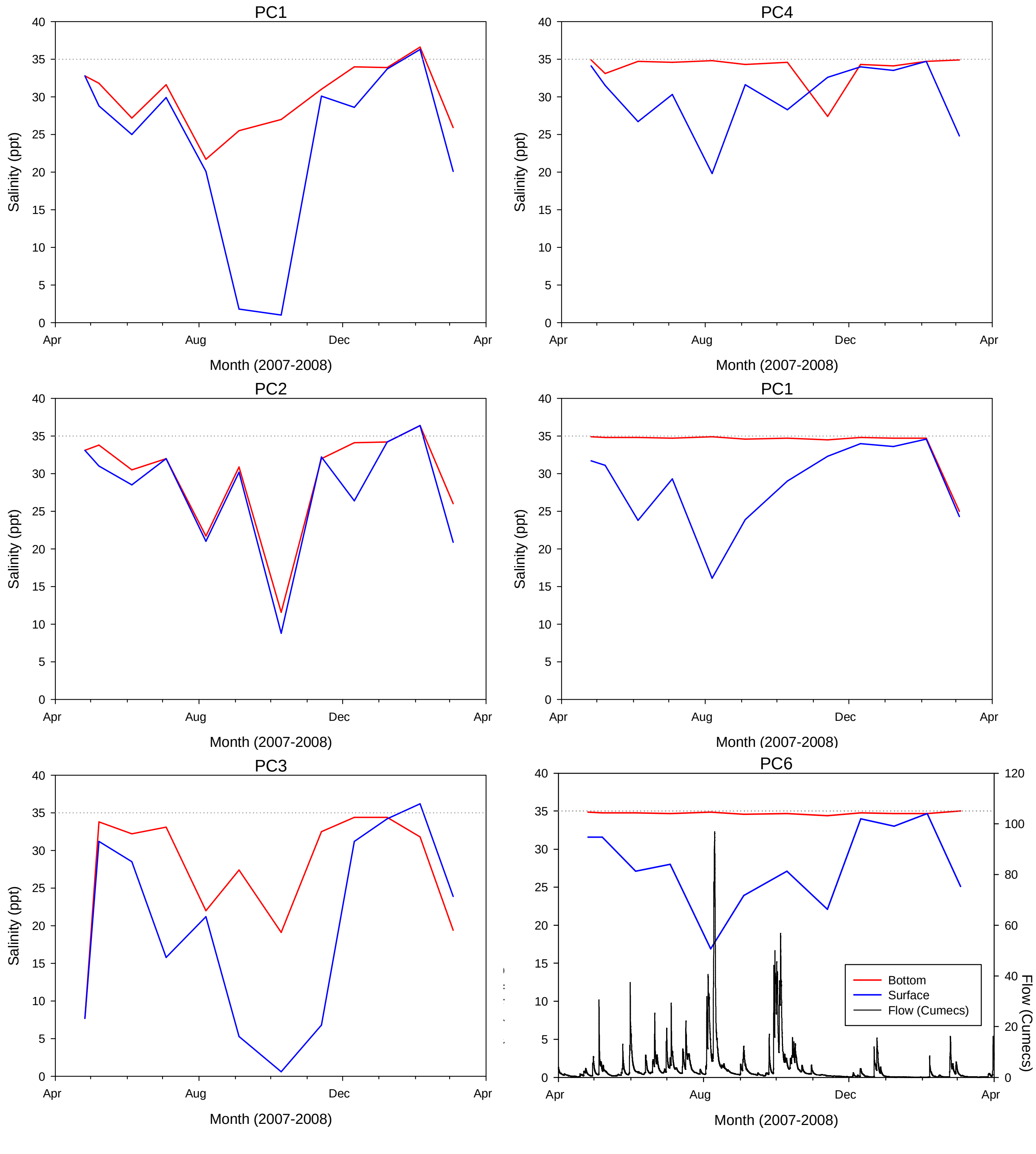


Figure 43. Annual salinity profiles in Port Cygnet showing deviations from typical marine conditions (35 ppt) and flow rates in the Huon River.

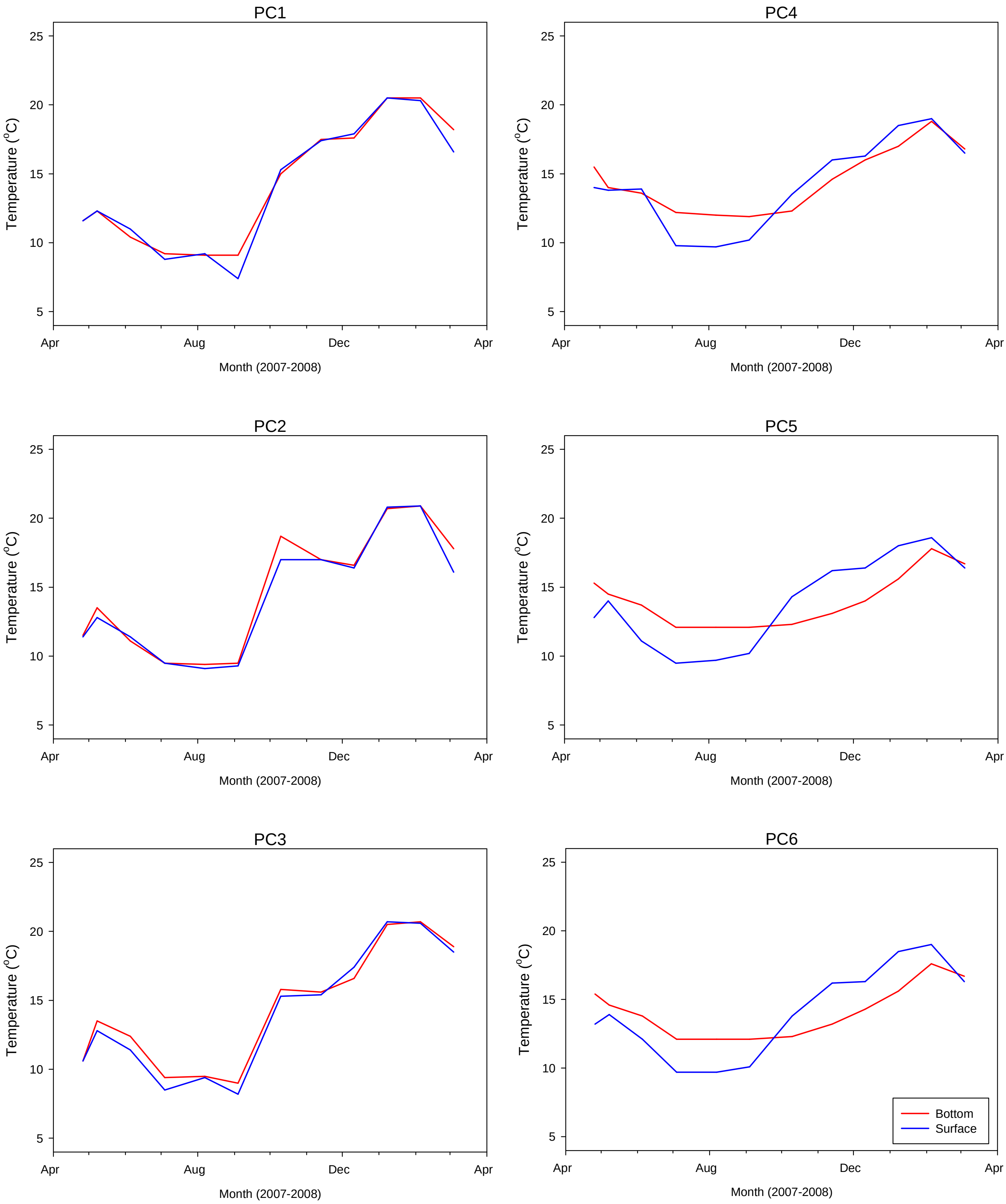


Figure 44. Annual temperature profiles in Port Cygnet.

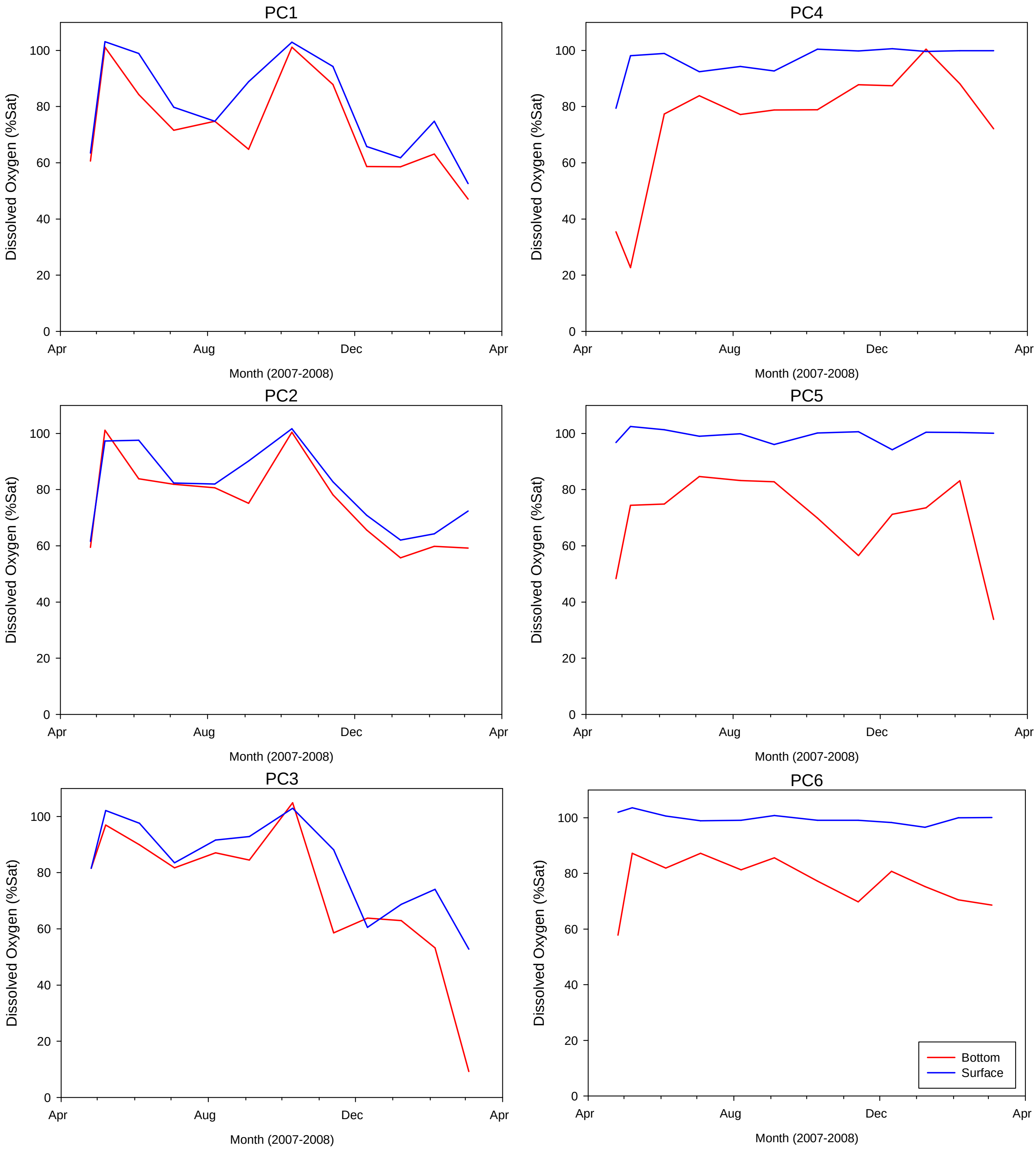


Figure 45. Annual dissolved oxygen profiles in Port Cygnet.

Turbidity and pH

Turbidity levels in Port Cygnet were distinctly different in the wetland area (range 3.0 to 34.1 NTU) in comparison to the Port area (range 0.3 to 4.1 NTU) (Fig 46). Turbidity peaked during spring in the wetland, when there was higher freshwater input from Agnes Rivulet (see salinity profiles, Fig 38). Slight peaks in turbidity in the Port sites were associated with increased flow in the Huon River (see flow graph, Fig 43).

The pH levels in Port Cygnet remained fairly stable all year, with little seasonal variation (Fig 47). Sites within the wetland showed higher variance and a lower average (pH 7.97) when compared to the Port sites (average 8.20).

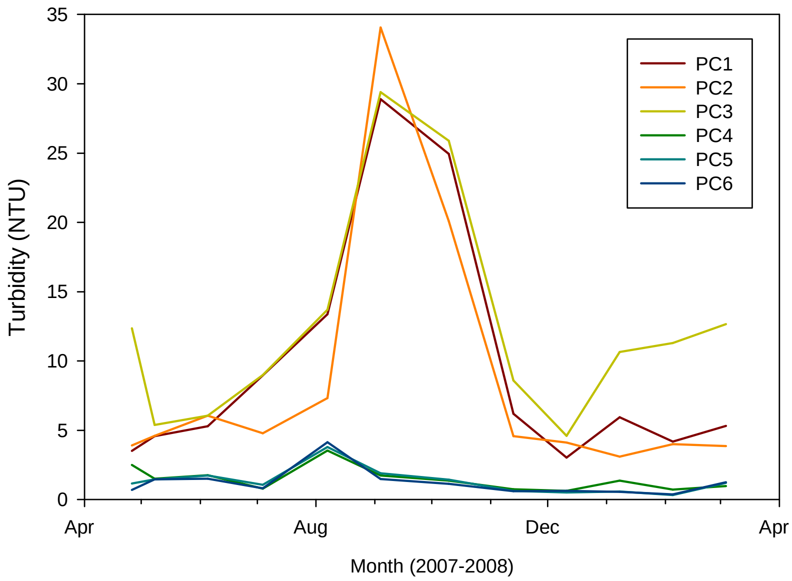


Figure 46. Annual turbidity levels in Port Cygnet.

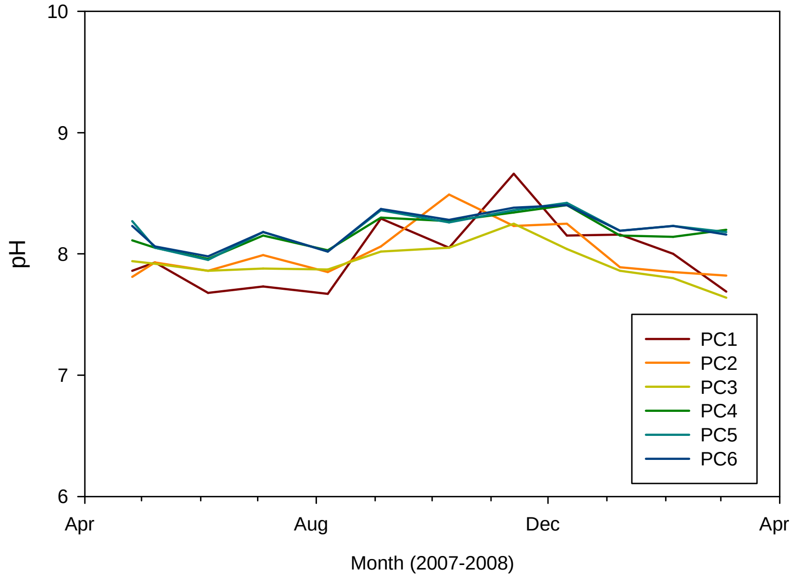


Figure 47. Annual pH readings in Port Cygnet.

Nutrients, silica and chlorophyll a

Bobbi (1998) found Agnes Rivulet to be the most degraded waterway in the Huon Catchment. It had the highest concentrations of dissolved salts and nutrients (especially Nitrate, TN and TP) and the highest turbidity levels. It also had the highest median temperature and the widest range (probably a consequence of the lack of riparian vegetation), as well as the highest pH records (and highest median pH).

The increase in suspended solids present in the wetland during spring (Fig 46) resulted in an influx of nutrients, indicating runoff via the Agnes Rivulet is the main source of nutrients to the estuary (via agricultural or municipal runoff). NOx, silica and chlorophyll a peaked at the wetland during September 2007, with NOx reaching 438 µg/L, silica reaching 11.0 mg/L and chlorophyll a reaching 5.81 µg/L (Fig 48). In comparison, nitrate plus nitrite (NOx) levels were relatively stable across the Port sites (PC4-6) throughout the year and were mostly below detection limits during summer. Similarly, ammonia levels were also relatively stable throughout the year across the Port sites, while ammonia levels at PC2 were consistently higher, peaking at 116 µg/L during June 2007.

Phosphorus levels were higher in winter than summer at the Port sites, while generally higher at PC2. Phosphorus levels peaked at PC2 during summer and autumn, with the highest levels recorded reaching 30 µg/L. Chlorophyll a levels appeared to relate to increased freshwater flow from either the Agnes Rivulet or the Huon River (PC2 peaked at 5.81 µg/L during high flow from the Agnes, while PC6 peaked at 3.49 µg/L during high flow from the Huon).

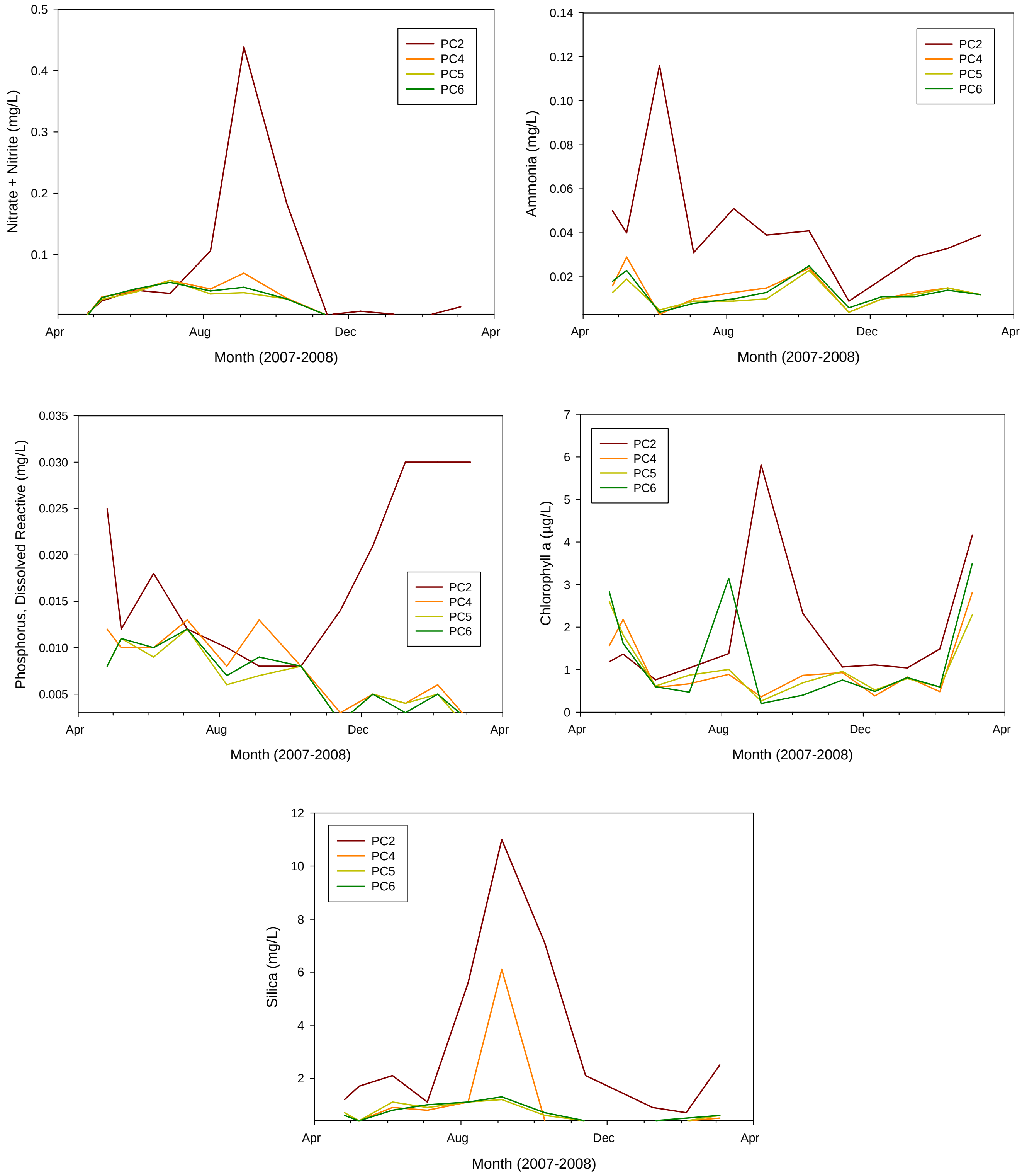


Figure 48. Nutrients, Chlorophyll a and Silica levels in Port Cygnet.

Pathogens

Themotolerant coliform bacteria were monitored by the Tasmanian Shellfish Quality Assurance Program (TSQAP) during 2007-2008 at Gardeners Bay (sites GB2-4) and Deep Bay (sites DB3, DB4, DB6) in Port Cygnet (Fig 49). Themotolerant coliform bacteria levels increased during winter months at all sites. Gardeners Bay is a restricted shellfish lease (i.e. it is always closed for the sale of mature shellfish for consumption), while salinities of less than 28 ppt will cause the Deep Bay lease area to be closed.

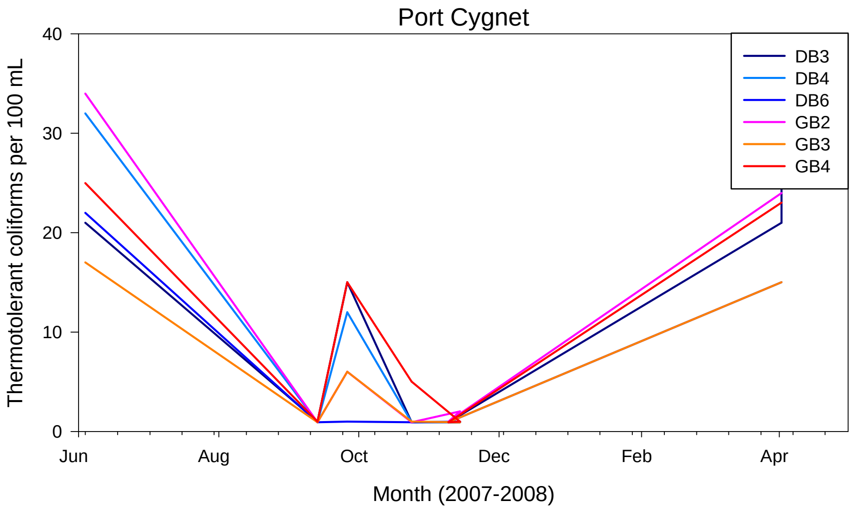
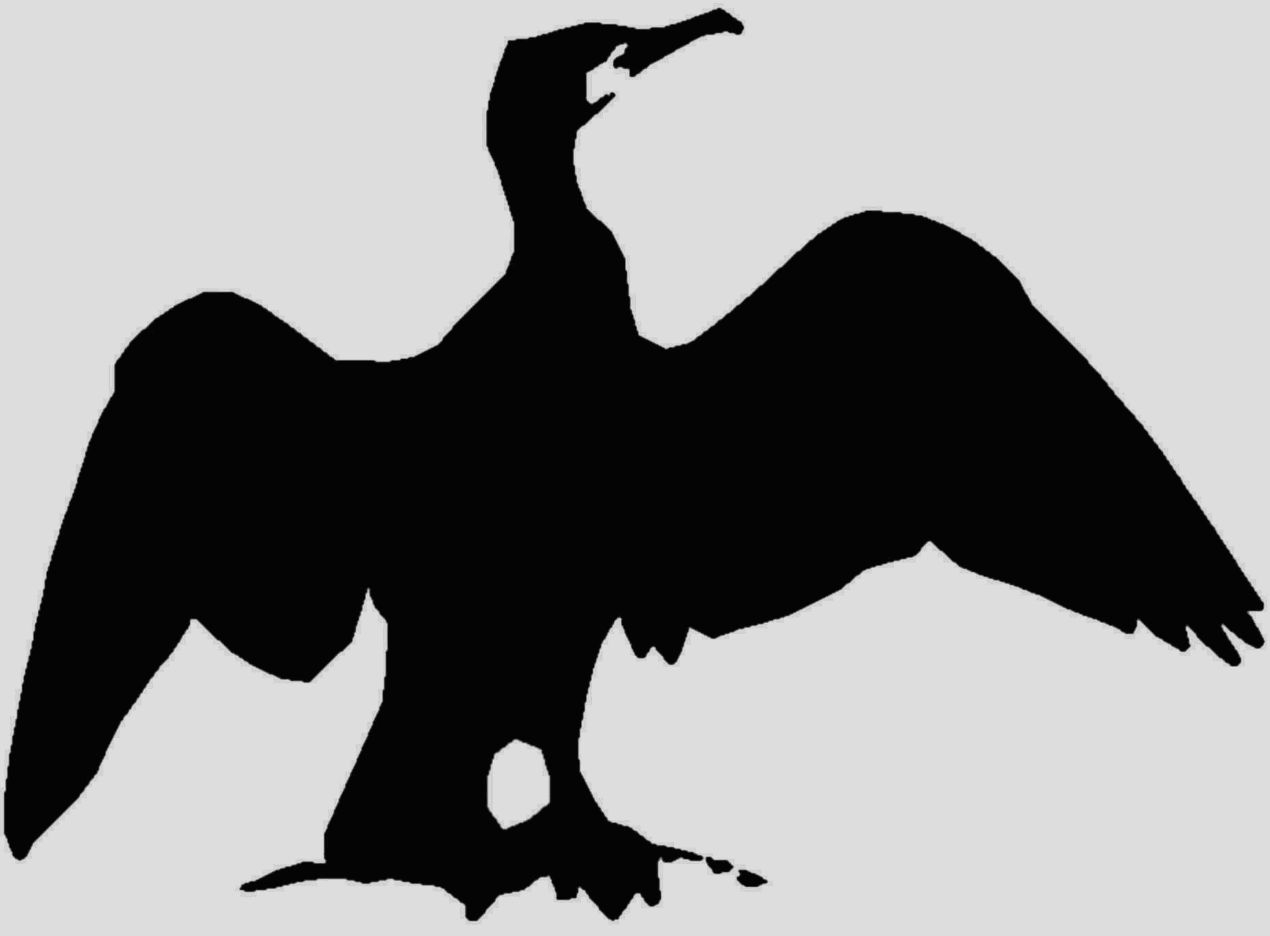


Figure 49. Thermotolerant coliform bacteria levels in Port Cygnet.

Macroinvertebrate Results



Macroinvertebrate Results

A total of 93 species were collected from the five estuaries, including three introduced species: bivalves *Corbula gibba* (Port Cygnet and North West Bay 7) and *Theora fragilis* (North West Bay) and the sabellid polychate *Euchone limnicola* (Port Cygnet) (Appendix 1). All have previously been recorded from this region (i.e. not new records).

In terms of biodiversity, sites from NW Bay contained the highest numbers of species (54 species), compared with 26 species at Little Swanport, 23 at Moulting lagoon, 22 at Pitt Water/Orielton and 19 at Port Cygnet (Figure 50). The three marine dominated sites in North West Bay contained significantly more species that the river dominated site, suggesting that the more stable marine environment in the bay is able to support a greater diversity of species. At Little Swanport (sites F1-3) species numbers decreased with increasing distance (and hence more fluctuating estuarine conditions) up the estuary. At Moulting lagoon the sites were more varied although lowest numbers were recorded near Apsley Marshes which periodically had degraded water quality. Species numbers from Port Cygnet and Pitt Water sites were generally average across all the estuaries, except for low numbers at the Pitt Water Causeway site.

Faunal abundances were varied across sites and estuaries and no clear patterns were evident (Figure 51). Commonly polluted sites in estuaries have few species, but those that can survive the conditions occur in high numbers. This was not evident is our samples and further sampling is required to better understand the macroinvertebrate assemblages that we observed

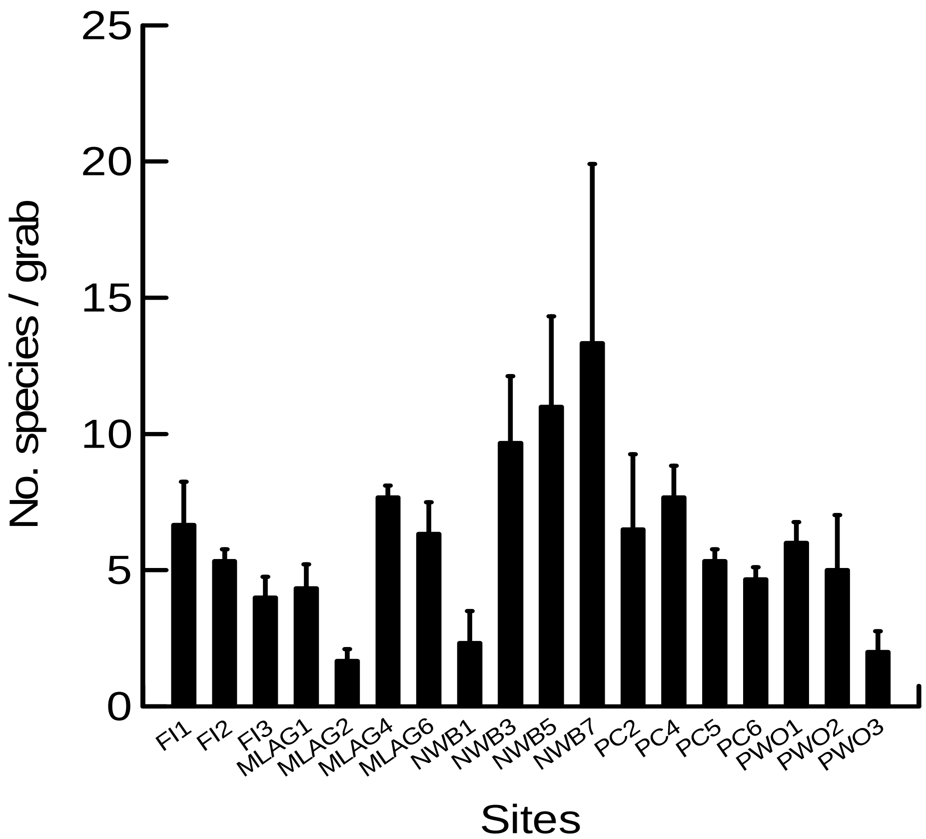


Figure 50. Number of macroinvertebrate species per grab at each sampling location in the 5 estuaries: Little Swanport (F), Moulting Lagoon and Great Swanport MLAG), North West Bay (NWB), Port Cygnet (PC) and Pitt Water – Orielton Lagoon (PWO).

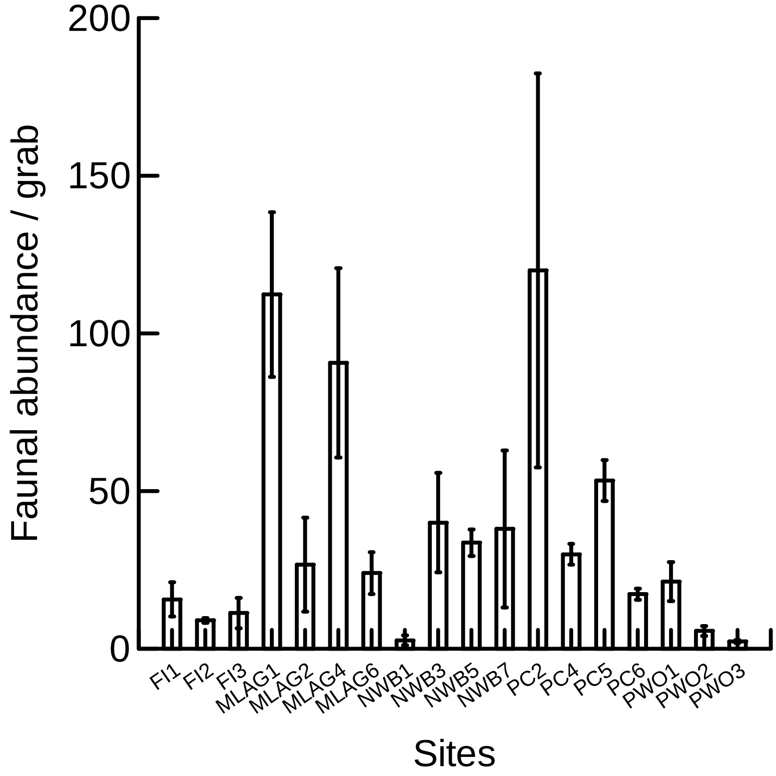


Figure 51. Abundance of macroinvertebrate fauna per grab at each sampling location in the 5 estuaries: Little Swanport (F), Moulting Lagoon and Great Swanport MLAG), North West Bay (NWB), Port Cygnet (PC) and Pitt Water – Orielton Lagoon (PWO).

A multi-dimensional scaling (MDS) analysis of the macroinvertebrate data from each estuary was conducted. MDS is a standard analytical technique commonly used to compare macroinvertebrate communities from different sites (it is described in texts on statistical methods for biological sciences and in reports and publications from TAFI on macroinvertebrate fauna). MDS takes into account the similarity/dissimilarity of the species composition and abundance of each species between sites and displays these differences graphically. Basically, the more different sites are with respect to species composition and abundance, the further apart they are on a graph.

The MDS plot for macroinvertebrates from five estuaries in southern Tasmania (Figure 52) shows a gradual transition from marine to brackish water communities. The macroinvertebrate assemblages from sites to the left of Figure 52 are marine/lower estuarine (PC4,5,6, NW3,5,7 and MLAG 6). Three Port Cygnet sites in the bottom-left hand corner are further distinguished on the basis of high densities of the introduced bivalve *Corbula gibba*. In the bottom-right hand corner the group of four sites (MLAG1,2,4, and PC2) are, based on their faunal composition, river-dominated estuarine environments (i.e. dominated by *Paracorophium* sp., *Ascorbis* sp. and *Arthritica helmsi*). The Little Swanport (F1-3) and Pitt Water (PWO1-3) sites show mid estuarine fauna.

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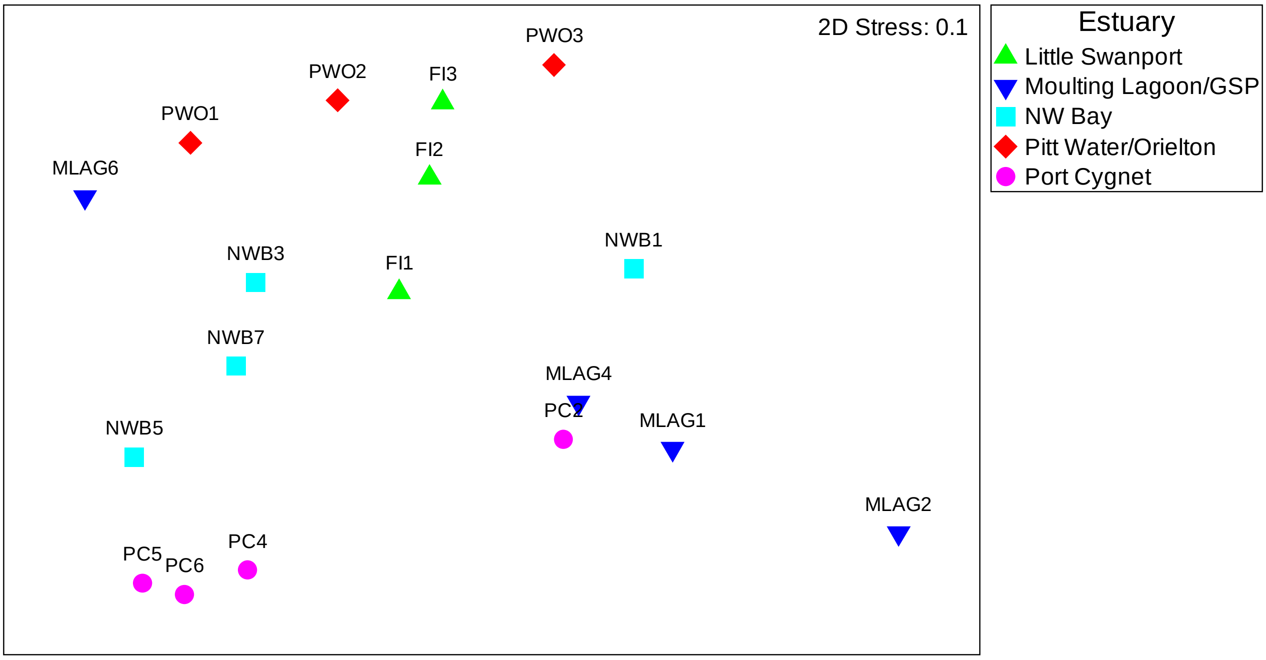
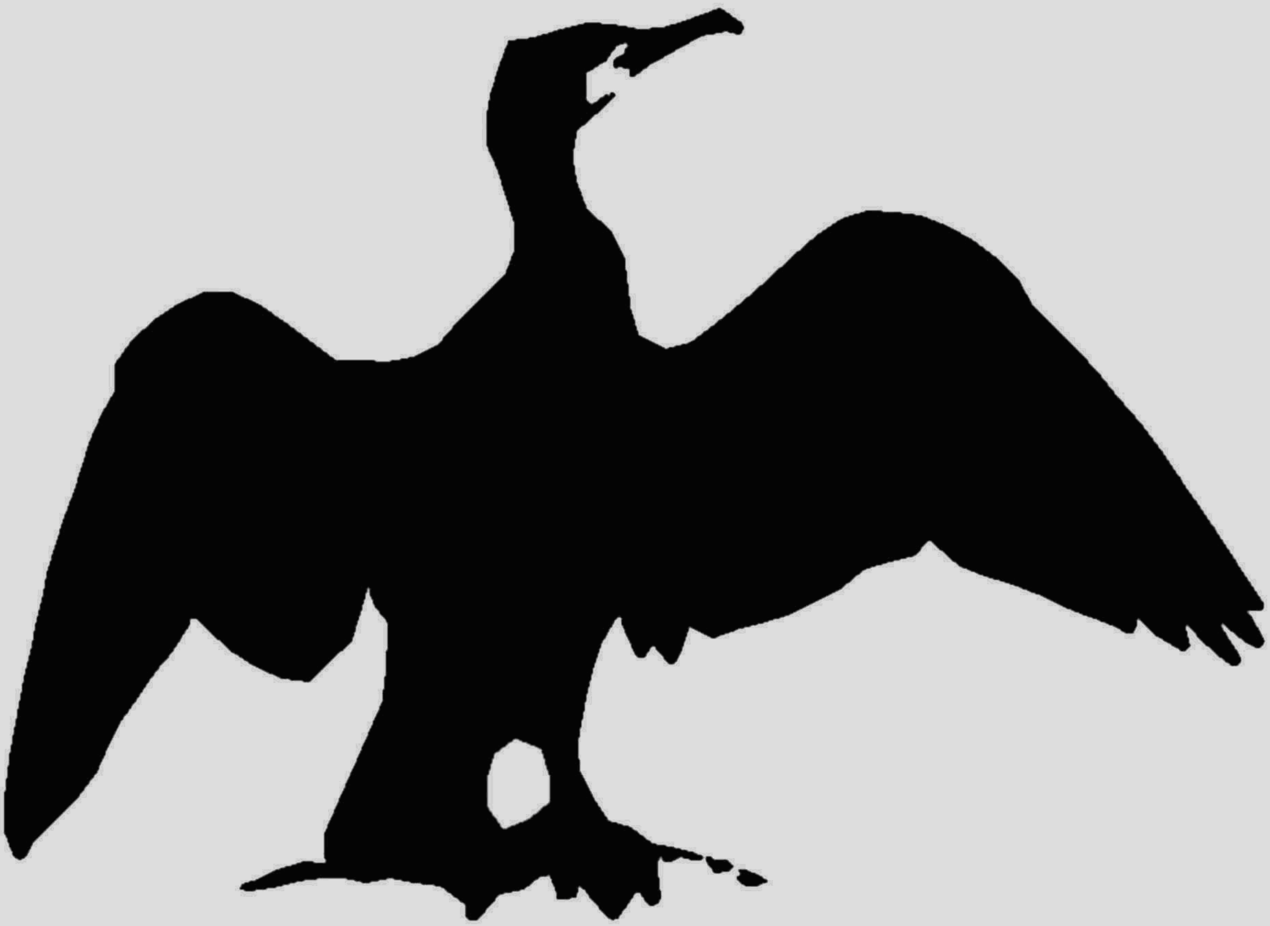


Figure 52. Multi-dimensional scaling (MDS) plot of macroinvertebrate data from each sampling location at the five estuaries.

Management of Coastal and Estuarine Condition



Background

ANZECC guidelines for water quality

The ANZECC Water Quality Guidelines (2000) recommend a number of steps for assessing water quality (see Introduction). To a large extent the 12 month CERCA baseline water quality monitoring program described in this report was developed and trialled using these guidelines. We have followed the ANZECC (2000) format to develop "draft" trigger values for some estuaries in the Southern NRM Region. These values are designed to be specific to local areas and should be updated as more data become available. The ANZECC Water Quality Guidelines (2000) recommend a minimum of 24 months baseline data are to be used for setting trigger values, so it is important that values be updated as more data become available.

Low-risk trigger values for specific indicators can be defined as the 20^{th} or 80^{th} percentile of the baseline data depending upon whether low or high effects are being considered for the protection of the aquatic ecosystem (ANZECC 2000). Trigger levels are a threshold value above or below which there is a risk of adverse biological effects (i.e. within the trigger value range – low risk to the environment, outside the trigger value range – possible risk to environment and need for further action to investigate and/or fix the cause (Dept Environment and Conservation 2006)). However, the use of 20^{th}/80^{th} percentiles assumes that the site/catchment/estuary is in pristine condition and must therefore be used in conjunction with site specific information on the actual condition of these systems (i.e. determine whether the system is degraded already and whether it possible to compare it to a reference site). Also, water quality information does not necessarily provide information on the ecological health of the estuary. For example, high nutrient levels may not be apparent because they have been taken up by algae or because they have been diluted by the tides and flushed out to sea.

Although water quality trigger values as described by ANZECC guidelines (2000) have been widely used around Australia, their value for measuring estuarine condition is currently being questioned by several State Governments. For example, the NSW Department of Environment and Conservation found that water quality alone was not sufficient to determine the condition of coastal lagoons and a range of indicators including ecological ones, were necessary (Scanes et al 2007). There have been many meetings of scientists and Australian and State Government representatives to discuss how to assess estuarine condition. A set of national indicators have been developed (Scheltinga et al 2004), however, so far there has been no consensus on a minimum set of indicators or trigger values. It is worth noting that The European Union Water Framework Directive for water quality has shifted from targets based on chemistry to include those related to the ecological structure of natural systems, The ecological quality status of coastal and transitional waters is now assessed on biological, hydromorphological and physico-chemical elements; with the biological elements considered being phytoplankton, macroalgae, benthos and fishes (Muxika, 2007).

Because the Tasmanian State Government still uses trigger values according to ANZECC guidelines (2000), draft trigger values, based on the 20^{th} and/or 80^{th} percentiles of the baseline data, are assessed in this report . Box plots were used to visually compare the data with reference data (i.e. baseline values, national trigger values or other guideline values).

Water Quality in estuaries

Nationally, the ANZECC Water Quality Guidelines define coastal waters as either "estuarine" or "marine" and classify these into 5 regions, including New Zealand. Tasmania is part of the "South-east Australia" region, which covers Tasmania, Victoria, the Australian Capital Territory, New South Wales and south-east Queensland. The trigger levels for marine and estuarine waters in South-east Australia are outlined in Table 3.

Table 3. The default trigger values (ANZECC 2000) applicable to Victoria, New South Wales, south-east Queensland, the Australian Capital Territory and Tasmania.

Ecosystem	Chl a (µg/L)	TP (µg/L)	FRP (µg/L)	TN (µg/L)	NOx (µg/L)	NH4 (µg/L)	Dissolved oxygen lower limit	Dissolved oxygen upper limit	pH lower limit	pH upper limit	Turbidity (NTU)
Estuaries	4	30	5	300	15	15	80	110	7	8.5	0.5–10
Marine	1	25	10	120	5	15	90	110	8	8.4	0.5–10

ANZECC (2000) recommends that trigger levels are used as default values where regional or local trigger values are not available. However, they were developed without using any data from Tasmania and thus should be used with caution in this region. Where individual states or territories have developed their own regional guideline trigger values, those values should be used in preference to the default values provided by ANZECC (2000). The most appropriate level at which to set trigger levels can be determined by characterising baseline data according to location, site and/or season.

Baseline water quality data were characterised by comparing box and whisker plots that described the 20th and 80th percentiles, 10th and 90th percentiles, median and outliers (Fig 53). Data could be pooled to give Regional descriptions/values, but were better refined by grouping by estuary. Significant differences between estuaries meant that data should be at least refined to this level in order to be meaningful. In some cases, areas within an estuary varied so much (i.e. wetland area different to the open bay), that they needed to be grouped separately.

Although there was evidence of seasonality there are insufficient data to satisfactorily refine/characterise data to this level.

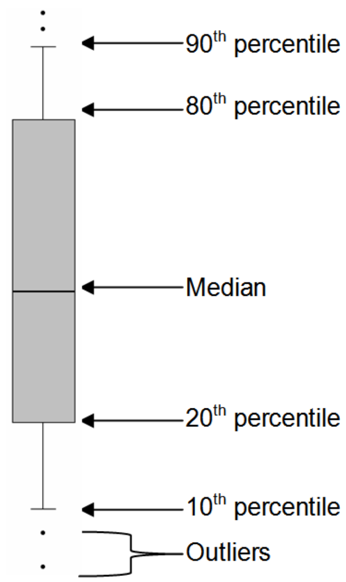


Figure 53. Description of box plots showing 20th and 80th percentiles.

Water Quality Results for the NRM South Region

The indicators used to determine preliminary water quality condition and trigger levels for the NRM South Region are dissolved oxygen, turbidity, pH, nitrate plus nitrite, ammonia, soluble reactive phosphorus and chlorophyll a. Trigger levels for temperature and salinity were not considered useful due to strong seasonality patterns. In the longer term, temperature may become a useful indicator of climate change.

Preliminary condition and trigger levels have been assessed for the Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), the Port Cygnet wetland area (PC Wetland), and the Port Cygnet port area (PC Port). Baseline data for these systems were collated from a variety of sources (Table 4). In many cases these data were collected after the systems had been modified, and for some, severely degraded.

Table 4. Data sources for the development of preliminary trigger levels for the NRM South Region.

Ecosystem	Abbreviation	Data inclusions	Years collected
NRM South Region	Region	All outlined below	
Moulting Lagoon	MLAG	TAFI CERCA baseline	2007-2008
Great Swanport	GSP	TAFI CERCA baseline	2007-2008
		Murphy *et al.* (2003)	1999-2000
Little Swanport	LSP	Brown & McCausland (1999)	1992-1997
		Murphy *et al.* (2003)	1999-2000
		Crawford & Mitchell (1999)	1991-1994
		TAFI/NAP/DPIW	2003-2008
Pitt Water & Orielton Lagoon	PWO	TAFI CERCA baseline	2007-2008
		Crawford & Mitchell (1999)	1991-1994
North West Bay	NWB	TAFI CERCA baseline	2007-2008
		Jordan *et al.* (2002)	2001-2002
Port Cygnet wetland	PC Wetland	TAFI CERCA baseline	2007-2008
Port Cygnet port	PC Port	TAFI CERCA baseline	2007-2008
		CSIRO Huon Estuary Study	1996-1998

The Water Assessment Branch (DPIW) has examined trigger values for freshwater at sites upstream of these systems (in the Apsley River, Coal River, White Kangaroo Rivulet, Huon River, Little Swanport River, Snug Rivulet, and the Swan River) (see Water Assessment Branch 2008, but summarised in Table 5).

Table 5. Average percentiles for sites upstream of key estuaries in the Southern NRM Region (see Water Assessment Branch 2008).

Parameter	20th Percentile	80th Percentile
Turbidity NTU	1.5	5.5
pH field - sensor TC	7.0	7.7
Dissolved Oxygen Percent Saturation	88.1	102.7
Total Nitrogen as N µg/L	341.7	568.3
Total Phosphorus µg/L	9.0	15.4
Phosphorus, Dissolved Reactive as P µg/L	2.6	4.6
Nitrate as N µg/L	40.3	90.7
Nitrite as N µg/L	2.0	4.8
Ammonia as N µg/L	6.5	15.5

Results have been compared with the default trigger levels for estuaries and marine waters (ANZECC 2000), the draft indicator levels developed for estuaries by Murphy *et al.* (2003) and the Tasmanian water quality guideline (trigger) values for freshwater (Water Assessment Branch 2008). A major gap identified in these trigger values is the lack of triggers and baseline data for wetlands.

Dissolved Oxygen

Dissolved oxygen levels for systems in the Southern NRM Region are variable, and dependant on local factors (Fig 54). DO levels in lagoons and wetland areas (e.g. Moulting Lagoon and the Port Cygnet wetland) are highly variable and susceptible to anoxia due to high organic loads, warm temperatures and/or low flow. These can be natural or human induced causes. Estuaries that are lower in the catchment, are deeper and/or have higher flushing capabilities (e.g. Great Swanport and Little Swanport) are not as susceptible to anoxia, and 20th percentiles for surface waters are above 85% saturation. This is consistent with the ANZECC Water Quality Guidelines for estuaries in South-eastern Australia, which recommend a lower limit of 80% saturation and an upper limit of 110% saturation (ANZECC 2000). Dissolved oxygen levels in marine dominated estuaries (e.g. Pitt Water, North West Bay and the port area of Port Cygnet) are much less variable, and fall within the ANZECC Water Quality Guidelines for marine waters in South-eastern Australia, which recommend a lower limit of 90% saturation and an upper limit of 110% saturation.

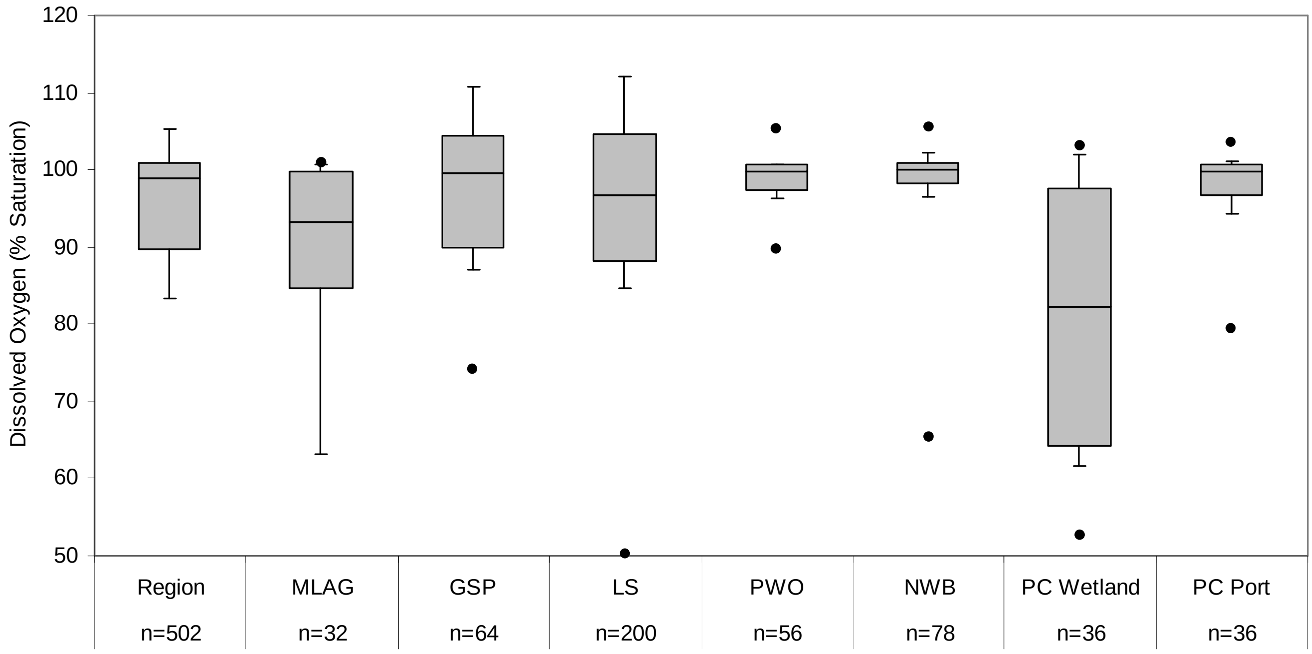


Figure 54. Dissolved oxygen baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 120% Saturation.

Turbidity

ANZECC Water Quality Guidelines recommend that turbidity in estuaries and marine waters should range from 0.5-10 NTU (ANZECC 2000). Low turbidity values are normally found in offshore waters, while higher values may be found in estuaries or inshore coastal waters due to wind-induced resuspension or to the input of turbid water from the catchment (ANZECC 2000).

Turbidity levels for systems in the Southern NRM Region are variable, and dependant on local factors (Fig 55). Turbidity levels in the upper-reaches of estuaries, lagoons and wetland areas (e.g. Moulting Lagoon, the Port Cygnet wetland, Little Swanport and Pitt Water) are highly variable and susceptible to high readings due to high sediment loads carried in freshwater. These areas can potentially exceed ANZECC Water Quality Guidelines (2000) due to poor riparian conditions and land use management upstream (e.g. Port Cygnet wetland). Estuaries that are lower in the catchment (e.g. Great Swanport) and open coastal bays (e.g. North West Bay, and the port area in Port Cygnet) are not as susceptible to high turbidity events and 80th percentiles remain below 5 NTU.

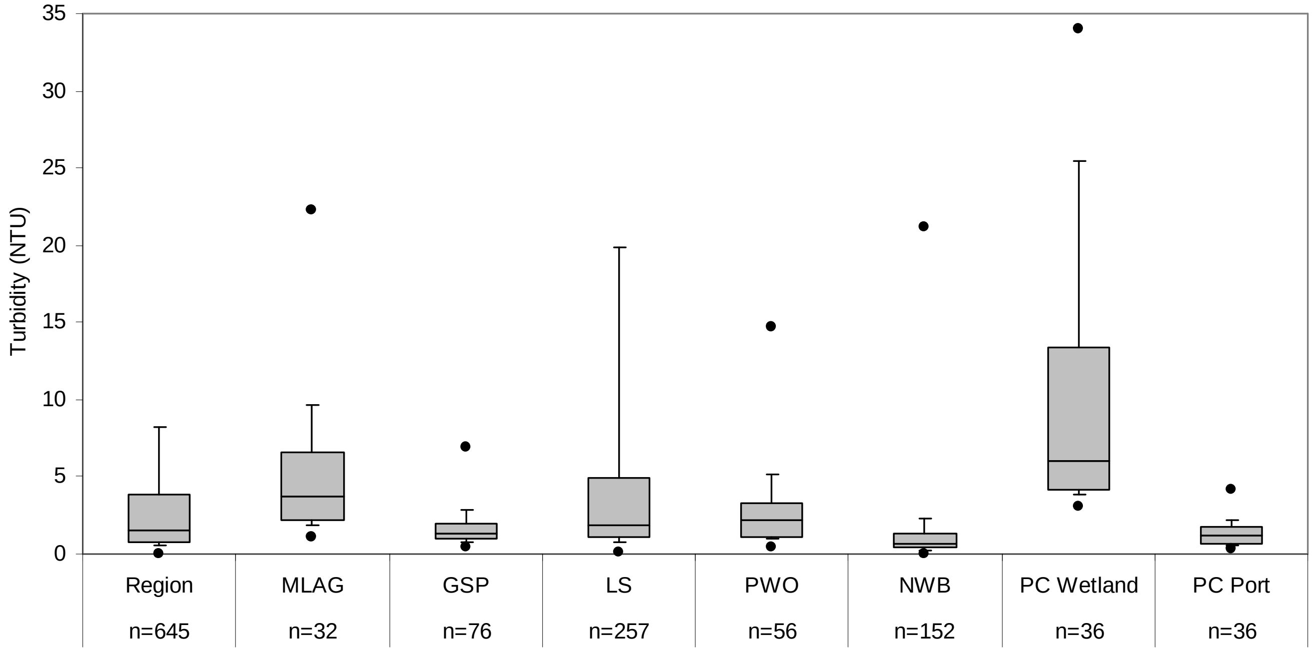


Figure 55. Turbidity baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 35 NTU.

pH

pH levels in the coastal systems of the Southern NRM Region are generally quite stable, but slightly higher than the default triggers recommended in the ANZECC Water Quality Guidelines, where the pH range for estuaries is 7.0-8.5 and 8.0-8.4 for marine waters (Fig 56). pH levels also differ between systems due to freshwater input and other local factors.

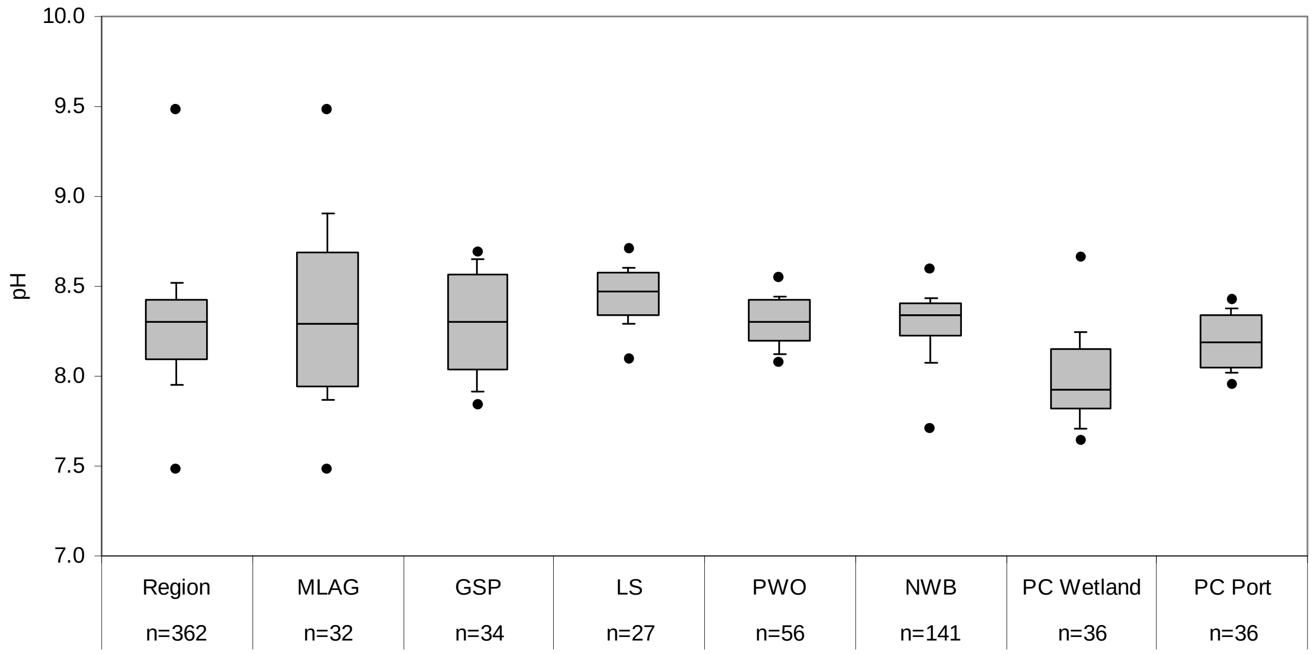


Figure 56. pH baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).).

Nitrate plus nitrite (NOx)

As with other variables, NOx levels for systems in the Southern NRM Region were often higher in the upper-reaches of estuaries and wetland areas, especially during flooding, due to the catchment origins of nutrients. Southern Ocean waters which are usually high in nutrients during winter months can also increase nutrient levels in estuaries during this time. These areas can potentially exceed ANZECC Water Quality Guidelines (2000) due to poor riparian conditions and land use management upstream (e.g. Port Cygnet wetland). ANZECC Water Quality Guidelines recommend that NOx levels in estuaries should not exceed 15 µg/L and 5 µg/L in marine waters (except where upwelling occurs) (ANZECC 2000). According to DPIW data for sites upstream of these systems, freshwater inputs of nutrients are also very high (average 80th percentile for nitrate is 90.7 µg/L and 4.8 µg/L for nitrite). Murphy *et al.* (2003) indicate that NOx levels below 20 µg/L in Tasmanian estuaries should be considered to be very low. The 80th percentile levels for NOx fall below 20 µg/L at most of the systems examined here. The exception to this is the Port Cygnet wetland, which exceeds Murphy *et al*,'s definition of very high levels and the Port Cygnet port area, which falls within Murphy *et al*,'s definition of medium levels of NOx.

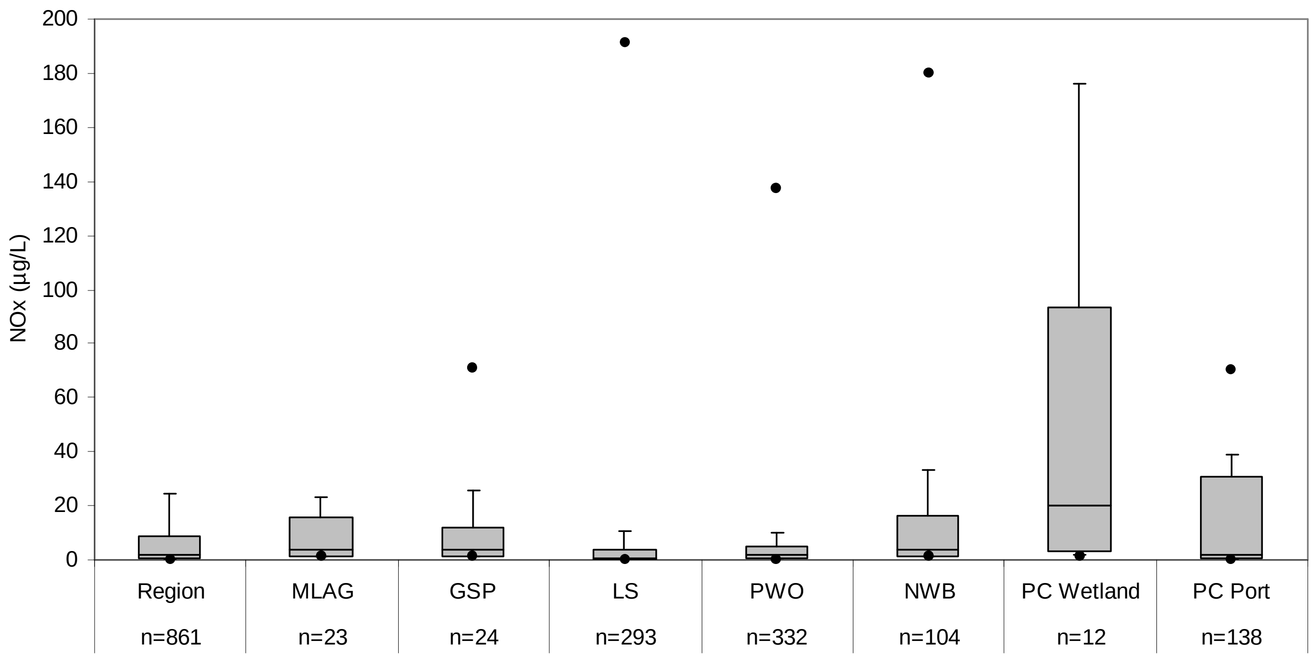


Figure 57. Nitrate plus nitrite (NOx) baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 200 µg/L.

Ammonia

Ammonia levels for systems in the Southern NRM Region were higher in the upper reaches of estuaries and wetland areas due to the catchment origins of nutrients (Fig 58). These areas can exceed ANZECC Water Quality Guidelines (2000) in most cases (excluding Little Swanport). ANZECC Water Quality Guidelines recommend that ammonia levels in estuaries and marine waters should not exceed 15 µg/L (ANZECC 2000). According to DPIW data for sites upstream of these systems, freshwater inputs of ammonia are within ANZECC expectations (average 80th percentile for ammonia is 15.5 µg/L). This indicates that high ammonia levels are caused by site specific inputs rather than input from the catchment via freshwater flow regimes. Very high ammonia levels were recorded for Moulting Lagoon, and high levels were recorded for Great Swanport and the Port Cygnet wetland – probably as a result of bacterial activity and the breakdown of organic matter.

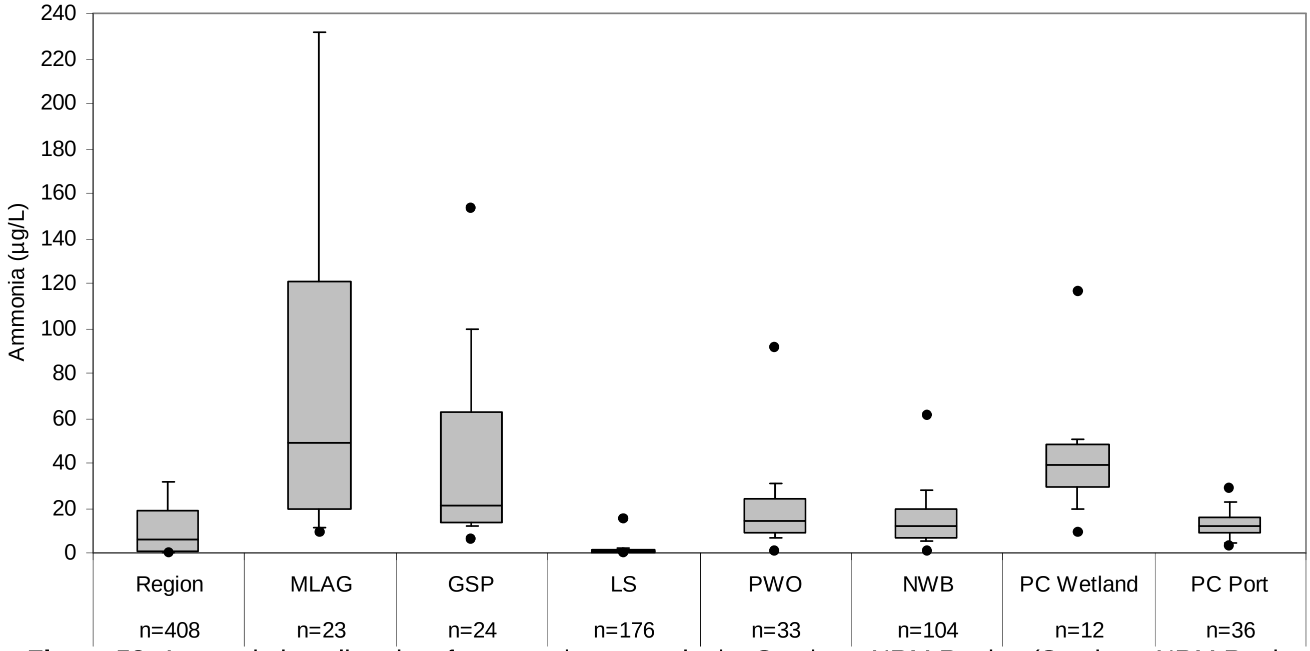


Figure 58. Ammonia baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 240 µg/L.

Soluble Reactive Phosphorus (SRP)

SRP levels for systems in the Southern NRM Region were variable and differed greatly between systems (Fig 59). ANZECC Water Quality Guidelines recommend that SRP levels in estuaries should not exceed 5 µg/L and 10 µg/L in marine waters (ANZECC 2000). Tasmanian marine waters have higher levels of nutrients due to influxes of nutrient-rich waters from the continental shelf and the Southern Ocean. Murphy *et al.* (2003) indicate that SRP levels below 5 µg/L in Tasmanian estuaries should be considered to be very low. The 80th percentile levels for SRP fall below 15 µg/L at most of the systems examined here, which is considered by Murphy *et al.* (2003) to be a medium level of SRP for Tasmanian estuaries. Again, the exception to this is the Port Cygnet wetland and port area, which both exceed 30 µg/L, which is considered by Murphy *et al.* (2003) to be a very high level of SRP.

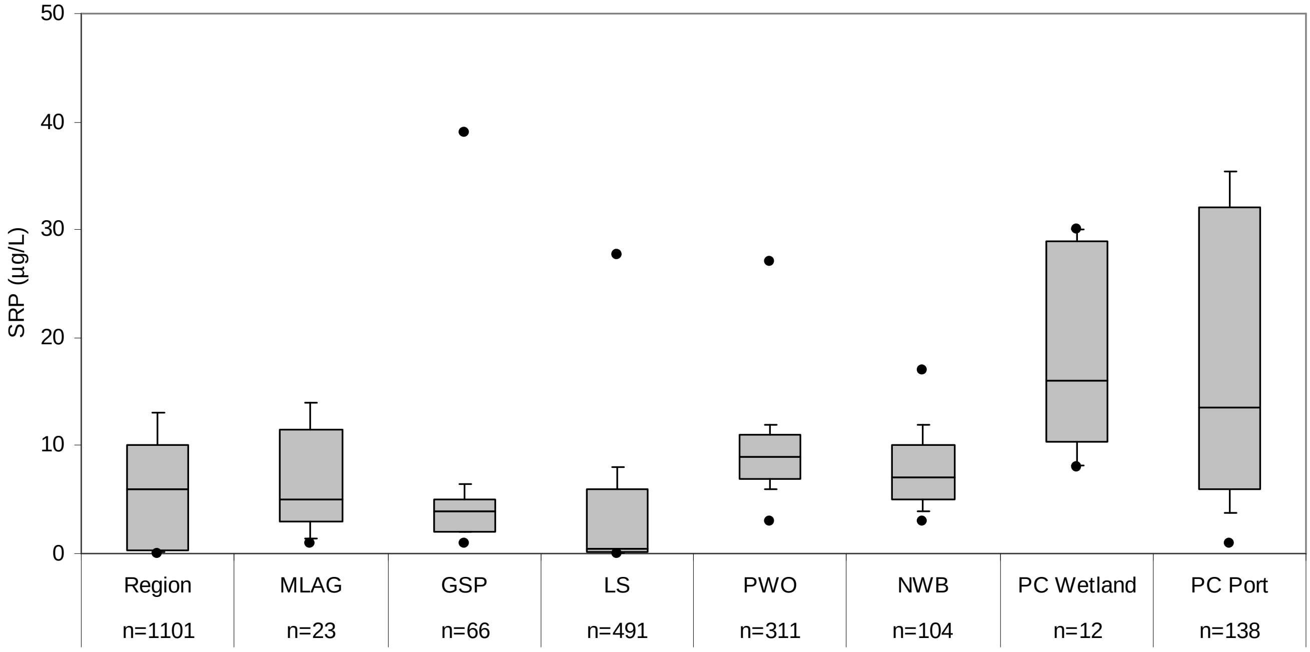


Figure 59. Soluble Reactive Phosphorus baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 50 µg/L.

Chlorophyll a

Chlorophyll a levels for systems in the Southern NRM Region were variable and differed greatly between systems (Fig 60). ANZECC Water Quality Guidelines recommend that chlorophyll a levels in estuaries should not exceed 4 µg/L and 1 µg/L in marine waters (ANZECC 2000). Murphy *et al.* (2003) indicate that chlorophyll a levels below 2 µg/L in Tasmanian estuaries should be considered to be very low. The 80th percentile levels for chlorophyll a fall below 5 µg/L at most of the systems examined here, which is considered by Murphy *et al.* (2003) to be a medium level of chlorophyll a for Tasmanian estuaries. The exception to this is Moulting Lagoon, which falls into Murphy *et al.*'s definition of a high level of chlorophyll a (5.1-10 µg/L).

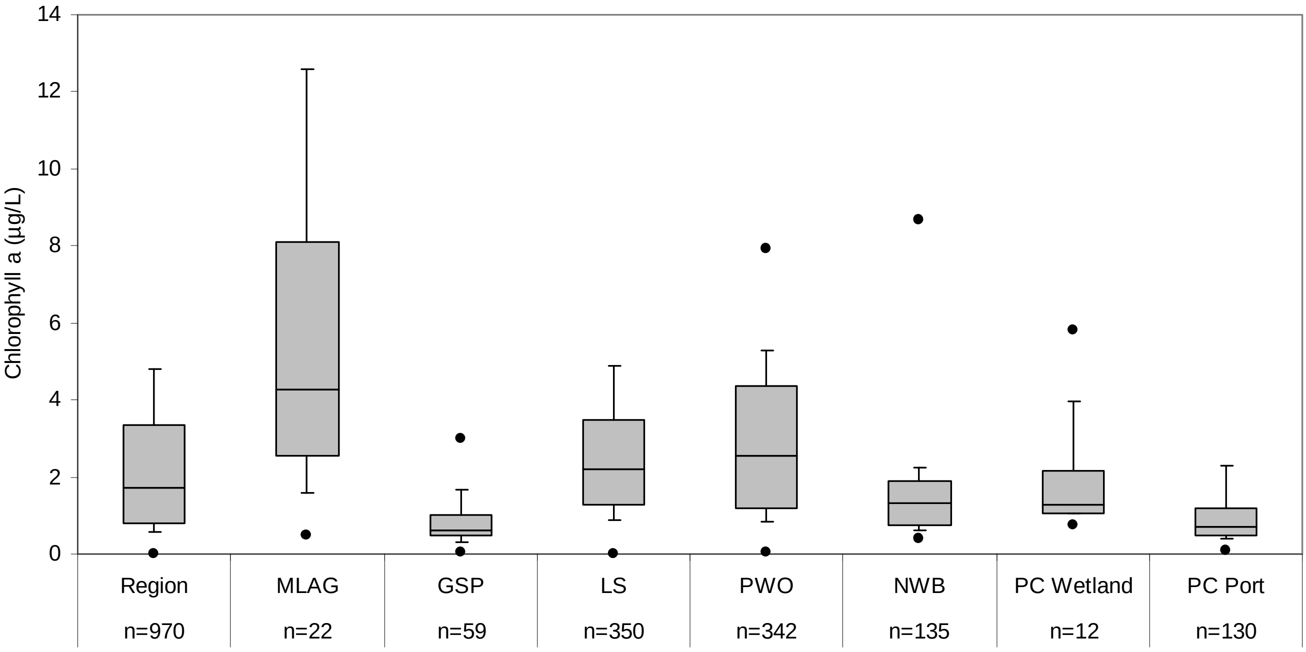


Figure 60. Chlorophyll a baseline data for coastal systems in the Southern NRM Region (Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), Port Cygnet wetland (PC Wetland), and Port Cygnet port (PC Port).). The highest reading outliers are not displayed where they exceed 14 µg/L.

Summary

Preliminary trigger levels for the Southern NRM Region (Region), Moulting Lagoon (MLAG), Great Swanport (GSP), Little Swanport (LSP), Pitt Water and Orielton Lagoon (PWO), North West Bay (NWB), the Port Cygnet wetland area (PC Wetland), and the Port Cygnet port area (PC Port) are summarised in Table 6.

Table 6. 20th and 80th percentiles for key coastal systems in the Southern NRM Region.

Estuary	REGION		MLAG		GSP		LSP		PWO		NWB		PC Wetland		PC Port	
Percentile	20th	80th	20th	80th	20th	80th	20th	80th	20th	80th	20th	80th	20th	80th	20th	80th
pH	8.1	8.4	7.9	8.7	8.0	8.6	8.3	8.6	8.2	8.4	8.2	8.4	7.8	8.2	8.1	8.3
DO (% Sat)	89.6	100.9	98.2	100.9	90.0	104.4	88.2	104.6	97.4	100.6	98.2	100.9	64.3	97.6	96.8	100.6
Turbidity (NTU)	0.7	3.8	2.2	6.6	1.0	2.0	1.1	4.9	1.1	3.3	0.4	1.3	4.2	13.4	0.6	1.7
NOx (ug/L)	0.6	9.0	1.0	15.4	1.0	11.8	0.2	4.0	0.8	5.0	1.0	16.0	3.4	93.2	0.8	31.0
NH4 (ug/L)	0.9	18.6	19.4	120.8	13.6	62.6	0.0	1.6	9.4	23.8	6.6	19.4	29.4	48.2	9.0	16.0
SRP (ug/L)	0.4	10.0	3.0	11.4	2.0	5.0	0.1	6.0	6.9	11.0	5.0	10.0	10.4	29.0	6.0	32.0
Chl a (ug/L)	0.8	3.3	2.5	8.1	0.5	1.0	1.3	3.5	1.2	4.4	0.7	1.9	1.0	2.2	0.5	1.2

Conclusions and Recommendations

The information provided in this report aims to present coastal and estuarine baseline condition information for southern Tasmania. Future monitoring may not necessarily remeasure all variables from the benchmark dataset as monitoring programs are improved and refined and the resources available may vary, but it is very important to have a comprehensive baseline so that a variety of comparisons can be made as required in the future.

The ANZECC Water Quality Guidelines (2000) recommend a minimum of 24 months baseline data is to be utilised for setting trigger values, so it is important that values be updated as more data become available. As data become available, further information should be used to strengthen the classification of estuaries. For example, benthic macroinvertebrate data could be used in future to support these classifications and once sufficient data are available, seasonally-specific trigger values could be considered. To develop satisfactory trigger levels for highly variable locations where very little data are available (e.g. Moulting Lagoon), new sites should be selected and monitored in addition to the sites outlined in this report.

Further incorporation of data from other organisations to strengthen triggers is also possible in the future. In addition to the data obtained for use in this report, existing sources of water quality data to be considered for consideration include municipal recreational health data, aquaculture-based data (e.g. TSGA), and quality-assured community group data (e.g. Waterwatch).

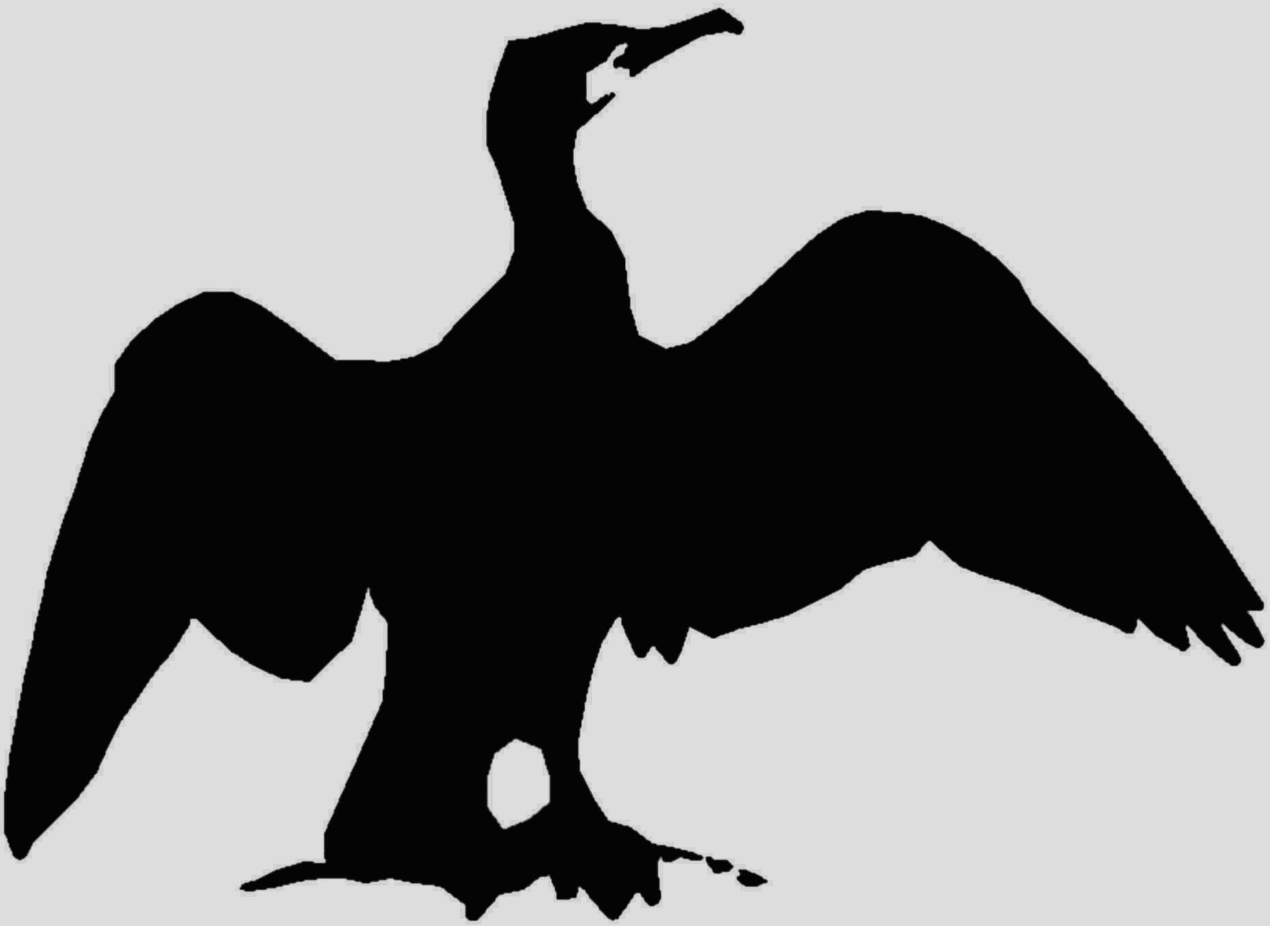
Data availability for wetlands is severely lacking. However, it is difficult to set targets for water quality in such variable environments. Other options for trigger-setting in wetlands could include indicators such as benthic macroinvertebrates, vegetation mosaics and bird species/abundance indices. Some water quality data for estuaries are now available, but they are not sufficient to confidently set aspirational, default or specific targets. Obtaining and maintaining baseline water quality and ecological condition data for estuaries remains a priority.

If sufficient resources are available in the future, additional indicators should be monitored. For example:

- total nitrogen (TN) and total phosphorous (TP) if information is required on nutrient loads from rivers into estuaries
- invasive species (some data available from DPIW, but location-specific information is required)
- algal blooms/biomass (some data available from TSQAP)
- mass mortalities (some data is available from DEPHA)
- toxicants, including metals where possible (some freshwater data is available from DPIW)
- shoreline position (e.g. TASMARC)
- habitat extent baseline where information is not available (e.g. North West Bay upper estuary and Port Cygnet) and updated every 5 years

A new project, Landscape Logic, funded by the Commonwealth Environment Research Facility, will be assessing conition indicators and appropriate triggers for some estuaries in the Southern NRM Region (especially Pitt Water,, Little Swanport) based on relationships between water quality/quantity and indicators of river and estuarine condition (www.landscapelogic.org.au). The Landscape Logic project aims to investigate water quality responses to changes in land use and land management, and how water quality in turn affects riverine and estuarine health and function. Methodologies for setting triggers for condition indicators of estuaries developed through the Landscape Logic project will reinforce the further implementation of CERCA in the Southern NRM Region. A framework for CERCA implementation has been recommended by Temby & Crawford (2008).

References



ANZECC & ARMCANZ (2000) *Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy*, Australian and New Zealand Environment and Conservation Council, Canberra.

Bobbi, C. (1998) Water quality of rivers in the Huon catchment. Department of Primary Industry and Fisheries. Report Series WRA 98/01

Blackhall, S.A. (1986) *Moulting Lagoon Proposed Game Reserve Stage II, Planning for the Reservation and Management of a Wetland of International Importance - Revised Draft Plan*. National Parks and Wildlife Service, Tasmania.

Brown, M. R. & McCausland, M. A. (1999). Increased production of juvenile Pacific oysters (*Crassostrea gigas*) through supplementary feeding. Final report to the Fisheries Research & Development Corporation (FRDC), Project 94/83, CSIRO, Division of Marine Research, Hobart, Tasmania

CFEV (2006). *Conservation of Freshwater Ecosystem Values Project – Project Update, October 2006.* Department of Primary Industries and Water, Hobart.

Crawford, C.M. (2006) *Indicators for the condition of estuaries and coastal waters*. Tasmanian Aquaculture and Fisheries Institute.

Crawford, C. and Mitchell, I. (1999) *Physical and Chemical Parameters of Several Oyster Growing Areas in Tasmania*. Technical Report Series, Number 4.Tasmanian Aquaculture and Fisheries Institute, Marine Research Laboratories.

Crawford, C., Neira, F.J. and White, C. (2005) *Environmental Flows in the Little Swanport Estuary*. NHT/NAP Project No. 46932. Tasmanian Aquaculture and Fisheries Institute, Marine Research Laboratories.

CSIRO Huon Estuary Study Team (2000) *Huon Estuary Study — environmental research for integrated catchment management and aquaculture.* Final report to Fisheries Research and Development Corporation. Project number 96/284. CSIRO Division of Marine Research. Marine Laboratories, Hobart.

Davies, P.E., Cook, L.S.J., and Sloane, T. (2006) *Orielton Lagoon: Changes in the benthic macroinvertebrate community between 1999 and 2005.* Report to Sorell Council March 2006. Freshwater Systems, Tasmania.

Dept Environment and Conservation (2006) Using the ANZECC Water Quality Guidelines and Water Quality Objectives in NSW Sydney

DPIWE (2005) *Waterways Monitoring Reports.* Published online by the Department of Primary Industries and Water http://www.dpiw.tas.gov.au/inter.nsf/WebPages/JMUY-6BV8GJ?open accessed 26/6/2008.

DPIW (2007) *Waterways Monitoring Reports.* Published online by the Department of Primary Industries and Water http://www.dpiw.tas.gov.au/inter.nsf/WebPages/JMUY-6BV8GJ?open accessed 26/6/2008.

Edgar, G.J., Barrett, N.S. and Graddon, D.J. (1999) *A Classification of Tasmanian Estuaries and Assessment of their Conservation Significance using Ecological and Physical Attributes, Population and Land Use.* Tasmanian Aquaculture and Fisheries Institute Technical Report Series, 2.

Green, G. (1999) North West Bay River Catchment Management Plan. Kingborough Council.

Hirst, A.J., and Kilpatrick, R. (2007) Spatial and temporal variation in the structure of estuarine macroinvertebrate assemblages: implications for assessing the health of estuaries. *Marine and Freshwater Research* 58(9): 866-879.

Hirst, A.J., Kilpatrick, R., Mount, R.E., Guest, M.A., and Crawford, C. (2005) Biodiversity and Degradation of Estuaries in North-western Tasmania, Cradle Coast NRM Region, NHT/NAP 46927

Jordan, A., Doole, J., Archer, L., Lawler, M., Halley, V., and Sanderson, C. (2002) *Assessment and monitoring of nutrients and habitats in North West Bay: Supporting Sustainable Management.* Kingborough Council Natural Resource Management Strategy, Hobart.

Macleod, C and Forbes, S. (2004) Guide to the assessment of sediment condition at marine finfish farms in Tasmania. Tasmanian Aquaculture and Fisheries Institute, Hobart Tasmania. Available at: http://www.utas.edu.au/tafi/PDF_files/Field%20Manual_FINAL.pdf

MacLeod, C, Bissett, AP, Burke, CM, Forbes, SE, Holdworth, D, Nichols, P, Revill, A, and Volkman, J, (2004) *Development of novel methods for the assessment of sediment condition and determination of management protocols for sustainable finfish cage aquaculture operations*. Aquafin CRC Final Report, Tasmanian Aquaculture & Fisheries Institute, Hobart, Tasmania, Australia.

Mount, R. (2006) *Trialing NRM Resource Condition Indicators in the Coastal Zone: the Tasmanian Extension*. http://www.environment.tas.gov.au/cm_draft_tasmanian_estuarine_coastal_marine_indicators.html Published online by DPIW, accessed 25/6/2008

Mount, R., Lucieer, V., Lawler, M. and Jordan, A. (2005) *Mapping of Estuarine and Marine Habitats in the Southern NRM region*. NHT/NAP Project No.46937

Murphy, R., Crawford, C. and Barmuta, L. (2003) *Estuarine health in Tasmania, status and indicators: water quality*. Tasmanian Aquaculture and Fisheries Institute Technical Report Series, 16.

Muxika, I., Borja, A. and Bald, J. (2007) Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive, *Marine Pollution Bulletin*, 55,16-29.

NLWRA (2002) Australian Natural Resources Atlas - Water Resources Allocation and Use, http://nlwra.gov.au/Natural_Resource_Topics/Water_Quality/ accessed 25/6/2008

NRM South (2005) *Natural Resource Management Strategy For Southern Tasmania*. May 2005. Natural Heritage Trust, Australia.

OzEstuaries (2003) *Coastal Indicator Knowledge and Information System I: Biophysical Indicators*. [Web document]. Canberra : Geoscience Australia . www.ozestuaries.org/indicators accessed 26/6/2008

Parks and Wildlife Service (2003) *Moulting Lagoon Game Reserve Management Plan*. Parks and Wildlife Service Tasmania. Department of Tourism, Parks, Heritage and the Arts. Hobart.

Scanes, P., Coade, J., Doherty, M., Hill, R. (2007) Evaluation of the utility of water quality based indicators of estuarine lagoon condition in NSW, Australia. *Estuarine, Coastal and Shelf Science*, 74: 306-319.

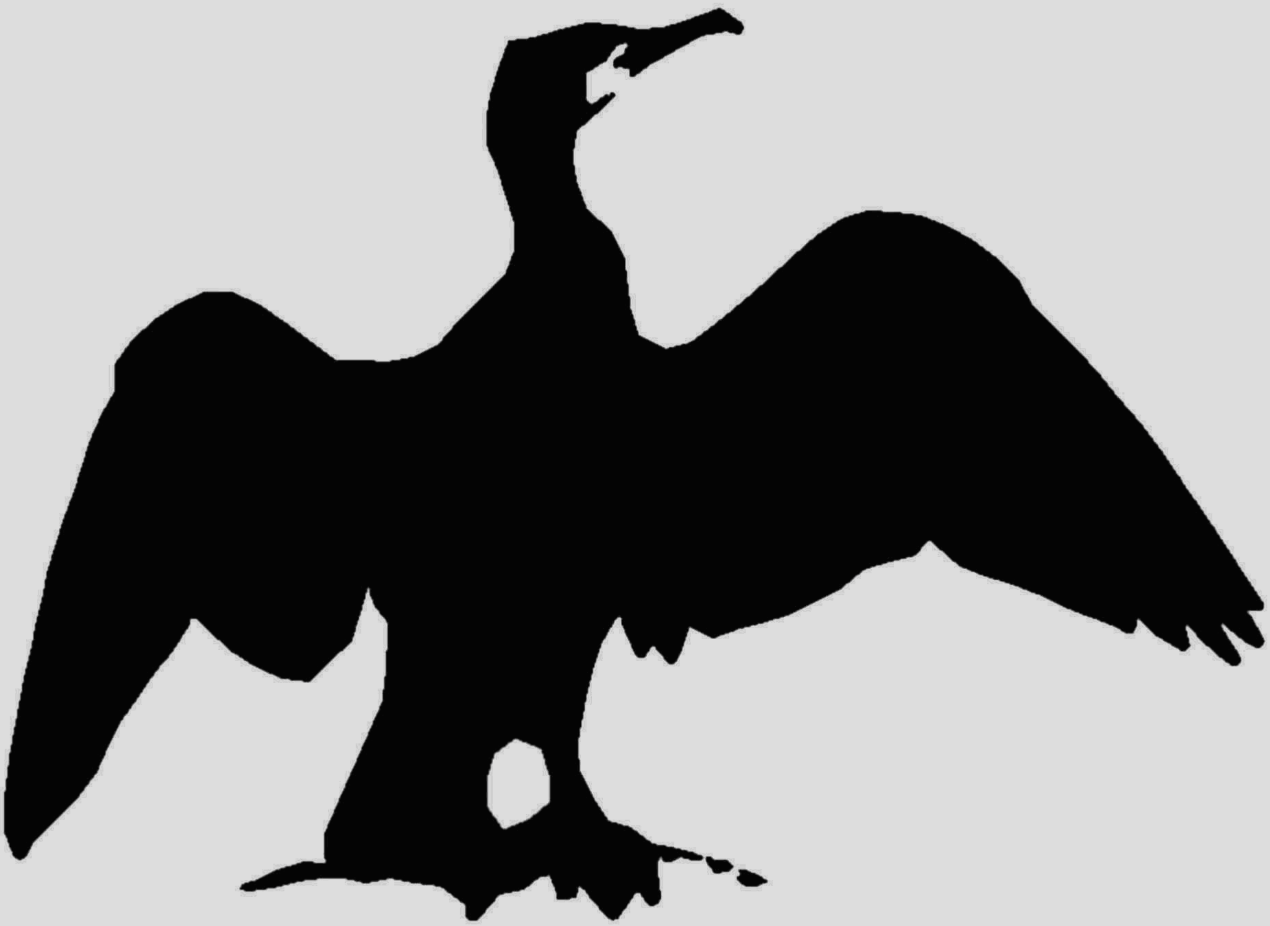
Scheltinga, D.M., R. Counihan, A. Moss, M. Cox and J. Bennett, 2004. *Users' Guide to Estuarine, Coastal and Marine Indicators for Regional NRM Monitoring.* Report to DEH, MEWG, ICAG Revised version, December 2004

Temby, N and Crawford, C. (2007) *A discussion paper for Coastal and Estuarine Resource Condition Assessment (CERCA) in NRM South.* Tasmanian Aquaculture and Fisheries Institute, Tasmania.

Temby, N and Crawford, C. (2008) *A framework for Coastal and Estuarine Resource Condition Assessment (CERCA): Sharing resources and knowledge for better management.* Tasmanian Aquaculture and Fisheries Institute, Tasmania.

Water Assessment Branch (2008) *Tasmanian Water Quality Guideline (Trigger) Values.* Briefing paper for the Bureau of Rural Sciences for the development of the Water Quality Statistical Analysis and Reporting Tool (WQSAR). Department of Primary Industries and Water.

Appendix



Appendix 1 List of macroinvertebrate species/taxa collected from each estuary.

Estuary	Taxonomic name
Port Cygnet	*Anapella cycladea*
(19 spp.)	*Arenicola* sp.
	Arthritica helmsi
	Biffarius spp.
	Capitella spp.
	Chaetozone sp.
	Clymenella sp.
	*Corbula gibba**
	Edwardsia sp.
	*Euchone limnicola**
	Hesionidae unid.
	Labioleanira sp.
	Melita sp.
	Nassarius spp.
	Ophiuroidea unid.
	Paracorophium sp.
	Pilumnid unid.
	Simplisetia aequisetis
	Tethygeneia sp.
North West Bay	*Amoria undulata*
(54 spp.)	*Anapella cycladea*
	Anthurid isopod unid.
	Aricidea pacifica
	Armandia sp. MoV 282
	Biffarius spp.
	Byblis mildura
	Capitella spp.
	Caprellid amphipod unid.
	Chaetozone sp.
	Cirolanidae sp.
	Clymenella sp.
	*Corbula gibba**
	Cyclaspis sp.
	Cymadusa sp.
	Dexaminidae unid.
	Echinocardium cordatum
	Edwardsia sp.
	Electroma georgana
	Glycerid sp.
	Goniada sp.
	Halicarcinus rostratus
	Heloecius cordiformis
	Labioleanira sp.
	Levinebalia sp.
	Liljeborgia sp.
	Lumbrinereis spp.
	Lysarete sp.
	Lysilla sp. A
	Lysilla sp. B
	Munida haswelli
	Nassarius spp.
	Nemerteans unid.
	Neothyonidium sp.
	Nephtys australiensis

Estuary	Taxonomic name
Moulting Lagoon / GSP	*Armandia* sp.
(23 spp.)	*Armandia* sp. MoV 765
	Arthritica helmsi
	Ascorbis victoriae
	Australonereis ehlersi
	Biffarius spp.
	Capitella spp.
	Chironomidae spp.
	Cirolanidae sp.
	Eusirid sp. A
	Gammaropsis sp.
	Glycerid sp.
	Limnoporeia sp.
	Microspio granulata
	Nassarius spp.
	Nemerteans unid.
	Nephtys australiensis
	Paracallope lowryi
	Paracorophium sp.
	Scoloplos normalis
	Simplisetia aequisetis
	Sphaeromatidae unid.
	Urohaustorius spp.
Pitt Water / Orielton	*Anapella cycladea*
(22 spp.)	*Chaetozone* sp.
	Elminius covertus
	Glycerid sp.
	Goniada sp.
	Katelysia spp.
	Limnoporeia sp.
	Lumbrinereis spp.
	Lysianssidae sp. A
	Magelona sp.
	Mysella donaciformis
	Nassarius spp.
	Neanthes vaalii
	Nemerteans unid.
	Nephtys australiensis
	Paracalliope australis
	Paracorophium sp.
	Paraprionospio coora
	Phoxocephalidae unid.
	Scoloplos normalis
	Tellina deltoidalis
	Tethygeneia sp.
Little Swanport	*Armandia* sp. MoV 282
(26 spp.)	*Australonereis ehlersi*
	Batillaria australis
	Capitella spp.
	Cirriformia sp.
	Corophium sp.
	Cymadusa sp.
	Dexaminidae unid.

	Oediceratidae unid.
	Ophiuroidea unid.
	Paracorophium sp.
	Paraprionospio coora
	Phoxocephalidae unid.
	Phyllodoce sp.
	Pilumnid unid.
	Polynoidae unid.
	Reteterebella aloba
	Scalibregma sp.
	Scoloplos simplex
	Serpulid unid.
	Simplisetia aequisetis
	Tanaid sp. A (SE Est)
	Terrebella sp.
	Terrebellides sp.
	Tharyx sp.
	*Theora fragilis**
	Venerupis sp.

	Felaniella globularis
	Gammaropsis sp.
	Glycerid sp.
	Goniada sp.
	Halicarcinus ovatus
	Hyale sp.
	Limnoporeia sp.
	Lumbrinereis spp.
	Macrobrachium novaehollandiae
	Nephtys australiensis
	Palaemonid unid.
	Paracorophium sp.
	Paragraspus gaimardii
	Phoxocephalidae unid.
	Schistomeringos loveni
	Solemya australis
	Tethygeneia sp.
	Travisia sp.

*Introduced species