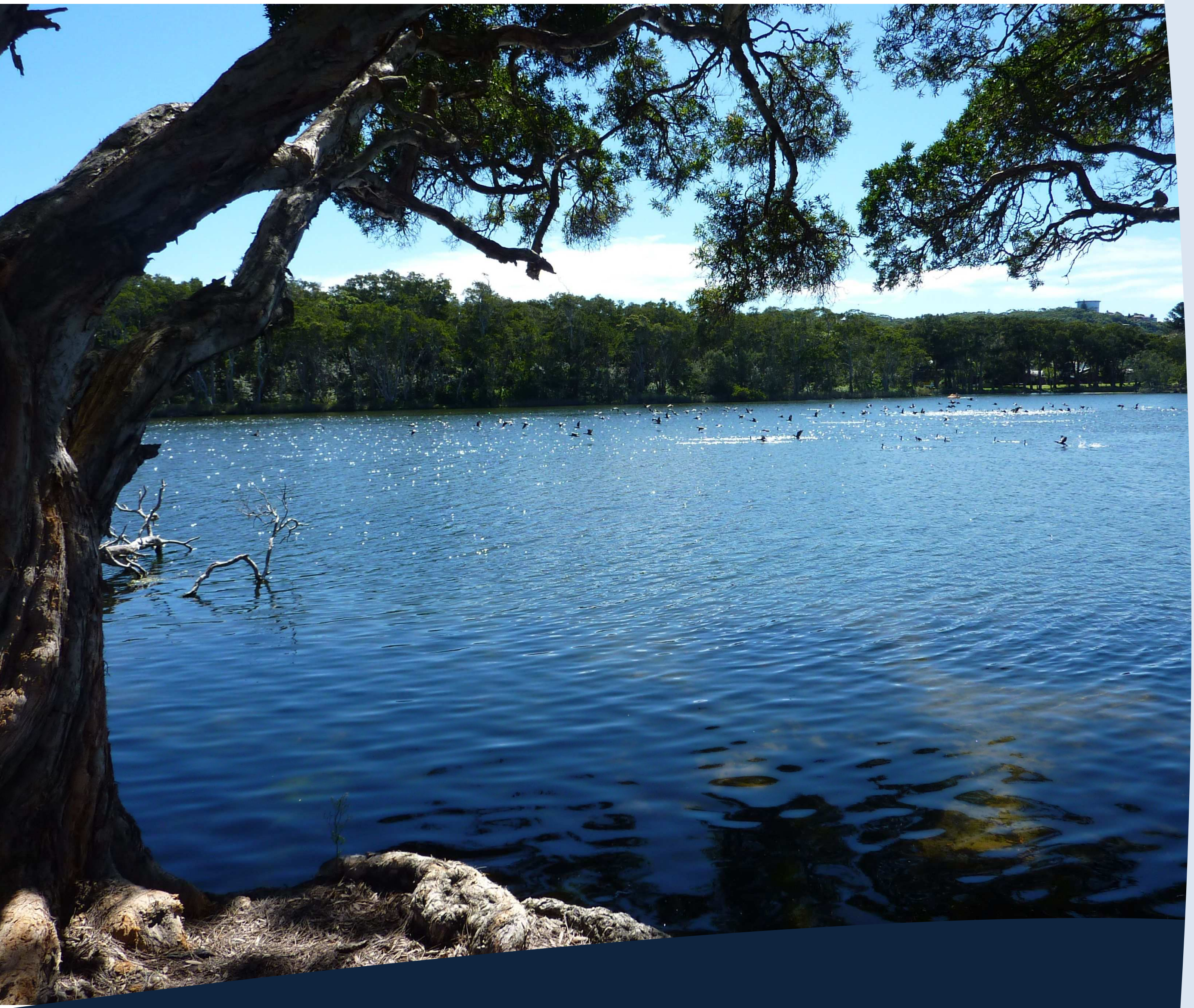

Gosford Coastal Lagoons Processes Study

Volume 2 – Appendices

LJ2713/R2472/V2

Prepared for Gosford City Council

July 2010

Appendix A

Site Photolog

Gosford Coastal Lagoons Site Visit (13 January 2009)

Photo 1: Wamberal Lagoon Photo Locations

Photo 2: North shore of Wamberal Lagoon

Photo 3: East shore of Wamberal Lagoon

Photo 4: Properties on the north shore of Wamberal Lagoon

Photo 5: Recreational fishers on the southwest shore of the Lagoon

Photo 6: People swimming near the lagoon entrance

Photo 7: Banks on the southern end of the Lagoon

Photo 8: Swimmers in the southern end of the lagoon near the entrance

Photo 9: Lagoon entrance near the beach

Photo 10: Terrigal Lagoon Photo Locations

Photo 11: Northern shoreline of Terrigal Lagoon

Photo 12: Recreational fishers on the east banks of the lagoon

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Photo 19: Avoca Lagoon Photo Locations

Photo 20: Swimmers in Avoca Lagoon near the entrance

Photo 21: Recreational users near Heazlett Park

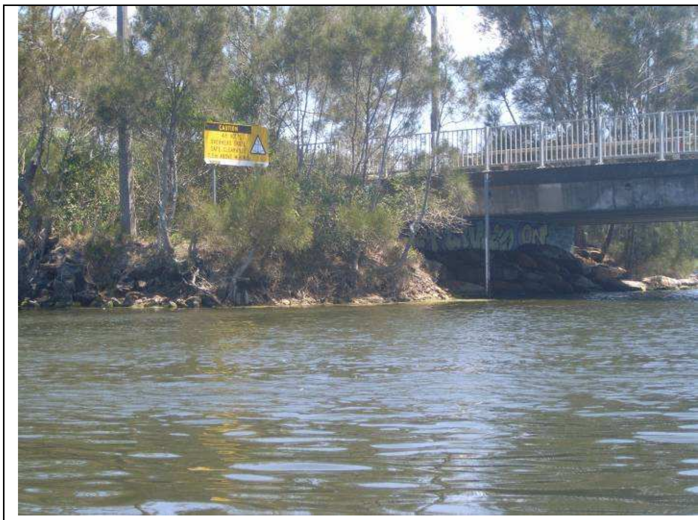

Photo 22: Near Avoca Drive Bridge

Photo 23: Properties on the southern shores of the lagoon

Photo 24: South west banks of the lagoon

Photo 25: Banks near Avoca Drive

Photo 26: Western shoreline of the lagoon

Photo 27: Banks of Bareena Island

	
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Photo 30: Cockrone Lagoon Photo Locations

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Photo 33: Recreational fishers on the south east banks of the lagoon	**Photo 34:** Southern shoreline of the lagoon
	
Photo 35: Towards the western shore of the lagoon	**Photo 36:** Property on the northern shoreline of the lagoon
	
Photo 37: North-eastern banks of Cockrone Lagoon	**Photo 38:** Towards the lagoon entrance

Cockrone Lagoon Entrance Opening (3 June 2009)

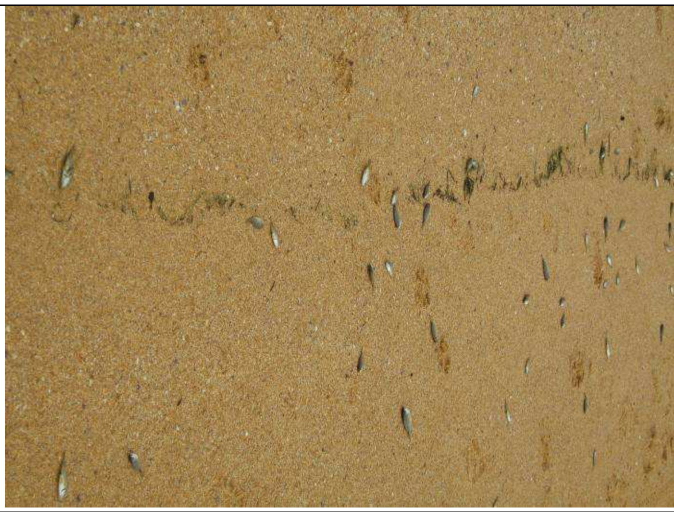





Post-Lagoon Opening, Cockrone Lagoon Entrance (4 June 2009)





Appendix B

Consultation Materials

Cardno
Shaping the Future

Our Ref LJ2713/L1580aa:TJM/PDT

Contact Doug Treloar

Cardno Lawson Treloar Pty Ltd
ABN 55 001 882 873

Level 2, 910 Pacific Highway
Gordon New South Wales
2072 Australia
Telephone: 02 9499 3000
Facsimile: 02 9499 3033
International: +61 2 9499 3000
Email: cltnsw@cardno.com.au
Web: www.cardno.com.au

Cardno Offices
Brisbane
Sydney
Canberra
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Perth
Darwin

Cairns
Townsville
Mackay
Rockhampton
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Toowoomba
Gold Coast
Gosford
Baulkham Hills
Wollongong
Busselton

Papua New Guinea
Indonesia
Vietnam
China
Kenya
United Arab Emirates
United Kingdom
United States

Contact Name
Title
Organisation
Address Line 1
Address Line 2

11 July 2008

Dear Sir or Madam,

RE: GOSFORD COASTAL LAGOONS ESTUARY PROCESSES STUDY

We are writing to inform you that Cardno Lawson Treloar has been engaged by Gosford Council and the Department of Environment and Climate Change (DECC) to undertake the Gosford Coastal Lagoons Estuary Processes Study.

The study area includes Wamberal, Terrigal, Avoca and Cockrone Lagoons, as indicated in the attached figure.

The aim of the Estuary Processes Study is to characterise the factors governing the functioning of each of the four lagoons. This will include consideration of the following:

- Catchment processes,
- Cultural heritage,
- Recreational uses,
- Foreshore land uses,
- Estuarine ecological processes,
- Hydraulic processes,
- Water quality processes,
- Estuarine morphology, and
- Any interactions between any of the abovementioned processes.

The outcome of the Estuary Processes Study will guide the development of the subsequent stages of the Estuary Management Process, the Estuary Management Study and Plan, as outlined in the Estuary Management Manual (NSW Government, 1992). The Data Compilation Study, representing the second stage of the process was also undertaken by Cardno Lawson Treloar, and was completed in April 2008.

We would be grateful for your assistance in identifying (and providing, where possible) any additional studies have been undertaken since the completion of the Data Compilation Study. In addition, we would appreciate your input on any issues you are aware of with respect to the management of the four lagoon systems.

Please do not hesitate to contact either myself or Tanja Mackenzie, at tanja.mackenzie@cardno.com.au, should you require any further information.

Yours faithfully

Doug Treloar
for **Cardno Lawson Treloar**


N
W
E
S
Wamberal Lagoon
Catchment
Forresters
Beach
Wamberal
Terrigal Laoon
Catchment
Terrigal
Avoca Lagoon
Catchment
North Avoca
Picketts Valley
Avoca Beach
Copacabana
Cockrone Lagoon
Catchment
Macmasters
Beach
Lagoon Catchment
Boundary
0
1
2
kilometres

From: CEN Lagoons [lagoons@cccen.org.au]
Sent: Wednesday, 3 September 2008 11:28 AM
To: Tanja Mackenzie
Subject: Re: Gosford Lagoons EPS
Hi Tanja,

We have completed a Rehabilitation Plan for Cochrone Lagoon and the plans for Avoca and Terrigal are currently released for public comment until 3rd Oct, so are in DRAFT stage. As NPWS are the governing agency for Wamberal Lagoon we wont be completing a Rehabilitation Plan for Wamberal, but will support NPWS with their plan and on-ground works.

I will post a CD containing the plans ASAP.

Regards,
Jen

Jen Dwarte
Gosford Lagoons Project Officer
Community Environment Network
PO Box 149 Brush Rd Ourimbah 2258
0243484327 / 0243494759
lagoons@cccen.org.au
www.cccen.org.au

----- Original Message -----
From: Tanja Mackenzie
To: lagoons@cccen.org.au
Sent: Friday, July 11, 2008 2:21 PM
Subject: Gosford Lagoons EPS

Jan,

Please find attached a letter advising that we are currently undertaking the Gosford Lagoons Estuary Processe Study, and requesting your input into the study.

Kind regards,

Tanja Mackenzie
Environmental Scientist
Phone:02 9499 3000
Fax:02 9499 3033
XTN:337
Email:tanja.mackenzie@cardno.com.au
Web:http://www.cardno.com.au

NSW GOVERNMENT
Department of Planning

Contact: Ben Holmes
Phone: 02 4348 5003
Fax: 02 4323 6573
Email: ben.holmes@planning.nsw.gov.au

To	POT	
Date	5-8-08	
File		
Circulation		

Our ref: CC08/108
Your ref: LJ2713/L1580j:TJM/PDT
File: C08/00005

Mr Doug Treloar
Cardno Lawson Treloar Pty Ltd
Level 2
910 Pacific Highway
GORDON NSW 2072

Dear Mr Treloar

Gosford Coastal Lagoons Estuary Processes Study

I refer to your letter dated 11 July 2008 whereby you seek the Department's advice regarding lagoon estuary issues that should be addressed as part of the preparation of the Gosford Coastal Lagoons Estuary Processes Study.

I wish to advise that the Estuary Processes Study should give consideration to the following issues:

- impacts associated with increased urban development in coastal lagoon catchments, particularly stormwater impacts and pet faecal matter; and
- impacts associated with climate change/ sea level rise.

Should you have any queries or require further information, please contact me on 4348 5003 or by email ben.holmes@planning.nsw.gov.au.

Yours sincerely

31/7/08

Ben Holmes
Environmental Planner
Hunter & Central Coast

NSW Government
Department of Water & Energy

To	TJM
Date	4-08-08
File	

Cardno Lawson Treloar Pty Ltd
Level 2, 910 Pacific Highway
GORDON NSW 2072

Contact: Peter Johns
Phone: (02) 4904 2538
Fax: (02) 4904 2503
Email: peter.johns@dnr.nsw.gov.au

Your Ref: LJ2713/L1580f:TJM/PDT
Our Ref: ER20195

30 July 2008

Attention: Tanja Mackenzie

Dear Madam

Gosford Coastal Lagoons Estuary Processes Study

I refer to your letter of 11July 2008 in this matter.

The former Department of Natural Resources (DNR) had a Coastal, Estuary and Floodplain (CE&F) Branch. With the abolition of DNR (April 2007) and the creation of the Department of Water and Energy and the Department of Environment and Climate Change (DECC) the staff in the CE&F Branch were transferred to DECC.

The contact in DECC's CE&F Branch is:

Neil Kelleher, Senior Natural Resource Officer on (02) 4348 5013
Level 3, 107-109 Mann Street, Gosford NSW 2250

Yours sincerely

Peter Johns
Project Officer
Major Projects and Planning
Newcastle

Interested in your local lagoon?

Free Information Day

Saturday 22 May 2010, 9:30am-12:30pm

Erina Centre Meeting Space 3, The Hive, Erina Fair

Presenting findings of the Coastal Lagoons Processes Study being undertaken on behalf of Gosford City Council by Cardno Lawson Treloar. The study investigates ecological, morphological, catchment and hydraulic processes, as well as cultural heritage and recreational usage. This includes land use, flooding, lagoon entrance openings, flushing, estuarine biodiversity, sediment control, public access, etc.

You are invited to attend just the presentation on your local lagoon, or several of the presentations:

9:30am	**Introduction**
9:40am	**Wamberal Lagoon**
10:20am	**Terrigal Lagoon**
11:00am	**Avoca Lagoon**
11:40am	**Cockrone Lagoon**
12:20pm	**Where to from here?**

For further information, contact Council's Senior Environment Planning Officer, Tim Macdonald, on tim.macdonald@gosford.nsw.gov.au or 4304 7658.

GOSFORD CITY COUNCIL
CENTRAL COAST

Printed by Gosford City Council, 49 Mann Street, Gosford, NSW. May, 2010.

Appendix C

Climate Summary Statistics

Table C.1: Climate Averages for Gosford (Narara Research Station; after: BoM, 2009)

Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	No. of Years
Mean Monthly Rainfall (mm)	133.3	153.4	151.2	137.6	118	128.2	78.8	74	68.5	84.1	92.3	102.6	1319.7	92
Mean No. Rain Days	11.3	11.2	11.6	11.3	10	10.3	9	8.6	8.7	9.3	10.1	10.2	121.6	78
Highest Monthly Rainfall (mm)	517.5	597.7	500.3	661.9	634	664	455.6	426.2	232.1	344.1	361.5	417.1	2232	92
Lowest Monthly Rainfall (mm)	4.3	0	6	4.6	6.1	1.9	0	0	2	1	4.1	2.6	630.2	92
Mean Daily Max. Temp. (°C)	27.5	27.1	25.9	23.6	20.4	17.9	17.5	19	21.3	23.8	25	26.9	23	29
Highest Daily Max. Temp. (°C)	43.8	43	40.1	32.9	28	25	25.5	29.3	36.1	38	41.8	43	43.8	26
Mean Daily Min. Temp. (°C)	16.7	17.1	15.3	11.9	8.3	6.5	4.6	5.3	7.7	10.7	13	15.2	11	29
Lowest Daily Min. Temp. (°C)	7.5	9.7	5.8	1.5	0.1	-1.1	-4.2	-1.1	-0.6	1.1	3.9	6	-4.2	26
Mean 9am Air Temp. (°C)	22.9	22.3	20.7	18.3	14.3	11.7	10.5	12.8	16.3	19.2	20.4	22.3	17.6	28
Mean 9am Wet Bulb Temp. (°C)	19.4	19.7	18.5	15.8	12.5	10	8.7	10.3	12.7	15.1	16.6	18.1	14.8	23
Mean 9am Dew Point (°C)	17.5	18.2	17.1	14.2	10.9	8.7	7.3	7.6	9.8	11.1	14	15.8	12.7	12
Mean 9am Rel. Humidity (%)	72	79	83	77	80	81	79	70	65	62	67	68	74	15
Mean 3pm Air Temp. (°C)	26.3	25.9	24.5	21.8	19	16.4	16.1	17.7	19.9	21.9	23	25.1	21.5	14
Mean 3pm Dew Point (°C)	16.9	17.6	16.3	13.5	10.6	8.9	6.7	6.2	8.7	10.7	13.5	15.3	12.1	12
Mean 3pm Rel. Humidity (%)	59	63	62	62	61	62	55	49	51	53	59	58	58	12
Mean Daily Solar Exposure (MJ/m*m)	22.8	20.4	17.6	14.1	10.4	9.1	10	13.5	17.1	20.2	21.6	23.1	16.7	19

Table C.2: Climate Averages for Coastal Gosford (Norah Head Station; after BoM, 2009)

Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	No. of Years
Mean Monthly Rainfall (mm)	106.4	142	129	118.1	132.3	126.5	78.8	70.7	75.1	76.9	96.5	80.6	1229.6	35
Mean No. Rain Days	12.2	11.9	13	11.2	13	11.3	9.8	9.1	9.9	11.1	12.7	10.7	135.9	35
Highest Monthly Rainfall (mm)	439	605.8	339.4	416.6	445.2	424.1	370.3	334.1	289.8	206.4	231	236.8	1995.8	35
Lowest Monthly Rainfall (mm)	7.2	6.7	13.2	6.4	5.2	1.8	0.3	2.8	0.4	1	11.6	8.2	722.7	35
Mean Daily Max. Temp. (°C)	25	25.1	24.3	22.6	20.1	17.8	17.3	18.5	20.2	21.7	22.5	24.7	21.7	30
Highest Daily Max. Temp. (°C)	42.3	39.9	41.9	35.6	28.5	25	26	30.1	34.8	38.2	41.8	42.4	42.4	30
Mean Daily Min. Temp. (°C)	19.2	19.5	18.3	15.7	12.8	10.2	9.3	9.9	11.9	14.2	15.9	18.2	14.6	30
Lowest Daily Min. Temp. (°C)	13.3	11.6	11.1	8.5	6.1	3.6	3.4	4	5.5	6.6	9.5	8.3	3.4	30
Mean 9am Air Temp. (°C)	22	22.1	21.3	19.3	16	13.3	12.4	13.8	16.4	18.5	19.3	21.4	18	32
Mean 9am Wet Bulb Temp. (°C)	19.9	20.2	19	17	14	11.3	10.3	11.3	13.3	15.4	16.8	18.8	15.6	27
Mean 9am Dew Point (°C)	18.4	19	17.5	15.2	12.2	9.2	8	8.6	10.4	12.9	14.7	17	13.6	27
Mean 9am Rel. Humidity (%)	81	83	80	78	79	77	76	72	70	72	76	78	77	27
Mean 9am Wind Speed (km/h)	15.4	16.1	14.7	13.3	13.2	13.9	12.9	13.1	13.8	15.4	15.6	15.2	14.4	31
Mean 3pm Air Temp. (°C)	23.7	23.8	22.9	21.2	18.8	16.6	16.2	17.1	18.4	19.5	20.9	23	20.2	32
Mean 3pm Dew Point (°C)	20.7	21.1	19.9	18	15.6	13.4	12.6	13.1	14.4	16	17.7	19.6	16.8	27
Mean 3pm Rel. Humidity (%)	18.8	19.4	17.9	15.7	13	10.2	9.1	9	10.8	13.1	15.4	17.4	14.2	27
Mean 3pm Wind Speed (km/h)	76	77	75	73	71	67	65	63	64	70	73	73	71	27
Mean Daily Solar Exposure (MJ/m*m)	22.9	22.5	21.1	19.8	17.4	17.8	16.7	19.3	22.2	22.8	23.5	23.2	20.8	31

Appendix D

Ecological Report

Flora and Fauna of Gosford's Coastal Lagoons

Prepared for
Cardno Lawson Treloar Pty Ltd
March 2010

Dr Peter Freewater
Director Coastal & Estuarine Research Facility
School of Environmental and Life Sciences University of Newcastle, Central Coast PO Box 127 Ourimbah NSW 2258 Australia

Associate Professor William Gladstone
Deputy Director Central Coast (Research)
School of Environmental and Life Sciences University of Newcastle, Central Coast PO Box 127 Ourimbah NSW 2258 Australia

Coastal & Estuarine Research Facility

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Appendices

Acknowledgements

The authors wish to thank the following individuals who assisted at various stages of the research: field assistants (Kylie Freewater, Jack McPhee, Ian Bernard, Daniel Camilleri, Lindsay Doyle, Tristan Varman, Wayne Davis, Vanessa Owen, David Powter, Hamlet Giragossyan, Margaret O'Bryan, Jill Clancy, Steve Fartek and Norm Boardman), Tom Trnski and Sally Reader for help in larval fish identification, Nicole Hacking for assistance with invertebrate specimen sorting and identification, and Malcolm Ricketts for assistance with maps. The authors also wish to acknowledge Les Edwards for his significant contributions to field work, experimental design, statistical analyses and reporting. We would also like to acknowledge significant contributions by Rachel Lonie on biodiversity management. The authors would also like to further acknowledge the contributions of Jack McPhee, Ian Bernard and Daniel Camilleri in regard to the sorting and identification of invertebrates and statistical analyses. The authors also wish to acknowledge Dr John Runcie for assistance with Chlorophyll *a* analyses. The collection of fishes that occurred in this study was done under approval from NSW Department of Primary Industries and the University of Newcastle's Animal Care and Ethics Committee.

Introduction

This document reports on the flora and fauna of the four main Coastal Lagoons of Gosford (i.e. Wamberal, Terrigal, Avoca and Cockrone). A locality map with catchment boundaries for each lagoon is provided in Figure 1. Geo-referenced spatial data for each lagoon (sourced from Gosford City Council) was analysed to provide a summary of catchment size, surface area and shoreline length (Table 1).

Table 1 Catchment size, surface area and shoreline length for coastal lagoons

Lagoon	Catchment area (ha)	Surface area (ha)	Shoreline length (km)
Wamberal	734.24	46.12	4.88
Terrigal	1027.15	26.57	5.68
Avoca	1227.24	67.83	11
Cockrone	786.02	34.25	5

These lagoons are similar and collectively classified as Intermittently Closing and Opening Lakes and Lagoons (ICOLLs). These estuarine systems open naturally into the sea when rising flood water from the catchment or ocean storm waves breach the beach berm. Properties have been developed along the foreshore such that they some may become periodically inundated between lagoon openings. To mitigate flooding of these properties Water level gauges in each lagoon allow Council to monitor water levels and open the lagoons by mechanically breaching the berm with an excavator. This has resulted in changes to the natural hydrological regime of the lagoons and as a consequence has influenced the distribution and abundance of biota.

Intermittently opening coastal lagoons are a significant component of the estuarine environments of many countries, representing 49% of estuaries in south-east Australia (Roy *et al.*, 2001); 70% of South African estuaries (Whitfield, 1992); and 18% of the North American coastline (Barnes, 1980). Globally, they represent 13% of the world's coastline (Barnes, 1980). These normally small estuaries are isolated from the sea for extended periods of time because their small catchments provide only limited inflows of fresh water. This, combined with a low tidal range, allows beach sand to accumulate at the entrance. The water level of intermittently open estuaries is naturally dynamic and responsive to catchment run-off, evaporation, and rainfall events. Entrance barriers that separate the closed estuary from the ocean are naturally breached during periods of elevated water levels or by high seas, causing the estuary to drain. These estuaries may remain open for hours to months, receiving incoming seawater and immigrating marine biota until the barrier is re-formed by wave action (Kjerfve & Magill, 1989; Elwany *et al.*, 2003). Unpredictable rainfall means that the timing and frequency of natural openings are intermittent.

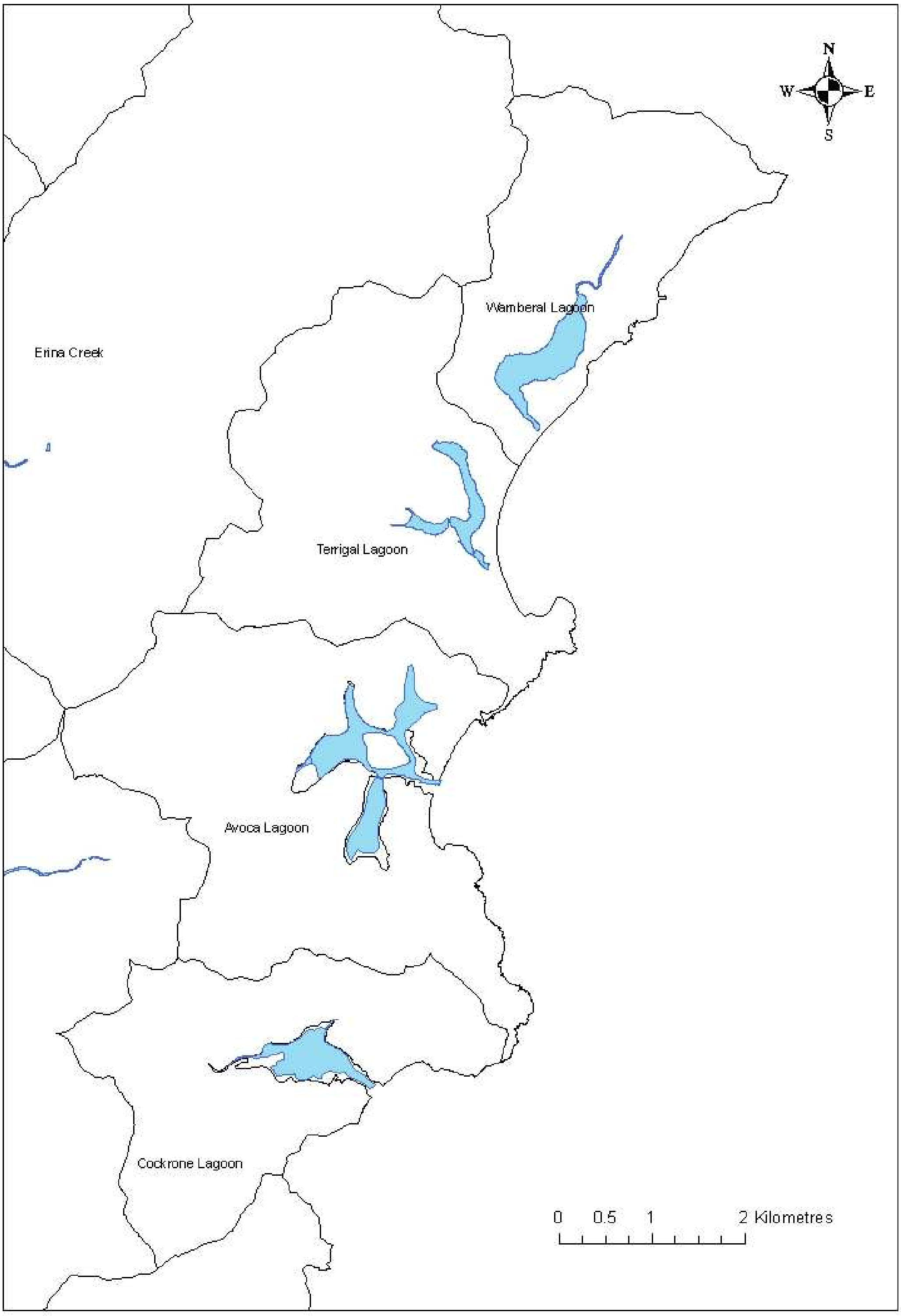


Figure 1 Locality map showing catchment boundaries of each of Gosford's coastal lagoons

Human uses, foreshore property developments, and community expectations have forced local management authorities in Australia (Roy *et al*., 2001) to intervene in this natural process by artificially breaching entrance barriers to improve water quality, recreational amenity and fishing opportunities, and to prevent flooding of adjacent property (Healthy Rivers Commission, 2002).

Artificial openings alter the natural cycles of flooding, drainage, and filling upon which the ecological processes of these ecosystems depend. The practise is regarded by one Australian state government as a threat to the biodiversity of these ecosystems (NSW EPA, 2000). Artificial openings lead to reduced water volume, increased salinity, sediment re-suspension, and a rapid exchange of the remaining water body (Saad *et al*. 2002; Suzuki *et al*. 2002). Death of submerged macrophytes upon exposure increases dissolved and total nutrients and primary production shifts from being macrophyte- to phytoplankton-dominated (Knoopers, 1994; Suzuki *et al*. 2002). In other systems artificial openings have led to a short-term reduction in biomass of phytoplankton and zooplankton (Froneman, 2004).

Aims and Objectives

The overarching aims of this report are to document the flora and fauna of Gosford's Coastal Lagoons; investigate the influence of anthropogenic processes such as foreshore development, artificial openings and recreational use of the lagoons on these biota; and discusses these issues with regard to changes in habitat and biodiversity.
The broad objectives are to:

1. Identify and map riparian and floodplain habitat
2. Assess and rank riparian habitats in terms of condition
3. Survey and map benthic estuarine habitats
4. Assess phytoplankton populations
5. Assess fish and prawn populations
6. Discuss the encouragement of tourism and any perceived conflicts between recreational fishing and the amenity of the natural environment
7. Describe the spatial and habitat-related patterns in the biodiversity of macroinvertebrates
8. Assess the loss of habitat and habitat diversity
9. Assess biodiversity loss
10. Relate the influence of anthropogenic processes to changes in estuarine habitat and biota

1.0 Flora

1.1 Riparian and Floodplain Vegetation

This study provides a review of the fringing or foreshore vegetation at each lagoon and assesses the condition of the foreshore with regard to anthropogenic disturbance. Discussion is provided on the implications of climate change together with other recommendations and options to consider in the future management of the lagoons.

1.1.2 Methods

Each of the four lagoons was surveyed and photographed to document and assess foreshore vegetation type and general condition. Bell (2004) was used as the basis for vegetation community mapping and maps were updated following site inspections (ground-truthed) as required. The vegetation communities and species were cross referenced with other historical records including Gosford City Councils georeferenced data bases.

Vegetation surveys were also done to quantify fringing vegetation communities at a variety of spatial scales. These communities can be categorised into three main types; namely Estuarine *Baumea* Sedgeland; *Phragmites* Rushland; and Paperbark Forest. Bell (2004) defines a variety of Paperbark Forest communities that are found around the foreshores of the coastal lagoons:

- Alluvial Paperbark Sedge Forest;
- Coastal Sand Swamp Forest;
- Estuarine Paperbark Scrub Forest;
- Estuarine Swamp Oak Forest; and
- Swamp Mahogany - Paperbark Forest.

These different Paperbark communities, by definition, have very different species compositions with varying abundance of species. Therefore, it was considered unnecessary to use powerful statistical procedures to demonstrate these differences. Because *Phragmites* Rushland and *Baumea* Sedgeland communities were the most abundant and best replicated among the four lagoons, the decision was made to focus sampling effort and statistical analyses on both of these as distinct communities.

For both of these communities (*Phragmites* Rushland and *Baumea* Sedgeland) eight locations (two in each of the four lagoons) were sampled to examine the variability in vegetation at the scales of kilometres, 100s of metres and metres (Figures 1.2-1.5). Two randomly nested sites were sampled at each location. Each location was situated on the foreshore and at some locations the fringing vegetation was relatively narrow. At each site a 20 m transect was randomly placed along the shoreline and the percentage cover of each species was recorded.

To test for significant differences between sites and locations, univariate (ANOVA) statistical routines were used to analyse the data. One-factor analyses of variance (ANOVA) were used to test the hypothesis that there was no spatial variation. Any significant spatial variation was then investigated *post-hoc* using Student-Newman-Keuls (SNK) tests (Underwood 1997).

A rapid assessment method, similar to the one used by Sainty and Roberts (2007) to assess foreshores in Brisbane Water, was applied in this Study for comparisons and consistency with reporting. However, the method is modified to suit the Gosford ICOLLs and their different foreshore vegetation communities. The salinity of Brisbane Water is generally between about 20 – 35 ppt and this inhibits most weeds from colonising the intertidal shores. Lagoon foreshores are only intermittently intertidal and the salinity of the lagoons is generally between 6 – 19 ppt making them more vulnerable to weed invasion by non-halophilic weed species.

The method uses a *Disturbance Index* developed by Sainty and Roberts (2007) to assist in characterising ecological values and quantifying disturbance (Table 1.1). The index is scaled from 1 – 5, the most highly modified or most disturbed foreshores recorded as a *1*, whilst the least modified foreshore with undeveloped catchments were recorded as a *5*. A description of each index is provided in Table 1. The 4th index describes a natural foreshore with a catchment that is modified by development; the presence of weeds, trampling or similar; and 6 describes a more pristine foreshore, with few or no weeds. To compare with the foreshore of Brisbane Water, 5 and 6 can be summed together as index 5.

A kayak was used to access the foreshore to assess disturbance and to survey vegetation. Catchment land use and ecological character observed and photographed in the field were used to ground truth aerial photographs (2005 and 2007) and geo-referenced data compiled by Bell (2004).

The vegetation communities described herein are based on the regional classification of NPWS (2000) as used by Bell (2004).

Table 1.1 Disturbance Index used to assess each section of foreshore around the Brisbane Water estuary (after Sainty and Roberts 2007).

INDEX	DESCRIPTION
1	**Highly disturbed** or modified foreshore. Includes seawalls with limited ecological niches e.g. vertical concrete or stone. Includes buildings in close proximity to the seawall, often with jetties and stormwater inlets. Catchment* substantially developed.
2	**Disturbed** or modified foreshore. Seawall with limited ecological niches. Includes foreshore with *Phragmites* or other native vegetation limited to narrow discontinuous strip. Catchment substantially developed.
3	**Modified foreshore**. Seawall absent. Includes irregular strip of fringing vegetation or natural rock platform associated with a variable width forest, contiguous to water's edge. Catchment partly/variably developed.
4	**Modified catchment**. *Phragmites*, *Baumea* or other native forest type on water's edge. Catchment partially or wholly developed, weeds, trampling or other disturbance.
5	**Native forest and foreshore**. *Phragmites*, *Baumea*, or other native forest type on water's edge. Catchment with no development. Few if any weeds or other signs of disturbance.

*Catchment refers to adjacent subcatcment draining to particular section of shoreline

1.1.3 Results

1.1.3.1 Vegetation communities

The relative proximity of the four coastal lagoons means that they generally share very similar vegetation communities. Each of these communities is described below and given a colour that can be used to identify it where present around the foreshore of each lagoon (Figures 1.2-1.5). The descriptions include the plant species used by Bell (2004) to characterise each vegetation community. Common names are provided where known.

A written summary of the foreshore vegetation for each lagoon is also provided:

Alluvial Paperbark Sedge Forest contains *Eucalyptus robusta* (Swamp Mahogany) with dense stands of *Melaleuca biconvexa* (threatened species), *Melaleuca styphelioides* (Prickly-leaved Paperbark), *Callistemon salignus* (Pink-tip Bottlebrush) and *Livistona australis* (Cabbage Tree Palm) with a dense understorey of *Gahnia clarkei* (Tall Saw-edge).

Coastal Sand Swamp Forest is similar to Alluvial Paperbark Sedge Forest as it includes *Eucalyptus robusta* but is dominated by *Melaleuca quinquenervia* (Broad-leaved Paperbark) with an understorey dominated by *Gahnia clarkei, Phragmites australis* and *Baumea spp* (Figure 1.7).

Estuarine *Baumea* Sedgeland is dominated by *Baumea juncea* (Figure 1.6).

Estuarine Paperbark Scrub Forest is characterised by dense thickets of paperbarks (*Melaleuca nodosa, Melaleuca styphenoides* – Prickly-leaved Paperbark) with stunted emergent eucalypts including *Eucalyptus paniculata* (Grey Ironbark) and *Eucalyptus resinifera* (Red Mahogany), and the occasional *Eucalyptus robusta* (Swamp Mahogany) (Figure 1.8).

Estuarine Swamp Oak Forest is dominated by *Casuarina glauca* (Swamp Oak), with an understorey of sedges and rushes such as *Juncus kraussii* (Sea Rush) and *Baumea juncea* (Bare-twig Rush). It also includes the herb *Apium prostratum* (Sea Celery).

Phragmites Rushland (Common Reed) is generally dominant in the shallow near shore areas and is often associated with the seagrass *Ruppia megacarpa* (Figure 1.9).

Swamp Mahogany - Paperbark Forest is dominated by *Eucalyptus robusta* (Swamp Mahogany) and *Melaleuca spp*.

The relative area (ha) of each vegetation community is summarised in Figure 1.10.

Figure 1.2 Wamberal Lagoon foreshore vegetation communities (see section 1.1.3 for colour key/legend) and locations of transects (●= transect)

Figure 1.3 Terrigal Lagoon foreshore vegetation communities (see section 1.1.3 for colour key/legend) and locations of transects (●= transect)

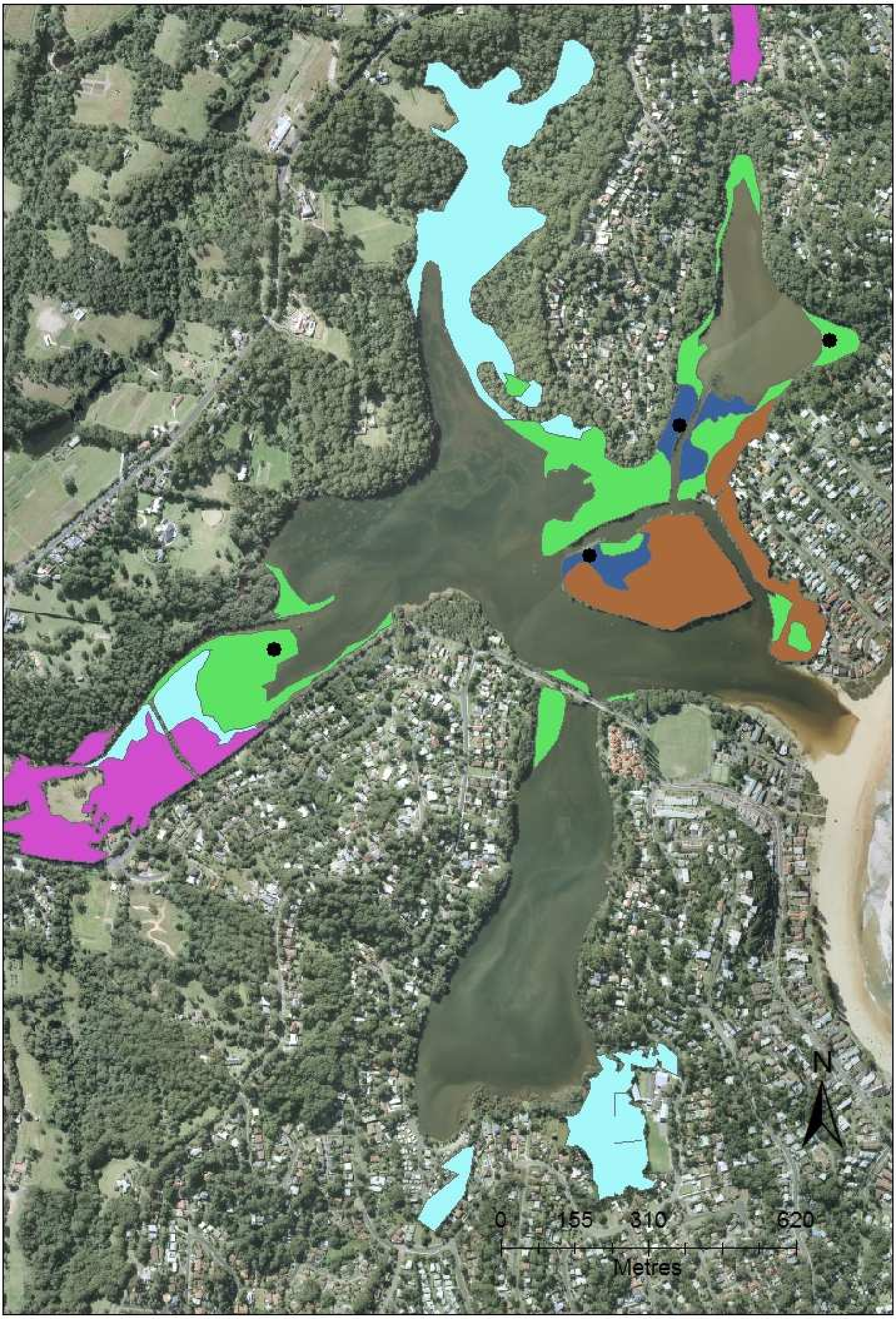


Figure 1.4 Avoca Lagoon foreshore vegetation communities (see section 1.1.3 for colour key/legend) and locations of transects (●= transect)

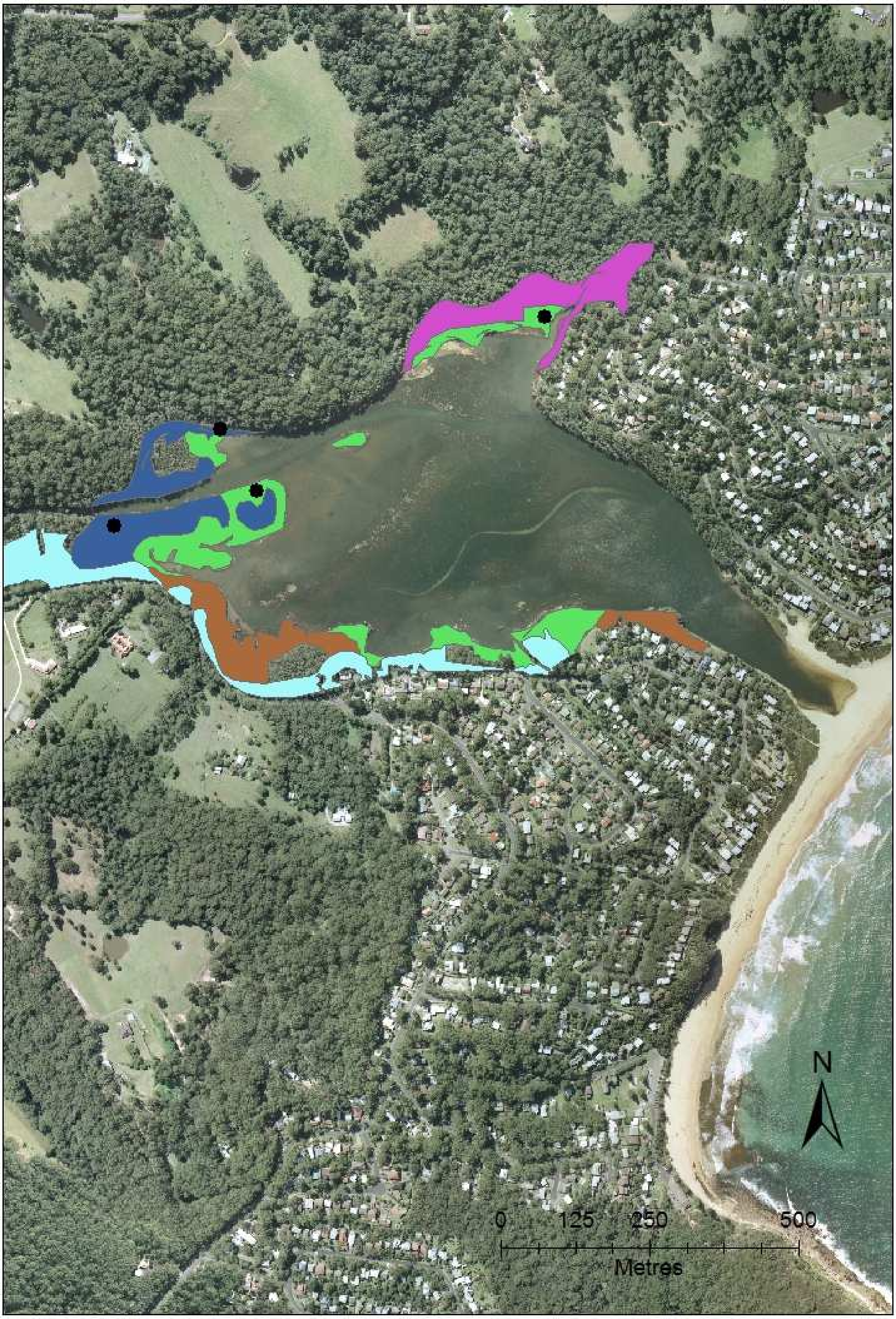


Figure 1.5 Cockrone Lagoon foreshore vegetation communities (see section 1.1.3 for colour key/legend) and locations of transects (●= transect)

Figure 1.6 Coastal Sand Foredune Scrub with Baumea Sedgeland (Wamberal)

Figure 1.7 Alluvial Paperbark Sedge Forest (Avoca)

Figure 1.8 Estuarine Paperbark Scrub-Forest (Wamberal)

Figure 1.9 *Phragmites australis* (Avoca)

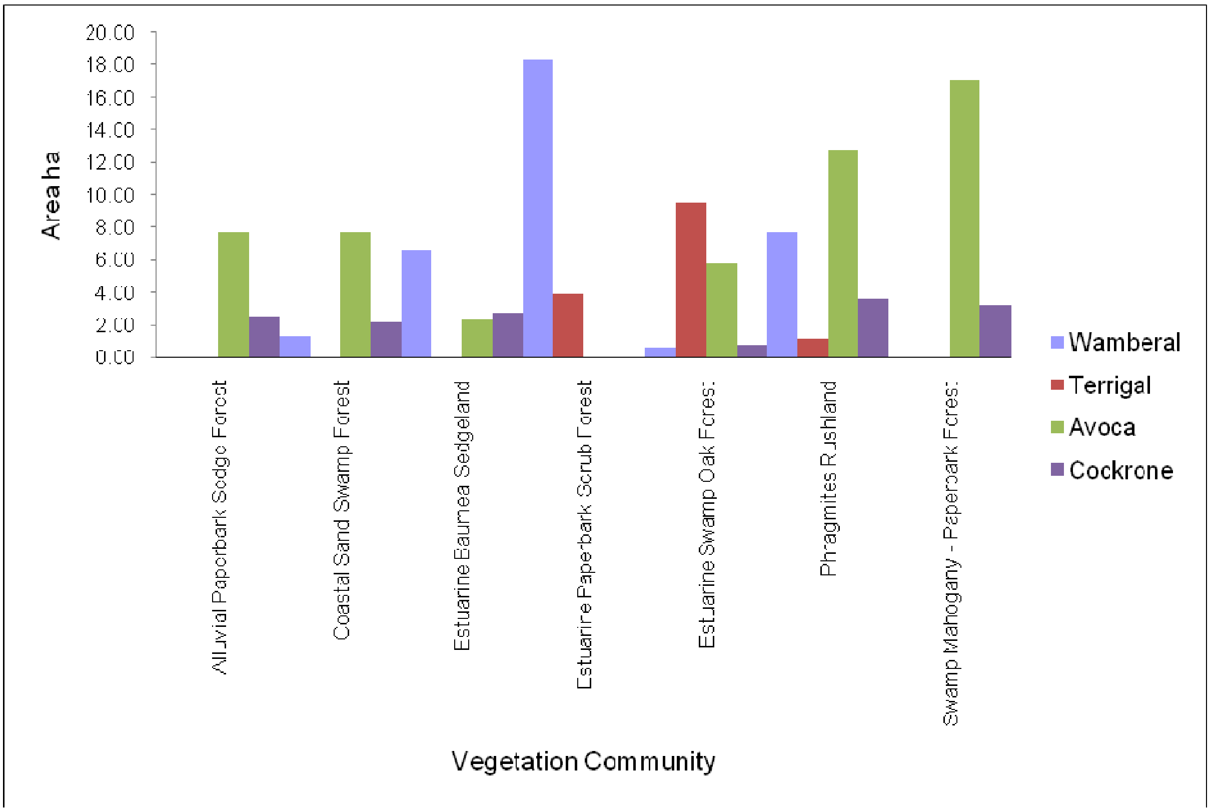


Figure 1.10 Areas of each vegetation community surrounding each of the four lagoons (ha)

Phragmites Rushland communities were completely dominated by *Phragmites australis* having almost 100% cover at all sites in all lagoons. Statistical analyses indicated that there was no significant difference in the percentage cover of *Phragmites australis* between sites ($p = 0.24$, where the critical value was $p < 0.05$) and whilst there was slightly lower percentage cover at Terrigal Lagoon (88.5%, Figure 1.11) there was no significant difference between lagoons ($p = 0.08$, where the critical value was $p < 0.05$).

Similarly, Estuarine *Baumea* Sedgeland was dominated by *Baumea juncae* (with an average of 78% cover across the lagoons, Figure 1.12). However, there were no Estuarine *Baumea* Sedgeland communities at Terrigal Lagoon; therefore, Terrigal was excluded from the statistical analyses. For the remaining lagoons, statistical analyses indicated that there was no significant difference in the percentage cover of any species at either of the investigated spatial scales. The p results of one-way ANOVA are summarised in Table 1.2 below and the complete analyses are provided in Appendix 1.

Table 1.2 Summary of p results for one-way ANOVA for Estuarine *Baumea* Sedgeland demonstrating no significant difference (where the critical value was $p < 0.05$) for percentage cover of any species within or between lagoons (omitting Terrigal).

	Baumea juncae	***Baumea articulta***	***Apium prostratum***	***Selliera radicans***
within	0.17	0.96	0.56	0.22
between	0.31	0.63	0.22	0.48

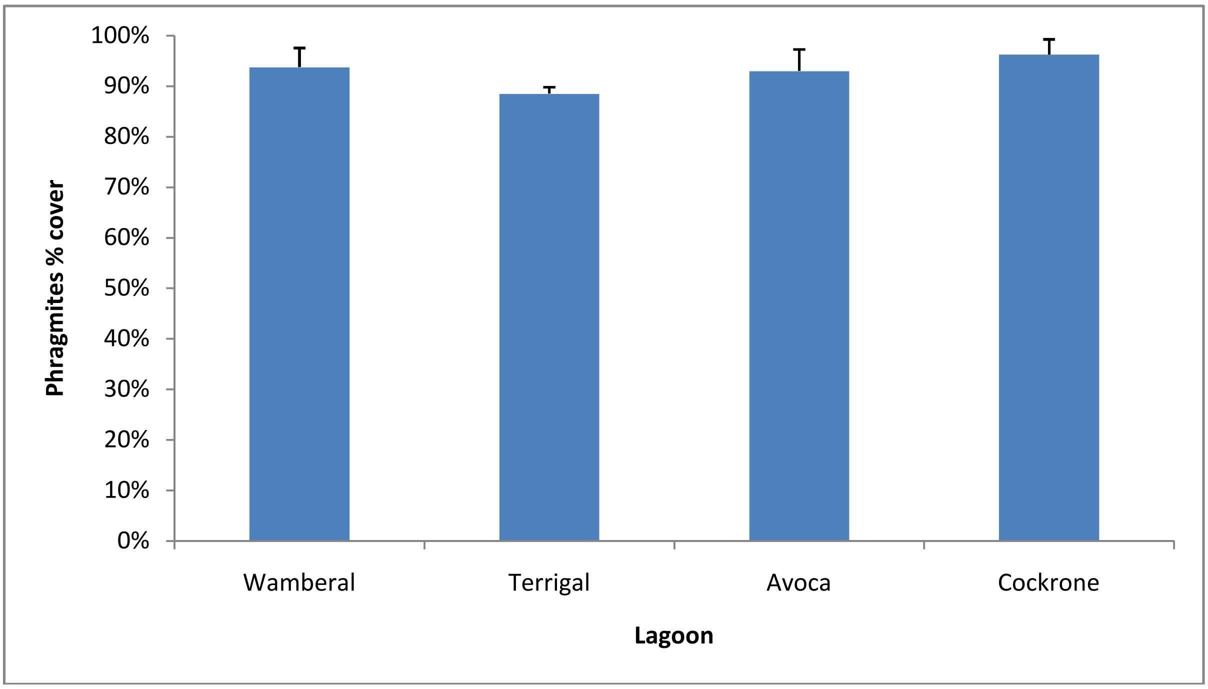


Figure 1.11 Mean percentage cover (with standard deviation) of *Phragmites australis* in *Phragmites* Rushland communities at each lagoon

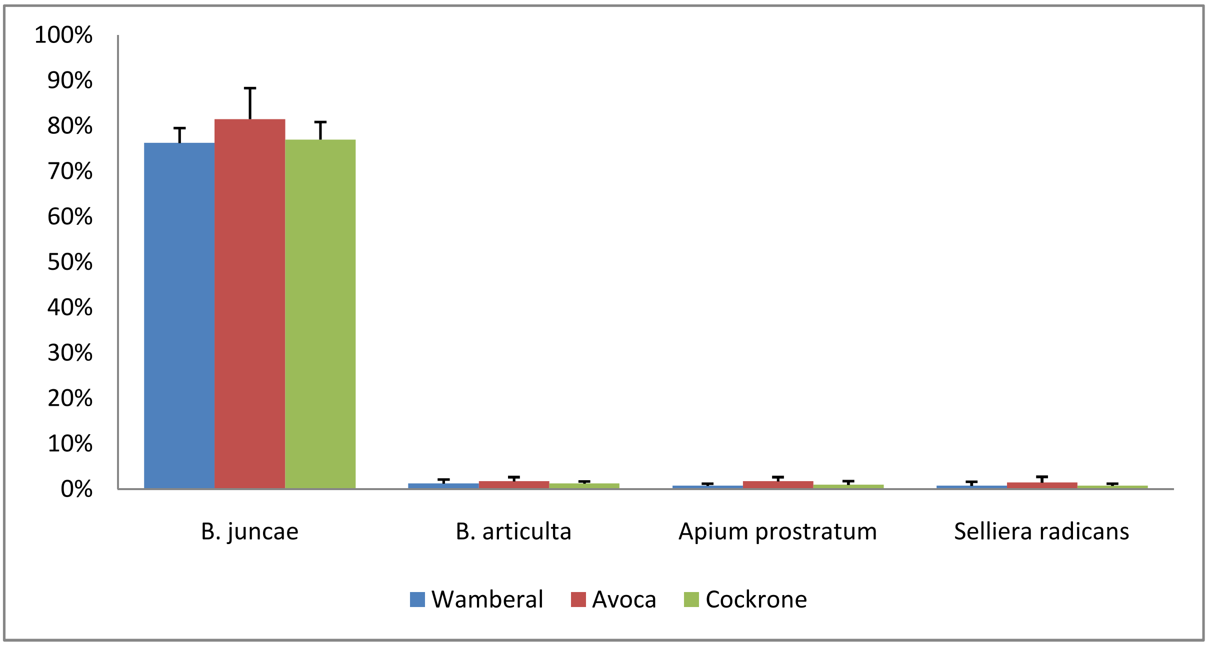


Figure 1.12 Mean percentage cover (with standard deviation) of main species present in Estuarine *Baumea* Sedgeland communities at each lagoon.

Vegetation of Wamberal Lagoon foreshore

The vegetation communities of Wamberal are mapped using the colour keys provided in section 1.1.3 (Figure 1.2). Wamberal Lagoon Nature Reserve separates the lagoon from the sea and dominates the seaward shore. A patch of threatened Coastal Sand Littoral Rainforest saddles the dune located between the lagoon and the ocean. This habitat is in very good condition, however, there are weeds present, the most dominant being Bituo Bush (*Chrysanthemoides monilifera*). On the seaward shore of the reserve is Coastal Sand Foredune Scrub and the landward shore contains Coastal Sand *Banksia* Scrub. Bituo Bush is also abundant in these latter two habitats.

Wamberal Low Open Heath Forest is present on the north-western shore below a stand of Tumbi Spotted Gum Ironbark Forest. Estuarine Baumea Sedgeland is present on the north-eastern shore with Phragmites Rushland, which fronts much of the lagoon shoreline. The south-western and north-western foreshore of is dominated by Estuarine Paperbark Scrub Forest whilst the Casuarina variant of this ecological community occupies the riparian fringe of the creek feeding the northern reaches of the lagoon. It is likely that the presence of *Casuarina glauca* here is a result of previous anthropogenic disturbance.

Vegetation of Terrigal Lagoon foreshore

The vegetation communities of Terrigal are mapped using the colour keys provided in section 1.1.3 (Figure 1.3). Terrigal Lagoon has undergone more significant modifications to its catchment and foreshore than the other lagoons. The foreshore of the lagoon contains extensive urban development that has encroached to such an extent that the lagoon must be opened monthly to prevent flooding of property and Council managed assets. It is believed that more frequent openings have resulted in changes in salinity and have subsequently modified foreshore vegetation communities.

The eastern shore of the lagoon has been significantly modified by urban encroachment, especially the southern corner where vertical seawalls dominate the foreshore (Figure 1.13). Phragmites Rushland is scattered around some sections of the shore often accompanied by a narrow strip of remnant Estuarine Swamp Oak Forest and variants of this ecological community. The north-western corner of the North Arm has a small stand of Swamp Mahogany - Paperbark Forest.

Estuarine Swamp Oak Forest is better represented on the western shore where there is still a good understorey of sedges and rushes. Phragmites Rushland fringes larger areas of shore here and the presence of mangroves (*Avicennia marina* - Grey Mangrove and *Aegicerus corniculatum* – River Mangrove) may be symptomatic of salinity differences (between Terrigal and the other lagoons) resulting from frequent openings. Mangroves have not been previously mapped for this location.

The seagrass *Ruppia megacarpa* was not found in Terrigal Lagoon, which is also in contrast to the other three lagoons, for which field surveys confirmed that *R. megacarpa* was present. The mud substrate is made up of fine sediments with a sparse cover of macroalgae. Regular emptying of the lagoon exposes large mudflats (Figure 1.14).

Figure 1.13 Example of seawalls on Terrigal Lagoon

Figure 1.14 Muddy substrate without seagrasses (Terrigal)

Remnant Coastal Headland Shrubland and remnant Coastal Sand Foredune Scrub can be found along the foreshore near the entrance to the lagoon. These habitats are highly disturbed and modified with weed species, such as Asparagus Fern and Lantana.

Alluvial Bluegum – Paperbark Forest is found higher in the catchment to the north-west with some Narrabeen Coastal Blackbutt Forest, the latter community is also found above the western shore.

Vegetation of Avoca Lagoon foreshore

The vegetation communities of Avoca are mapped using the colour keys provided in section 1.1.3 (Figure 1.4). Avoca Lagoon is roughly star-shaped with a considerable area of wetlands around its perimeter. Bareena Island is near the centre of the lake and whilst it has predominantly native vegetation some weeds are present, the most noticeable being Bitou Bush.

Forest communities include Coastal Narrabeen Moist Forest, Coastal Narrabeen Ironbark Forest and Narrabeen Coastal Blackbutt Forest. Vegetation communities at or near the foreshore of Avoca Lagoon are very similar to the other lagoons. They include; Estuarine Swamp Oak Forest, *Phragmites* Rushland, *Baumea* Sedgeland and Coastal Sand Foredune Scrub. The foreshore vegetation also includes Alluvial Paperbark Sedge Forest and Coastal Sand Swamp Forest. Bareena Island has one of the few remaining stands Coastal Sand Swamp Forest in the Gosford LGA.

Avoca Lagoon suffers from extensive algal mat blooms from during the summer. The algal mats are made up of a few species of filamentous algae, mostly *Enteromorpha intestinalis* and *Chaetomorpha linum* (Figures 1.15-1.16).

Figure 1.15 Algal mats at Avoca Lagoon

Figure 1.16 *Enteromorpha intestinalis*

Vegetation of Cockrone Lagoon foreshore

The vegetation communities of Cockrone are mapped using the colour keys provided in section 1.1.3 (Figure 1.5). Forest communities within the Cockrone Lagoon catchment are similar to those found in the Avoca Lagoon and Terrigal Lagoon catchments. They include Coastal Narrabeen Moist Forest, Coastal Narrabeen Ironbark Forest and Narrabeen Coastal Blackbutt Forest, Alluvial Paperbark Sedge Forest and Coastal Sand Swamp Forest. Cockrone Lagoon catchment also has stands of Coastal Warm Temperate Rainforest.

Cockrone Lagoon also shares similar wetland communities with the other lagoons. They include Swamp Mahogany - Paperbark Forest, Estuarine Swamp Oak Forest, *Phragmites* Rushland and *Baumea* Sedgeland. Likewise, Coastal Sand Foredune Scrub is also represented.

The seagrass *Ruppia megacarpa* is abundant in Cockrone Lagoon (Figure 1.17). Unfortunately algal mats are also a common feature during the early months of summer.

Figure 1.17 *Ruppia megacarpa* at Cockrone Lagoon

1.1.3.2 Condition of lagoon foreshores

Foreshore condition of Wamberal Lagoon

Much of the shoreline of the Wamberal Lagoon is relatively undisturbed (54% undisturbed, see Figure 1.18 and Table 1.3) with a significant portion of the undisturbed foreshore vegetation protected by the Wamberal Lagoon Nature Reserve on the eastern or seaward side. The nature reserve encloses the whole of the coastal barrier, whilst at other locations around the waterway the riparian buffer is of variable width, generally affording some protective separation from other land uses. As can be seen from Table 3, aside from a stormwater culvert, which is a modification of the natural foreshore, there are no sections of foreshore scored as highly disturbed (1) or disturbed (2).

Figure 1.18 Foreshore assessment for Wamberal Lagoon illustrating condition (1 Highly disturbed = red, 2 Disturbed = orange, 3 Modified = yellow, 4 Modified catchment = light green, 5 Unmodified catchment = dark green)

Table 1.3 The length (km) and percentage (%) of foreshore represented by each of the five disturbance indices in Wamberal Lagoon.

Disturbance Index	Condition	Percentage	Kilometres
1	Highly disturbed	0	0.01
2	Disturbed	0	0
3	Modified Foreshore	16	0.78
4	Modified Catchment	30	1.45
5	Native forest and foreshore	54	2.65
TOTAL		100	4.88

Foreshore condition of Terrigal Lagoon

Approximately 68% of the Terrigal Lagoon foreshore has been disturbed or modified (see Figure 1.19 and Table 1.4). The remaining foreshore areas (32%) have native riparian vegetation, however the portion of the catchment draining to/adjacent to these areas is developed and is likely to be impacting on the ecological integrity of these habitats. There are no foreshores with native riparian vegetation and undeveloped catchments.

There is a 390 m long strip of seawalls (comprised mainly of vertical revetments) on the south-eastern shore of the North Arm (Figure 1.19; marked in *red*, Disturbance Index 1). A smaller section of about 30m in length can be found at the entrance on the northern shore.

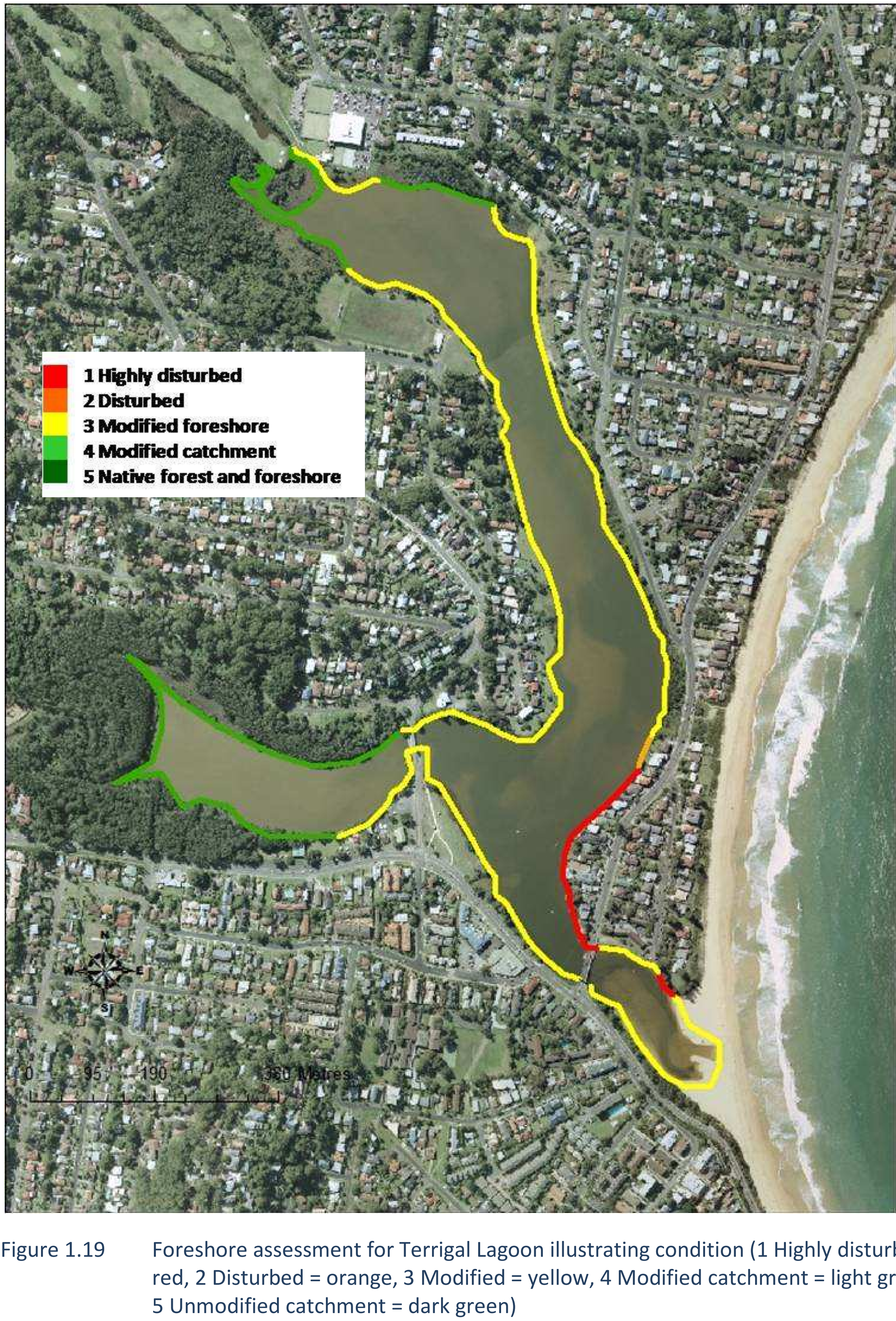


Figure 1.19 Foreshore assessment for Terrigal Lagoon illustrating condition (1 Highly disturbed = red, 2 Disturbed = orange, 3 Modified = yellow, 4 Modified catchment = light green, 5 Unmodified catchment = dark green)

Table 1.4 The length (km) and percentage (%) of foreshore represented by each of the five disturbance indices in Terrigal Lagoon.

Disturbance Index	Condition	Percentage	Kilometres
1	Highly disturbed	6.84	0.39
2	Disturbed	0.67	0.04
3	Modified	60.60	3.43
4	Modified Catchment	31.89	1.81
5	Native forest and foreshore	0	0
TOTAL		100	5.66

Foreshore condition of Avoca Lagoon

Approximately 28% of the Avoca Lagoon foreshore has been modified in some way (see Figure 1.20 and Table 1.5). The majority of the foreshore (72%) has relatively good quality native riparian vegetation. This includes 21% of the foreshore with both undisturbed vegetation and undeveloped catchments (Figure 1.20; marked in *dark green*, Disturbance Index 5). The remaining 51% of the native foreshore has some development within the catchment (Figure 1.20; marked in *light green*, Disturbance Index 4).

The only highly disturbed section (0.5%) is around the piers for the bridge that crosses the southern arm of the lagoon (Figure 1.20; marked in *red*, Disturbance Index 1). The southern arm has the most modified sections of shoreline. These areas have generally been turned into lawns and have had the understorey cleared (Figure 1.20; marked in *yellow*, Disturbance Index 2). Areas near the beach on either side of the lagoon are subject to recreational impacts such as launching of kayaks and pedestrian traffic. These results are summarised in and Table 1.5.

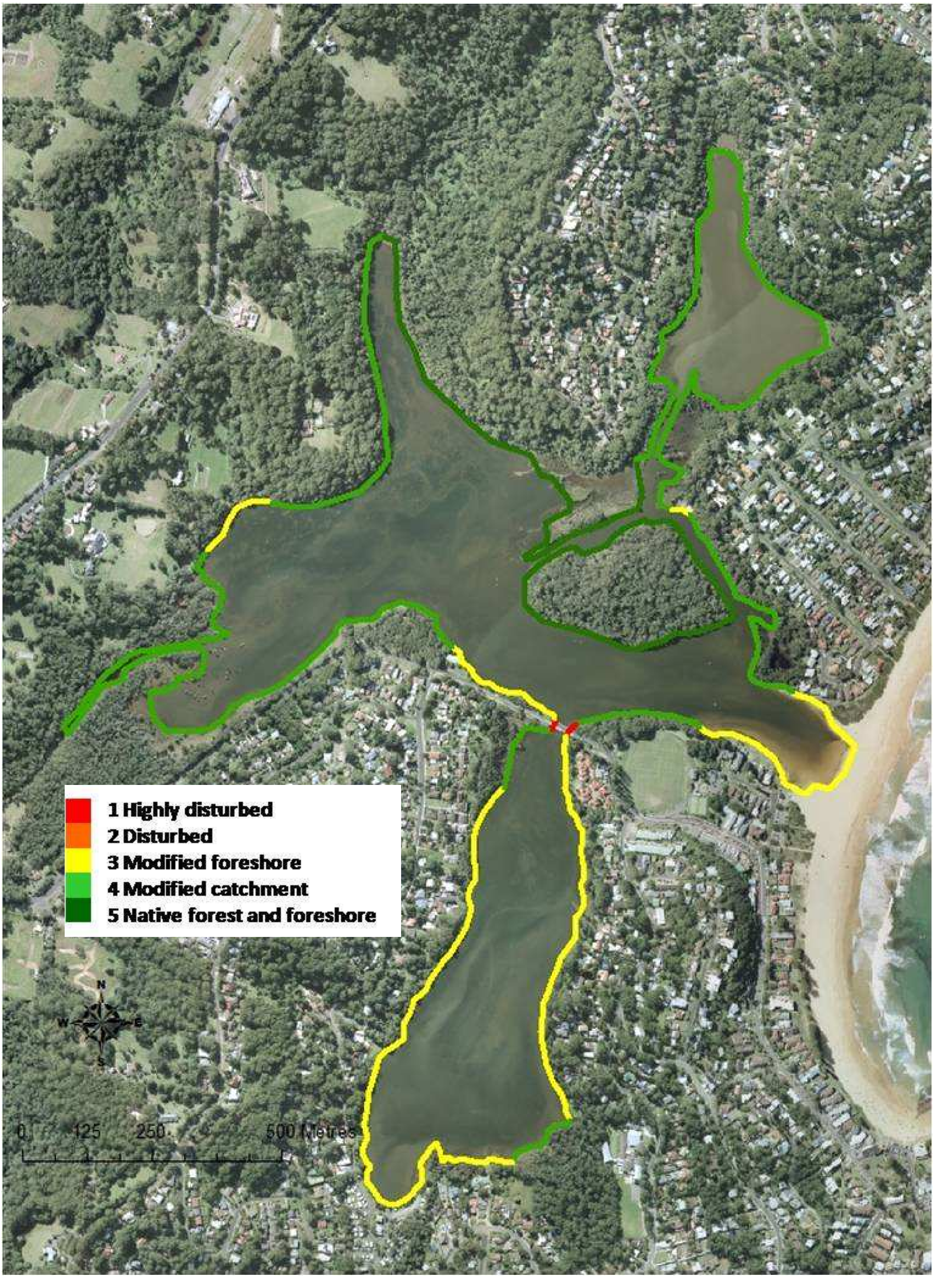


Figure 1.20 Foreshore assessment for Avoca Lagoon illustrating condition (1 Highly disturbed = red, 2 Disturbed = orange, 3 Modified = yellow, 4 Modified catchment = light green, 5 Unmodified catchment = dark green)

Table 1.5 The length (km) and percentage (%) of foreshore represented by each of the five disturbance indices in Avoca Lagoon.

Disturbance Index	Condition	Percentage	Kilometres
1	Highly disturbed	0.46	0.50
2	Disturbed	0	0
3	Modified	27.65	3.03
4	Modified Catchment	51.17	5.61
5	Native forest and foreshore	20.72	2.27
TOTAL		100	10.97

Foreshore condition of Cockrone Lagoon

Only about 22% of the Cockrone Lagoon foreshore has been modified (see Figure 1.21 and Table 1.6). The majority of the foreshore (78%) has relatively good quality native riparian vegetation. This includes 31% of the foreshore with both undisturbed vegetation and undeveloped catchments (Figure 1.21; marked in *dark green*, Disturbance Index 5). The remaining 47% of the native foreshore has development within the catchment (Figure 1.21; marked in *light green*, Disturbance Index 5).

There are no sections of highly disturbed foreshore and only about 200 m (4%) were scored as disturbed (Figure 1.21; marked in *orange*, Disturbance Index 3). There is a section of the shore near the entrance to Merchants Creek that has been modified with lawns behind a narrow fringe of native vegetation (Figure 1.21; marked in *yellow*, Disturbance Index 2). Like Avoca Lagoon, Cockrone Lagoon has areas near the beach on either side of the lagoon that are subject to regular pedestrian traffic and have also been scored as modified (i.e. Disturbance Index 2). These results are summarised in and Table 1.6.

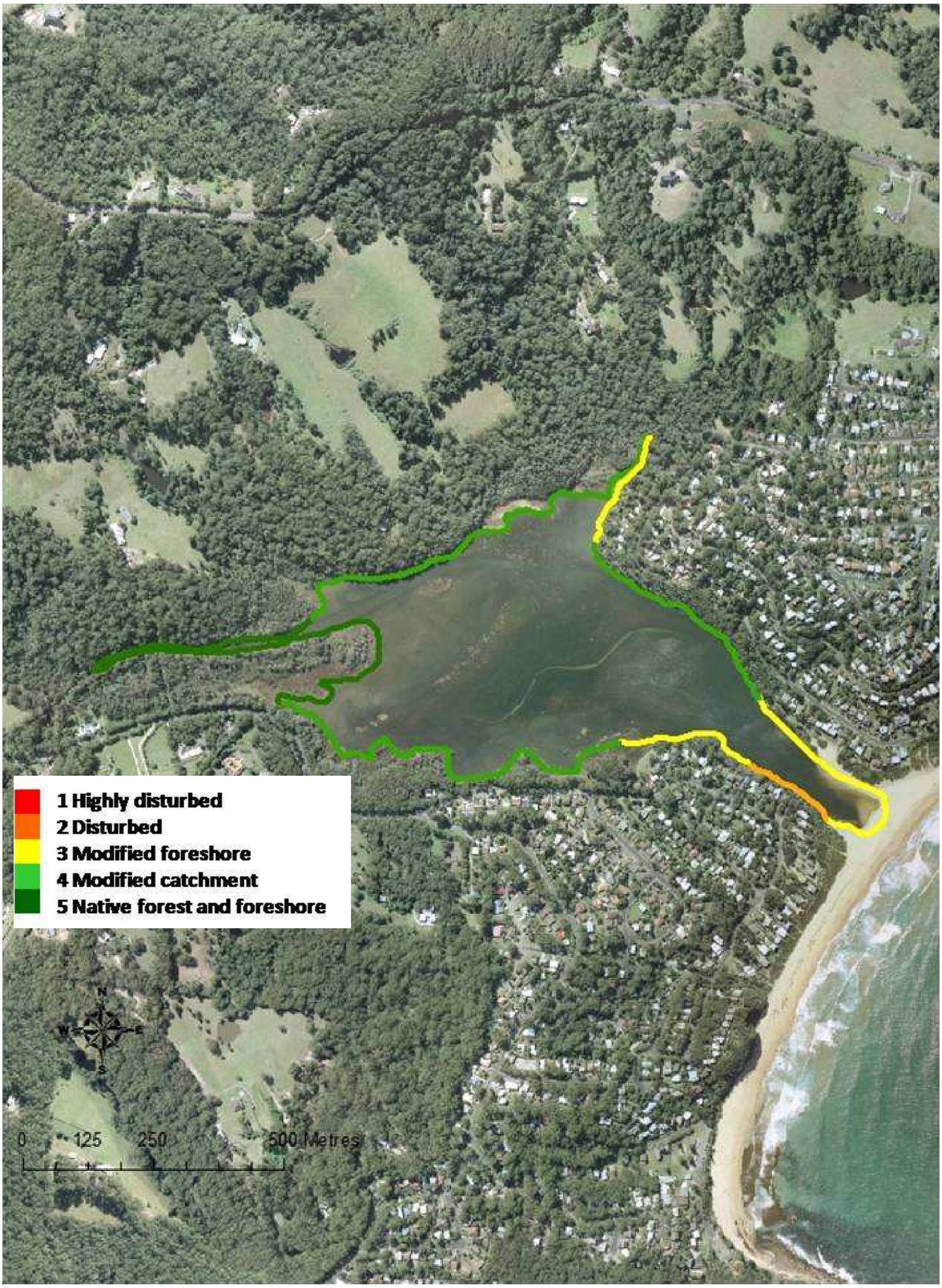


Figure 1.21 Foreshore assessment for Cockrone Lagoon illustrating condition (1 Highly disturbed = red, 2 Disturbed = orange, 3 Modified = yellow, 4 Modified catchment = light green, 5 Unmodified catchment = dark green)

Table 1.6 The length (km) and percentage (%) of foreshore represented by each of the five disturbance indices in Cockrone Lagoon.

Disturbance Index	Condition	Percentage	Kilometres
1	Highly disturbed	0	0
2	Disturbed	4.13	0.21
3	Modified	18.13	0.90
4	Modified Catchment	46.86	2.34
5	Native forest and foreshore	30.87	1.54
TOTAL		100	4.99

1.1.4 Discussion and Recommendations

The distribution of foreshore vegetation in each of the lagoons is dynamic and linked to hydraulic, hydrological and seasonal factors. Water levels within the lagoons are controlled primarily by freshwater inflows. However, when the entrance is open, ocean water levels can also influence lagoon water levels. The entrance is currently subject to an entrance management program by which the lagoon entrances are mechanically opened for flood mitigation reasons, thereby draining the lagoons. This has led to changes in the frequency of lagoon opening, particularly at Terrigal Lagoon with the current frequency of lagoon openings (based on both natural breakout events and mechanical openings) being up to 12 times/year, up from generally only about 2 times/year prior to mechanical manipulation of the entrance (GCC, 1995). This practise is thought to be having a profound influence on the composition and distribution of foreshore vegetation.

Hydrology controls the abiotic and biotic characteristics of wetlands. Abiotic characteristics such as soil and water quality depend on the distribution and movement of water, as do the abundance, diversity, and productivity of plants, vertebrates, invertebrates, and microbes. Water flows and levels in most wetlands are dynamic and the temporal pattern of water level for an individual wetland is part of its ecological signature. Water level fluctuates daily and seasonally in almost all wetlands, on arbitrary scales referenced to the surface of the substrate. It also varies significantly from year to year in some wetlands. For these reasons, the practice of stabilizing water level in managed wetlands is misled by the notion that most wetland wildlife species require year-round standing water for their life cycles. In fact, dry periods are often important for reasons that are less obvious but no less important.

This investigation identifies the extent and foreshore location of vegetation communities and indicates that the most significant impact on this flora is with Terrigal Lagoon, whereas Wamberal Lagoon is least affected (Table 1.7). Urban encroachment of Terrigal Lagoon has resulted in the development of private and local government assets below natural lagoon water levels. Because of this, Terrigal Lagoon is opened more frequently than the other lagoons, resulting in higher salinities and subsequent changes in foreshore vegetation, such the introduction of mangroves and a reduction in the seagrass, *Ruppia megacarpa*.

Table 1.7 Summary of foreshore condition of Coastal Lagoons (%) and total percentage of each condition classification across all lagoons

	Highly Disturbed	Moderately Disturbed	Modified	Modified Catchment	Native Forest and Foreshore
Wamberal	0	0	16	30	54
Terrigal	6.84	0.67	60.6	31.89	0
Avoca	0.46	0	27.65	51.17	20.72
Cockrone	0	4.13	18.13	46.86	30.87
Total %	**3.34**	**0.93**	**30.19**	**41.58**	**23.96**

The mechanical opening of Gosford's ICOLLs is a source of concern for the conservation of foreshore vegetation communities. Wetland vegetation communities, which include the various flood plain forests, dominate the lagoon foreshores. The communities are dependent on periods of wet and dry. The natural boundaries of these communities are changing in response to reduced inundation.

Whilst the frequent opening of Terrigal Lagoon is changing foreshore vegetation it is also effecting the regular flushing of nutrients from the estuary and as a consequence, Terrigal does not have the excessive algal mats that Avoca and Cockrone experience. In ICOLLs it is generally not possible to use engineering solutions to solve all environmental degradation problems and generally estuarine environmental restoration can only be carried out by enhancing the biotic integrity of the ecosystem to absorb or process nutrients and pollutants. Restoring foreshore vegetation or fringing wetlands is one such option. Feedback mechanisms between hydrology and biota can be used as a management tool by using and manipulating vegetation within the creeks, lagoons, fringing and forest wetlands and flood plains and the coastal zone, to address specific problems of water, sediment, nutrients and pollutants. For example, wetlands can be used as a remediation tool to sequester excess nutrients into biomass and limit their delivery to the estuary. Similarly, aquatic biota may be manipulated to control algal.

However, the fragile nature of ICOLLs suggests that these estuaries can only be protected by adopting a total catchment management approach, which includes regulating human activities that impact upon them. Adherence to stormwater management and water sensitive urban design policies would be paramount in this regard. Also the enforcement of tree and habitat preservation policies would negate the need to remediate mown or underscrubbed foreshores. A common source of disturbance to foreshores was associated with maintenance of parks and roads and the construction of private jetties and buildings close to the edge of the water. Untreated and unmanaged stormwater and sewage overflows also reduce the ecological value of foreshore areas.

Climate change predictions present potential problems to the management of Gosford’s ICOLLs. Beach berms may respond to sealevel rise because they are function of beach dynamics and change to maintain equilibrium with coastal processes. The berms may increase in height and migrate landward with increased sealevel. Higher berms mean that water levels within the lagoons may also rise. Tidal inundation experienced during periods when the lagoons are open may increase. This will be problematic if coastal storms become more intense and frequent as a predicted consequence of climate change. If floor levels remain constant around the lagoon foreshore then mechanical openings will continue to protect properties and infrastructure from fluvial flooding but mechanical openings may offer no protection from stormwave inundation.

It is recommended that Council develops a comprehensive foreshore management plan to address each of the coastal lagoons that balances social and economic needs whilst ensuring that natural shoreline habitats and their ecological function are not impacted. This plan needs to address habitat conservation and ecosystem services in the face of potential climate change. It should consider the advantages of raising floor levels in conjunction with planned retreat as a strategy to conserve and protect ecosystem integrity.

1.2 Aquatic habitats and flora

Historical assessments of benthic habitats of Gosford's Coastal Lagoons are very limited. West *et al.* (1985) developed maps of seagrass habitats based on aerial photography with limited on-ground inspections and Williams *et al.* (2006) undertook a similar exercise. An assessment of seagrass habitat was also undertaken for the previous Gosford Coastal Lagoons Estuary Processes Study (WMA, 1995). A further study limited to Wamberal Lagoon also recorded the abundance of seagrasses (GCC, 1987).

The Wamberal Lagoon Catchment Study reports the presence of *Ruppia spiralis* and *Zostera carpricorni* in Wamberal Lagoon (GCC, 1987). West *et al.* (1985) mapped *Ruppia megacarpa* for Wamberal Lagoon. Williams *et al.* (2006) indicate a cover of *Ruppia megacarpa* of approximately 0.436 km^2 (43.6 ha) with some small patches of seagrass of the Family of Zosteraceae (total waterway area is approximately 46.12 ha).

The Zosteraceae Family was also mapped for Terrigal Lagoon by West *et al.* (1985) for Terrigal Lagoon. WMA (1995) report historical records of *Z. capricorni*, which they believe to have decreased from 15% cover in 1984 to 1% cover in 1991. Williams *et al.* (2006) do not show records for any seagrasses Terrigal.

Historical records of *Ruppia spiralis* and *Zostera capricorni* are reported for Avoca Lagoon by WMA (1995). West *et al.* (1985) mapped the extent of *Ruppia megacarpa* Avoca Lagoon. Williams *et al.* (2006) do not show records for any seagrasses Avoca either.

West *et al.* (1985) do not report any seagrasses for Cockrone Lagoon and neither do WMA (1995) who report that no aquatic angiosperms (i.e. flowering plants like seagrasses) were observed in the lagoon in 1984. However, Williams *et al.* (2006) report a cover of 0.289 km^2 (28.9 ha) of *Ruppia megacarpa* (total waterway area is approximately 34.25 ha).

Given the discrepancies between these reports and observations of *Ruppia megacarpa* in Avoca Lagoon it was decided that new surveys were required. These surveys recorded the habitat (*Ruppia megacarpa*, *Zostera* capricorni, macroalgae, rock or bare muddy substratum) and depth. Surveys were redone during the 2009-2010 summer to investigate any short-term changes in distribution of seagrass communities and to refine associated maps. These data are also used in section 2.1 below to investigate the influence of these environmental variables on fish communities.

1.2.1 Methods

The dominant habitats present in each lagoon were mapped by visual inspection while walking in shallow water adjacent to the shorelines and while snorkelling. Cross-lagoon transects were inspected at approximately 50 m intervals along the shorelines. The habitat information (i.e. *Ruppia megacarpa*, *Zostera* capricorni, macroalgae, rock, bare muddy substratum and depth) was recorded at 20 m intervals along each transect. At each 20 m interval a core of sediment (10 cm wide x 10 cm deep) was collected. The sediment cores were returned to the lab where they were oven-dried at 60^{0}C and separated into ≥ 1 mm, 0.5 mm, 212 μm, 63 μm, and < 63 μm fractions. The weight of each fraction was determined and expressed as a percentage of total weight of the sediment sample. Sediment was classified into the following fractions: coarse sand (2.0 - 0.6 mm), medium sand (0.6 - 0.2 mm), fine sand (0.2 - 0.06 mm), and coarse silt (0.06 - 0.02 mm) (Briggs 1977).

Depth is relative term, which in the case of ICOLLs, is dependent upon the relative water level and time since the lagoon was last opened. Therefore bed levels were also used and determined from bathymetrical survey data provided by DECC as series of datum recorded along transects. These data were interpolated using ESRI GIS software to provide predicted bed levels in AHD format.

1.2.2 Results

Lagoons varied substantially in the composition of their habitats (Figure 1.22-24). Wamberal Lagoon (Figure 1.22) was dominated by large areas of *Ruppia megacarpa* (27.67 ha), with smaller areas of algae (3.69 ha - generally *Enteromorpha intestinalis* and *Chaetomorpha linum*). Small areas of *Zostera capricorni* (0.46 ha) were present adjacent to the northern and southern shores of the lagoon near the entrance. The majority of the lagoon was < 1 m to 1 m depth (with deeper areas of 3-4 m) (Figure 1.25 and 1.26) and contained extensive areas of medium and fine sand (Figure 1.30). Terrigal Lagoon consisted entirely of unvegetated sediment, of < 1 m to 1 m depth (with deeper areas of 3-4 m) (Figure 1.25 and 1.27), and coarse-fine sand (Figure 1.31). Avoca Lagoon (Figure 1.23) consisted of large areas of algae (44.09 ha - generally *E. intestinalis* and *C. linum*) and *Ruppia megacarpa* (8.14 ha) in the southern arm of the lagoon and small patches of *Z. capricorni* (0.68 ha) in the central section near the entrance). Average depth of Avoca lagoon was < 1 m to 1 m with a deep section (2-4 m depth) south of the island (Figure 1.25 and 1.28). The dominant sediment in Avoca lagoon was coarse and medium sand (Figure 1.32). The dominant habitat in Cockrone Lagoon was algae (23.95 ha - generally *E. intestinalis* and *C. linum*) and *Ruppia megacarpa* (6.85 ha) (Figure 1.24), with average depth being < 1 m to 1 m apart from a deeper 2-3 m section near the entrance (Figure 1.25 and 1.28). The sediment composition of Cockrone lagoon was coarse and medium sand (Figure 1.33).

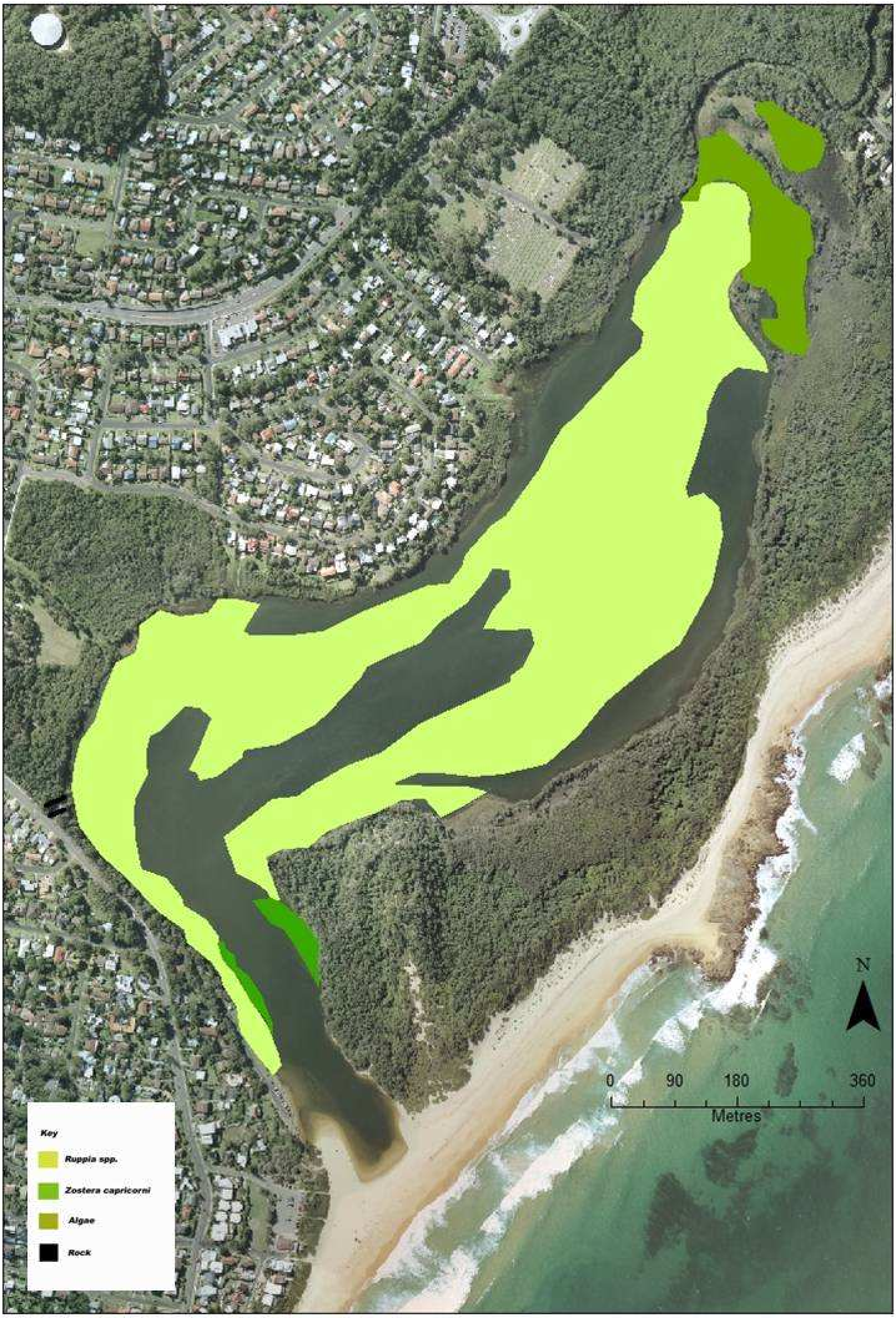


Figure 1.22 Habitat composition of Wamberal Lagoon.

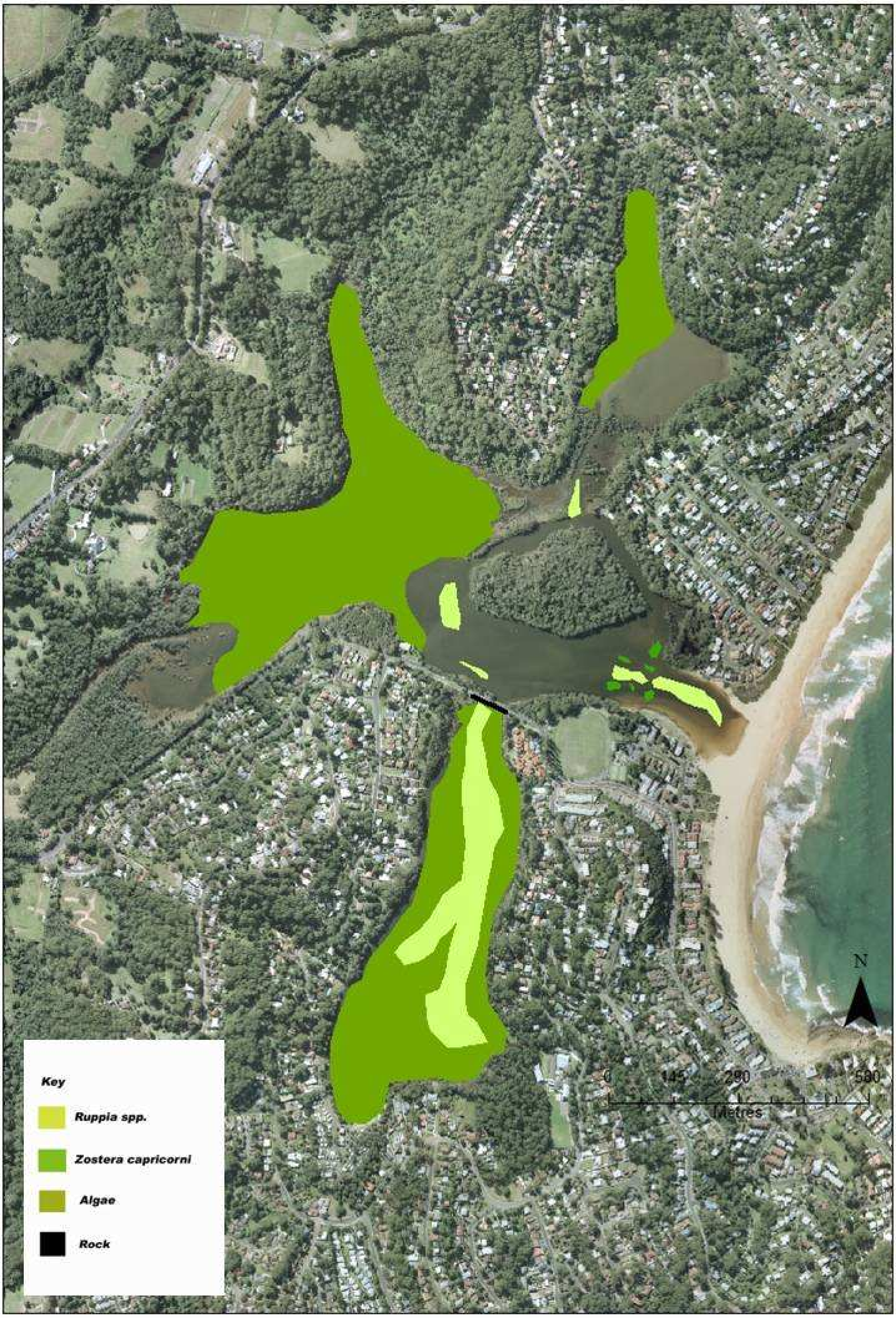


Figure 1.23 Habitat composition of Avoca Lagoon.

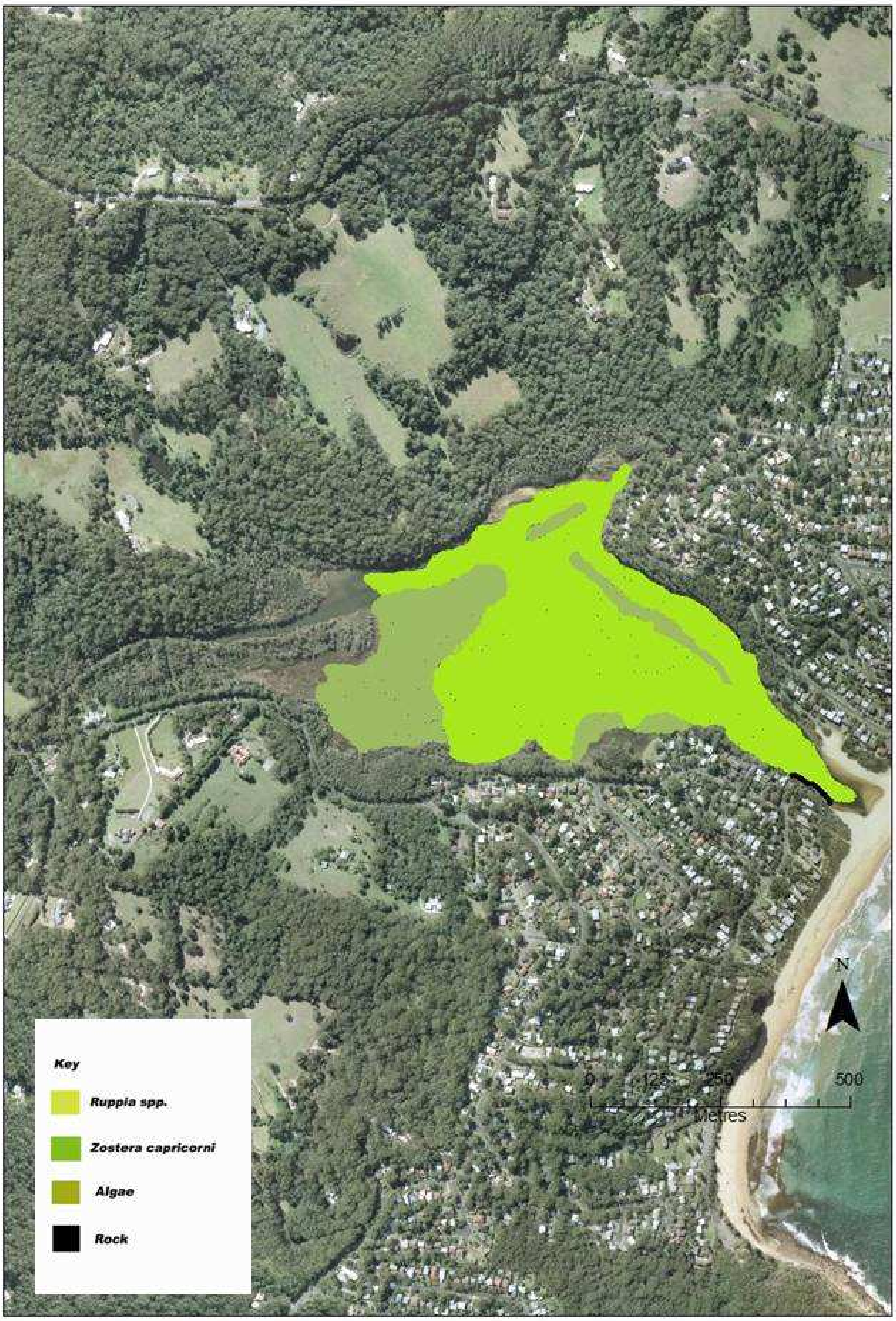


Figure 1.24 Habitat composition of Cockrone Lagoon.

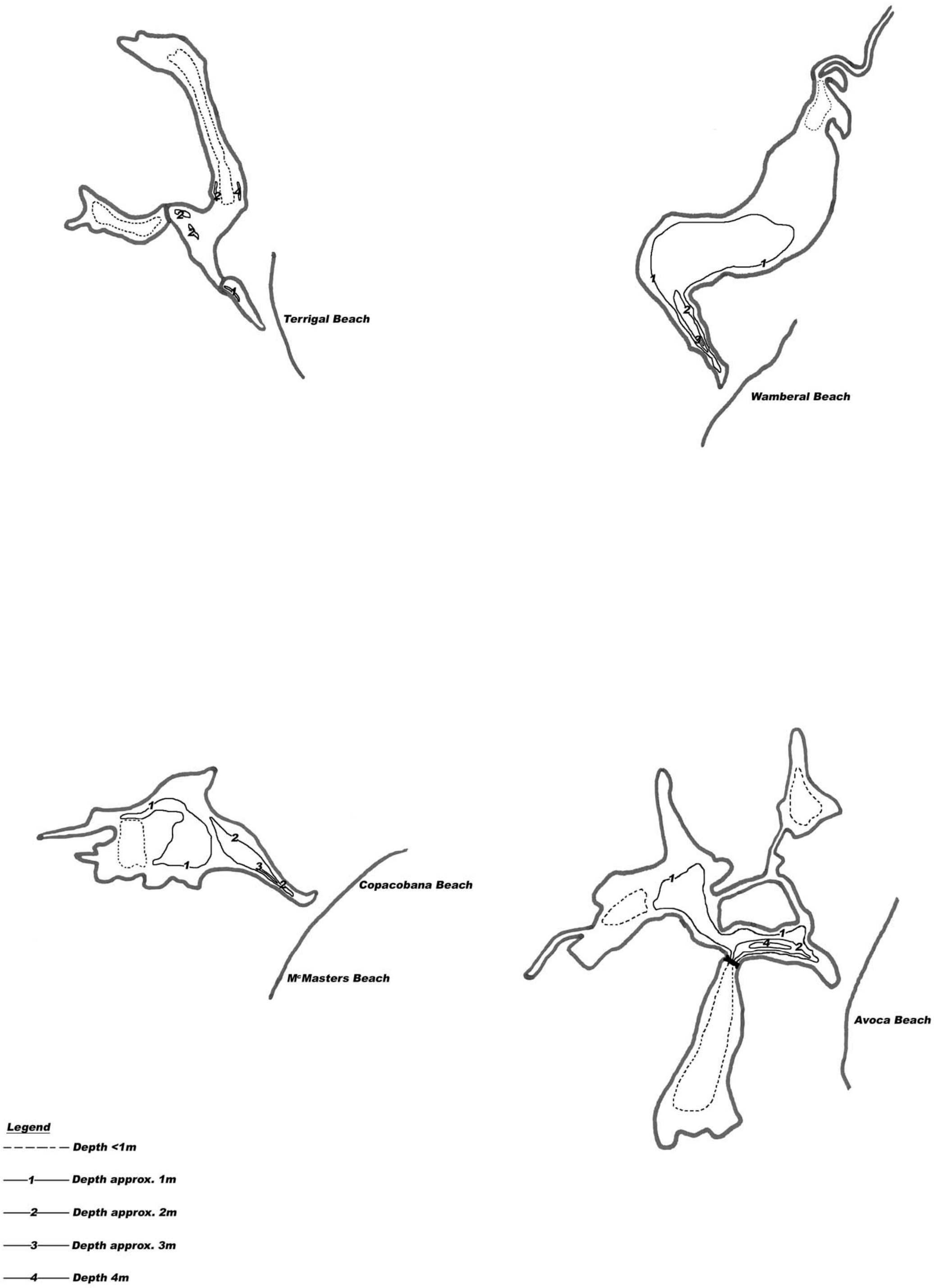


Figure 1.25 Depths of Gosford's coastal lagoons.

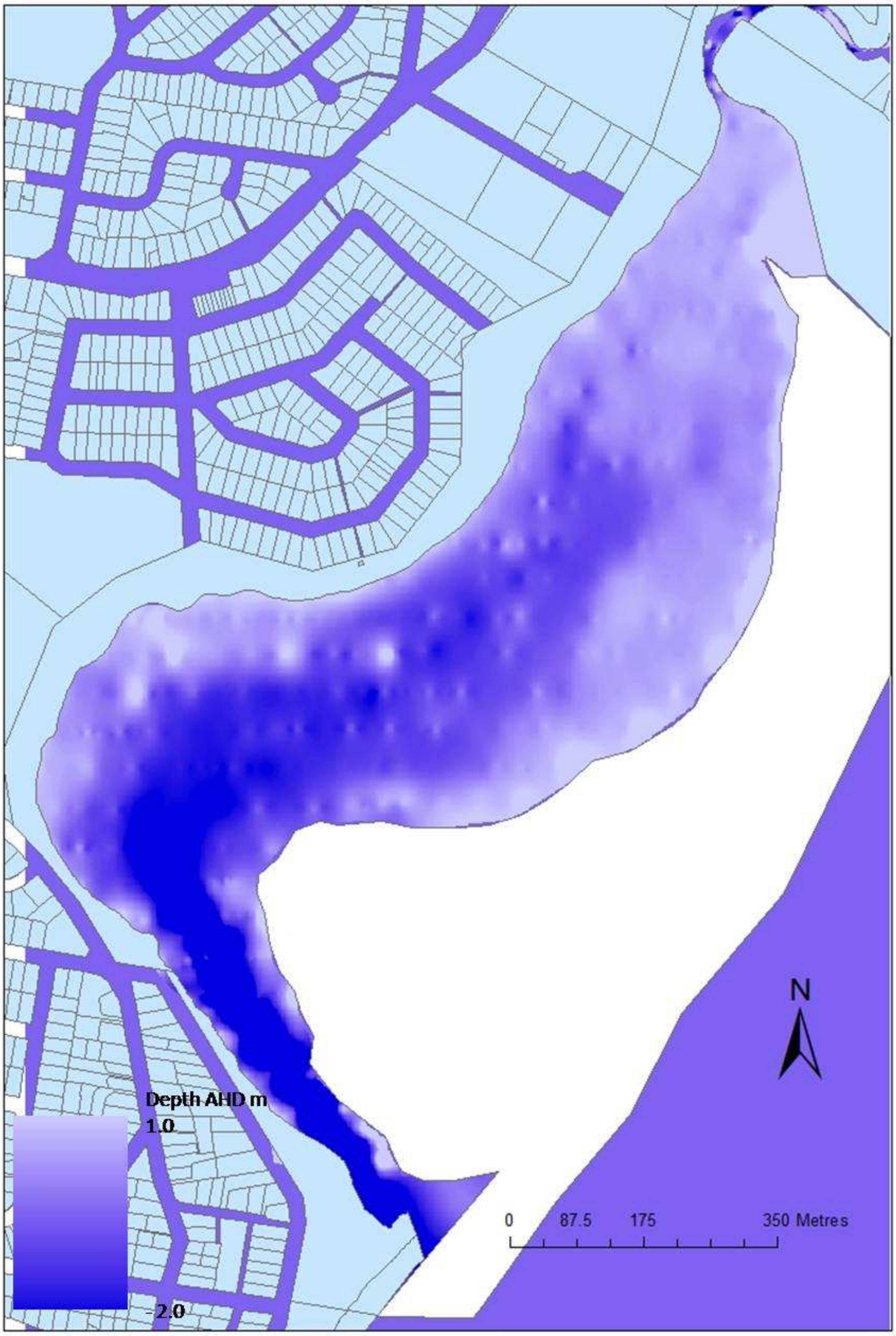


Figure 1.26 Bed levels for Wamberal Lagoon (AHD m).

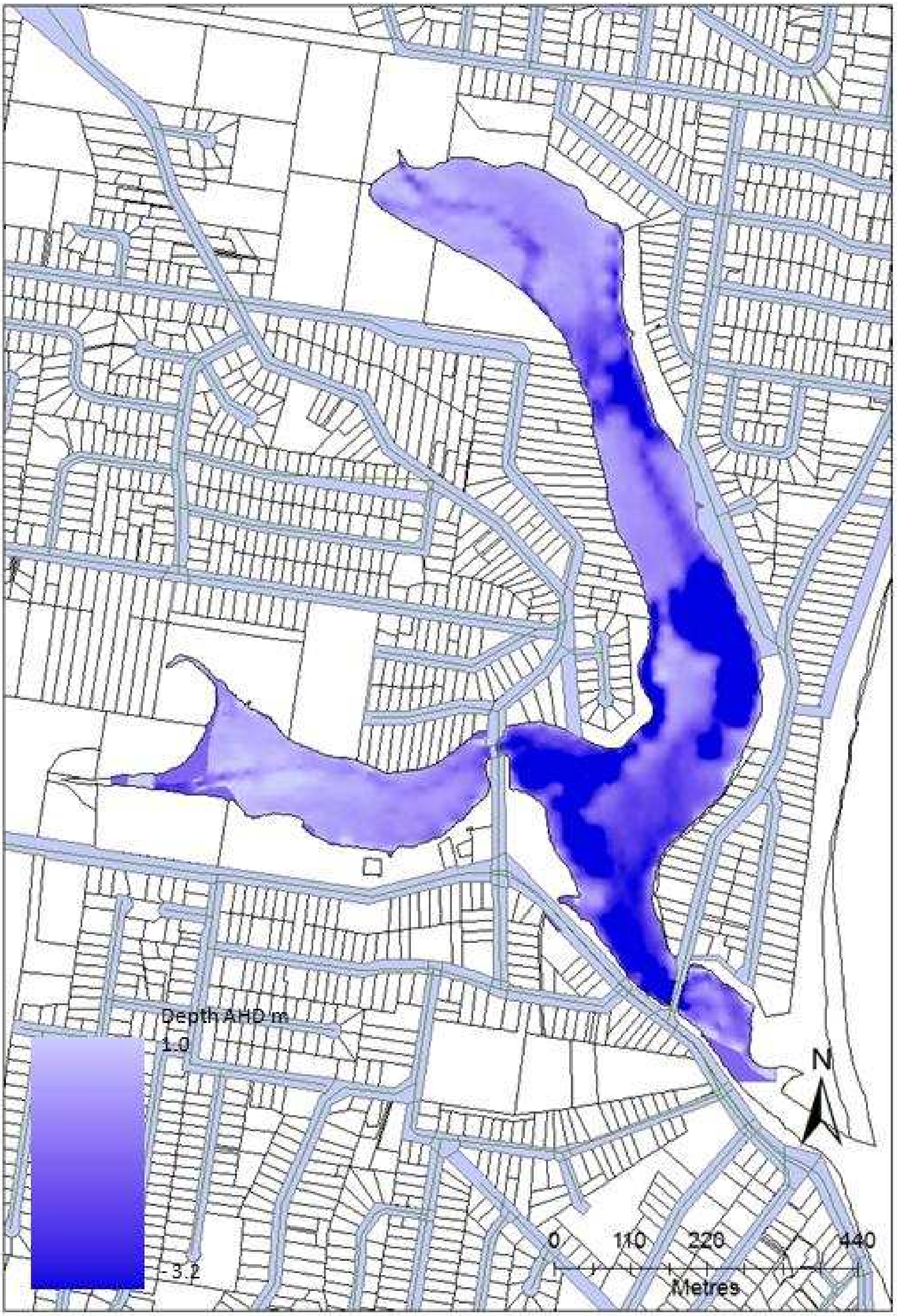


Figure 1.27 Bed levels for Terrigal Lagoon (AHD m).

Figure 1.28 Bed levels for Avoca Lagoon (AHD m).

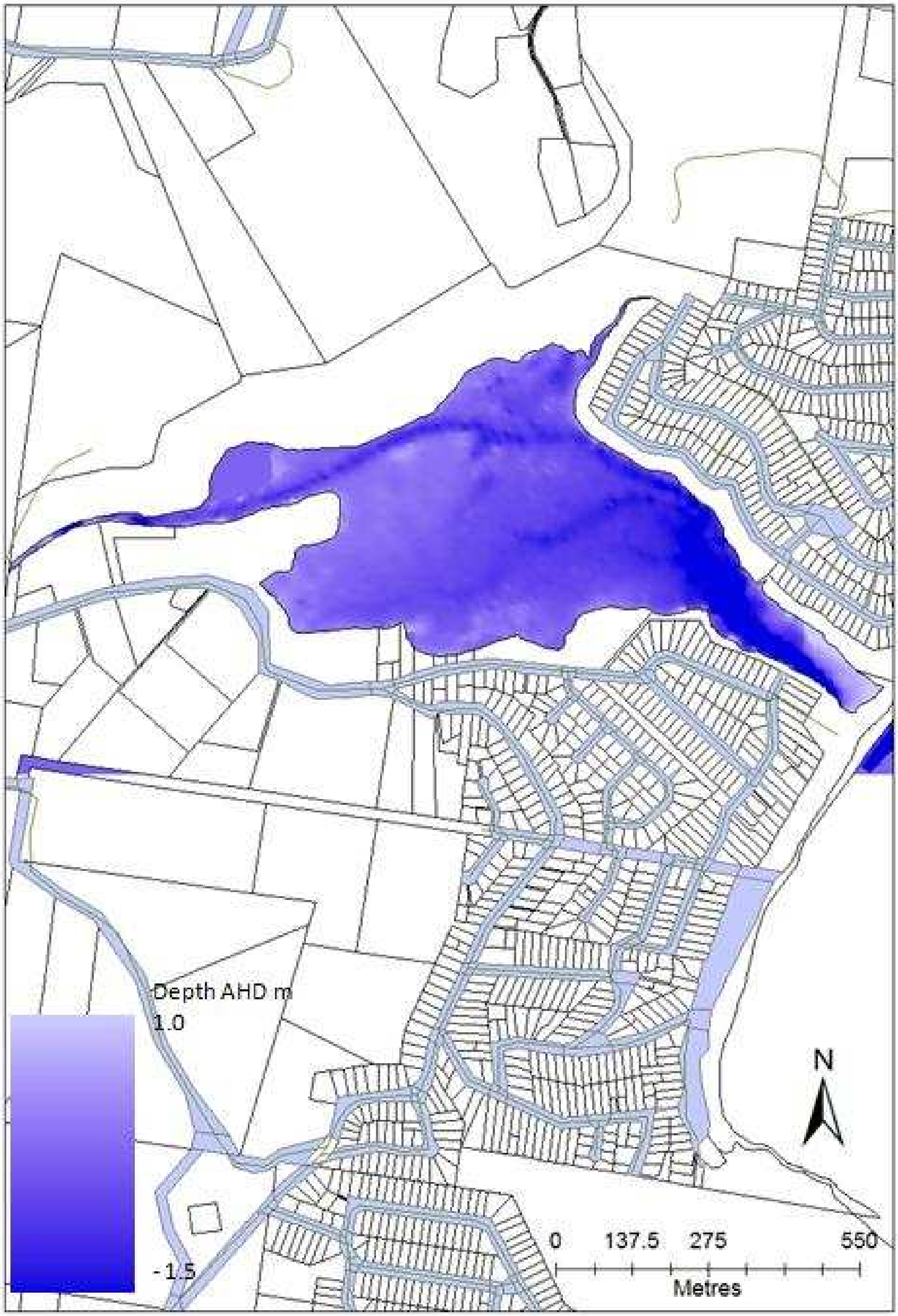


Figure 1.29 Bed levels for Cockrone Lagoon (AHD m).

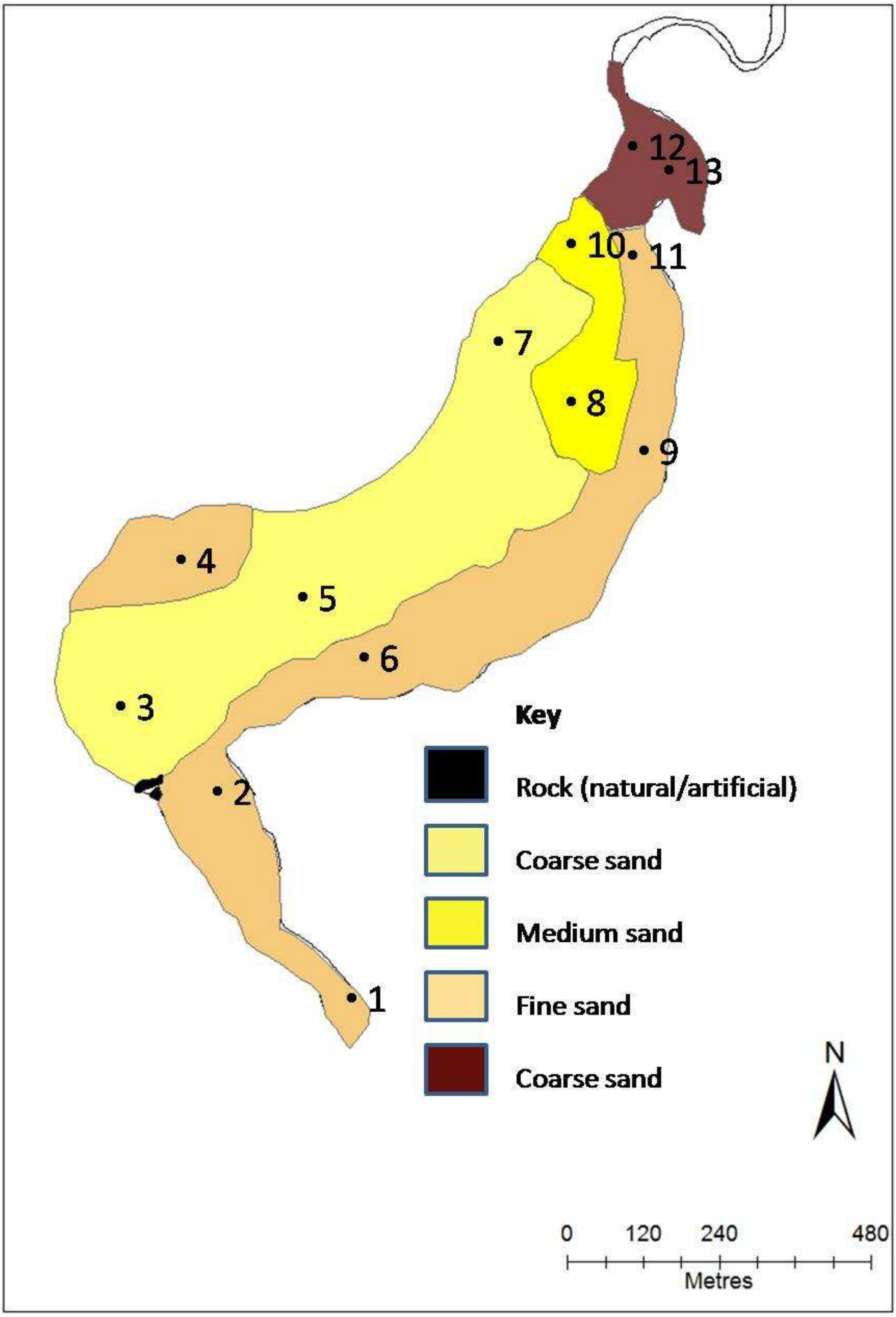


Figure 1.30 Sediment compositions of Wamberal Lagoon (coarse sand = 2.0-0.6 mm, medium sand = 0.6-0.2 mm, fine sand = 0.2-0.06 mm, coarse silt = 0.06-0.02 mm).

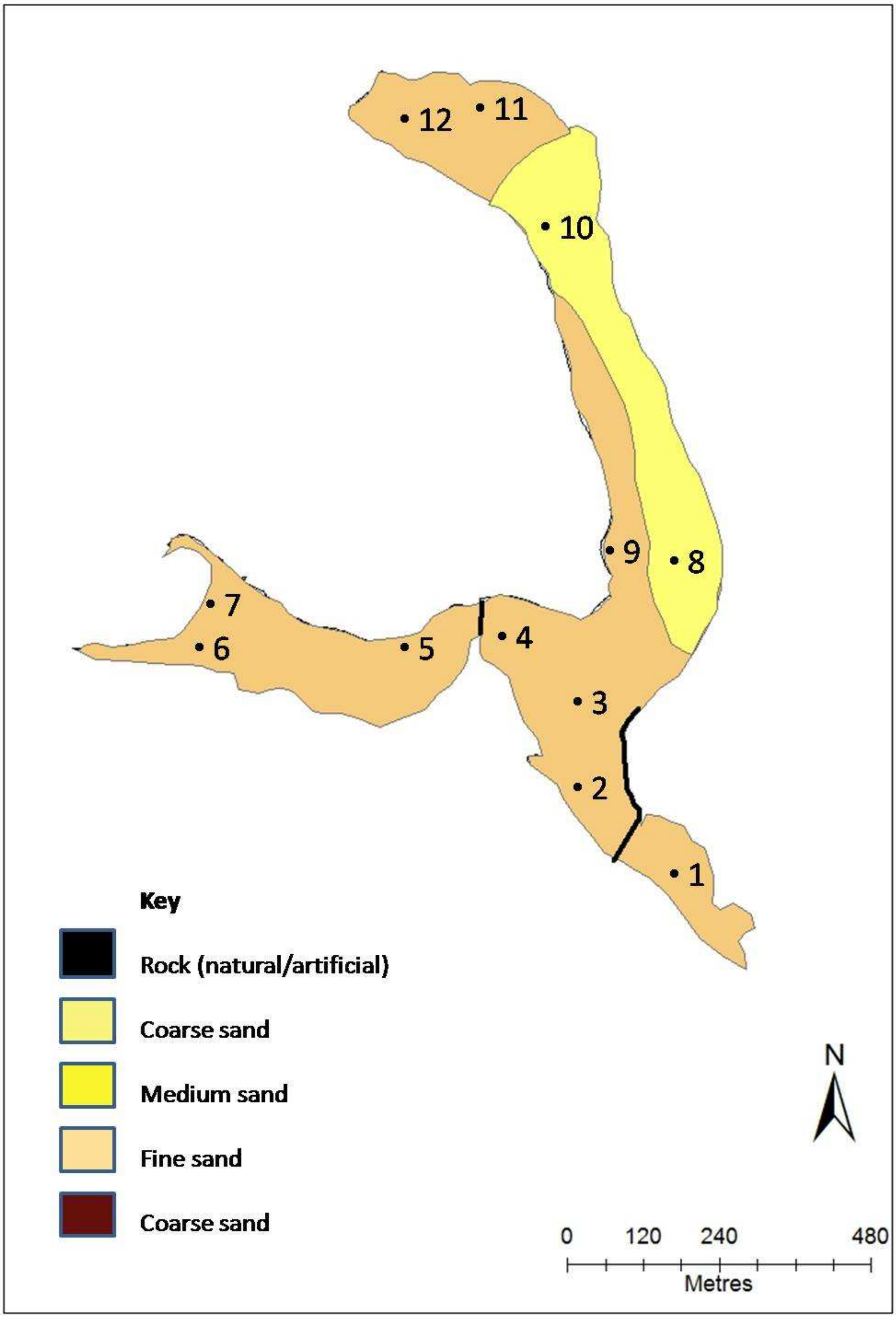


Figure 1.31 Sediment compositions of Terrigal Lagoon (coarse sand = 2.0-0.6 mm, medium sand = 0.6-0.2 mm, fine sand = 0.2-0.06 mm, coarse silt = 0.06-0.02 mm).

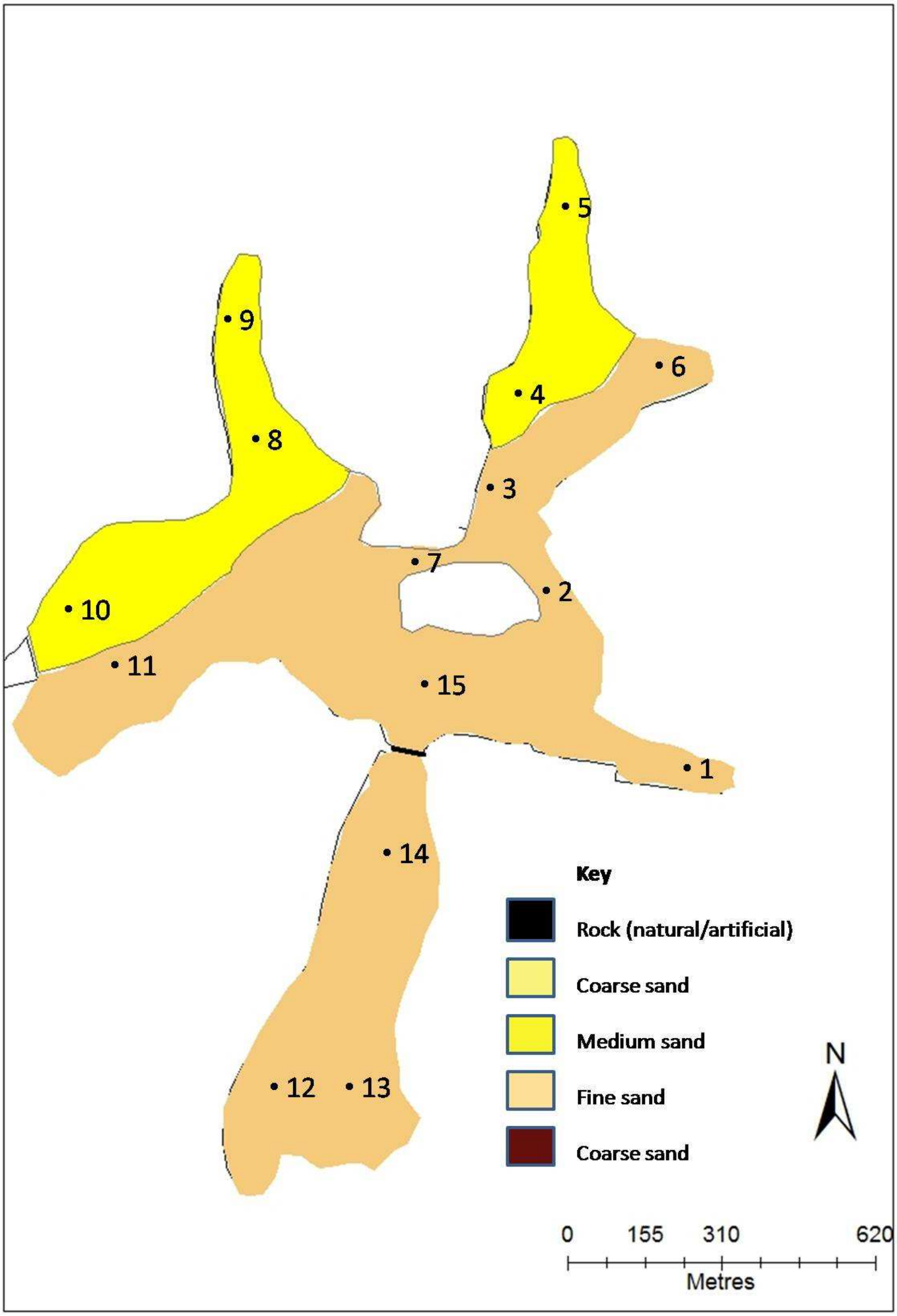


Figure 1.32 Sediment compositions of Avoca Lagoon (coarse sand = 2.0-0.6 mm, medium sand = 0.6-0.2 mm, fine sand = 0.2-0.06 mm, coarse silt = 0.06-0.02 mm).

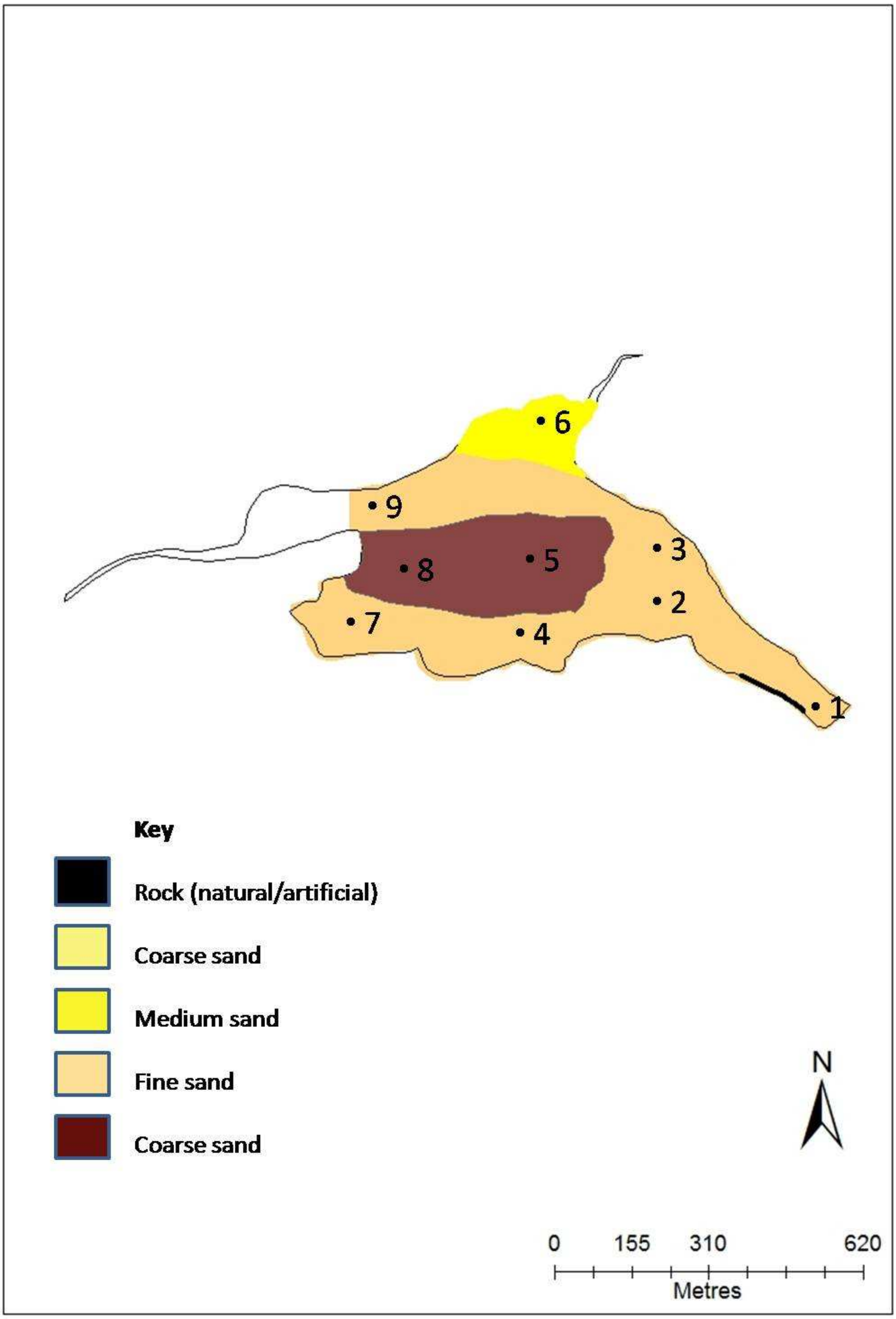


Figure 1.33 Sediment compositions of Cockrone Lagoon (coarse sand = 2.0-0.6 mm, medium sand = 0.6-0.2 mm, fine sand = 0.2-0.06 mm, coarse silt = 0.06-0.02 mm).

1.2.3 Discussion

The results of this survey are greatly different from all those undertaken previously. The roughly 94% cover of *Ruppia megacarpa* reported by Williams *et al.* (2006) was recorded in this survey to be less than 60%. Similarly, Williams *et al.* (2006) indicates the cover of *Ruppia megacarpa* at Cockrone Lagoon to be approximately 84%, whilst result here indicates the cover to be closer to 20%. Whilst it is possible that the cover of seagrass has changed so significantly since 2006, it is more likely that the differences are an artefact of the different methods.

WMA (1995) indicate that *Z. capricorni* was present in Terrigal and that it had decreased from 15% cover in 1984 to 1% cover in 1991. Williams *et al.* (2006) recorded no seagrasses in Terrigal and none were found during this study. Williams *et al.* (2006) recorded no seagrasses at Avoca either. However, this study indicates the cover of *Ruppia megacarpa* at Avoca Lagoon to be approximately 8%.

With the exception of Terrigal, all lagoons recorded large areas of benthic algae (generally *Enteromorpha intestinalis* and *Chaetomorpha linum*). These species can form extensive algal mats that generally appear in late spring and persist until mid-Summer almost every year. However, observations suggest that there occurrence and extent has been decreasing in recent years. The substratum of Terrigal Lagoon is dominated by unvegetated sediment.

1.3 Phytoplankton

Phytoplankton is composed mainly of microscopic free floating or suspended algae. The word phytoplankton is derived from the Greek language (phyto = plant; plankton = wanderer). It is a term used to describe plants that are so small that their movement is primarily controlled by the motion of the water.

The majority of phytoplankton is made up of holoplankton, organisms that spend most of their life cycle in the planktonic community. However, many phytoplankton species are capable of producing resting spores, which can to be found in deeper water or in the bottom sediment. These 'resting stage' spores are generally what cause the algal blooms often seen in freshwater environments. Phytoplankton is usually rich in green algae. However, it also includes diatoms, flagellates and blue-green algae. Although, it is generally accepted that blue-green algae are actually bacteria and not algae.

Chlorophyll *a* is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. They can be an effective measure of trophic status, are potential indicators of maximum photosynthetic rate (P-max) and are a commonly used measure of water quality. High levels often indicate poor water quality and low levels often suggest good conditions. However, elevated chlorophyll a concentrations are not necessarily a bad thing. It is the long-term persistence of elevated levels that is a problem.

Phytoplankton are a food source for benthic filter feeders and for zooplankton. Zooplankton include larvae and encompass representatives of all the major invertebrate phyla, including some that can only be found in the plankton. Zooplankton are the principal diet of many larger pelagic animals. Phytoplankton also help to oxygenate the water and thus are an important component of a healthy water body.

Chlorophyll *a* is the most commonly used measure for phytoplankton biomass. However, like other water quality variables, the concentration of chlorophyll *a* is highly variable and any sample only provides a snap shot and is not truly indicative of ambient conditions. To obtain a better, time integrated understanding of phytoplankton abundance in the coastal lagoons, a statistical summary of chlorophyll *a* is provided.

1.3.1 Methods

To assess contemporary levels of Chlorophyll *a* water samples were collected from three locations at each lagoon (beach berm, basin and creek delta) and pooled with Council data from the period between January 2006 and August 2007 to form a contemporary data set (2006-2010). At each location there were two replicate sites (50 to 100 m apart) to consider spatial replication. Water was sampled at approximately 100 mm below the surface using 750 ml sterile bottles. To minimise post sampling photosynthesis, brown coloured bottles were used and the samples were removed from the light, transported to the laboratory in ice filled eskies and then frozen.

Frozen samples were allowed to defrost in the dark. To concentrate phytoplankton cells, water sub-samples (100 ml) were centrifuged at 2500 rpm for 5 minutes. The supernatant was poured off then the remaining sample was passed through filter paper which was then ground in 10 ml ethanol (Ritchie 2006, 2008). The supernatant was then examined in a Varian Cary 50 UV-VIS spectrophotometer at wavelengths between 600 and 750 nm to look for peaks indicating the presence of photosynthetic pigments. The fluorescence of collected samples was also examined using a commercially available fluorometer (Aquation Pty Ltd). With this technique, the intensity of fluorescence increases in proportion to the concentration of cells (see APHA Standard Methods "Fluorometric determination of Chlorophyll *a*"). After zeroing the fluorometer output against an ethanol blank, three 3 ml replicates from each water sample were measured.

A review of historical water quality (1992-2003) reports on the coastal lagoons was also undertaken to compare with the contemporary data set. A variety of data were obtained from Council reports (Cheng, 1992; Laxton, 1999; Ecoscience Technology 2000a and b; Insearch, 2000; WBM Oceanics, 2003) and from other sources, such as internal Council reports. Chlorophyll *a* (µg/L) values were sorted by sample dates to calculate seasonal averages.

1.3.2 Results

Phytoplankton species recorded for the lagoons indicate that motile flagellates, such as dinoflagellates and chrysophytes, dominate the lagoons. Species composition in each lagoon is similar, consisting of dinoflagellates, diatoms, chrysophytes (golden-brown) and blue-green algae. A list of recorded phytoplankton is provided in Table 1.8.

Table 1.8 Phytoplankton of Gosford's coastal lagoons

Dinophyceae (dinoflagellates)	**Bacillariophyceae** (diatoms)	**Chrysophyceae** (golden-brown)	**Cyamnophya** (blue-green algae)
Ceratium*	Cyclotella*	Cryptomonoas*	Oscillatoria******
Gymnodinium*	Navicula**		Anabaena*******
Peredinium*	Synedra***		
	Surirella****		
	Coconeis*****		
	Gyrosigma***		

* Found in all lagoons, **not found in Cockrone, *** Wamberal only, ****not found in Terrigal, ***** Terrigal only,******Cockrone only,*******Cockrone and Wamberal

Data collected since 2006 are highly variable from year to year. There is no evidence to indicate that concentrations of chlorophyll *a* are decreasing overall. Results from analyses of the contemporary data set (2006-2010) are summarised in Figure 1.34. A clear trend can be seen for Cockrone and Avoca lagoons, whereby chlorophyll *a* levels begin to increase in spring and summer and then decline into autumn and winter.

Seasonal analyses of data recorded prior to 2006 were not possible because of lack of available data. An historic period between 1992 and 2003 was analysed and the annual means for this period are provided in Figure 1.35. A comparison of this historic data set with the contemporary data (using annual averaged means) suggests that chlorophyll a levels have decreased in Avoca and Cockrone Lagoons but have increased in Wamberal and Terrigal Lagoons (Figure 1.36).

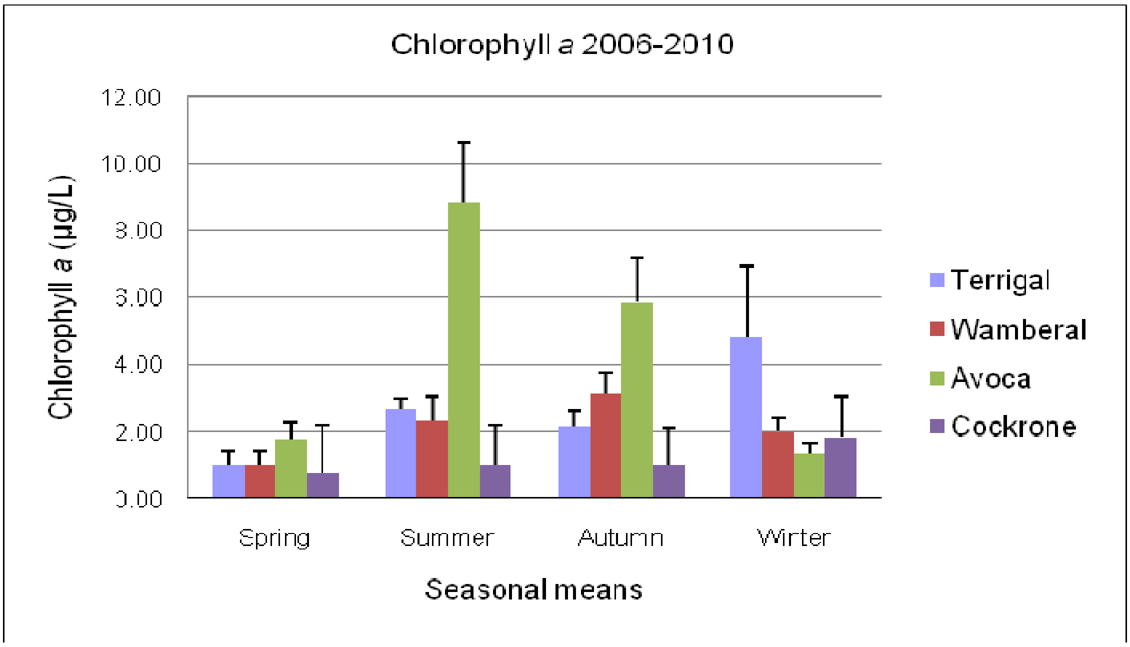


Figure 1.34 Seasonal means for chlorophyll *a* (µg/L, mean + SD) in coastal lagoons between 2006 and 2010

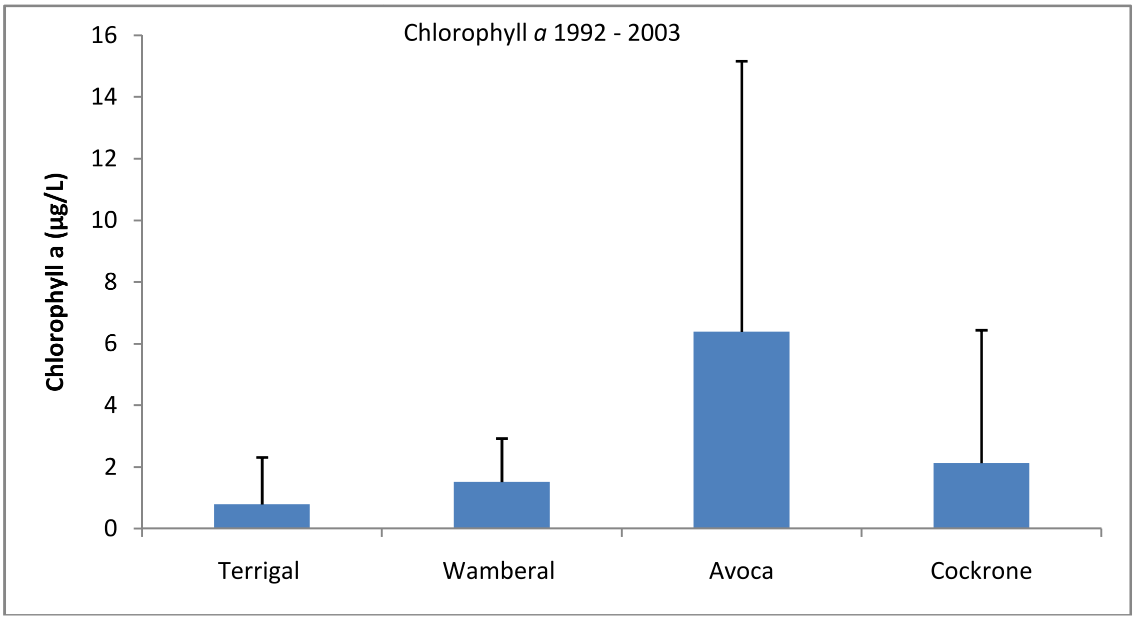


Figure 1.35 Annual means for chlorophyll *a* (µg/L, mean + SD) in coastal lagoons between 1992 and 2003

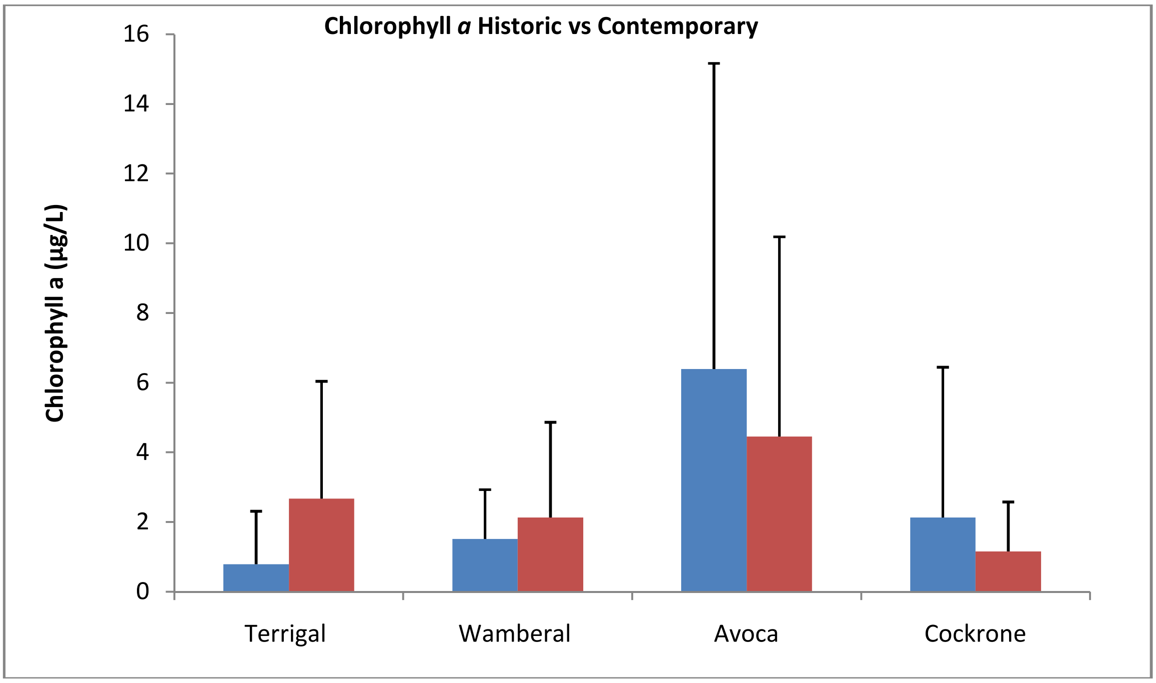


Figure 1.36 Comparison of historic (1992-2003, mean + SD) and contemporary (2006-2010) annual means for chlorophyll *a* (µg/L) in coastal lagoons

1.3.3 Discussion

The phytoplankton found in the lagoons are dominated by generally harmless species of dinoflagellates and chrysophytes. These motile flagellates are well suited to the often turbid water of the lagoons as they can rise towards the photic zone near the surface. Aside from Cockrone and Wamberal, few toxic blue-green algae have been recorded. Oscillatoria and Anabaena are known for producing a suite of cyanotoxins and under bloom conditions they constitute a real threat to waterway users.

Chlorophyll *a* concentrations are highly variable from year to year, however, a discernable trend can be seen from season to season. There is a general increase from spring to summer and then concentrations fall until late winter when they begin to rise again. This is not unusual as phytoplankton response to warmer temperatures and increased light.

There appears to be an increase in chlorophyll *a* concentrations in both Terrigal and Wamberal Lagoons in recent years. This may be related to increased development, resulting in increased nutrient enriched stormwater input that has occurred within these catchments. In contrast, the chlorophyll *a* levels have decreased in Avoca and Cockrone Lagoons over this same period. The authors can only speculate that better land-use management may be attributed to this decline.

The entrance openings of the coastal lagoons seem to cause a number of ecological problems, such as massive algal growth (and reduced dissolved oxygen levels – resulting in fish kills), and the lagoon openings need to be more sympathetic to lagoon ecology.

2.0 Fauna

2.1 Fish and Prawns

Coastal lagoons are inhabited by a diverse fish fauna that differs from the fish fauna of other coastal and estuarine ecosystems (Pollard, 1994). The taxonomic makeup of fish assemblages found in these environments is determined by estuary type, geographical location and the life history strategies of the fishes that utilise them. Resident groups of fishes that spend their entire life in these environments (e.g. atherinids, eleotrids and gobiids) dominate many estuaries (Miskiewicz 1987). Marine–estuarine dependant species (such as *Acanthopagrus australis, Mugil cephalus, Myxus elongatus* and *Sillago ciliata*) utilise estuaries during juvenile and adult stages and adults emigrate to marine environments to spawn (SPCC 1981). Estuarine and marine species (such as *Ambassis jacksoniensis*, *A. marianus* and *Hyperlophus vittatus*) are found at all life-cycle stages within estuaries while many transient marine species frequent estuaries when hydrographic conditions reflect marine environments.

Alternate shelter is needed when the entrances of coastal lagoons are closed, so species of larval and juvenile fish that utilise coastal lagoons accumulate in other coastal habitats until transition into coastal lagoons can occur (Lenanton 1984; Strydom 2003; Geraghty 2004). Surf zones have been shown to provide this shelter (Watt-Pringle and Strydom 2003). Highly energetic environments, surf zones physically change regularly due to wave action, tides, weather and current intensity (Ayvazian and Hyndes 1995). Common features such as sand ripples, rip channels and troughs can provide temporary alternate nursery areas for certain species of larval and juvenile fishes by decreasing wave exposure and current velocity (Watt-Pringle and Strydom 2003).

Little attention has been given to surf zone larval and juvenile fish assemblages along the coastline of southeast Australian except for Gearghty (2004) who found that beach position relative to the entrance of an estuary had no influence on larval density in surf zones regardless of life history strategy. High numbers of juvenile fishes found in surf zones along the coast of southwest Australia (Ayvazian and Hyndes 1995), Japan (Senta and Kinoshita 1985) and Mauritius (Sato *et al*. 2008) indicate these environments are used as alternate nursery habitats for many species of marine fishes. South African studies (Harris and Cyrus 1996; Cowley *et al*. 2001; Strydom 2003) have shown that surf zones are transition or accumulation areas for larval and juvenile fishes waiting to be recruited into coastal lagoons.

In order to fully understand the processes leading to replenishment of fish populations within coastal lagoons, certain gaps in our knowledge need to be addressed. Larval and juvenile fish assemblages of surf zones and coastal lagoons need to be identified and comparisons made before and after opening events to establish if fish movements occur between the two environments. This is of great importance as most coastal lagoons are now opened artificially numerous times. Also, recruitment processes need to be identified for species that utilize coastal lagoons and to determine if surf zones are transition sites for fish waiting to enter coastal lagoons when barriers are opened or via overwash events.

The fish fauna of coastal lagoons also includes fishes such as syngnathids (pipefish, seahorses) that are protected in New South Wales under the NSW Fisheries Management Act. Predation by fishes on benthic invertebrates is a key step in the cycling of energy and nutrients. Fish are, in turn, preyed upon by a large number of bird species that utilize the shallow foreshores of Gosford's coastal lagoons. Gosford's coastal lagoons are also used by residents and visitors for fishing. Maintenance of the natural spatial and temporal patterns in fish biodiversity and of the natural ecological processes involving fishes is essential to the maintenance of the health and to the sustainable provision of the human-use values of coastal lagoon ecosystems.

Management of intermittently open estuaries is a complex issue that requires the full range of impacts from management actions to be understood. Although there is some understanding of the impacts of artificial openings (summarized above), most of these studies are from intermittently open estuaries in other countries. An earlier study for Gosford City Council found that macroinvertebrate assemblages of the entrance barrier of Gosford's lagoons were resilient to the effects of artificial openings (Gladstone *et al*, 2006). The present study will expand this work to the entire lagoon ecosystem and will focus on the impacts of artificially opening coastal lagoons on two critical components of the lagoons' fish fauna: biodiversity and population replenishment. Information collected on the effects of artificial openings on fishes, when combined with the earlier study of the impacts of artificial openings on the invertebrate fauna, will provide for an ecosystem-wide perspective about the implications of current management practices for Gosford's coastal lagoons.

This study was undertaken to determine the natural variation in the assemblages of fishes inhabiting Gosford's lagoons and to assess the effects of lagoon openings on the fish assemblages. The approach taken involved collection of fishes by two methods (gill net, seine net) to ensure the greatest proportion of the fish assemblage was sampled. Fish were sampled in multiple sites in each lagoon at regular intervals in 2009. Lagoons were opened at least once during the sampling period which allowed an analysis of the possible effects of openings. As all lagoons opened at the same time, excluding the possibility of using unopened lagoons as controls, the results presented here are indicative. However, the consistent trends that emerged from the analyses suggest that the results are likely to depict real effects of lagoon openings.

2.1.2 Methods

NSW Fisheries Records

NSW Fisheries sampled fish and prawns from Gosford's ICOLL's between 1986 and 2008. Three general sampling methods were used; gill nets, seine nets and poisoning:

- gill net 30m x 1.5 inches to 4 inches mesh size mixed (3.81mm to 10.16 mm)
- gill net 25m mixed mesh (5m panels of 36mm, 76mm, 100mm, 130mm and 150mm)
- seine net 30m x 1.5m x 4mm
- seine net 20m x 2m x 12mm stretched mesh with 3m bunt
- poison station $50m^2$

All three methods were used at each location between 1986 and 1988. Poisoning was discontinued after 1988 and only netting was used in 2002 and 2008.

For each sample the method used, species and number of fish, and the minimum and maximum lengths of each species were recorded.

Field fish collection and laboratory analyses[1]

Sampling occurred at five sites in each of Wamberal, Avoca and Cockrone Lagoons and at four sites in Terrigal Lagoon (Figure 2.1). At each site fish were sampled by a combination of gill and seine nets. Two different types of net were used to ensure that a greater proportion of the total fish assemblage would be sampled. For example, larger mobile fishes that are able to avoid gill nets are more likely to be captured by other methods such as gill nets. The gill net was a sinking, multi-panel, monofilament net with five net panels, a total length 25 m and a drop 2 m. The length of each panel was 5 m. The mesh sizes (mm) of the five net panels were: 25x19; 30x50; 25x80; 40x65; 25x36. Three gill nets were simultaneously deployed at each site during daylight for 1-1.5 hr per net. The dimensions of the seine net were length 20 m, drop 1 m, and mesh size 10 mm. Three seine nets were deployed at each site, but separated from the gill nets by at least 100 m to minimize disturbance.

Sampling occurred in February, April, July, September and November 2009 (Table 1). Eleven lagoon openings occurred during this period. Fishes were sampled before and after openings at Cockrone, Avoca and Wamberal Lagoons. It was not possible to identify sampling periods before and after the opening of Terrigal lagoon because of the high frequency of openings (at least six occasions in the study period).

[1] The data presented here was collected by Mr Les Edwards, PhD student, University of Newcastle.

Table 2.1 Dates of sampling of Gosford's lagoons for fishes by seine and gill nets. # dates on which lagoons were opened (sampling did not occur on these dates).

Lagoon			
Cockrone	Avoca	Terrigal	Wamberal
25/2/09	23/2/09	**17/2/09#**	22/2/09
15/4/09	9/4/09	27/2/09	14/4/09
3/6/09#	**27/5/09#**	**3/4/09#**	**18/6/09#**
23/6/09#	**21/6/09#**	6/4/09	31/7/09
27/7/09	28/7/09	**28/5/09#**	8/9/09
11/9/09	3/9/09	**17/6/09#**	19/11/09
12/11/09	17/11/09	30/7/09	
		11/8/09#	
		4/9/09	
		26/10/09#	
		20/11/09	

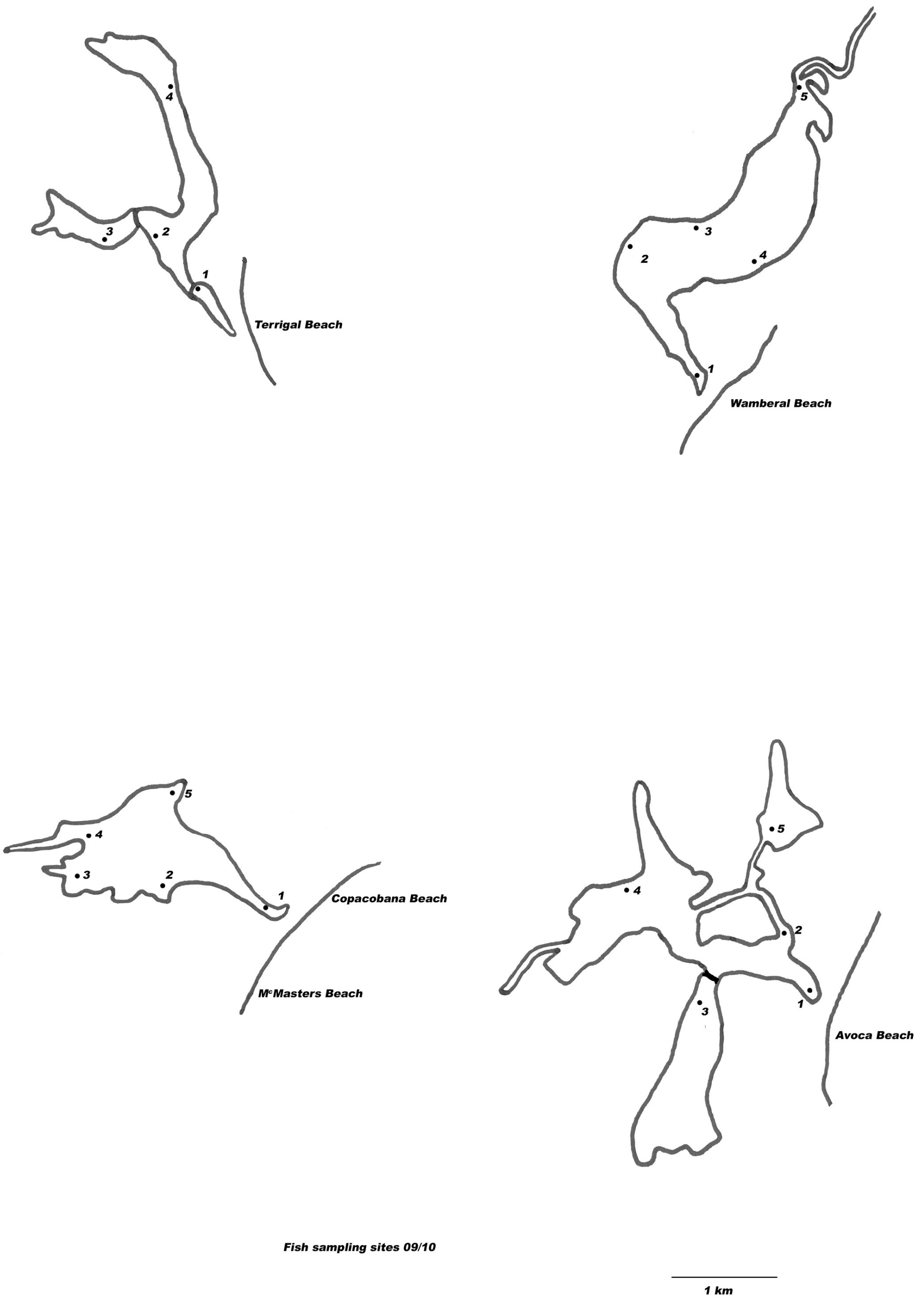


Figure 2.1 Locations of fish sampling sites in Gosford's coastal lagoons.

Statistical analyses

The null hypothesis that lagoon openings had no impact on fish assemblages was tested for each lagoon by analysis of similarities (ANOSIM). Prior to analysis samples were checked and those containing all zero values (i.e. no fish captured) were deleted. The analysis was done on the combined data set of samples collected by both fishing methods (seine net, gill net). Samples from all sites and both methods in a sampling period were pooled. Data for each sample were standardized (by the total number of fish collected in each sample) to eliminate differences in sample characteristics related to the method of capture (Clarke and Gorley 2006). Standardized data were square-root transformed and a Bray-Curtis similarity matrix created. One-way ANOSIM was done to test for significant variation in assemblages among times and pair-wise comparisons of times were examined to compare the magnitude of variation in assemblages from before to after openings. This method of detecting an effect of openings was necessary because of the lack of control lagoons in which openings did not occur over the same time period. Separate one-way ANOSIMS were done because the assemblages of each lagoon appeared to be substantially different (see summaries of species captured in Tables 2.2-2.5). Non-metric multidimensional scaling ordination plots (based on average abundance of each species at each sampling time) were produced to visually represent patterns of variation in assemblages over the sampling times. Multivariate analyses were done using the software Primer 6 + PERMANOVA (Primer E Ltd.)

The null hypothesis that lagoon openings had no effect on the number of fish species and total fish abundance was tested by three-factor analysis of variance (ANOVA) using the software GMAV (Institute of Marine Ecology, University of Sydney). Separate analyses were done for each sampling method. The factor Period was analysed as a fixed factor with two levels (Before, After). The factor Time was analysed as a random factor with two levels (Times 1 and 2) nested in Period. The factor Lagoon was analysed as an orthogonal fixed factor with three levels (Wamberal, Avoca, Cockrone Lagoons). Replicate samples from all sites were pooled for each sampling time to increase the power of the analyses. Data were checked for homogeneity of variance before ANOVA. Heterogeneous data were transformed and re-tested with Cochran's C-test (Underwood 1997). The analyses were still done if the transformation failed to remove the heterogeneity because ANOVA is robust to departures from this assumption for the sample sizes used in this analysis (Underwood 1997). The last sampling time was not included in this analysis to allow for a balanced analysis, with two Times nested in the Before and After Periods. Data from Terrigal Lagoon was not included in the analysis because it was not possible to distinguish times before and after openings because of the high frequency of openings during the study period. However, data from Terrigal Lagoon is included and was analysed by one-factor ANOVA to test the null hypothesis that number of fish species and total fish abundance did not vary among the sampling times.

2.1.3 Results

Effects of openings on fish assemblages

A total of 8967 fishes were sampled during the study, representing 3124 fishes (13 species) from Wamberal Lagoon, 1581 fishes (23 species) from Terrigal Lagoon, 2311 fishes (15 species) from Avoca Lagoon, and 1951 fishes (12 species) from Cockrone Lagoon (Tables 2.2-2.5).

Fish assemblages of Wamberal Lagoon did not vary significantly among the sampling times, even though sampling occurred before and after the lagoon was opened (Table 2.6, Figure 2.2). The one-factor ANOSIM found no significant variation among sampling times (Global R=-0.006, P=0.556) and all pairwise comparisons of sampling times were not significantly different, with the exception of the comparison of After 1 vs After 3 (R=0.156, P=0.038).

Terrigal Lagoon was repeatedly opened during the study, but there was no evidence of significant variation in fish assemblages over this time (Global R=-0.004, P=0.547) (Table 2.6, Figure 2.3). The MDS ordination plot (Figure 2.3) suggests that the fish assemblage at time 5 became more dissimilar to the assemblages present at other times, but the magnitude of the variation was not significantly different from random variation.

Variation among sampling times in the fish assemblage of Avoca Lagoon was marginally non-significant (Global R=0.04, P=0.072) (Table 2.2, Figure 2.4). However, two pairwise comparisons were significantly different: Before 1 vs After 3 (R=0.102, P=0.009) and Before 2 vs After 3 (R=0.122, P=0.018). Both samples of the fish assemblage collected before Avoca Lagoon opened (i.e. Before 1 and 2) were not significantly different from the first sample of the fish assemblage recorded after the lagoon opened (i.e. After 1) (Table 2.2).

The assemblage of fishes at Cockrone Lagoon varied significantly over the study period (Global R=0.064, P=0.022) (Table 2.2, Figure 2.5). This significant variation occurred because of a significant variation in the fish assemblage in the lagoon between the Before 1 and After 3 sampling times (R=0.188, P=0.01). The fish assemblage sampled immediately before the opening (i.e. Before 2) was not significantly different from the assemblages present after the opening.

Table 2.2 Summary of species sampled in Wamberal Lagoon between February and November 2009. Positions of sites are shown in Figure 1. Numbers shown are the total numbers of individuals of each species sampled by each method (seine, gill nets) pooled across all replicates in all sampling periods (see Table 2.1).

		Site										
Species	Common name	1		2		3		4		5		**Total**
		seine	gill	seine	gill	seine	gill	seine	gill	seine	gill	
Acanthopagrus australis	Yellow-finned bream								1			**1**
Arenigobius bifrenatus	Bridled goby			1								**1**
Atherinosoma microstoma	Small-mouth hardyhead	1691		368		425		157		178		**2819**
Gambusia holbrooki	Mosquito fish					4						**4**
***Hyporhamphus* sp.**	Garfish	6		14		24		7		11		**62**
Liza argenta	Flat-tail mullet		1									**1**
Mugil cephalus	Sea mullet	1	6	1	23		24	5	21	1	34	**116**
Myxus elongatus	Sand mullet	4	9	26		1				2	1	**43**
Philypnodon grandiceps	Flathead gudgeon	1		25		18		16		2		**62**
Platycephalus fuscus	Dusky flathead										1	**1**
Pseudomugil signifer	Pacific Blue-eye					5						**5**
Potamolsa richmondia	Freshwater herring										4	**4**
Unknown						**5**						**5**

Table 2.3 Summary of species sampled in Terrigal Lagoon between February and November 2009. Positions of sites are shown in Figure 1. Numbers shown are the total numbers of individuals of each species sampled by each method (seine, gill nets) pooled across all replicates in all sampling periods (see Table 2.1).

		Site								
Species	Common name	1		2		3		4		Total
		seine	gill	seine	gill	seine	gill	seine	gill	
Acanthopagrus australis	Yellow-finned bream	1	4	3	1	1	1	4		15
Arenigobius bifrenatus	Bridled goby					4		58		62
Ambassis jacksoniensis	Port Jackson glassfish			288		2		80		370
Ambassis marianus	Ramsay's glassfish					2				2
Centropogon australis	Fortesque	1						2		3
Gambusia holbrooki	Mosquito fish			3						3
Gerres subfasciatus	Common silver belly	1	10	3	1	4		11	1	31
Girrella tricuspidata	Luderick		2							2
Hyporhamphus sp.	Garfish	2		11		1		7		21
Heterodontus portusjacksoni	Port Jackson shark				1					1
Liza argenta	Flat-tail mullet			7		1		18		26
Macquaria colonorum	Estuary perch		2							2
Monodactylus argenteus	Silver batfish				1					1
Mugil cephalus	Sea mullet	10	25	4	38	17	8	2	31	135
Myxus elongatus	Sand mullet	181	204	70	67	27	2	4	0	555
Philypnodon grandiceps	Flathead gudgeon	1		2		16		172		191
Platycephalus fuscus	Dusky flathead	2			2				1	5
Pomatomus saltatrix	Tailor				1					1
Potamolsa richmondia	Freshwater herring	5	1	9						15
Pseudorhombus sp.	Flounder	1								1
Sillago ciliata	Whiting	3	11	55	2		5		7	83
Tetractenos sp.	Toadfish	2								2
Unknown		8		13		1		20		57

Table 2.4 Summary of species sampled in Avoca Lagoon between February and November 2009. Positions of sites are shown in Figure 1. Numbers shown are the total numbers of individuals of each species sampled by each method (seine, gill nets) pooled across all replicates in all sampling periods (see Table 2.1).

		Site										
Species	Common name	1		2		3		4		5		Total
		seine	gill	seine	gill	seine	gill	seine	gill	seine	gill	
Acanthopagrus australis	Yellow-finned bream	81	1	425	3	23	2	15	1	145		696
Arripis trutta	Eastern Australian salmon		1		4							5
Atherinosoma microstoma	Small-mouth hardyhead	952		106		18		11		17		1104
Gambusia holbrooki	Mosquitofish	3										3
Girella tricuspidata	Luderick				1							1
Hyperlophus vittatus	Sandy sprat									3		3
***Hyporhamphus* sp.**	Garfish				1			1				2
Mugil cephalus	Sea mullet	216	2	2	31		45		38		37	371
Myxus elongatus	Sand mullet										2	2
Philypnodon grandiceps	Flathead gudgeon	23		5		12		44		21		105
Platycephalus fuscus	Dusky flathead				2				1		1	4
Potamolsa richmondia	Freshwater herring									1		1
Pseudocaranx dentex	White trevally		1									1
Sillago ciliata	Sand whiting		1		1							2
Unknown		11										11

Table 2.5 Summary of species sampled in Cockrone Lagoon between February and November 2009. Positions of sites are shown in Figure 1. Numbers shown are the total numbers of individuals of each species sampled by each method (seine, gill nets) pooled across all replicates in all sampling periods (see Table 2.1).

		Site										
Species	Common name	1		2		3		4		5		Total
		seine	gill	seine	gill	seine	gill	seine	gill	seine	gill	
Acanthopagrus australis	Yellow-finned bream	537	8	198	2	51	2	255	12	256	6	1327
Acanthopagrus butcheri	Southern bream	9		14		28		12		41		104
Atherinosoma microstoma	Small-mouth hardyhead	74		3		3		4		2		86
Gambusia holbrooki	Mosquitofish			5								5
***Hyporhamphus* sp.**	Garfish	5		9		7				7		28
Liza argenta	Flat-tail mullet					0		1		1		2
Mugil cephalus	Sea mullet		15	42	8	0	13		15	0	15	108
Myxus elongatus	Sand mullet	20	30	2	4	0	8		4	1	15	84
Philypnodon grandiceps	Flathead gudgeon	46		62		21		19		73		191
Platycephalus fuscus	Dusky flathead	2	1									3
Sillago ciliata	Sand whiting	1	3		1							5
Unknown		1		4		1		1		1		8

Table 2.6 Summary of results of one-factor ANOSIM testing for variation in fish assemblages among sampling times in each lagoon. Sampling times are shown in Table 2.1 and are categorized here as Before and After lagoon openings (except Terrigal Lagoon where it was not possible to separate Before and After sampling because of the frequency of lagoon openings).

Lagoon	Global R (P-value)	Times compared	R-statistic	P-value
Wamberal	-0.006 (0.556)	Before 1 - Before 2	-0.014	0.624
		Before 1 - After 1	-0.017	0.502
		Before 1 - After 2	-0.047	0.897
		Before 1 - After 3	-0.006	0.451
		Before 2 - After 1	-0.031	0.71
		Before 2 - After 2	-0.016	0.553
		Before 2 - After 3	-0.011	0.487
		After 1 - After 2	0.056	0.233
		After 1 - After 3	**0.156**	**0.038**
		After 2 - After 3	-0.022	0.626
Terrigal	-0.004 (0.547)	Time 1 - Time 2	-0.01	0.581
		Time 1 - Time 3	-0.028	0.735
		Time 1 - Time 4	-0.028	0.85
		Time 1 - Time 5	0.041	0.88
		Time 2 - Time 3	0.009	0.307
		Time 2 - Time 4	-0.011	0.578
		Time 2 - Time 5	0.03	0.151
		Time 3 - Time 4	-0.045	0.914
		Time 3 - Time 5	0.001	0.45
		Time 4 - Time 5	0	0.43
Avoca	0.04 (0.072)	Before 1 - Before 2	0.004	0.34
		Before 1 - After 1	-0.004	0.493
		Before 1 - After 2	-0.049	0.735
		Before 1 - After 3	**0.102**	**0.009**
		Before 2 - After 1	0.001	0.388
		Before 2 - After 2	-0.072	0.902
		Before 2 - After 3	**0.122**	**0.018**
		After 1 - After 2	-0.051	0.463
		After 1 - After 3	-0.016	0.502
		After 2 - After 3	0.05	0.207
Cockrone	**0.064 (0.022)**	Before 1 - Before 2	0.003	0.351
		Before 1 - After 1	0.091	0.228
		Before 1 - After 3	**0.188**	**0.01**
		Before 2 - After 1	0.005	0.449
		Before 2 - After 3	0.091	0.067
		After 1 - After 3	-0.372	1

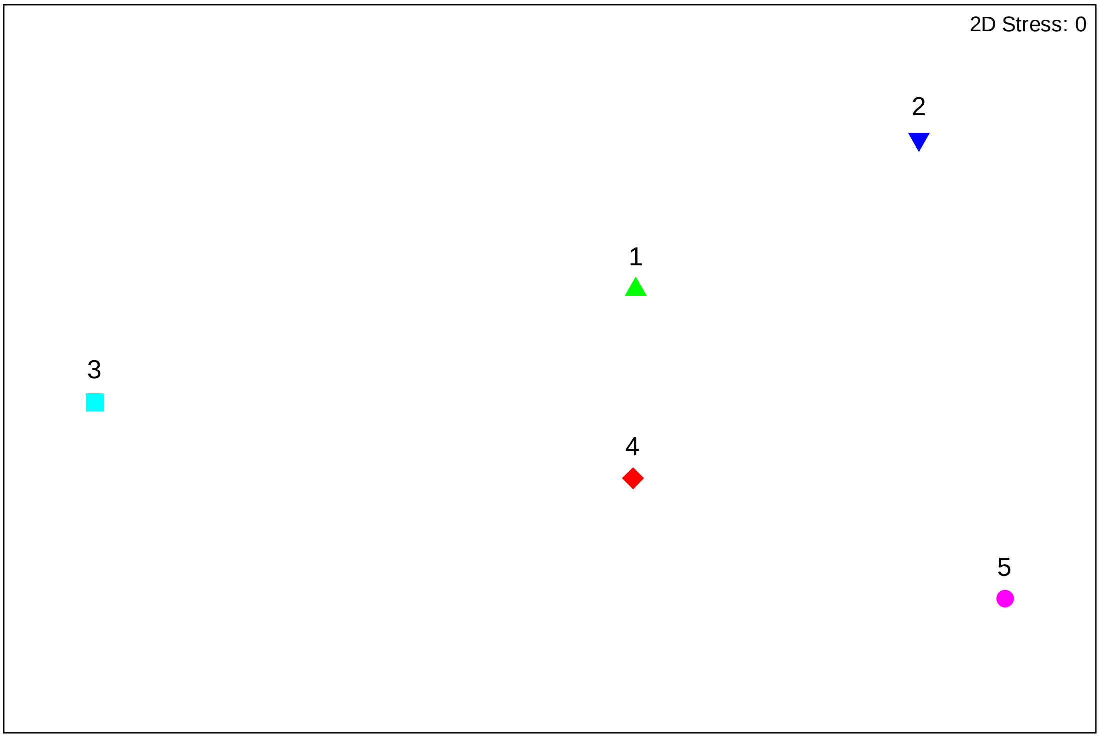


Figure 2.2 MDS ordination plot depicting similarity in species assemblages of fishes in Wamberal Lagoon at sampling times 1 and 2 (before lagoon was opened) and times 3, 4 and 5 (after lagoon was opened). Sampling and opening dates are shown in Table 2.1.

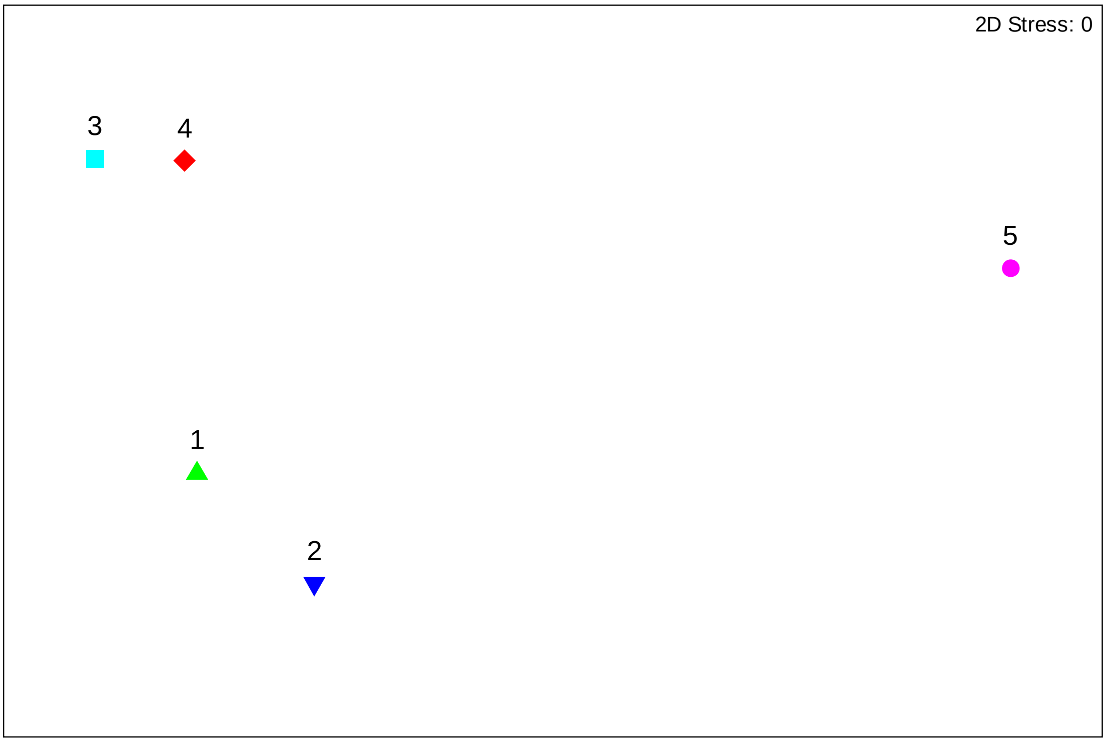


Figure 2.3 MDS ordination plot depicting similarity in species assemblages of fishes in Terrigal Lagoon at sampling times 1-5. Sampling and opening dates are shown in Table 2.1.

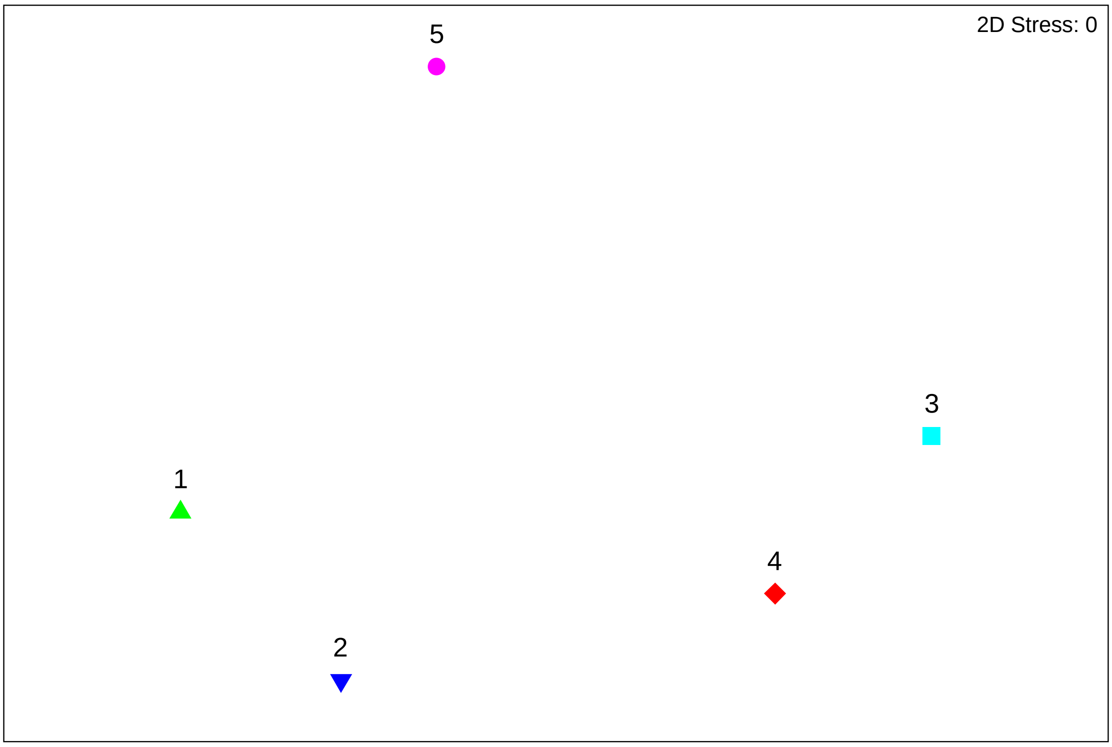


Figure 2.4 MDS ordination plot depicting similarity in species assemblages of fishes in Avoca Lagoon at sampling times 1 and 2 (before lagoon was opened) and times 3, 4 and 5 (after lagoon was opened). Sampling and opening dates are shown in Table 2.1.

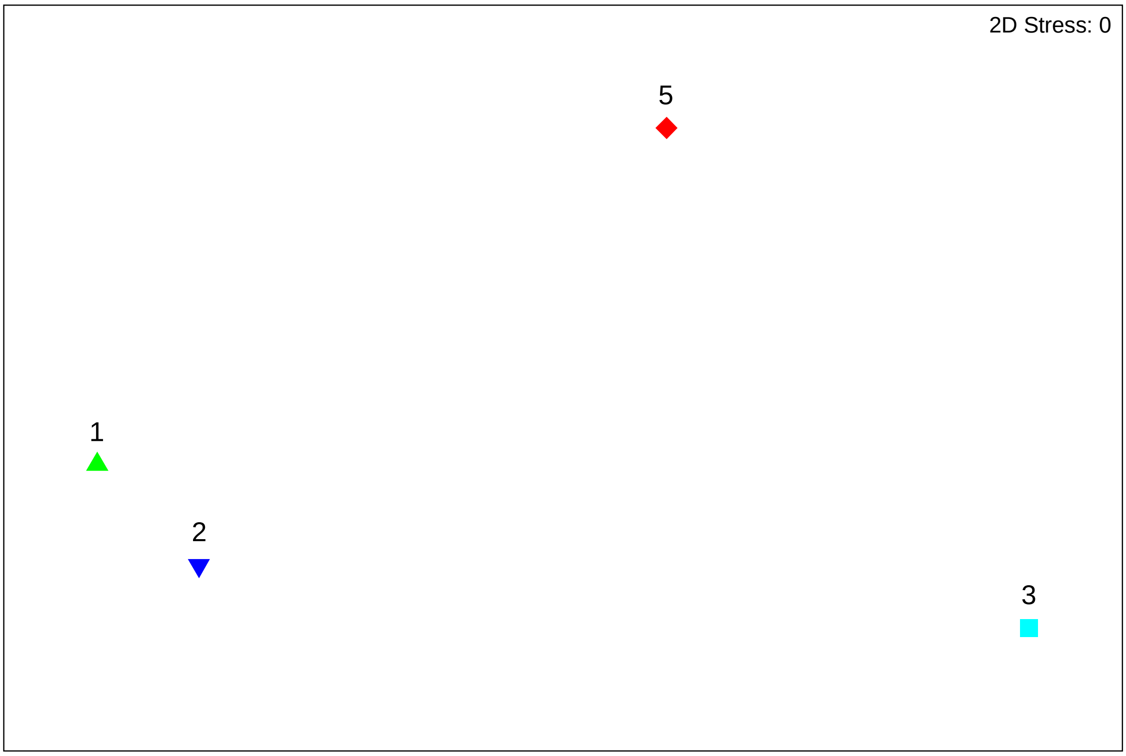


Figure 2.5 MDS ordination plot depicting similarity in species assemblages of fishes in Cockrone Lagoon at sampling times 1 and 2 (before lagoon was opened) and times 3 and 5 (after lagoon was opened). Sampling and opening dates are shown in Table 2.1. Sampling time 4 was deleted from the analysis because no fish were collected.

Effects of lagoon openings on numbers of species and total fish abundance

Numbers of fish species in seine nets were significantly reduced after lagoon openings (Table 2.7, Figures 2.6, 2.8, 2.9). The mean number of species captured declined from 2.1±0.12 (mean ± standard error) before the lagoons were opened to 0.2±0.05 after the lagoons had been opened. There was a marginally significant Period x Lagoon interaction, and examination of the mean values by SNK test found that the Before period was significantly greater than the After period in all lagoons, thereby confirming the existence of a significant main effect.

Total numbers of fish collected in seine nets did not differ from Before to After lagoon openings (Table 2.7), but there was significant variation between Times and only in the Before period (Figures 2.6, 2.8, 2.9).

Numbers of fish species sampled by gill nets declined significantly in the After period (Table 2.7, Figures 2.6, 2.8, 2.9). The mean numbers of species sampled by gill nets were 1.2±0.09 in the Before period and 0.3±0.06 in the After period. Total number of fish sampled by gill nets declined significantly in the After period (Table 2.7, Figures 2.6, 2.8, 2.9). The mean total number of fish declined from 4.1±0.78 before the lagoons were opened to 0.4±0.25 after the lagoons had been opened.

Fishes of surf zones

Surf zones were sampled bimonthly during the low tide period between April 2006 and March 2007 and again between December 2009 and 2010. A larval beach seine was used to collect larval and juvenile fishes. The results of the earlier sampling are provided in Gladstone and Edwards (2006). However, sampling during the latter period failed to yield results. The results of the earlier work is summarised below.

A total of 598 larval and juvenile fishes (16 species, 14 families) were collected from surf zones (Table 2.8). Clupeidae was the most abundant family collected (n=514 fishes). The greatest total number of fish was recorded from Terrigal Beach (n=388) and the smallest number of fish recorded from Copacabana Beach (n=19). The most abundant species collected from surf zones was Hyperlophus vittatus. Copacabana Beach (7 families, 7 species) was dominated by marine species such as the surfsardine Iso rhothophilus (Isonidae) (n=10). Avoca Beach (11 families, 13 species) was dominated by the estuarine and marine species sandy sprat H. vittatus (n=129). Terrigal Beach (8 families, 10 species) was dominated by H. vittatus (n=345) and Wamberal Beach (5 families, 5 species) was also dominated by H. vittatus (n=17).

Six families of fishes (Ambassidae, Atherinidae, Eleotridae, Gobiidae, Mugilidae and Sparidae) occurred in lagoons and surf zone sites. However, the numbers of fish collected from surf zones for each family were considerably less than the numbers collected from lagoons. Three families were recorded in lagoons but absent from surf zones: Hemiramphidae, Poecilidae, and Sillaginidae. Eight families that were recorded from surf zones were absent from lagoons: Clupeidae, Congridae, Gerreidae, Girellidae, Isonidae, Leptoscopidae, Lutjanidae, and Paralichthyidae (Table 2.8).

Mean total abundance of larval and juvenile fishes in the surf zones varied significantly through time only at Terrigal Beach (Figure 2.10). Across all lagoons the changes that occurred in the mean total abundance of larval and juvenile fishes in the surf zones were independent of the status of the lagoon entrance (Pearson's Chi-square=3.094, df=2, P>0.05).

Assemblages of larval and juvenile fishes from surf zones varied through time at all beaches but the temporal variation was significant only at Copacabana and Terrigal Beaches. The greatest changes at Copacabana occurred between periods 4 and 5 and between periods 5 and 6. The greatest change at Terrigal Beach occurred between periods 1 and 2. When all time periods and beaches were considered, the likelihood of a change in the assemblage of larval and juvenile fishes was unrelated to whether the lagoon entrance was opened or closed (Pearson's Chi-square=0.434, df=1, *P*=0.51).

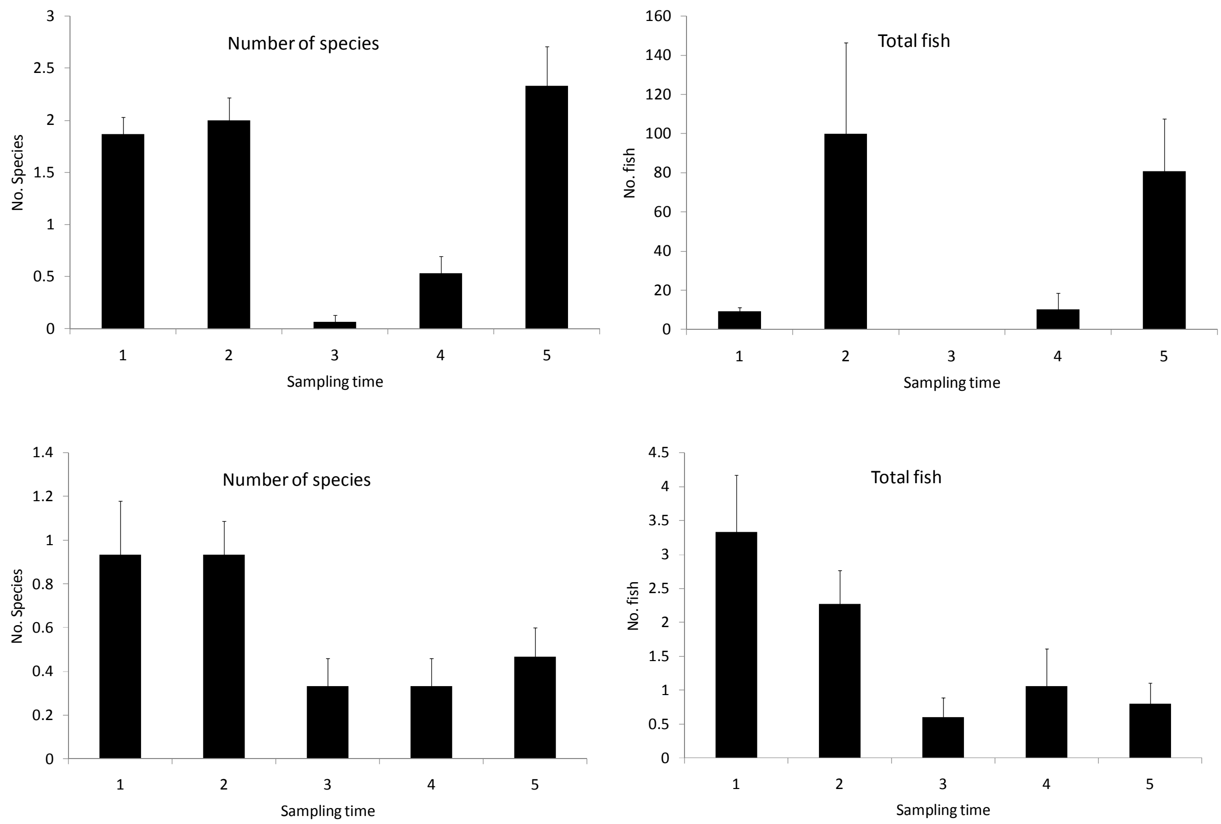


Figure 2.6 Number of species and total abundance of fishes sampled in seine nets (upper panels) and gill nets (lower panels) in Wamberal Lagoon in 2009. Sampling dates are shown in Table 2.1. Wamberal Lagoon was opened between sampling time 2 and 3. Values shown are mean + standard error (n=15).

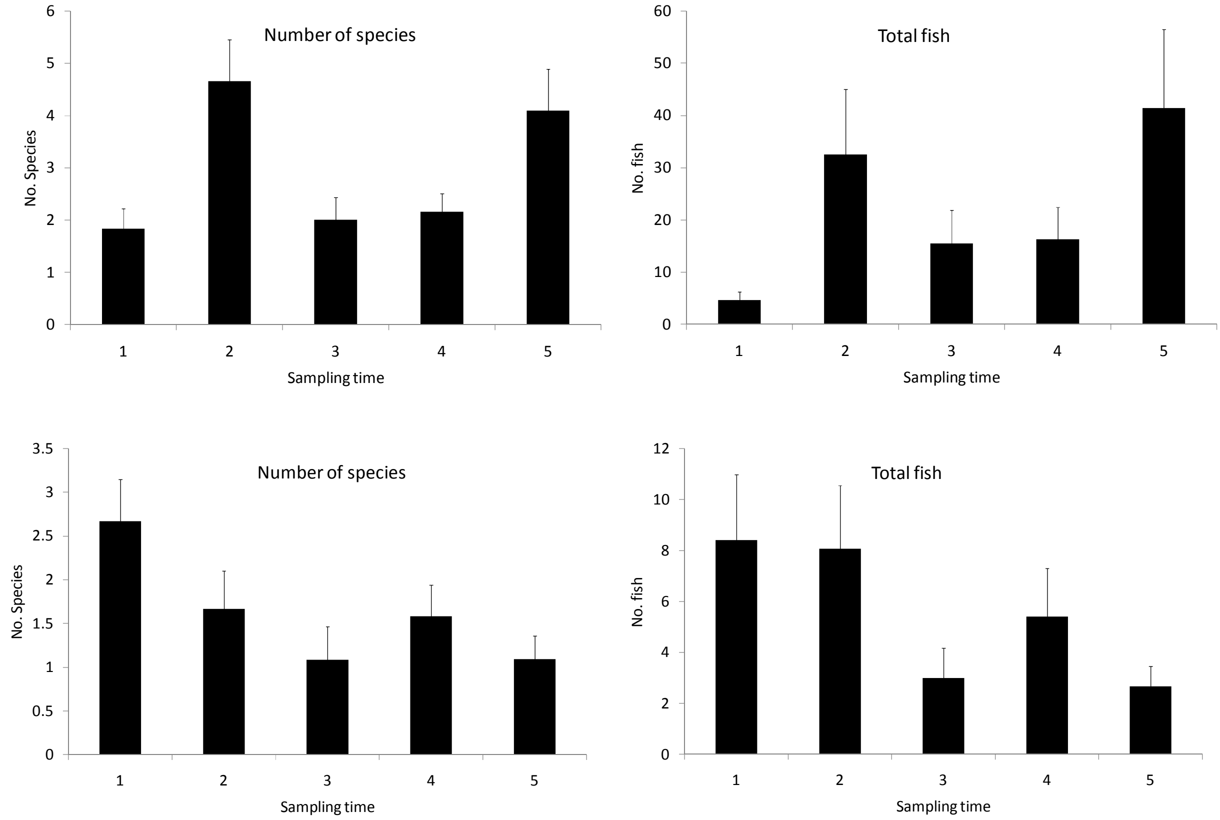


Figure 2.7 Number of species and total abundance of fishes sampled in seine nets (upper panels) and gill nets (lower panels) in Terrigal Lagoon in 2009. Sampling dates are shown in Table 2.1. Terrigal Lagoon was opened repeatedly and no attempt has been made to distinguish samples that were collected before and after lagoons were opened. Values shown are mean + standard error (n=15).

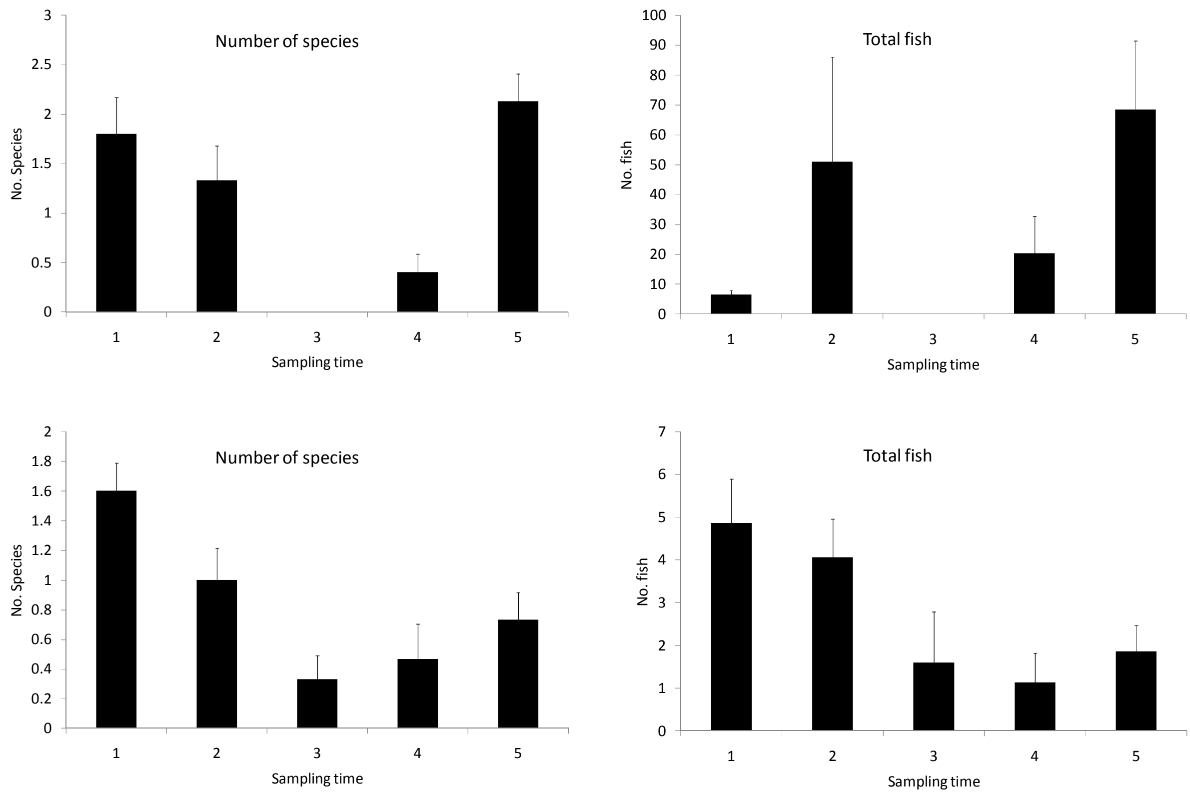


Figure 2.8 Number of species and total abundance of fishes sampled in seine nets (upper panels) and gill nets (lower panels) in Avoca Lagoon in 2009. Sampling dates are shown in Table 2.1. Avoca Lagoon was opened between sampling time 2 and 3. Values shown are mean + standard error (n=15).

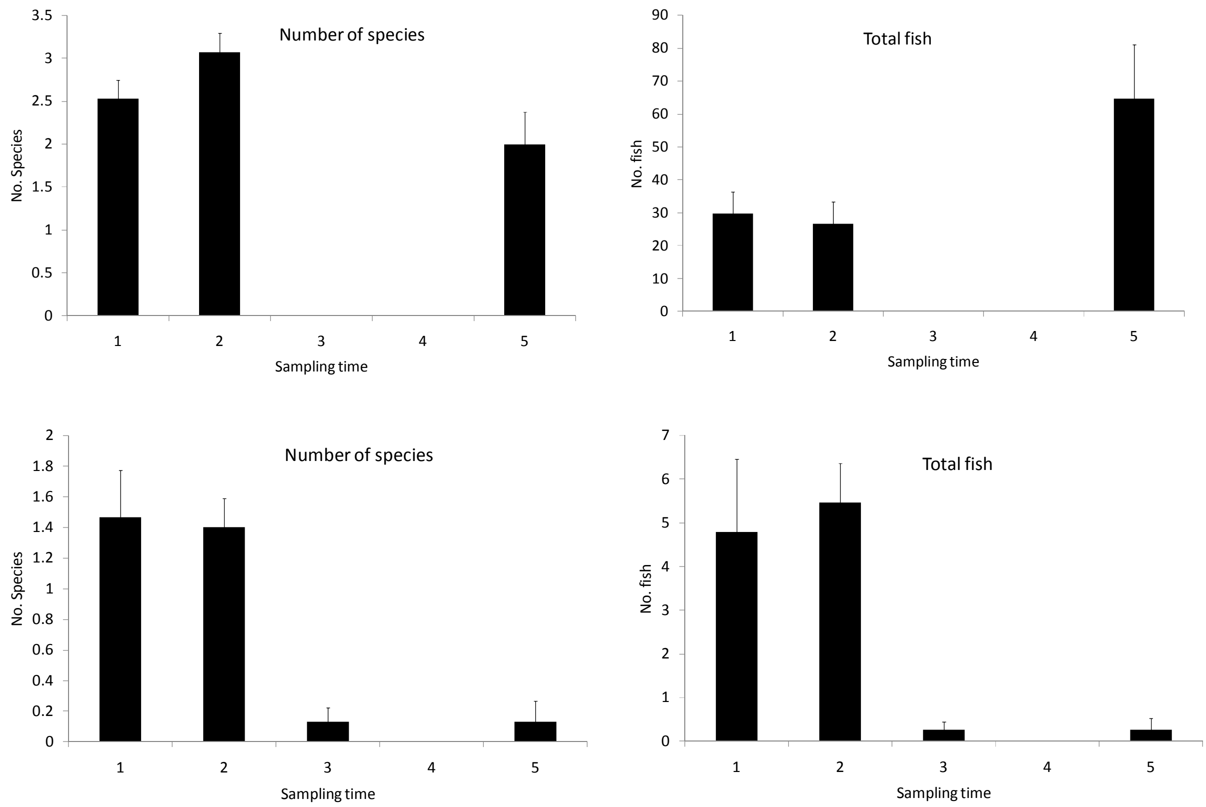


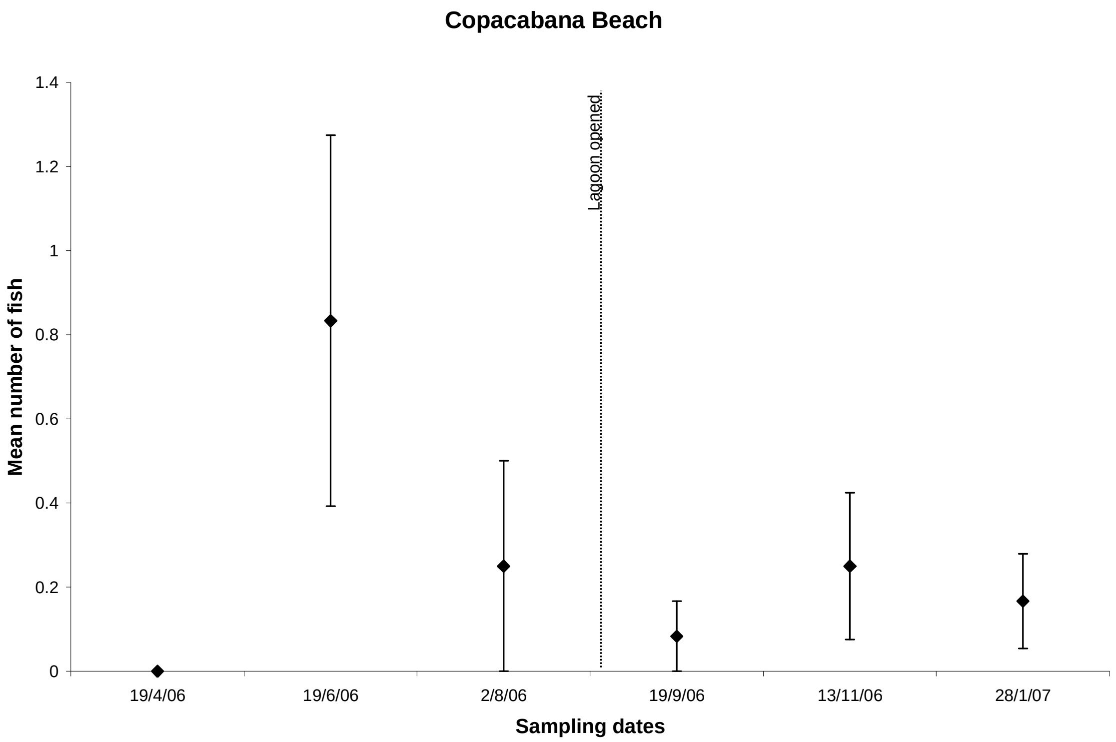
Figure 2.9 Number of species and total abundance of fishes sampled in seine nets (upper panels) and gill nets (lower panels) in Cockrone Lagoon in 2009. Sampling dates are shown in Table 2.1. Cockrone Lagoon was opened between sampling time 2 and 3. Values shown are mean + standard error (n=15).

Table 2.7 Summary of results of three-factor ANOVA testing for effects of Period (Before, After lagoon opening), Times (Time 1, Time 2 nested in each Period), and Lagoons (Wamberal, Avoca, Cockrone) on numbers of fish species and total fish abundance. Separate analyses were done for fish assemblages sampled by seine nets and gill nets.

Source of variation	**DF**	**Seine net: no. species (raw data, C=0.27, P<0.01)**			**Seine net: total no. fish (raw data, C=0.58, P<0.01)**			**Gill net: no. species (ln(x+0.5) transformed data, C=0.17, P>0.05)**			**Gill net: total no. fish (ln(x+1) transformed data, C=0.18, P>0.05)**		
		MS	F	P	MS	F	P	MS	F	P	MS	F	P
Period Pe	1	168.20	170.09	0.006	46208.09	2.01	0.29	30.10	256.78	0.004	47.85	8205.62	0.0001
Time Ti (Pe)	2	0.99	1.59	0.21	23016.5	4.98	0.01	0.12	0.39	0.68	0.01	0.01	0.99
Lagoon La	2	4.02	3.38	0.13	3859.22	0.45	0.67	0.25	0.56	0.61	0.58	0.92	0.47
PeXLa	2	8.72	7.33	0.05	3692.94	0.43	0.68	1.24	2.74	0.18	1.80	2.85	0.17
LaXTi(Pe)	4	1.19	1.91	0.11	8627.77	1.87	0.12	0.45	1.52	0.20	0.63	1.18	0.32
Residual	168	0.62			4626.00			0.30			0.54		

Table 2.8 Total number of larval and juvenile fishes collected in surf zones from April 2006 to March 2007. Three sites were sampled: ~100 m south of lagoon entrance (south), adjacent to lagoon entrance (adjacent), and ~100 m north of lagoon entrance (north). Values shown are total numbers of each species collected from each site, their life history category (F=Freshwater, R=Resident, MED=Marine–estuary dependant, EM=Estuarine and marine, T=Transient and M=Marine species), total length (TL mm), and total numbers of each species collected.

Family	Species	Life history	Surf zone												TL (mm)	Total number
			Copacabana			Avoca			Terrigal			Wamberal				
			North	Adjacent	South	North	Adjacent	South	North	Adjacent	South	North	Adjacent	South		
Ambassidae	*Ambassis jacksoniensis*	EM	0	0	0	0	0	0	6	0	0	0	0	0	15-19	**6**
	Ambassis marianus	EM?	0	0	0	0	0	0	0	0	1	0	0	0	12	**1**
Atherinidae	*Atherinosoma microstoma*	R	0	0	0	0	0	2	0	0	0	0	0	0	14-15	**2**
Clupeidae	*Hyperlophus vittatus*	EM	1	0	0	8	10	111	86	147	112	0	1	16	12-40	**492**
	Sardinops sagax	?	0	0	0	1	0	1	2	10	8	0	0	0	23-35	**22**
Congridae		M	1	0	0	0	0	0	0	0	0	0	0	0	96	**1**
Eleotridae	*Philypnodon grandiceps*	R	0	0	0	0	0	3	0	0	0	0	0	7	11-23	**10**
	Unknown A	?	0	0	2	0	0	0	0	0	0	0	0	0	10-12	**2**
Gerreidae	*Gerres subfasciatus*	EM	0	0	0	3	2	0	0	0	1	0	1	0	7-18	**7**
Girellidae	*Girella tricuspidata*	T	0	0	0	2	0	3	0	0	2	0	0	0	10-12	**7**
Gobiidae	*Gobiopterus semivestitus*	R	0	0	0	0	0	0	0	0	1	0	0	0	9	**1**
	Pseudiogobus olorum	R	0	0	0	0	0	2	0	0	0	0	0	0	12-14	**2**
Isonidae	*Iso rhothophilus*	M	4	3	3	0	0	0	0	0	0	0	0	0	19-27	**10**
Leptoscopidae	*Lesueurina platycephala*	M	0	0	0	0	0	1	1	3	6	0	0	1	16-21	**12**
Lutjanidae		?	0	0	0	1	1	0	0	0	0	0	0	0	8	**2**
Mugilidae	*Mugil cephalus*	MED	0	0	0	0	1	0	1	0	0	0	0	0	22-23	**2**
	Myxus elongatus	MED?	0	0	1	4	1	4	0	0	0	0	1	1	11-14	**12**
Paralichthyidae	*Pseudorhombus* sp.	EM	1	0	0	1	0	0	0	0	0	0	0	0	6-11	**2**
Sparidae	*Acanthopagrus australis*	MED	0	0	3	1	0	0	0	1	0	0	0	0	10-14	**5**
	Total number		**7**	**3**	**9**	**21**	**15**	**127**	**96**	**161**	**131**	**0**	**3**	**25**		**598**



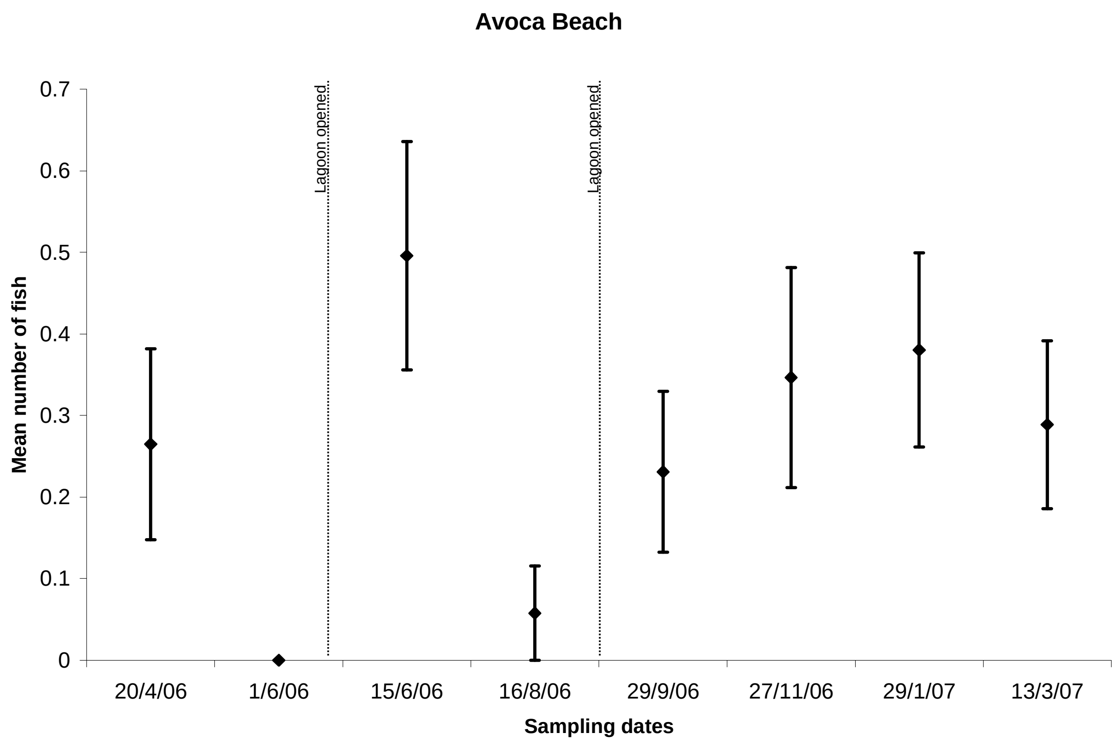
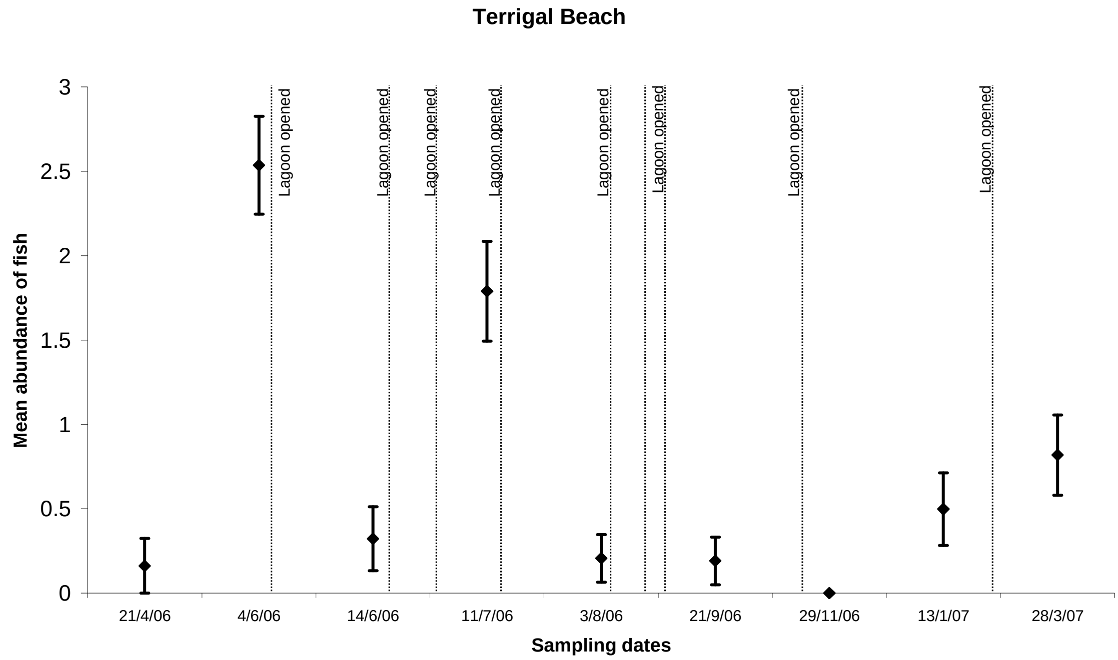


Figure 2.10 Mean abundance (± se) of larval and juvenile fishes collected from surf zones adjacent to Gosford's coastal lagoons from April 2006 to March 2007. The timing of lagoon openings in relation to sampling times is shown by the vertical lines.



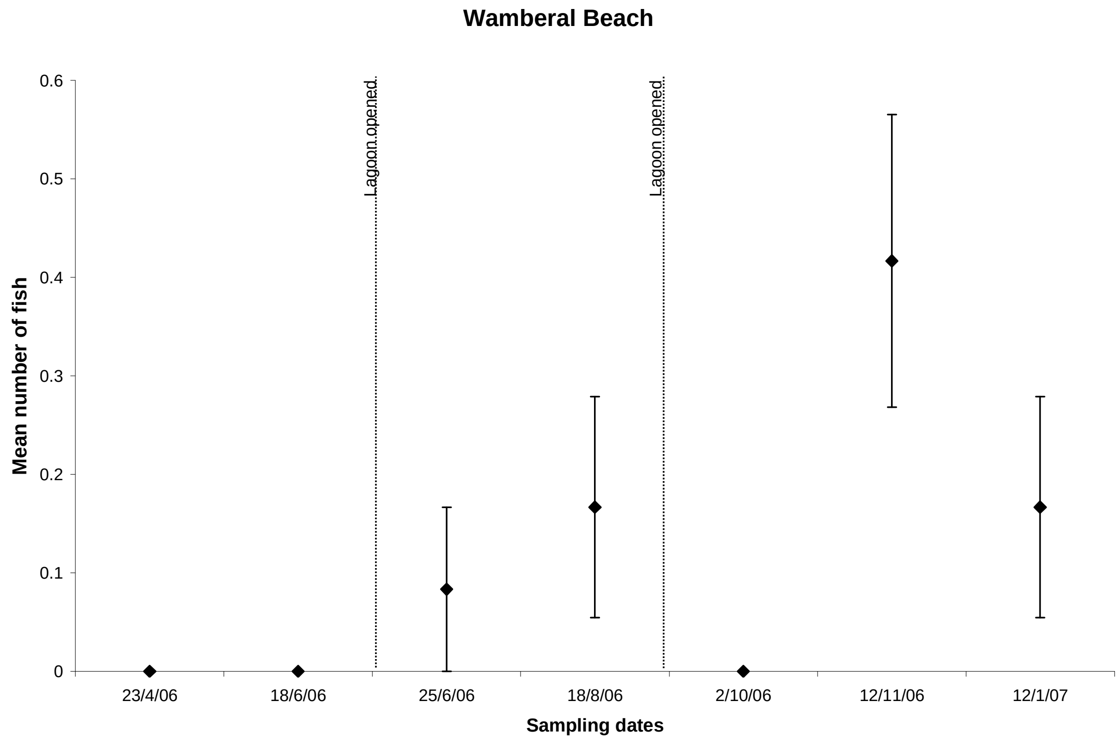


Figure 2.10 cont'd. Mean abundance (± se) of larval and juvenile fishes collected from surf zones adjacent to Gosford's coastal lagoons from April 2006 to March 2007. The timing of lagoon openings in relation to sampling times is shown by the vertical lines.

NSW Fisheries Data

Data collected by NSW Fisheries between 1986 and 2008 are tabled in Appendix 1. These tables pool sampling results for each year. The tables provide the total numbers for each species recorded for each lagoon. Because of the different methods used between 1986 and 2008, the data were not used for statistical analyses. However, some observations can be made:

- A total of 72 different species were collected.
- There was a general trend towards lower diversity and abundance of species through time until 2002 and then the trend reverses with increases in diversity and abundance of species in 2008 (Figures 2.11 – 2.21).
- Interestingly, Terrigal generally had the highest diversity of species. The authors attribute this to the frequency of lagoon openings rather than water quality or quality of habitat.
- A few species were recorded in particularly high abundance. Examples include *Ambassis jacksoniensis* (Glassfish, Figure 2.11), *Atherinosoma microstoma* (Small Mouth Hardyhead, Figure 2.12), and *Philypnodon spp*. (eg. *Philypnodon grandiceps* Flathead Gudgeon, Figure 2.13). However, the most abundant fishes were generally the smallest.
- The more abundant larger fish species included *Acanthopagrus australis* (Bream, Figure 2.14), *Myxus elongatus* (Sand grey mullet, Figure 2.15), *Liza argentea* (Flat-tail Mullet, Figure 2.16), *Mugil cephalus* (Flathead mullet, Figure 2.17), *Hyporhamphus regularis ardelio* (Eastern river garfish, Figure 2.18) and *Sillago ciliata* (Sand Whiting, Figure 2.19).
- Few prawns or other crustaceans were recorded. Those that were recorded included *Acetes sibogae australis* (a Sergestid shrimp), *Metapenaeus macleayi* (School Prawn) and *Palaemon spp.* (Prawns).

The abundance of fishes and prawns collected between 1986 and 2008 are illustrated in Figure 2.20. The diversity of species for this sample period is illustrated in Figure 2.21.

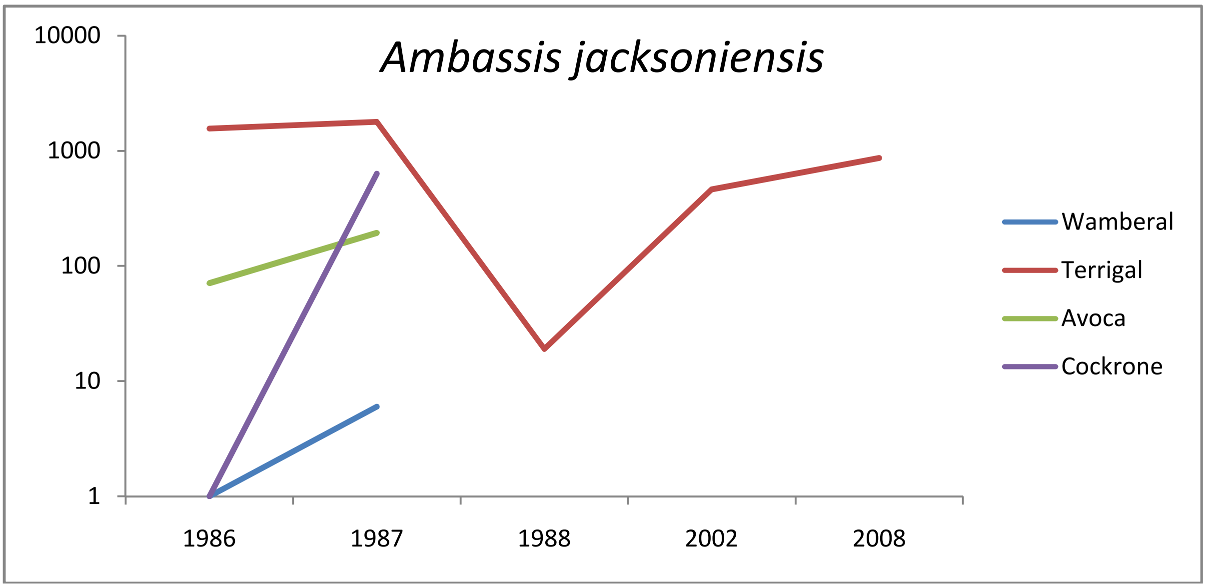


Figure 2.11 Abundance of Glassfish (*Ambassis jacksoniensis*) at each lagoon (1986-2008)

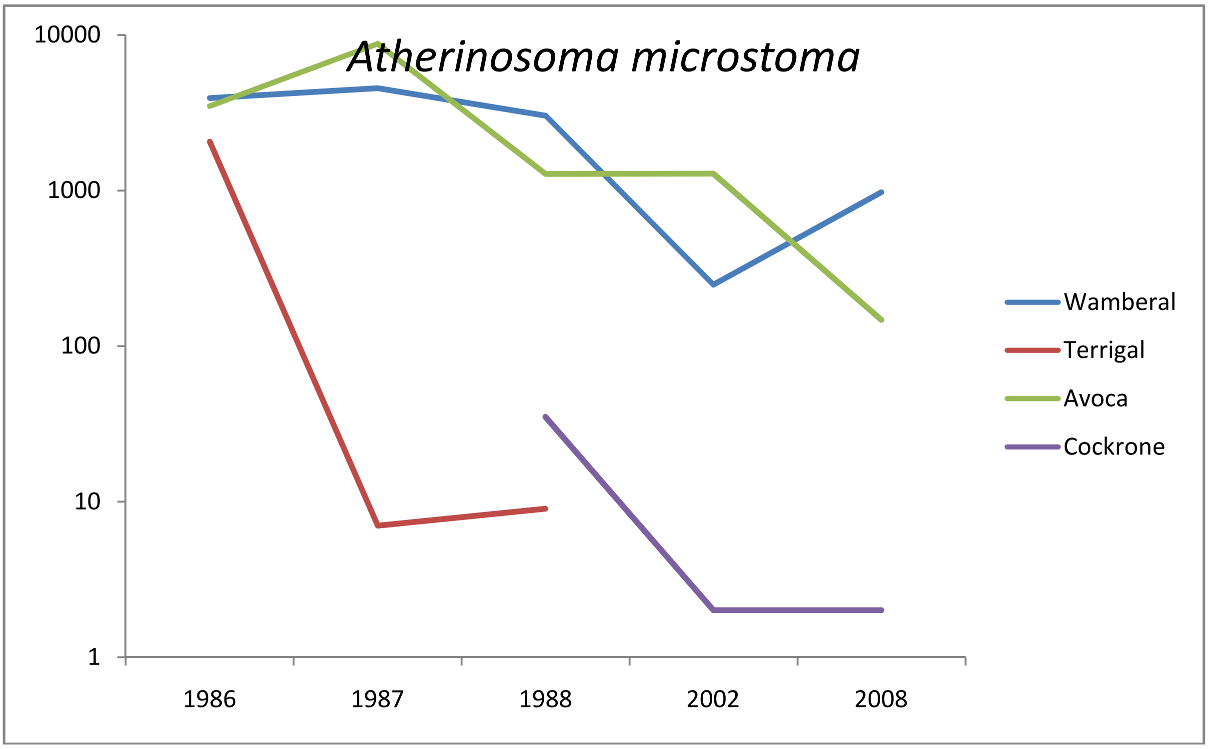


Figure 2.12 Abundance of Small Mouth Hardy head (*Atherinosoma microstoma*) at each lagoon (1986-2008)

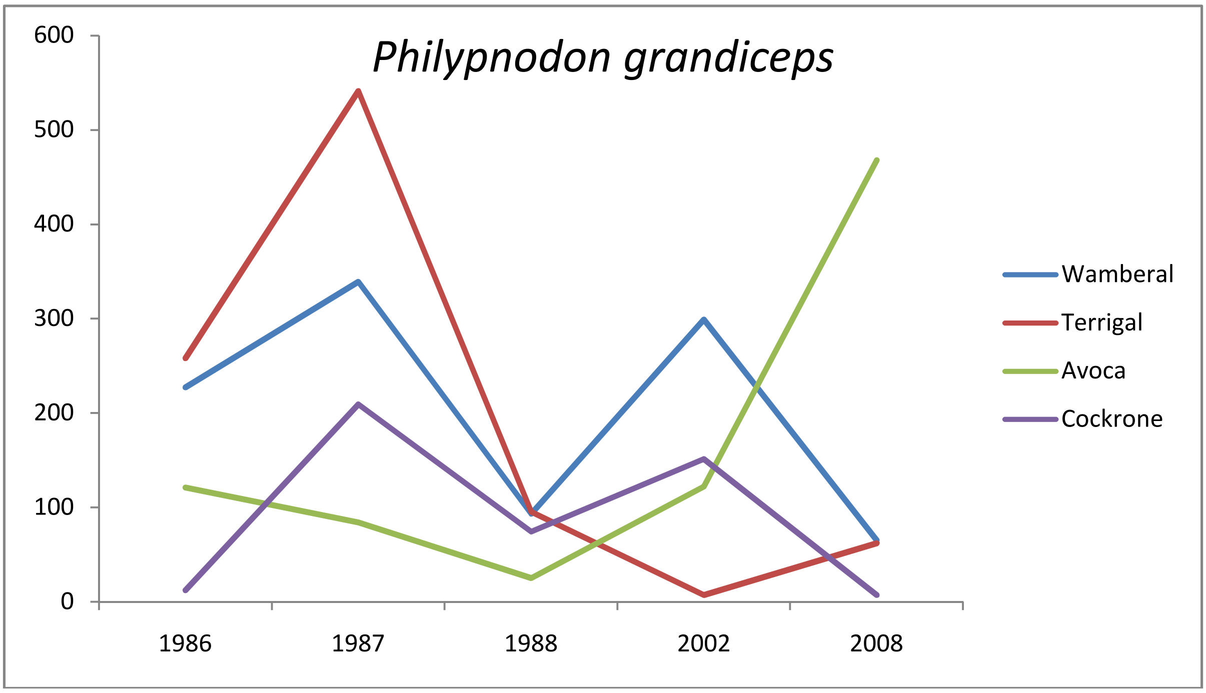


Figure 2.13 Abundance of Flathead Gudgeon (*Philypnodon grandiceps*) at each lagoon (1986-2008)

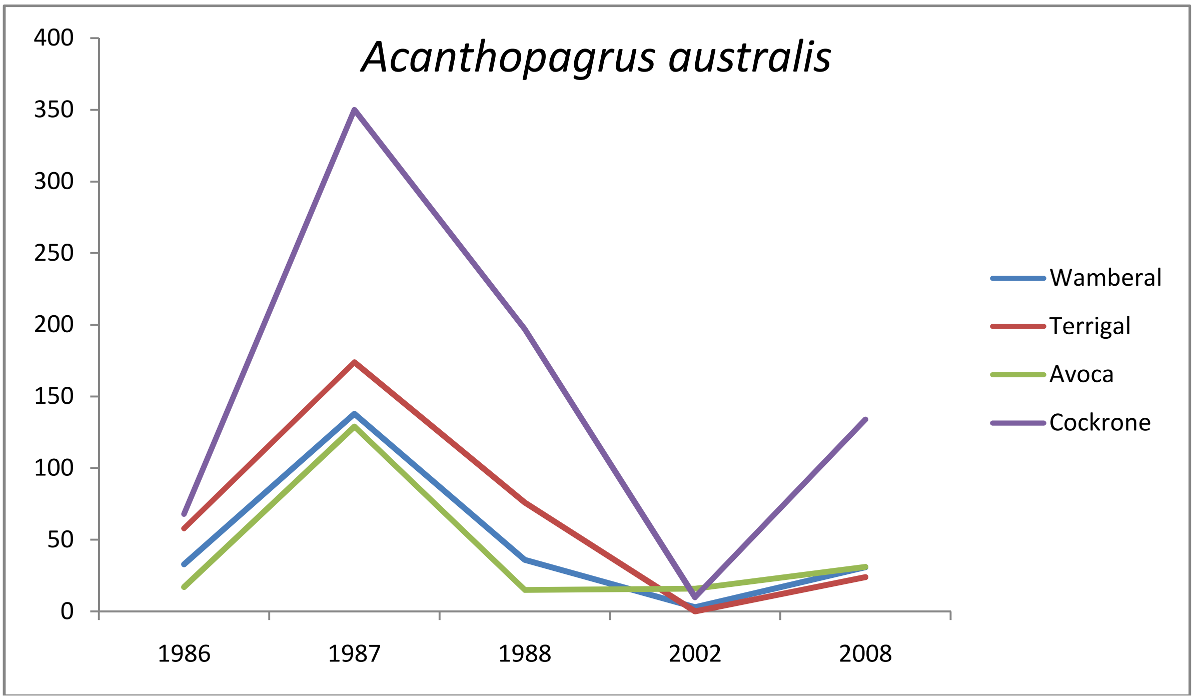


Figure 2.14 Abundance of Bream (*Acanthopagrus australis*) at each lagoon (1986-2008)

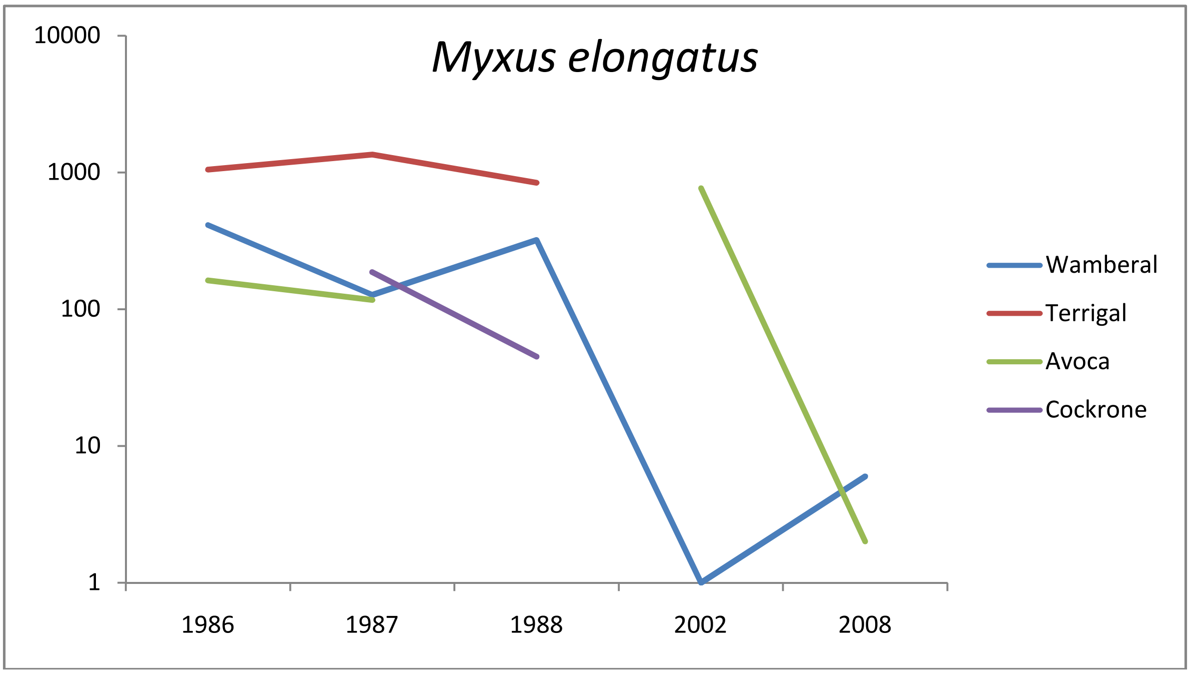


Figure 2.15 Abundance of Sand grey mullet (*Myxus elongatus*) at each lagoon (1986-2008)

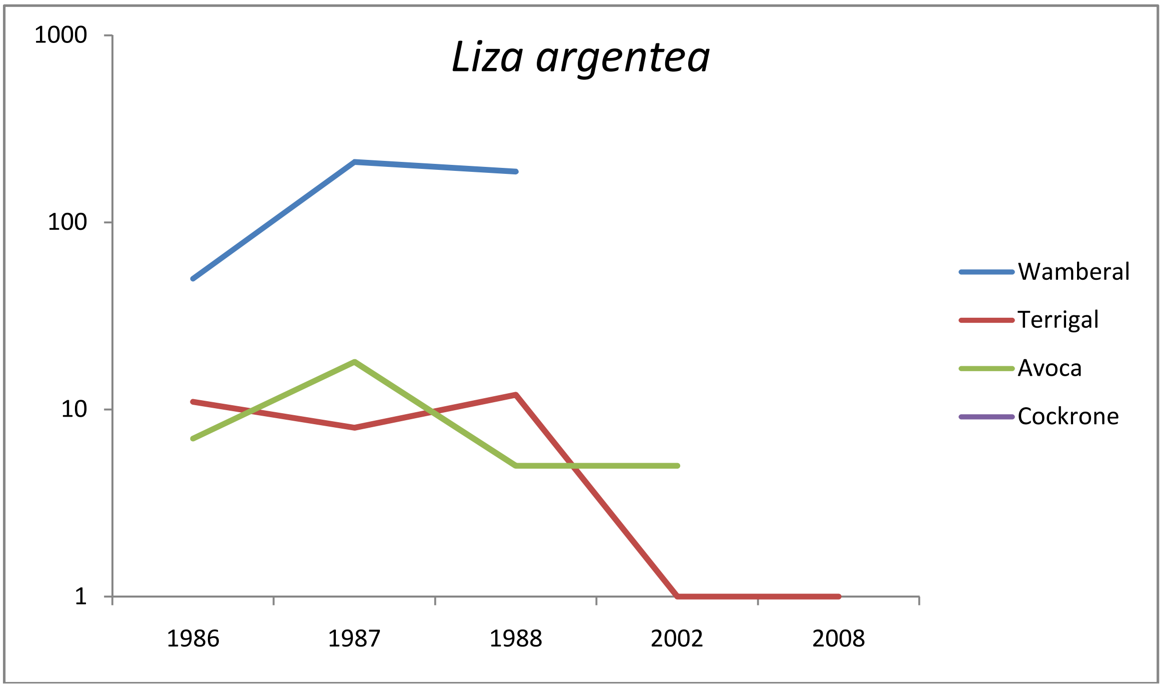


Figure 2.16 Abundance of Flat-tail Mullet (*Liza argentea*) at each lagoon (1986-2008)

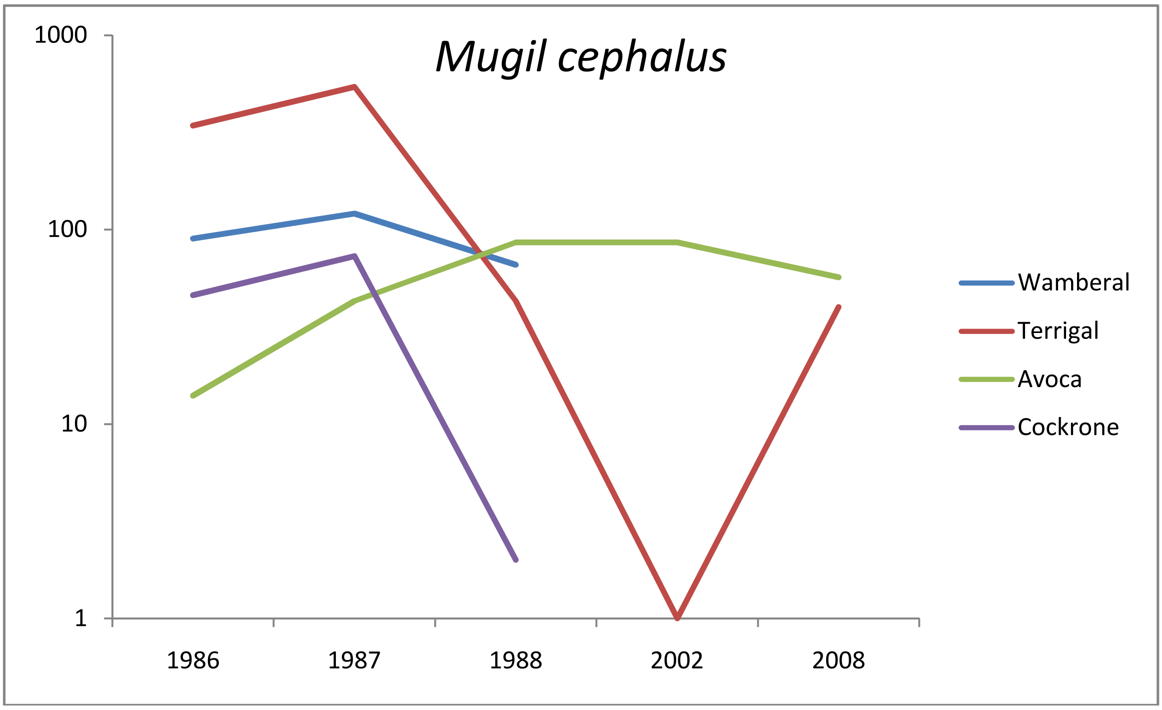


Figure 2.17 Abundance of Flathead mullet (*Mugil cephalus*) at each lagoon (1986-2008)

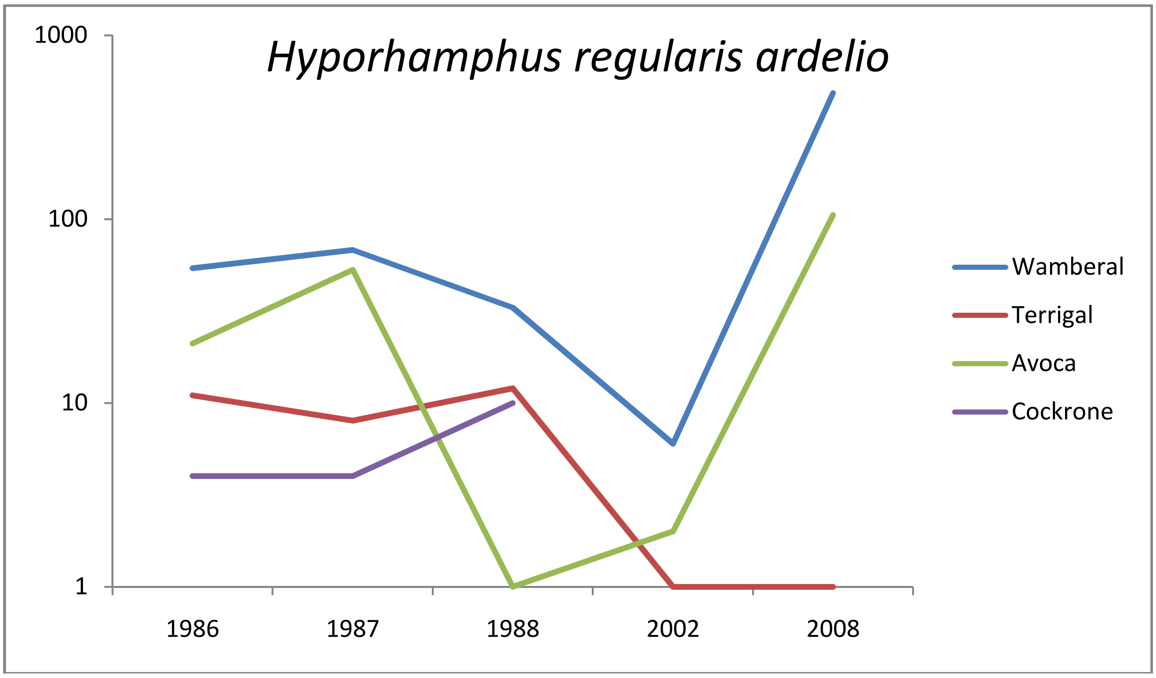


Figure 2.18 Abundance of Eastern river garfish (*Hyporhamphus regularis ardelio*) at each lagoon (1986-2008)

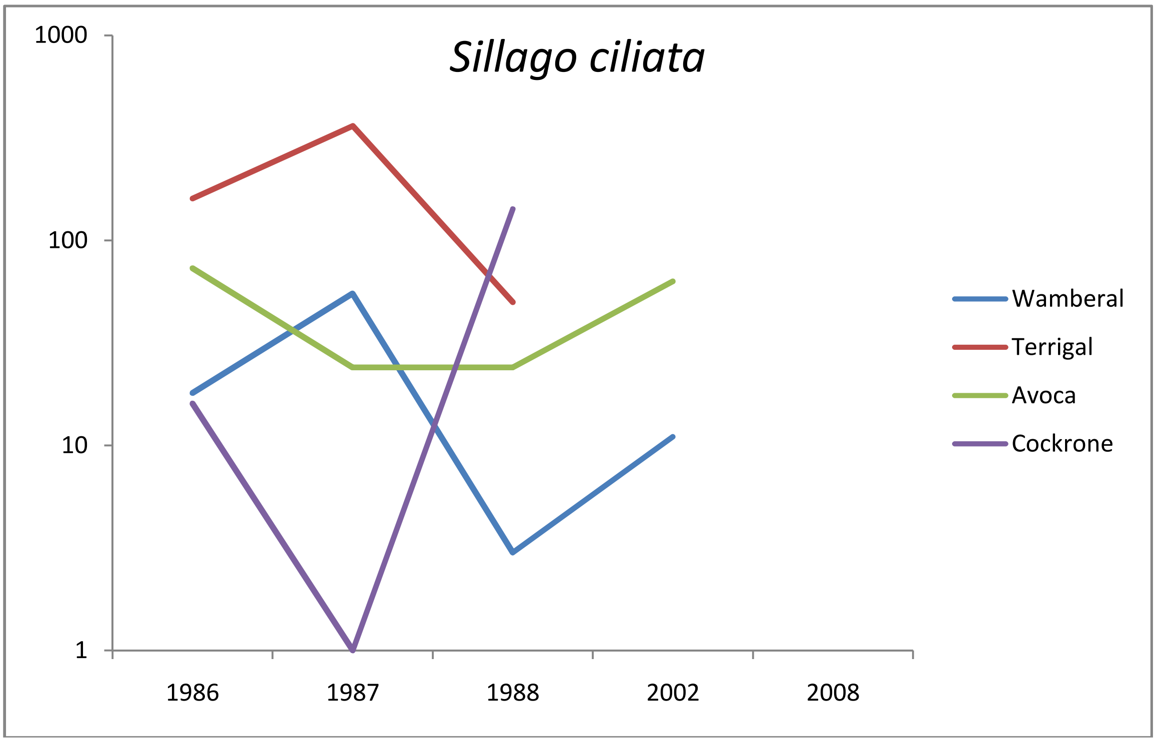


Figure 2.19 Abundance of Sand Whiting (*Sillago ciliata*) at each lagoon (1986-2008)

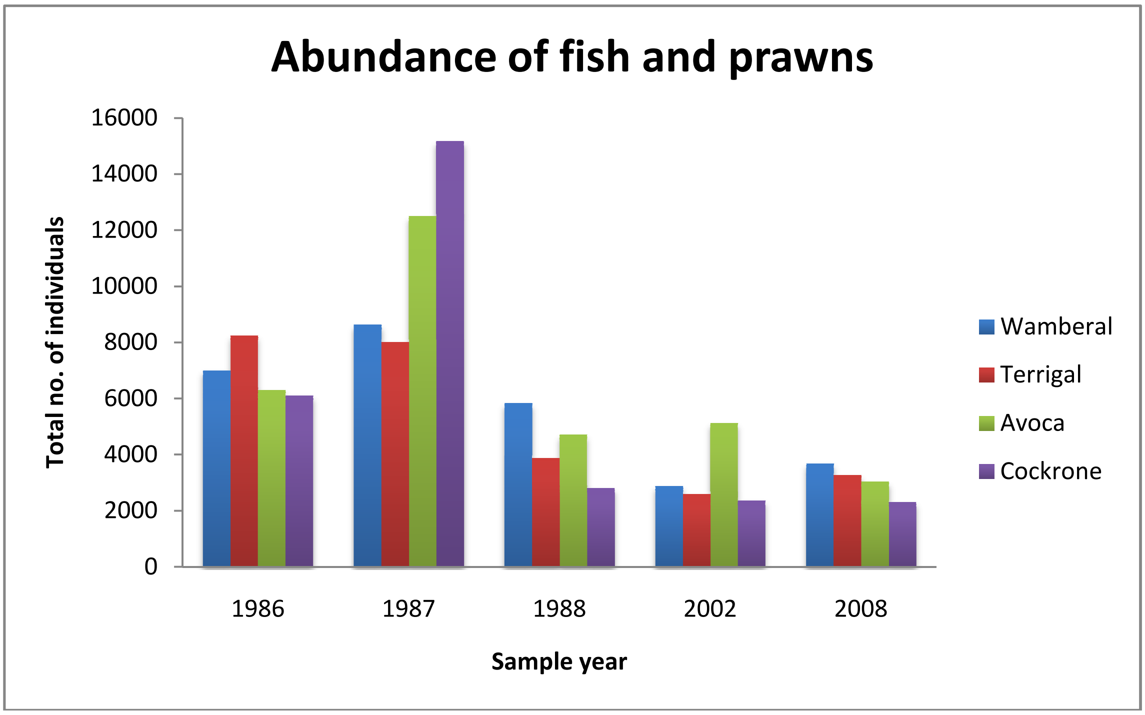


Figure 2.20 NSW Fisheries data showing abundance of fish and prawn species collected between 1986 and 2008 for each of the four lagoons

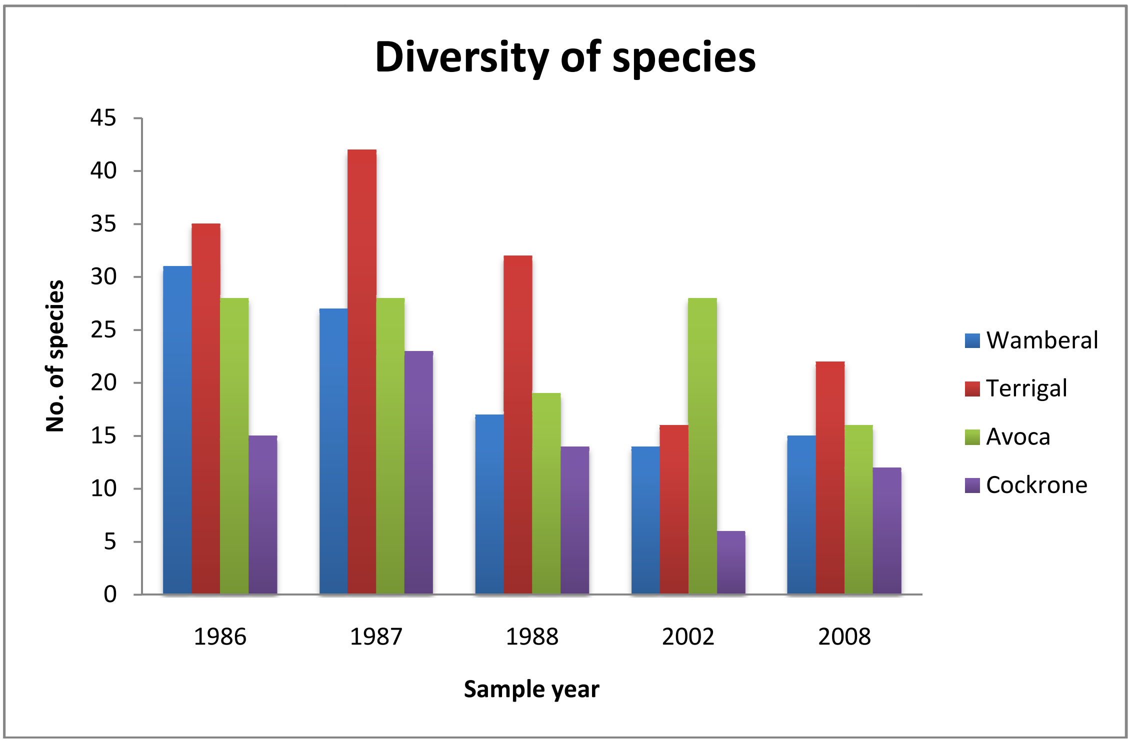


Figure 2.21 NSW Fisheries data showing diversity of fish and prawn species collected between 1986 and 2008 for each of the four lagoons

2.1.4 Discussion

Temporal and spatial patterns in larval and juvenile fish assemblages of lagoons

The study findings suggest that lagoon openings reduced the number of species of fish and the numbers of fish in all three lagoons, with the exception of the assemblage of fishes sampled by seine nets (which did not significantly decline in abundance). These results are based on analysis of three lagoons that opened at approximately the same time, and the results were consistent across all lagoons (as shown by the absence of significant interactions in the analyses in Table 7). However, a much stronger test of the effects of openings would include a comparison with control lagoons that did not open at the same time as it could be argued that the three lagoons could have also affected by another environmental disturbance at the same time as the opening. The use of controls, that would differ only in not being opened, would address this uncertainty.

The contrasting results between the seine and gill nets suggests that individuals of species sampled by seine nets are more resilient to the effects of openings, possibly by virtue of being able to shelter in the remaining habitat until water levels recovered. The sampling times analysed here are part of a continuing sampling regime that will conclude in February 2011 (being undertaken by Mr Les Edwards). It is therefore likely that a more detailed understanding of the effects of openings on these assemblages will emerge with a longer time series of data that includes periods when not all lagoons opened.

Analysis of data from Terrigal lagoon (shown in Figure 2.7) found the following: variation in numbers of species sampled by gill nets among sampling times was marginally non-significant ($F_{4,55}$=2.6, P=0.05). Total numbers of fish sampled by gill nets did not vary significantly among sampling times ($F_{4,55}$=2.03, P=0.10). Numbers of species sampled by seine net varied significantly among sampling times ($F_{4,55}$=5.04, P=0.002). Total numbers of fish sampled by seine net did not vary significantly among sampling times ($F_{4,55}$=1.78, P=0.15). The results for Terrigal are surprising and indicate that, even with a high frequency of openings, there is little variation in the fish assemblage. The sampling design was sufficiently powerful to detect substantial differences if they were present (as shown by the numbers of degrees of freedom in the F-ratio). The fish assemblage present in Terrigal Lagoon, which is governed by the relatively homogeneous habitat, appears to be resilient to the effects of opening, which include changes in water level, water quality, and access to habitat. This result is similar to earlier findings that the macroinvertebrate assemblages of the entrance berm of Terrigal Lagoon also appeared to be resilient to the effects of lagoon openings (Gladstone *et al.,* 2006).

Temporal and spatial patterns in larval and juvenile fish assemblages of surf zones

The dynamic nature of surf zone environments can influence larval and juvenile fish assemblages at a range of temporal and spatial scales (Harris and Cyrus 1996). Individual surf zones of the present study showed no significant temporal patterns in total abundances of larval and juvenile fishes except at Terrigal Beach where two abundance peaks occurred during winter periods (June and July) reflecting the high numbers of dominant species *Hyperlophus vittatus* collected. Like lagoons, peak abundances of estuarine-dependant larval and juvenile fishes generally occur during spring and summer periods (Strydom 2003), however a second peak may occur during winter months (Senta and Kinoshita 1985; Harris and Cyrus 1996). Apart from *H. vittatus* other species (such as *Sardinops sagas*, *Iso rhothophilus* and *Lesueurina platycephala*) were collected in low numbers (n<25), indicating the depauperate nature of surf zones.

Spatial patterns of larval and juvenile fish assemblages can reflect the characteristics of a location including its geographical position (Clark *et al*., 1996), environmental variables, diel period (Harris and Cyrus 1996), wind, coastal currents, lunar cycles (Kingsford and Finn 1997; Trnski 2001), tidal cycles, habitat type (Watt-Pringle and Strydom 2003; Sato et al. 2008), recruitment cues (Strydom 2003), larval swimming ability (Sato et al. 2008) and wave exposure (Romer 1990; Clark 1997). As wave exposure decreases diversity and abundances of fish assemblages increases (Romer 1990; Clarke 1997). This can be reflected by both Avoca and Terrigal beaches that have some protection by southern headlands which may result in lower wave exposure compared to Copacabana and Wamberal beaches that are more exposed. Rips are another factor which may influence spatial patterns of larval and juvenile fish assemblages however, the effectiveness of rips is yet to be determined.

Other studies of larval and juvenile fish abundances in surf zones reported increases during night sampling (Ruple 1984; Harris and Cyrus 1996) and at low tides (Whitfield 1989; Cowley *et al.,* 2001; Strydom 2003; Geraghty 2004). Increased abundances at night and low tide could be related to larval and juvenile fishes actively moving closer to shore for feeding or predator avoidance (Sato et al. 2008). In contrast, Senta and Kinoshita (1985) found increased abundances during the day as well as finding no relationship between abundances and tidal phase. Many pelagic species are able to avoid nets by vertical migration, however this is unlikely to occur when sampling in surf zones due to the shallow sampling depths encountered (Roper 1986). Assemblages of larval and juvenile fishes can also be related to sampling efficiency associated with using a fine meshed seine net. Fine mesh nets tend to scoop up sediments and vegetation which increases drag resistance and can decrease the capture of benthic and mobile species (Senta and Kinoshita 1985). Drag resistance can also be influenced by wave exposure (Romer 1990; Clark 1997).

There is a paucity of information regarding studies of fish assemblages in south-eastern Australian surf zones except for Geraghty (2004) who found 29 species from four sandy beach sites. Differences in numbers of species collected from Geraghty (2004) and the present study can be a result of physical processes described earlier and the different classification of beach sites studied. The present study sites are intermediate beaches that are of a high energy range, whereas sites studied by Geraghty (2004) were classified as reflective beaches that are low energy beaches hence decreased wave exposure (Short 2007). *Hyperlophus vittatus* was the most abundant species collected from both the present study and Geraghty (2004). High abundances of *H. vittatus* indicate that surf zones may be important environments for this species (Ayvazian and Hyndes 1995) also their life history suggests that they spawn many times during the year (Blaxter and Hunter 1982; Rogers and Ward 2007).

Effects of barrier openings on larval and juvenile fish assemblages of lagoons and adjacent surf zones

Surf zones and lagoons of the present study had distinct differences of larval and juvenile fish assemblages. The lagoons generally had lower numbers of species with a higher abundance of certain individuals compared to surf zones that had higher numbers of species, but lower abundances of individuals. Many species of larval and juvenile fishes take advantage of barrier openings to enter lagoons, however, recruitment into lagoons can be determined by other factors including spawning behaviour of species (Hannan and Williams 1998), accumulation of larvae near entrances (Cowley *et al.* 2001; Strydom 2003), ability of larval and juvenile fishes to actively or passively enter via open channels (Trnski 2001).

The present study suggests that recruitment into lagoons from surf zones was not an important process at the time of this study. The lagoons were dominated by resident species whereas surf zones were dominated by estuarine/marine species, the most abundant of which (*H. vittatus)* were not found in lagoons. Cockrone Lagoon was the only lagoon to have differing assemblages before and after a barrier opening, with large numbers of marine estuary-dependant species *A. australis* occurring only after the barrier was opened due to reasons described earlier. Some species were common to both environments, however, small numbers (n<10) of larval and juvenile fishes collected from surf zones were deemed insignificant.

2.1.5 Conclusion

This study showed that Gosford's lagoons have higher abundances and lower species diversity of larval and juvenile fishes than their adjacent surf zones, with resident species dominating lagoons. Results also suggest that temporal and spatial scales play a role in the variation of larval and juvenile fish assemblages in lagoons, while temporal variations of assemblages occurs in surf zones. The patchy distribution of surf zone larval and juvenile fishes and differences in the assemblages between the two ecosystems before and after barrier openings indicates recruitment into lagoons does not occur from surf zones and vice-versa and that lagoons are self-recruiting environments for resident species of fish.

2.2 Macrobenthic Communities

2.2.1 Introduction

The overarching objective of this study is to describe patterns of distribution and abundance of benthic macro-invertebrates in Gosford's Coastal Lagoons.

The distribution of benthic macro-invertebrates in estuaries has been described as a spatial and temporal mosaic (Morrisey *el al.*, 1992a; Morrisey *el al.*, 1992b). However, macrobenthic communities are sensitive to habitat disturbance and respond to pollutant stress through changes in species composition and abundance (Pearson and Rosenburg, 1978; Gray, 1981; Rygg, 1985; Gray *et al*., 1990; Warwick and Clarke, 1991; Reynoldson and Metcalfe-Smith, 1992; Warwick, 1993; Pinel-Alloul *et al*., 1996). As a result, macrobenthic assemblages probably provide the best potential indicator of ecological or environmental change in coastal habitats.

The dispersal and migration of benthic macroinvertebrates is governed by complex interactions between physical and biotic processes. Stochastic factors causing variations in recruitment can influence patterns of succession, community structure and composition (Davis and Van Blaricom, 1978; Underwood and Anderson, 1994). Immigration patterns for planktonic larvae are strongly influenced by prevailing hydrodynamic conditions. The "jetting" of larvae along topographically stable fronts on flood tides has been shown to influence the spatial patterns of recruitment in estuaries (Kingsford and Suthers, 1996). After the planktonic larvae of macroinvertebrates have been carried into an estuary their ultimate success depends on settlement and establishment. Substratum has been shown to influence patterns of establishment and change (Underwood and Anderson, 1994).

A benthic community is the assemblage of bottom dwelling species at a particular time and place. Benthic invertebrates are subdivided according to sieve mesh size into micro (<0.04mm) meio (0.04-0.1mm), macro (0.5-2.0mm) and megafaunal (>2.0mm) components.

Various models have been espoused to describe the different levels of macro-invertebrate communities. Macro-invertebrate communities in soft substrata have been termed low-grade communities, largely controlled by physical conditions or organic loadings, with less influence from biological interactions (Rainer, 1981; Horwitz and Blake, 1992). These fauna are apparently made up of a spatial mosaic of communities at different stages of maturity, constantly being "reset" by localised, small-scale disturbance. They are characterised by low diversity, high abundance and small size strata (O'Conner and Lake, 1994). However, many of these models come from a few investigations and a handful of observations. Because of the heterogeneous nature of macro-invertebrate assemblages, it is often more sensible to ignore broad generalisations about community structure and evolution and consider each estuarine ecosystem as unique.

Benthic macro-invertebrates have been used successfully as indicators of disturbance to marine ecosystems (Pearson and Rosenburg, 1978; Gray, 1981; Rygg, 1985; Gray *et al*., 1990; Warick and Clarke, 1991; Reynoldson and Metcalfe-Smith, 1992; Warick, 1993; Pinel-Alloul *et al*., 1996). Community structure, biomass and relative abundance of trophic groups and indicator species have been developed and used for this purpose. Measures of community structure are problematic because of gaps in understanding about interactions controlling diversity of communities and stability and resilience of the ecosystems. Species richness, diversity indices and measures of biomass are among the most commonly used indicators but there also exist problems with interpretation of the measurements. There are advantages and disadvantages of using macrobenthic assemblages as environmental indicators. The advantages include:

- numerous species are found together in very small patches of habitat;
- they come from a wide variety of types of fauna, notably polychaetes, molluscs and crustaceans, which means they represent a substantial element of local biodiversity;
- methods of sampling and quantifying them are well known;
- work on local species (particularly molluscs and crustaceans) has allowed development of experimental techniques to determine what causes changes in their composition and abundances; and
- research in other parts of the world continuously adds knowledge, understanding and predictive capacity about their ecology and ecological responses to disturbances.

The disadvantages include:

- in natural habitats, they are very variable in space and time, making sampling designs complex and requiring a lot of effort in replication of samples;
- fauna vary according to the structure of the habitat, previous history of the area, successes or failures of recruitment, etc.;
- there is a lot of uncertainty about the taxonomy and means of identifying species; and
- the complexity of numerous species and relevant sampling designs has required a lot of effort to develop statistical analytical procedures capable of detecting patterns of change in the fauna.

The advantages have generally been considered to outweigh the disadvantages, many of which can be addressed. The problems of multivariate spatial and temporal variance in faunal assemblages have been largely addressed (Dayton and Tegner, 1984; Underwood, 1991a & 1991b, 1992, 1993, 1994; Morrisey *et al*., 1992a, 1992b, 1994a, 1994b; Glasby and Underwood, 1996; Chapman and Underwood, 1997; Chapman, 1998; Underwood and Chapman, 1998). Temporal variation in macrobenthic fauna includes changes at many time-scales (including tide-to-tide, day-to-day, weekly, monthly and occasionally, seasonally). Impacts or other forms of environmental change must therefore be detected and interpreted against a background of temporal "noise". In general, environmental changes are pulse (relatively short-term) or press (relatively long-term), which can elicit pulse or press responses. The statistical underpinnings were developed by Bender *et al*. (1984) and considered in environmental contexts by Underwood (1991a & 1991b) and Glasby and Underwood (1996).

With regard to uncertainty about taxonomy, recent studies (Warwick, 1998; Gray *et al*., 1990; Warwick, 1993; Somerfield and Clarke, 1995; Chapman, 1998; MacFarlane and Booth, 2001) have indicated that patterns of anthropogenic disturbance may be as readily detected at coarse taxonomic resolution as could be detected at higher levels of taxonomic resolution. Generally, little difference in the perceived pattern of impact has been observed when species data were aggregated to the level of family, although distortions in the patterns were observed at coarser levels of taxonomic resolution.

Water quality variables such as dissolved oxygen, pH, salinity and turbidity have been shown to influence benthic community assemblages (Pearson and Rosenburg, 1978; Gray, 1981; Rygg, 1985; Gray *et al*., 1990; Warick and Clarke, 1991; Reynoldson and Metcalfe-Smith, 1992; Warick, 1993; Pinel-Alloul *et al*., 1996). A variety of sediment characteristics have also been shown to influence macrobenthic ecology (Gray, 1981; Edgar and Barrett, 2000). Sediment size, organic and nutrient content have been demonstrated to be of particular importance. Numerous studies have also demonstrated the influence of heavy metals to benthic assemblages (eg. Rygg, 1985; Stark, 1998a & 1998b). However, MacFarlane and Booth (2001), suggest that for Australian estuaries with only moderate pollutant disturbance, it is difficult to distinguish between anthropogenic effects (such as heavy metals) and the effects of natural variables (such as high organic content, high silt/clay content and high nutrient content) as these characteristics are generally found to be strongly correlated with each other. Therefore, measurements of dissolved oxygen, pH, salinity of water, turbidity, organic carbon content and percentage fines of sediments were included in the analyses. Other variables considered in this study include the distance from the estuary mouth (beach berm), the condition of adjacent foreshore and the phytoplankton content of the overlying water body.

There are two major methodologies for analysing ecological and environmental data collected to address investigations into environmental disturbance. The first is univariate analyses, which test hypotheses about single variables (e.g. the number of species in the samples or the abundance of a particular species). The logic, assumptions, methods and general procedures are well known. The most useful analyses for investigating ecological patterns are analyses of variance (Underwood, 1981). The major technical issues concern the design of sampling. These analyses can handle the complexities and variability of most marine ecological data.

The second set of methodologies is multivariate analyses, which test hypothesis about sets of species – where the data are the numbers of each of an array of different types of animals in each sample. The rationale and logic for using these procedures has been developed by Green (1979), Field *et al*. (1982), Clarke and Green (1988) and Clarke (1993). The general processes involve measuring the differences between samples by multivariate indices (e.g. Bray-Curtis measures of dissimilarity). These are then compared by permutation tests in procedures such as ANOSIM (Clarke, 1993). Results can be displayed as maps (called non-metric multi-dimensional scaling diagrams), that show differences among samples. Canonical correspondence analysis is a particular ordination technique that results in a diagram (biplot or triplot) displaying both the sites and the species and, if measured, the environmental variables in a reduced space (Ter Braak, 1995). It enables the researcher to evaluate differences in species composition between sites and to identify the environmental variables responsible for these differences in a single analysis. This property of ordination is the main advantage over other multivariate techniques that operate on (dis)similarity indices (e.g. similarity analysis, clustering and multidimensional scaling). Ordination techniques are capable of summarising very complex responses because they are not restricted to a single dimension (as for instance (dis)similarity analysis).

The first objective of this study is to collect and identify to family level the macrobenthic invertebrate community assemblages in each of the four lagoons. Another objective is to compare the benthic macroinvertebrate assemblages from different regions of the lagoons (i.e. beach berm, central basin and the fluvial deltas of creeks feeding the lagoons. This will be tested by comparing the benthic macroinvertebrate density, diversity and assemblage structure in each region. Another objective of the study is to determine whether environmental variables are influencing patterns of distribution and abundance of benthic macroinvertebrates.

The following hypotheses were tested:

- the number of families and number of individuals of all families of benthic macroinvertebrates will differ among the three regions, i.e. beach berm, basin and creek, of the four ICOLLs;
- the community composition of the benthic macroinvertebrates will differ amongst these regions;
- within a particular ICOLL region, the number of families, number of individuals and community composition of benthic macroinvertebrates will differ among the four ICOLLs; and
- differences in environmental variables among the three regions are related to any differences in the benthic macroinvertebrates of these ICOLLs.

2.2.2 Methods

Sampling was done on the same day, 30 July 2008, to prevent confounding the experimental design with differences that may be attributed to temporal change rather than habitat. Attempts were made to sample macroinvertebrates on and in the sediment from a variety of locations at each lagoon (beach berm, macro-algae, natural rock habitat, constructed seawall, deep basin soft sediment, *Ruppia megacarpa* and creek delta). However, natural rock habitat, constructed seawall, macro-algae and *Ruppia megacarpa* habitats proved either too difficult to sample or were void of macro-invertebrates. Rock habitats (natural and constructed seawalls) were surveyed but yielded few macroinvertebrates. Similarly, few macroinvertebrates were in sediments associated with macro algal habitats (*Enteromorpha intestinalis* and *Chaetomorpha linum*). Whilst macroinvertebrates were observed among *Ruppia megacarpa* the density of plant rhizomes and there shallow rooting prevented the sampling of sediment and associated macroinvertebrates using the methods described herein. Therefore, only beach berm, deep basin and creek delta habitats were included in the analyses. At each location there were two replicate sites (50 to 100 m apart) to consider spatial replication. Macroinvertebrates sampled from berm and delta habitats were approximately 5 m from the shoreline in water 200-300mm deep by inserting a PVC corer into the sediment to collect a sediment core. At each site, 7 sediment cores (100mm diameter x 100mm deep) were randomly collected. The core contents were transferred to plastic bags and transported to the laboratory where 5 cores from each site (2 cores were put aside for sediment analyses) were sieved through 1mm mesh screen (MacFarlane and Booth, 2001) and macroinvertebrate specimens were placed into 50ml plastic jars containing 5% formalin and Beibirch Scarlet stain. The specimens were later washed and preserved in 70% alcohol before identification to family level (Warwick, 1998; Gray *et al*., 1990; Warwick, 1993; Somerfield and Clarke, 1995; Chapman, 1998; MacFarlane and Booth, 2001). Identification was facilitated using dichotomous keys (Wadley, 1972; Robinson an Gibbs, 1982; Hutchings, 1984; Hutchings and Murray, 1984; Carpenter and Niem, 1998).

A YEO-KAL 2000 water quality probe was used to sample temperature, pH, salinity, dissolved oxygen concentration (DO) and turbidity. A variety of environmental variables were also assessed to explore relationships between these variables and community assemblages. These variables were recorded in the field.

Sediment cores were analysed for organic carbon content (%) and percentage fines of sediments (<63 µm). The surface (upper 10 mm) of each core was also subsampled (approximately 5 g), placed in acid-washed plastic jars, stored on ice and then stored frozen for chlorophyll *a* analyses. Each of the 48 sediment samples was transferred into an appropriately labelled metal tray. The trays were then transported into a 105˚C oven for three days in order to evaporate any water within samples. All traces of organic material (including plant matter and shells) were then removed from each sediment sample. An analysis of organic content (OC) for each sediment sample was then conducted by calculating the loss of ignition in a 550˚C oven (LOI%;

Allen, 1989). Using a mortar and pestle, each sediment sample was then ground. Taking 100g of sediment from each tray, samples were then sieved into size fractions of >63µm (sand and gravel) and <63 µm (silt and clay). These fractions were then converted into percentage proportions of >63 µm (sand and gravel) and <63 µm (silt and clay) for each sample.

A 3–5 g sample of the frozen sediment was placed in a glass centrifuge tube and left to thaw. It was then centrifuged to remove water, rinsed with 15 ml of acetone, mixed and sonicated. After a 2–3 min extraction the sample was centrifuged once more (10 min, ~ 2500 rpm). The extraction was repeated until the visual disappearance of the supernatant colour (usually no more than three times). The sample was passed through filter paper which was then ground in 10 ml ethanol (Ritchie 2006, 2008). The supernatant was then examined in a Varian Cary 50 UV-VIS spectrophotometer at wavelengths between 600 and 750 nm to look for peaks indicating the presence of photosynthetic pigments. The fluorescence of collected samples was also examined using a commercially available fluorometer (Aquation Pty Ltd). With this technique, the intensity of fluorescence increases in proportion to the concentration of cells (see APHA Standard Methods "Fluorometric determination of Chlorophyll *a*"). After zeroing the fluorometer output against an ethanol blank, three 3 ml replicates from each water sample were measured.

Other environmental variables included, depth, distance from lagoon entrance (beach berm) and fetch measured using GIS, condition of foreshore habitat (see section 1.1.3.2) Total Nitrogen, Total Phosphorous and chlorophyll *a* concentration in lagoon water (mean values derived from statistical analyses).

A combination of multivariate statistical analyses was used to investigate and test for differences between community assemblages. Multi-dimensional scaling (MDS), based on Bray-Curtis similarity matrices, was used to produce ordination plots. Goodness of fit was measures using Kruskal's stress formula (Kruskal and Wish, 1978). Analysis of similarity (ANOSIM) was then used to test for significant differences between locations. BIO-ENV analyses were also conducted in order to statistically link any biotic patterns to sampled environmental variables. These procedures were done using the Primer V6 software (Plymouth Routines in Multivariate Ecological Research 2005). Canonical correspondence analyses (Ter Braak, 1995) were done to evaluate differences in species composition between sites and to identify the environmental variables responsible for these differences. Canonical correspondence analysis was done using Canoco 4.5 (2002).

2.2.3 Results

Water quality and sediment parameters

Water temperature was relatively constant within lagoon sites though there was some variation between lagoons (Figure 2.22).

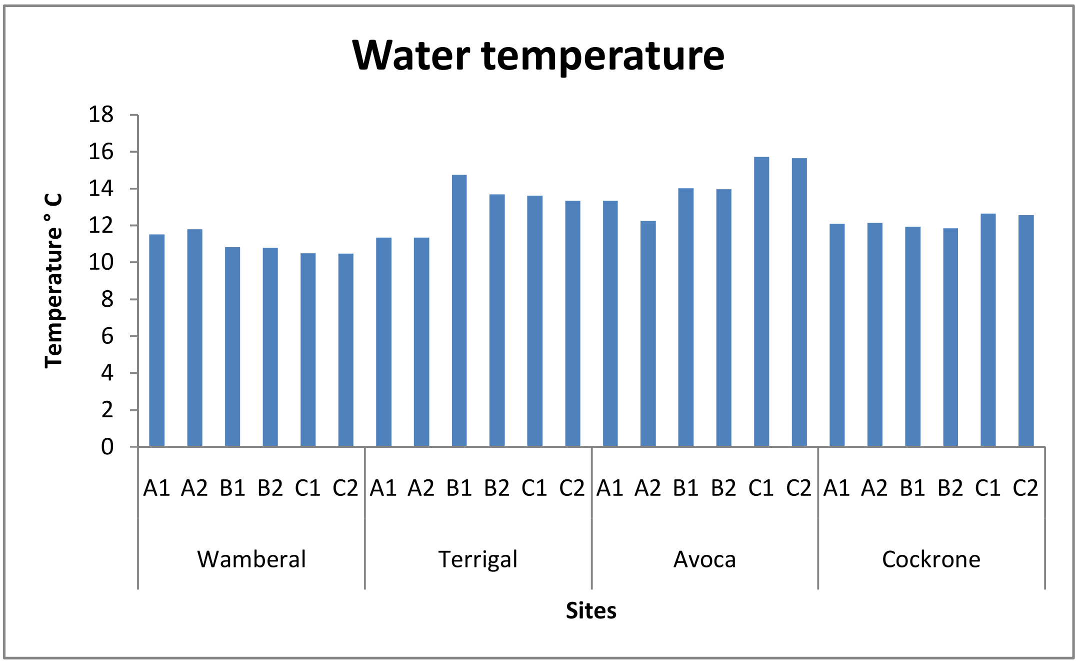


Figure 2.22 Mean water temperature (°C) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

Levels of dissolved oxygen were generally high (close to 100%) though marginally lower at Wamberal (Figure 2.23). The pH levels tended towards neutral (7.0) though slightly higher levels were recorded for Avoca and Cockrone (Figure 2.24).

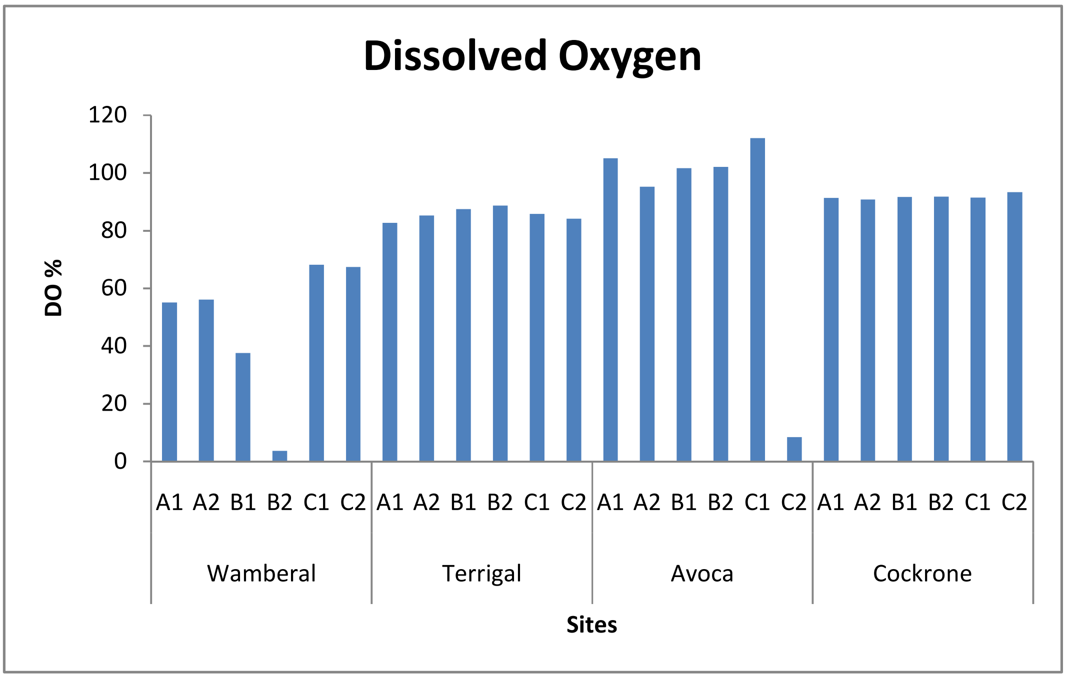


Figure 2.23 Mean dissolved oxygen concentration (%) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

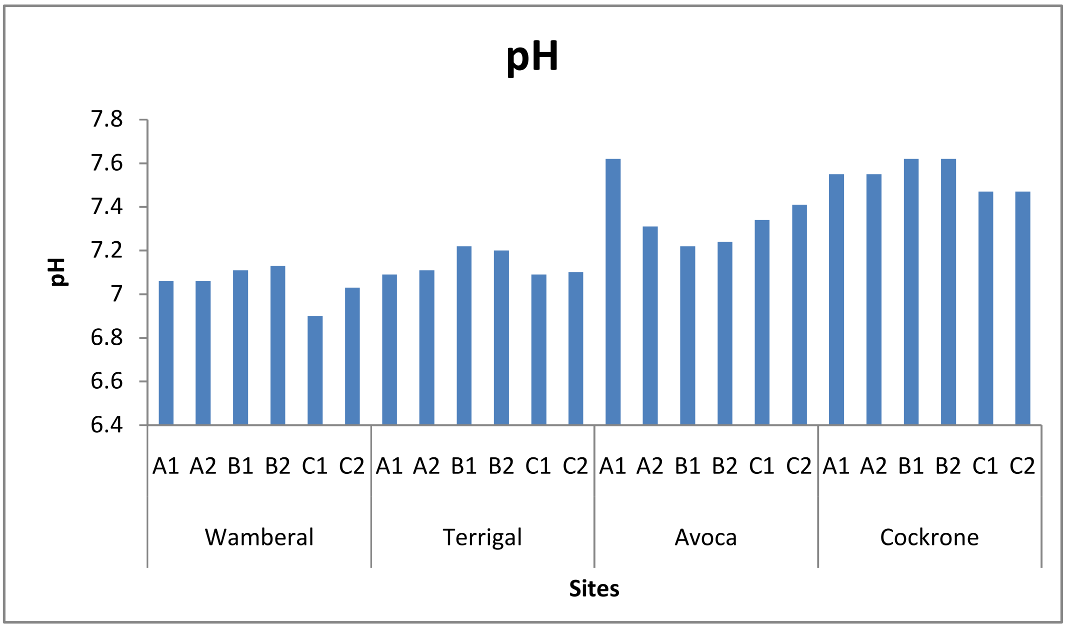


Figure 2.24 Mean pH at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

Salinity values (‰) were generally similar at all sites with the exception of Cockrone, which had slightly elevated values in basin and delta regions (Figure 2.25). These salinities are consistent for ICOLLs that have been closed for several weeks. The results for Terrigal are therefore surprising given the frequent openings to the sea.

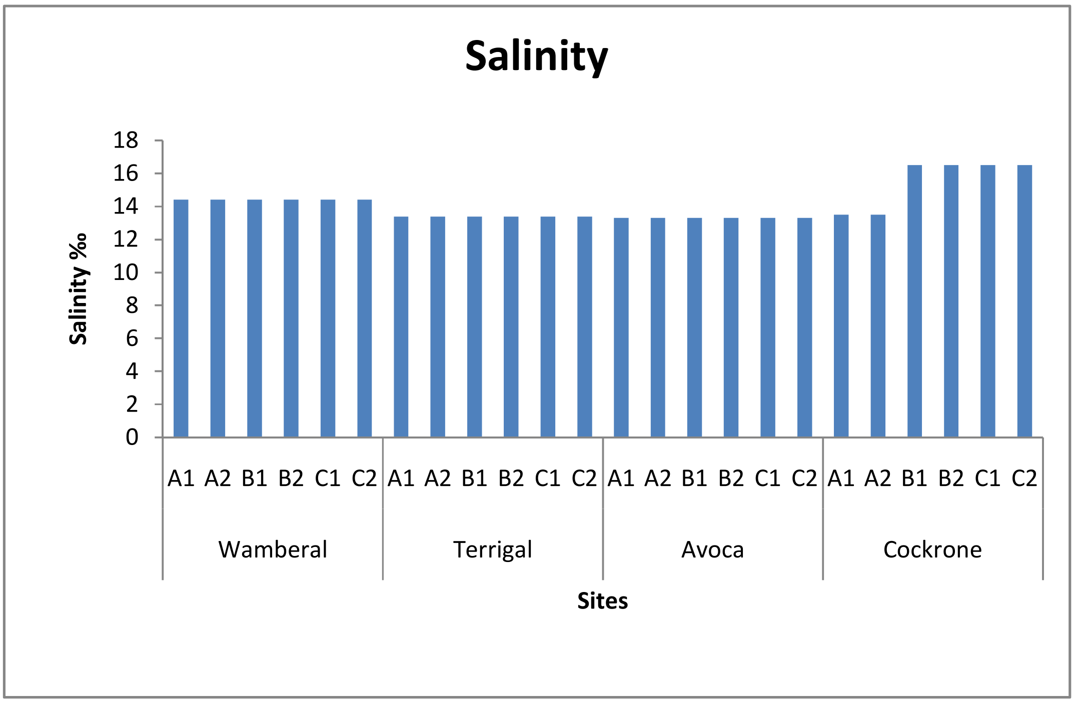


Figure 2.25 Mean salinity (‰) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

Turbidity levels (NTU) varied between sites with the highest levels recorded at Creek deltas. Generally, turbidity was low and water clarity was high (Figure 2.26).

Organic carbon concentrations (%) varied markedly between sites and lagoons (Figure 2.27). Not surprisingly, the beach berms sediments generally had low organic carbon content and were comprised of relatively coarse marine sands (Figure 2.28). The finest sediments (<63 µm) were generally found among the creek deltas (Figure 2.28).

Chlorophyll *a* concentrations in the water column are discussed in **Section 1.3 Phytoplankton**. The concentrations of sediment Chlorophyll *a* were below detectable limits of the methods used.

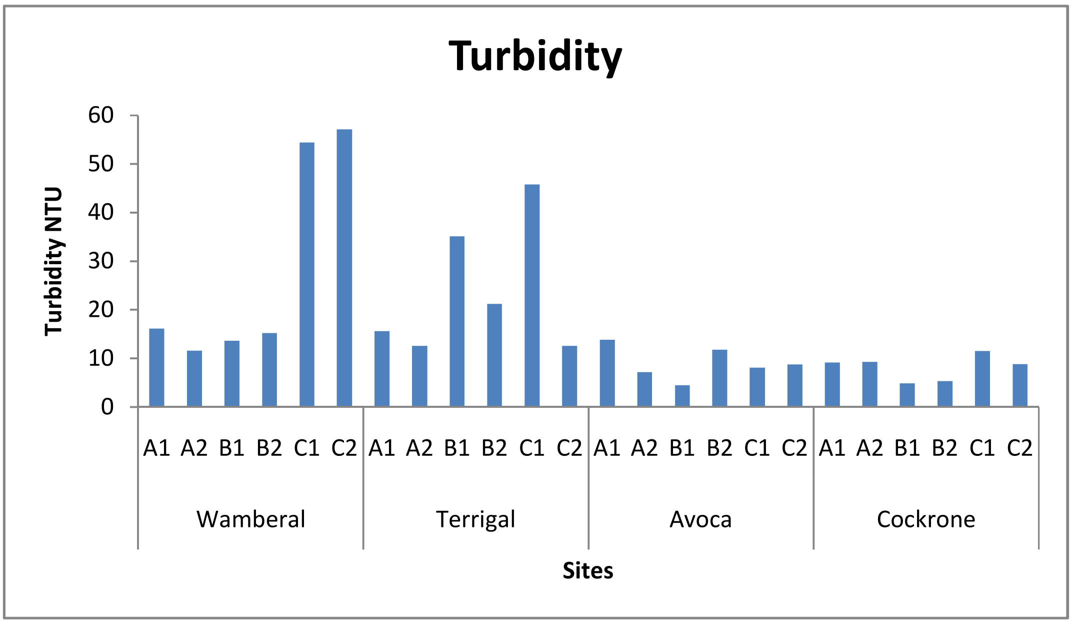


Figure 2.26 Mean turbidity (NTU) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

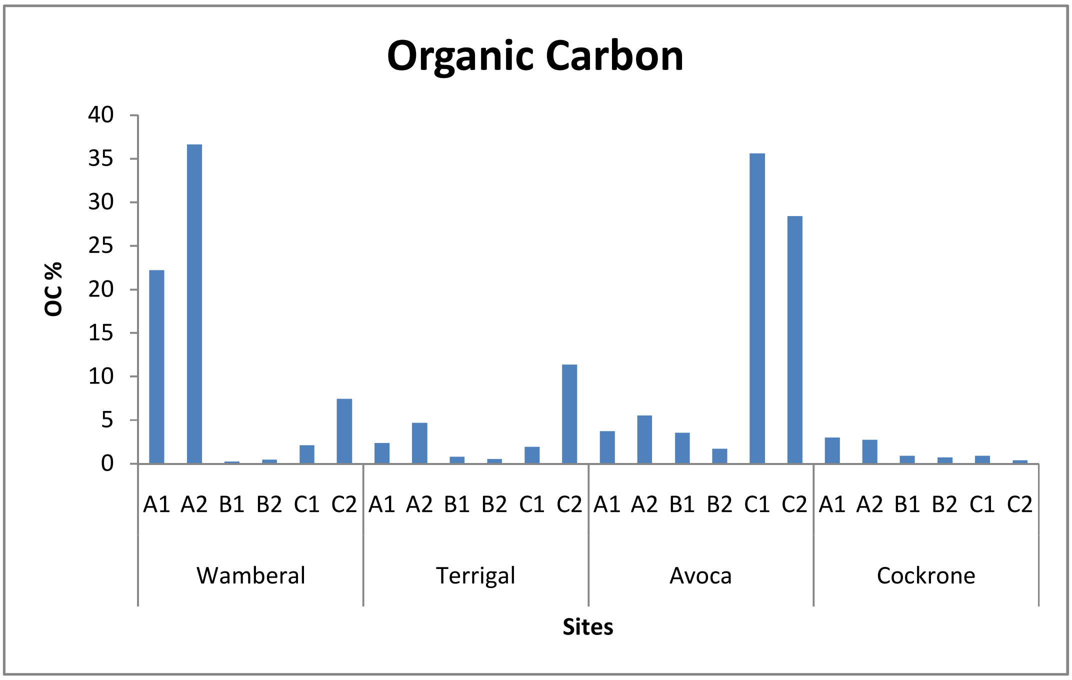


Figure 2.27 Mean organic carbon (%) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

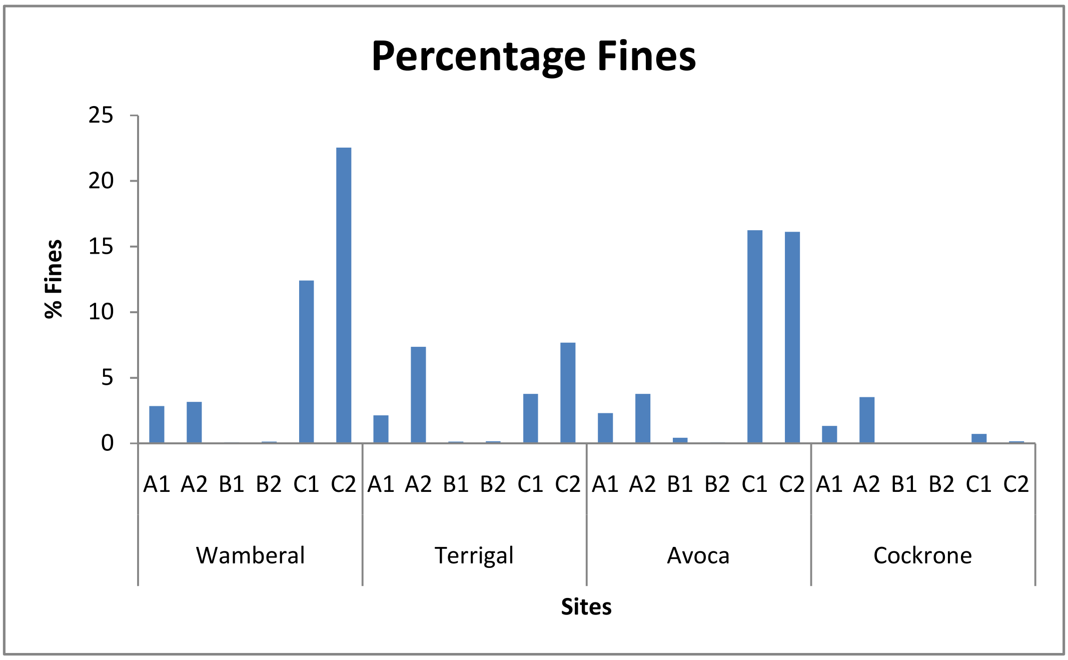


Figure 2.28 Mean percentage fines (% < 63 µm) at each site for each lagoon (A = Basin, B = Berm, C = Creek delta)

Macrobenthos

Macro-invertebrates collected were sorted and identified to family level. All specimens collected are listed in Table 2.9. Some general trends were apparent. Such as, Nerid worms were the most abundant invertebrate collected. Capitellid worms were also abundant. Paracalliopiid amphipods were the most abundant crustacean and were only found in beach berm sediments. Bivalves from the family Trapeziidae were the most abundant mollusc collected.

Table 2.9 Total number of macro-invertebrate specimens collected and identified to family level.

	Family	Total no. individuals
Crustraceans	Mictyridae	2
	Hymenosomatidae	3
	Paracalliopiidae	39
	Exoedicerotidae	51
	Sphaeromatidae	7
	Aegidae	2
Polycheates	Nereididae	210
	Hesionidae	7
	Spionidae	5
	Capitellidae	54
	Orbiniidae	29
Molluscs	Trapeziidae	44
	Eulimidae	1
	Trochidae	1
	Psammobiidae	0
	Donacidae	3
	Assiminidae	5
	Mytilidae	7
Insects	Chironomidae	21
	Lacewing larva	1
	Caddis fly larva	15

In total 412 individual macroinvertebrates were collected. This total consisted of 22 families: 7 families of Molluscs, 5 families of Polychaetes, 6 families of Crustaceans and 3 families of Insects (Table 2.9). Macroinvertebrates were most diverse and abundant within the central mud basin region (e.g. 9 families of macroinvertebrates were found within Avoca basin samples; Figures 2.29 – 2.32). Macroinvertebrates were least diverse within the beach berm region and no macroinvertebrates were found within Terrigal beach berm samples (Figures 2.29 – 2.32). Only one species from one macroinvertebrate family (Paracalliopiidae) was found within the beach berm. This family was also not found within any of the other two regions. Numbers of macroinvertebrate families were highest within the basin region of all ICOLLs, while being lowest within the beach berm region of all ICOLLs (Figures 2.33 – 2.36).

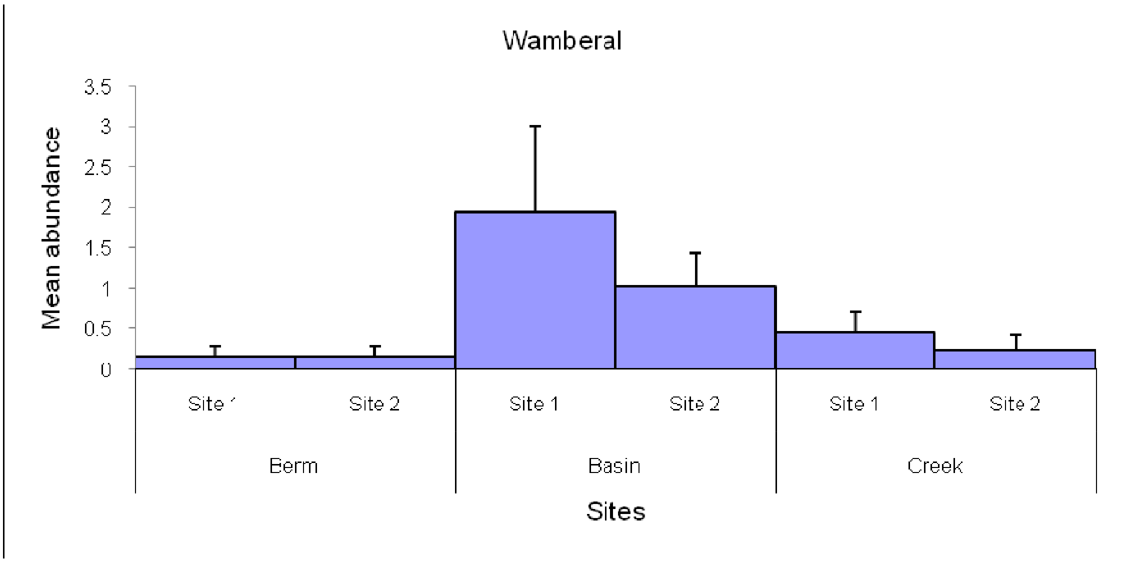


Figure 2.29 Mean densities of macroinvertebrates within Wamberal ICOLL

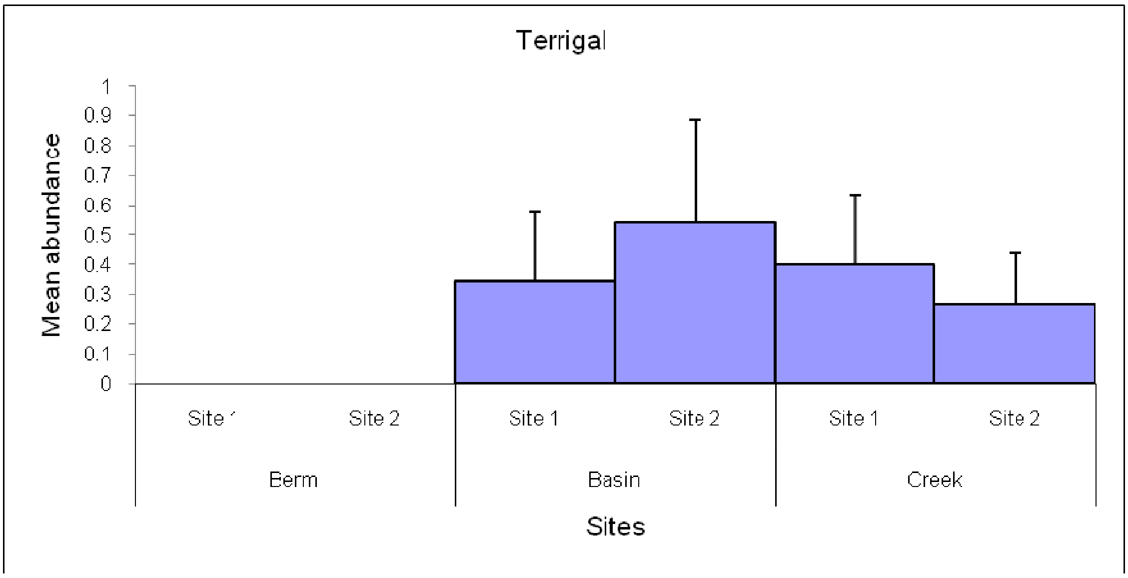


Figure 2.30 Mean densities of macroinvertebrates within Terrigal ICOLL

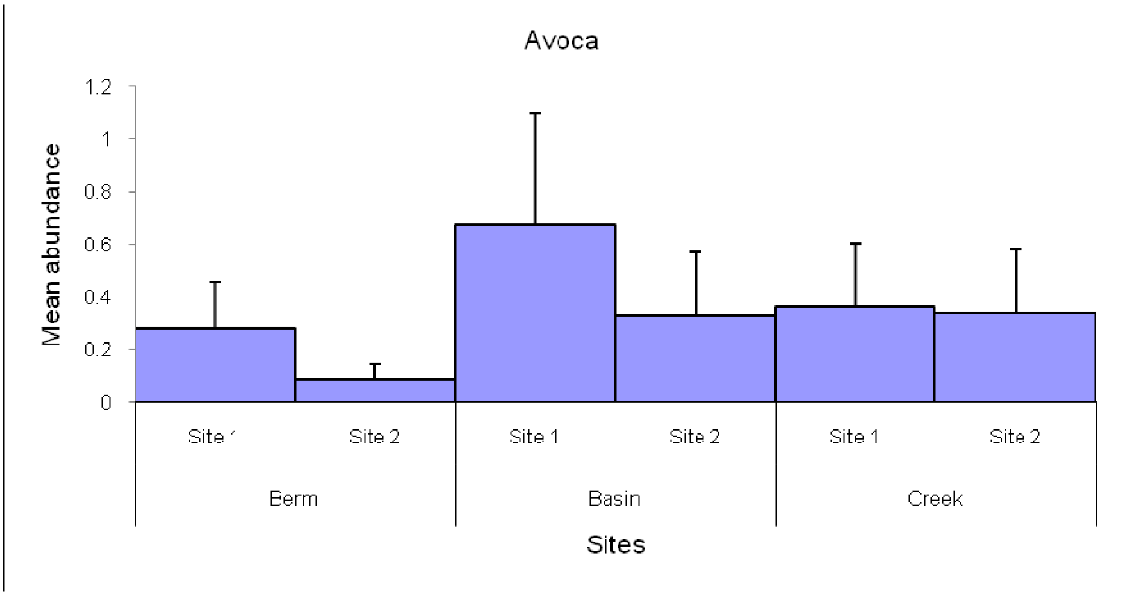


Figure 2.31 Mean densities of macroinvertebrates within Avoca ICOLL

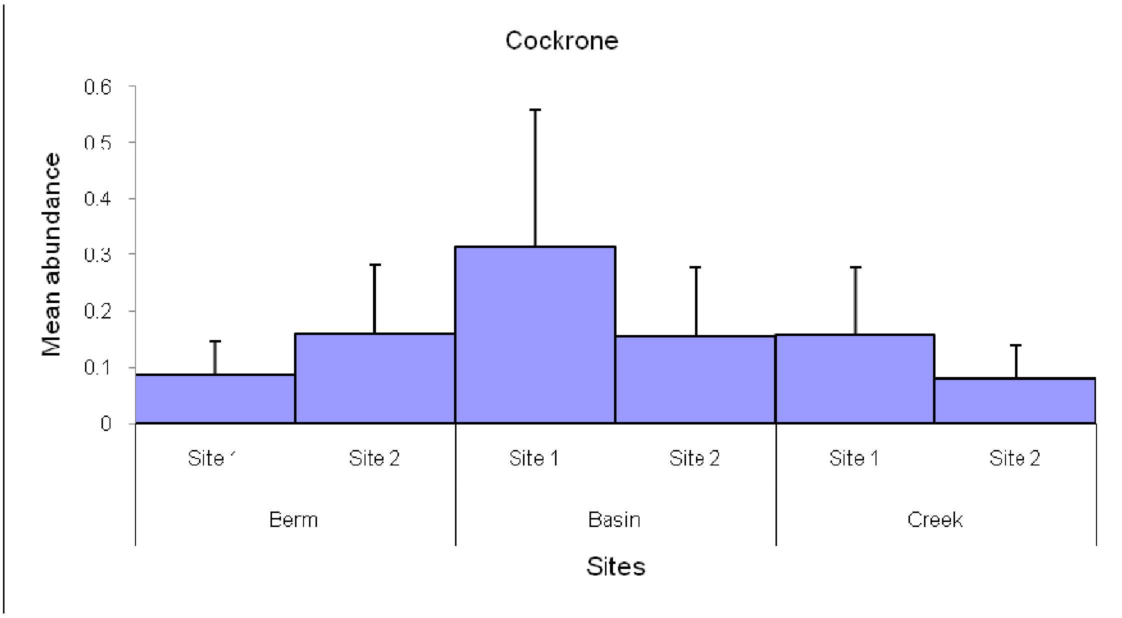


Figure 2.32 Mean densities of macroinvertebrates within Cockrone ICOLL

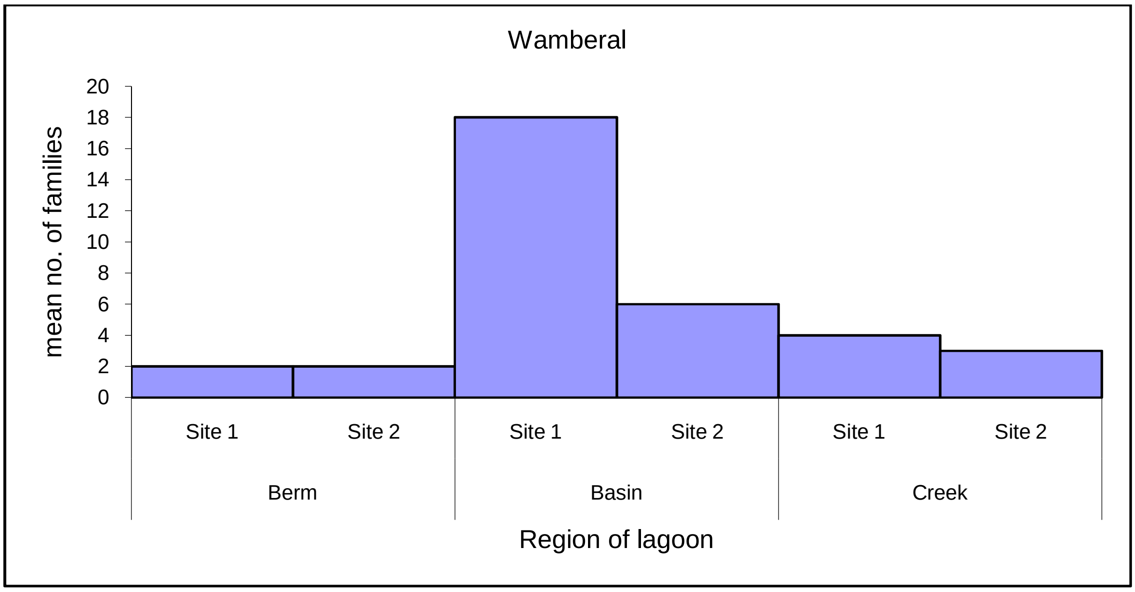


Figure 2.33 Mean number of macroinvertebrate families within Wamberal ICOLL

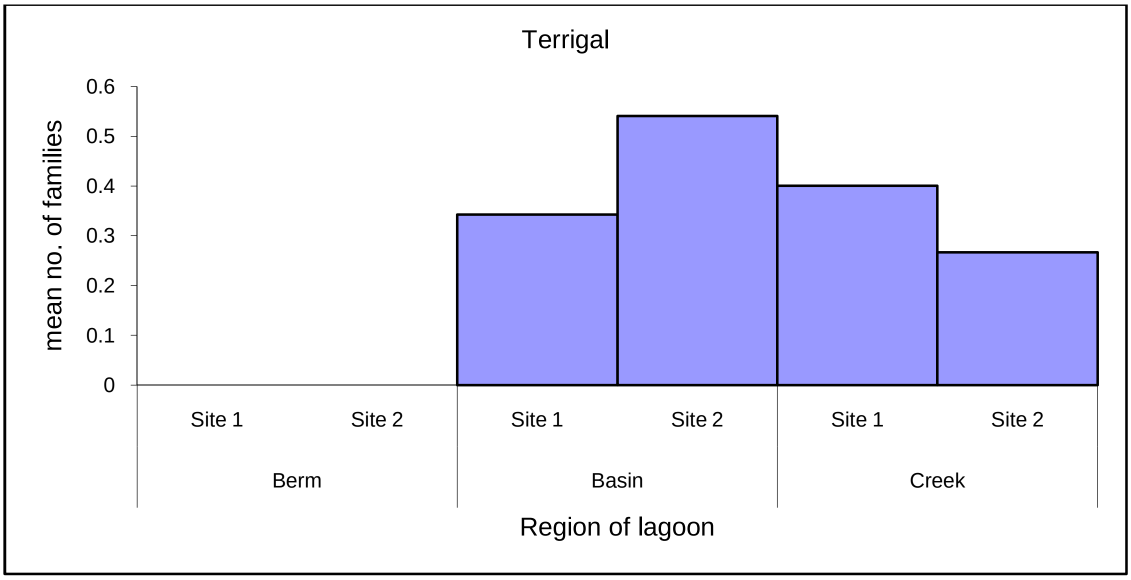


Figure 2.34 Mean number of macroinvertebrate families within Terrigal ICOLL

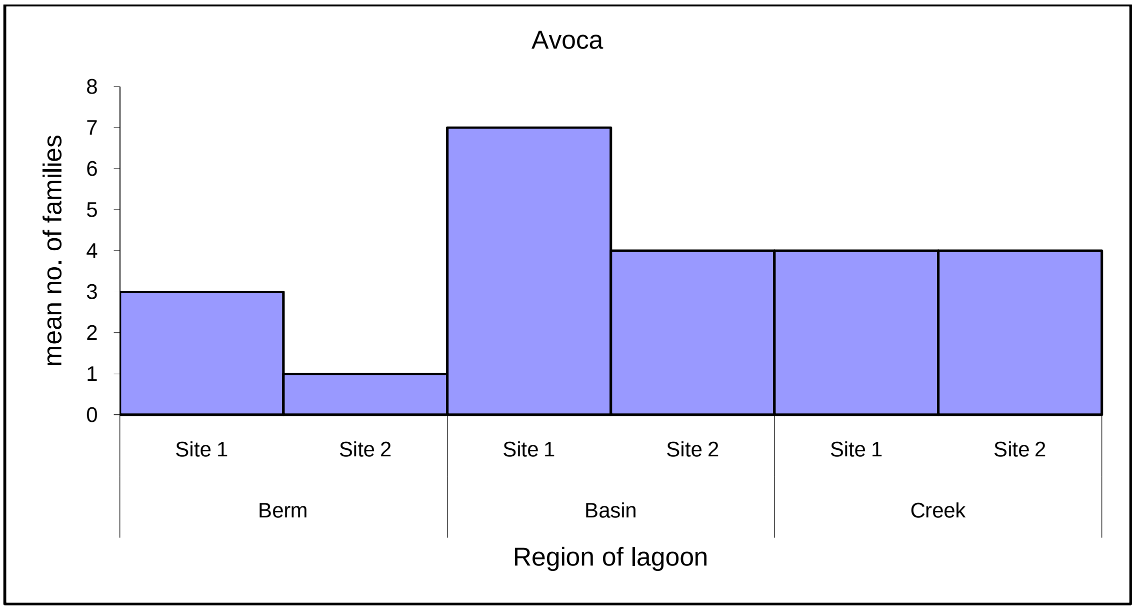


Figure 2.35 Mean number of macroinvertebrate families within Avoca ICOLL

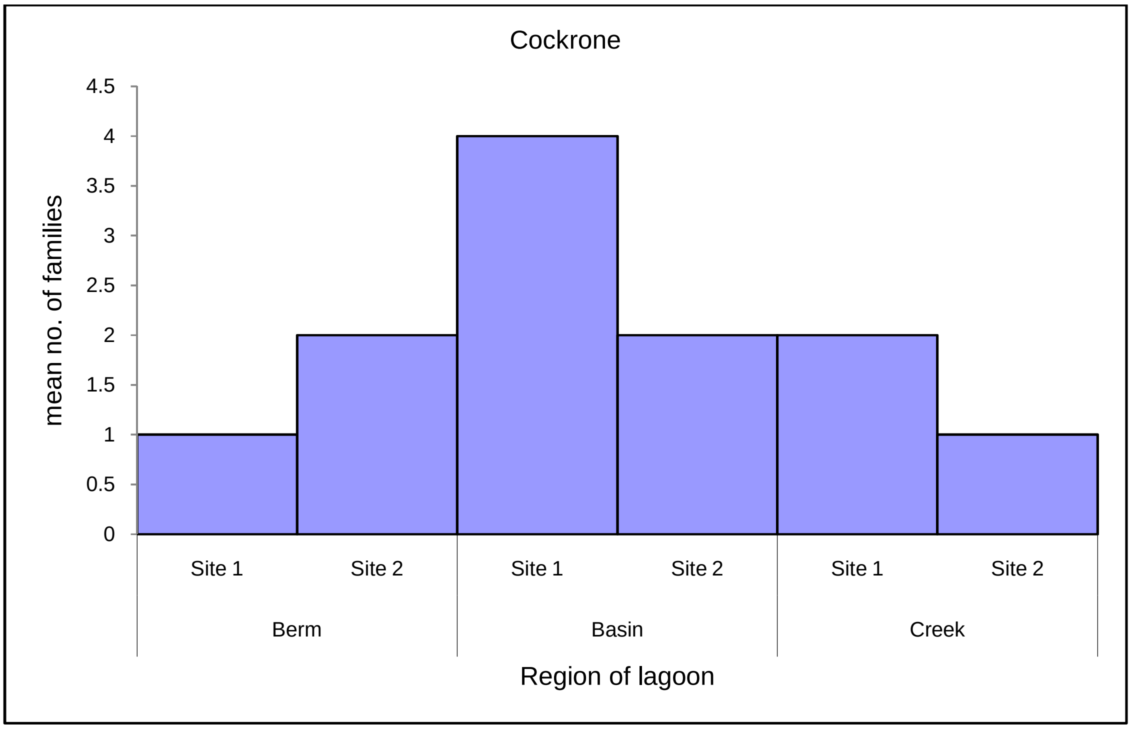


Figure 2.36 Mean number of macroinvertebrate families within Cockrone ICOLL

For the two-way nested ANOSIM (with region nested within ICOLL), there was an overall significant difference in the macrobenthic assemblages between regions (Table 2.10). However, there was not a significant difference in macrobenthic assemblages between any of the four ICOLLs (Tables 2.11 and 2.12). As the significant difference in macrobenthic assemblages between regions within ICOLLs may be offsetting any differences between ICOLLs, a one-way ANOSIM (just on region) was conducted in order to use pairwise tests to determine which regions differ (i.e. regions were treated separately). In doing this, there was a significant difference in macrobenthic assemblages between regions (Table 2.10 and 2.13) and by looking at pairwise tests, differences are high between the beach berm region and the other two (basin and creek), while (despite being significant) were relatively low between basin and creek regions (i.e. low R stat and higher Sig. level; Table 2.14).

Table 2.10 Two-way nested ANOSIM (with region nested within ICOLL) testing for differences between regions (a: across all ICOLLs; b: random sample from a large number).

Global Test	TESTS FOR DIFFERENCES BETWEEN REGIONS (a)
Sample statistic (Global R)	0.613
Significance level	0.10%
Number of permutations	999 (b)
Number of permuted statistics greater than or equal to Global R	0

Table 2.11 Two-way nested ANOSIM (with region nested within ICOLL) testing for differences between ICOLLs (a: using region as samples; b: random sample from 15400)

Global Test	TESTS FOR DIFFERENCES BETWEEN ICOLL (a)
Sample statistic (Global R)	-0.127
Significance level	74%
Number of permutations	999 (b)
Number of permuted statistics greater than or equal to Global R	739

Table 2.12 Pairwise tests for Two-way nested ANOSIM (with region nested within ICOLL)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Wamberal, Terrigal	-0.042	40	10	10	4
Wamberal, Avoca	-0.296	80	10	10	8
Wamberal, Cockrone	-0.167	80	10	10	8
Terrigal, Avoca	-0.083	70	10	10	7
Terrigal, Cockrone	0.167	30	10	10	3
Avoca, Cockrone	-0.222	70	10	10	7

Table 2.13 One-way ANOSIM (region) testing for differences between regions

Global Test	TESTS FOR DIFFERENCES BETWEEN REGIONS
Sample statistic (Global R)	0.326
Significance level	0.10%
Number of permutations	999 (a)
Number of permuted statistics greater than or equal to Global R	0

Table 2.14 Pairwise tests for One-way ANOSIM (region) between ICOLLs

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Basin, Beach	0.586	0.1	Very large	999	0
Basin, Creek	0.053	1.3	Very large	999	12
Beach, Creek	0.456	0.1	Very large	999	0

As five macroinvertebrate samples were so distinctively different from all others, overall MDS ordination plots of these data depict the majority of samples being clumped close together, while the five outliers are spread out far from the majority (Figures 2.37 and 2.39). As a result of this, the ordination plot was edited. Overall ICOLL macroinvertebrate assemblages were removed so that region based macroinvertebrate assemblages could be shown. The ordination plot for macroinvertebrates in regions shows that the beach berm region (on the left) is different from the other two regions (basin and creek; on the right; Figure 2.38). Additionally, the ordination plot depicts the same result as the pairwise test for the regional one-way ANOSIM; that the beach berm regions are very different from the others, while basin and creek regions are far less different from each other (Table 2.14; Figure 2.38).

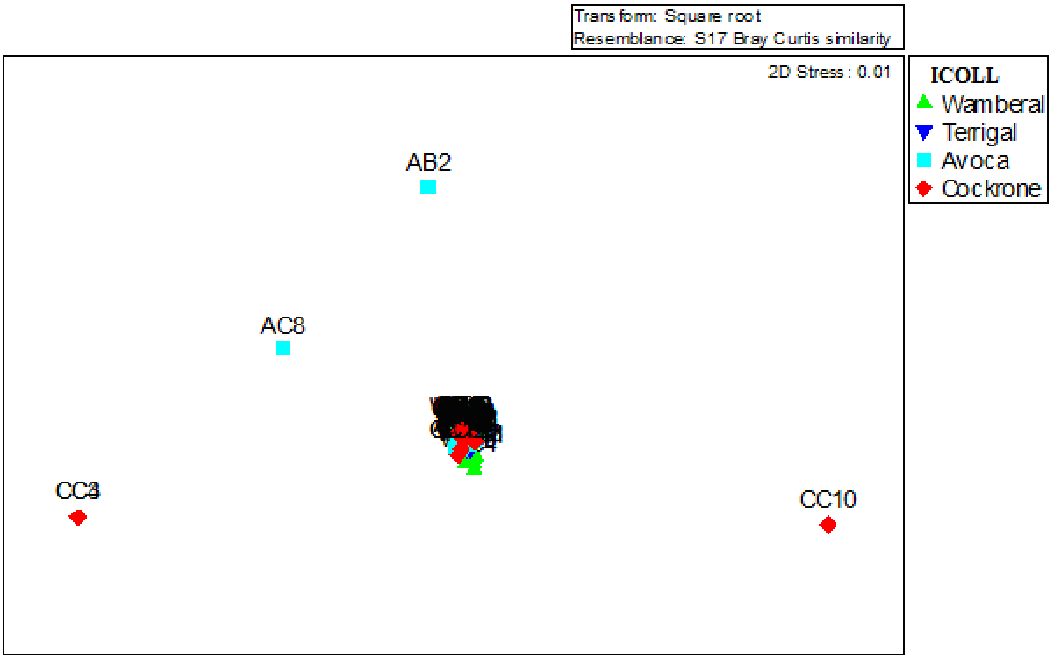


Figure 2.37 Two-dimensional MDS ordination of macroinvertebrates within ICOLLs

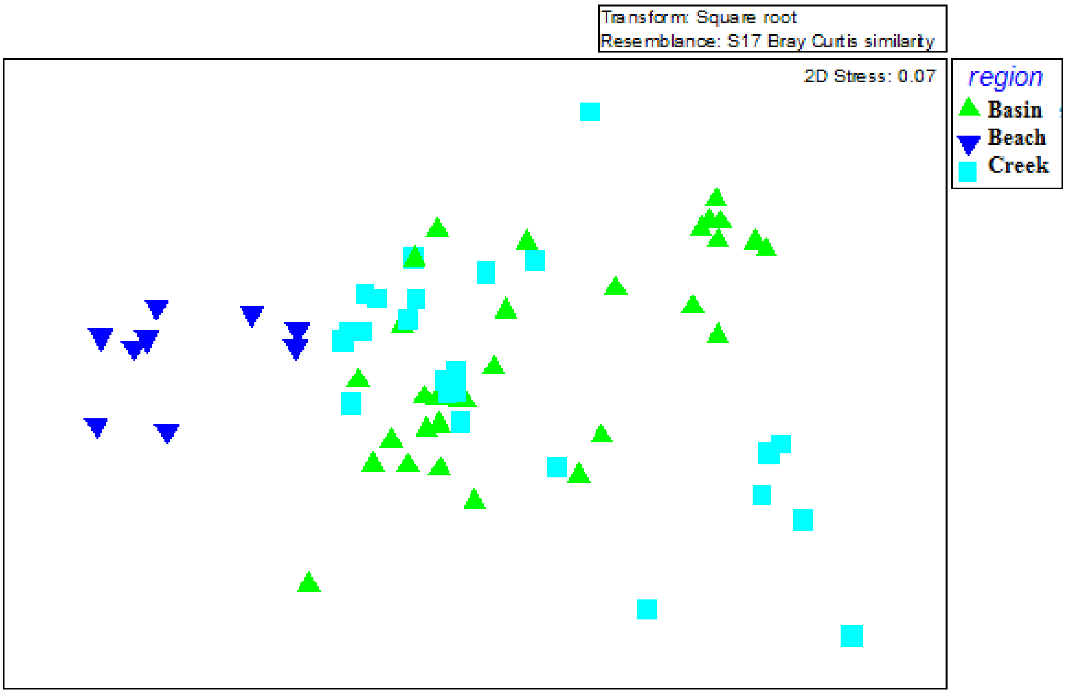


Figure 2.38 Two-dimensional MDS ordination of macroinvertebrates in regions from all ICOLLs

Similarities of percentages (SIMPER) for region depict which macroinvertebrate families have caused any significant difference in macroinvertebrate assemblages between regions of all ICOLLs. Only families that typify these differences are outlined, as these are the distinguishing taxa for each region.

The Arthropod family Paracalliopiidae was found to be the primary cause of difference between beach berm regions and the others (basin and creek; Table 2.15). This family was most abundant within the beach berm regions of the ICOLLs. Families Capitellidae and Exoedicerotidae were the main causes of difference between basin and creek regions, with these families being more abundant within creek regions (Table 2.15).

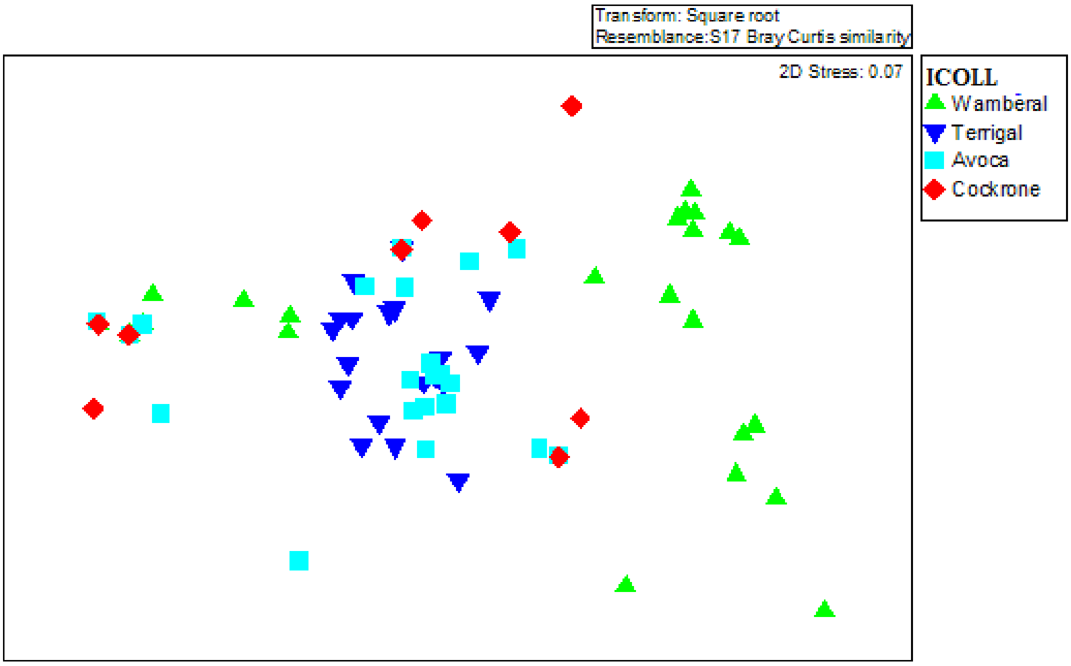


Figure 2.39 Two-dimensional MDS ordination of macroinvertebrates within ICOLLs

Table 2.15 SIMPER of region for all ICOLLs (* taxon is more important in region at top of column)

	Beach	Creek	Basin
Beach	Paracalliopiidae		
Creek	Paracalliopiidae* Nereididae	Nereididae Capitellidae Exoedicerotidae	
Basin	Paracalliopiidae* Nereididae	Capitellidae* Exoedicerotidae*	Nereididae Capitellidae Exoedicerotidae

Using one-way ANOSIM, regions of ICOLLs were also compared individually between ICOLLs (i.e. creek region alone was compared between ICOLLs). Beach berm regions were not compared due to insufficient samples containing counts of macroinvertebrates (e.g. no macroinvertebrates were collected from Terrigal beach berm samples). There was an overall significant difference between the creek regions of all ICOLLs (Table 2.16). Largest differences in creek regions were between Wamberal and Terrigal ICOLLs, Wamberal and Avoca ICOLLs, Terrigal and Cockrone ICOLLs and Avoca and Cockrone ICOLLs (Table 2.17). Smaller differences in creek regions were found to be between Wamberal and Cockrone ICOLLs and Terrigal and Avoca ICOLLs (Table 2.17).

Table 2.16 One-way ANOSIM (creek) testing for differences between ICOLLs (a: random sample from a large number)

Global Test	TESTS FOR DIFFERENCES BETWEEN ICOLLs
Sample statistic (Global R)	0.562
Significance level	0.10%
Number of permutations	999 (a)
Number of permuted statistics greater than or equal to Global R	0

Table 2.17 Pairwise tests for One-way ANOSIM (creek) between ICOLLs

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Wamberal, Terrigal	0.933	0.1	8008	999	0
Wamberal, Avoca	0.704	0.1	8008	999	0
Wamberal, Cockrone	0.5	0.2	462	462	1
Terrigal, Avoca	0.129	3	92378	999	29
Terrigal, Cockrone	0.817	0.1	8008	999	0
Avoca, Cockrone	0.518	0.1			

MDS ordination plots similarly show these differences and similarities. Macroinvertebrate assemblages are similar between the creek regions of Wamberal and Cockrone and especially Terrigal and Avoca ICOLLs (Figure 2.40 and 2.41). Alternatively, while still being significant significantly different Wamberal is dissimilar to Terrigal and Avoca ICOLLs, Terrigal is dissimilar to Cockrone and Avoca is dissimilar to Cockrone (Figures 2.40 and 2.41).

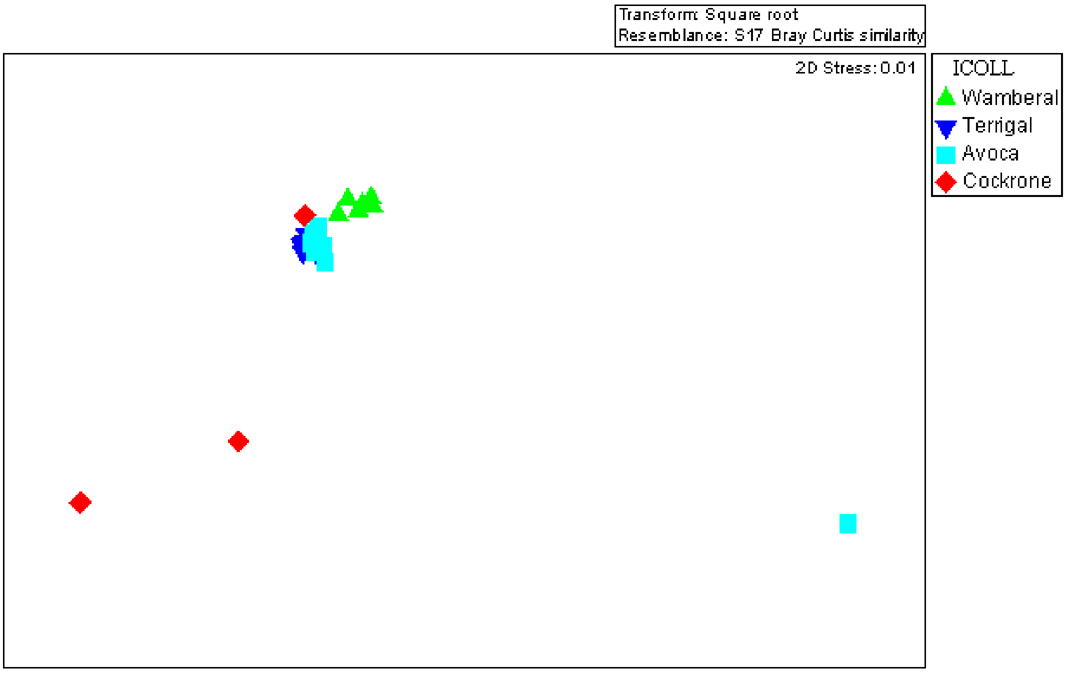


Figure 2.40 Two-dimensional MDS ordination of macroinvertebrates within creek region between ICOLLs

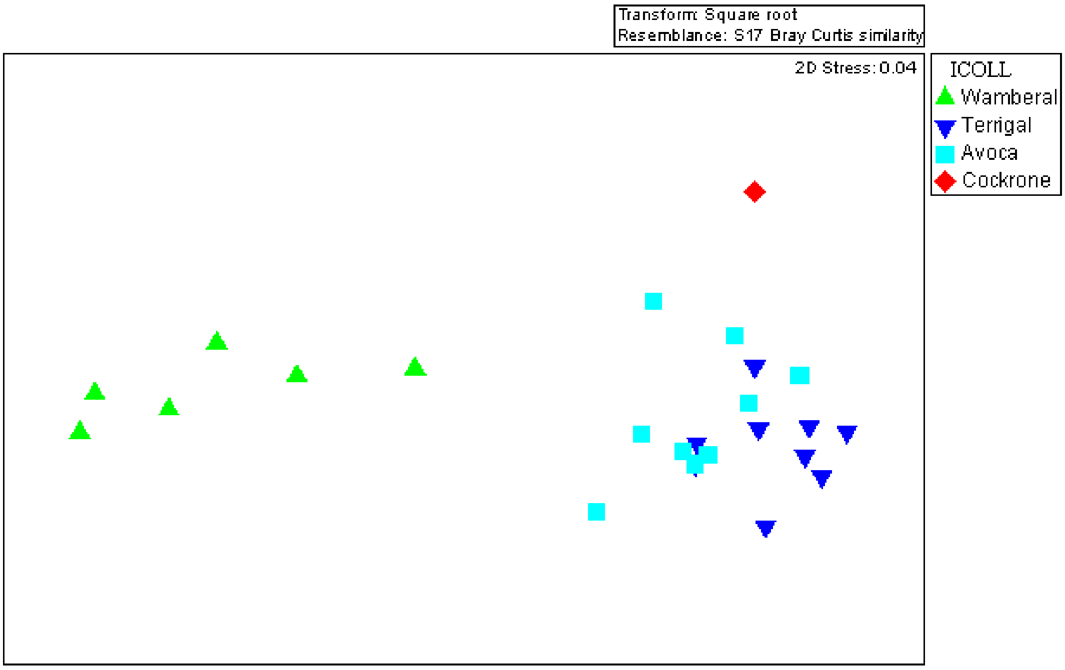


Figure 2.41 Two-dimensional MDS ordination of macroinvertebrates within creek region between ICOLLs (subset of clumped points within Figure 2.31)

The following similarities of percentages (SIMPER) for creek region depict which macroinvertebrate families have caused any significant difference in macroinvertebrate assemblages between creeks of ICOLLs. Only families that typify these differences are outlined, as these are the distinguishing taxa for each ICOLL's creek region.

Nereididae, Caddis fly larvae and Spaeromatidae families were found to be the primary cause of difference between creek regions of Wamberal and Terrigal ICOLLs, with these families being more abundant within Wamberal. Similar results were obtained for differences between creek regions of Wamberal and Avoca ICOLLs. Capitellidae and Hesionidae families were found to be the primary cause of difference between creek regions of Terrigal and Avoca ICOLLs, with these families being more abundant within Terrigal. Spaeromatidae, Caddis fly larvae and Exoedicerotidae families were found to be the primary cause of difference between creek regions of Wamberal and Cockrone ICOLLs, with these families being more abundant within Wamberal. Nereididae and Exoedicerotidae families were found to be the primary cause of difference between creek regions of Terrigal and Cockrone ICOLLs, with these families being more abundant within Terrigal. Nereididae and Capitellidae families were found to be the primary cause of difference between creek regions of Avoca and Cockrone ICOLLs, with these families being more abundant within Avoca.

There was an overall significant difference between the basin regions of ICOLLs (Table 2.18). Significant differences in basin regions were found between Wamberal and Terrigal, Wamberal and Avoca, Wamberal and Cockrone, and Terrigal and Cockrone ICOLLs (Table 2.19). However, there were no significant differences in basin regions between Terrigal and Avoca, and Avoca and Cockrone ICOLLs (Table 2.19). MDS ordination plots support these differences and similarities. Macroinvertebrate assemblages within Wamberal ICOLL are dissimilar to the other three ICOLLs (Figure 2.42). Similar differences occur between Terrigal and Cockrone ICOLLs, while Avoca and Terrigal, and Avoca and Cockrone ICOLLs are similar to each other (Figure 2.42).

Table 2.18 One-way ANOSIM (basin) testing for differences between ICOLLs (a: random sample from a large number)

Global Test	TESTS FOR DIFFERENCES BETWEEN ICOLLs
Sample statistic (Global R)	0.657
Significance level	0.10%
Number of permutations	999 (a)
Number of permuted statistics greater than or equal to Global R	0

Table 2.19 Pairwise tests for One-way ANOSIM (basin) between ICOLLs

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Wamberal, Terrigal	0.998	0.1	92378	999	0
Wamberal, Avoca	0.89	0.1	92378	999	0
Wamberal, Cockrone	0.885	0.1	3003	999	0
Terrigal, Avoca	0.076	7.2	92378	999	71
Terrigal, Cockrone	0.65	0.1	3003	999	0
Avoca, Cockrone	0.172	11	3003	999	109

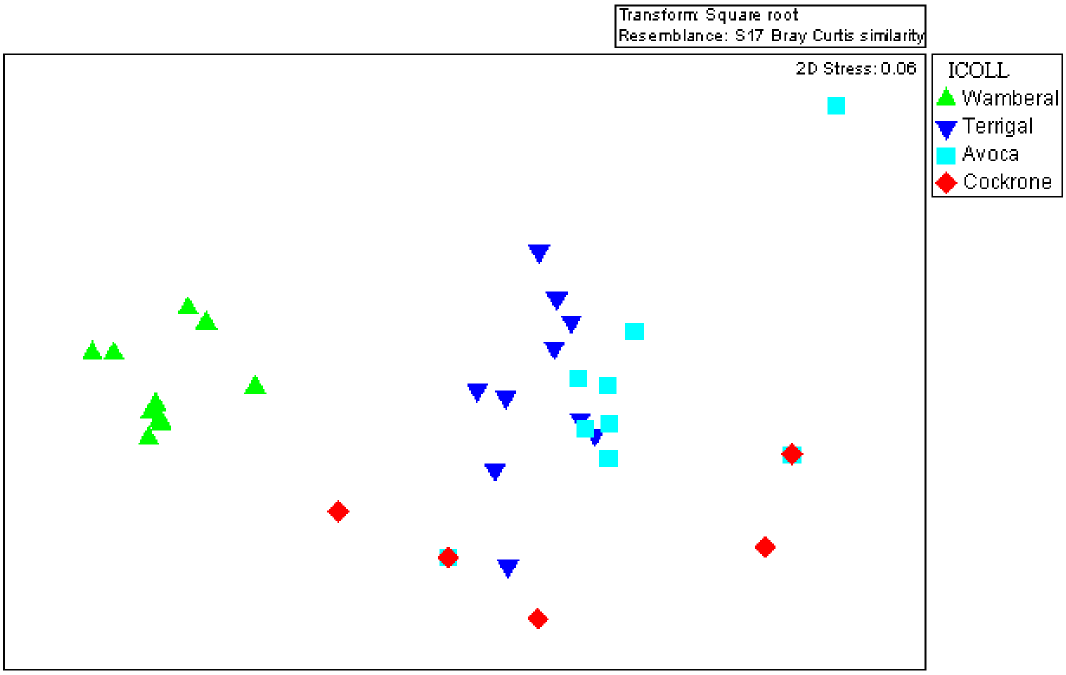


Figure 2.42 Two-dimensional MDS ordination of macroinvertebrates within basin region between ICOLLs

The following similarities of percentages (SIMPER) for basin region depict which macroinvertebrate families have caused any significant difference in macroinvertebrate assemblages between basins of ICOLLs. Only families that typify these differences are outlined, as these are the distinguishing taxa for each ICOLL's basin region.

Exoedicerotidae and Trapeziidae families were found to be the primary cause of difference between basin regions of Wamberal and Terrigal ICOLLs, with these families being more abundant within Wamberal. Trapeziidae and Exoedicerotidae families were found to be the primary cause of difference between creek regions of Wamberal and Avoca ICOLLs, with these families being more abundant within Wamberal. Capitellidae and Nereididae families were found to be the primary cause of difference between creek regions of Terrigal and Avoca ICOLLs, with these families being more abundant within Terrigal. Trapeziidae and Exoedicerotidae families were found to be the primary cause of difference between creek regions of Wamberal and Cockrone ICOLLs, with these families being more abundant within Wamberal. Nereididae and Capitellidae families were found to be the primary cause of difference between creek regions of Terrigal and Cockrone ICOLLs, with these families being more abundant within Terrigal. Capitellidae and Nereididae families were found to be the primary cause of difference between creek regions of Avoca and Cockrone ICOLLs, with these families being more abundant within Avoca.

BIO-ENV analyses were conducted to compare biotic patterns of macroinvertebrate assemblages to the environmental variables using mean data for two sites within each region of all four ICOLLs. Biota and environment matching was conducted using the BEST subroutine using Euclidean distances rather than transformed data based on Bray-Curtis similarity measures. The environmental variables considered were:

1. temperature
2. DO
3. pH
4. salinity
5. turbidity
6. OC
7. sediment fines

With a Spearman's correlation of 0.345, salinity and turbidity were found to be the most distinguishing environmental variables to the biotic patterns of macroinvertebrate assemblage within all regions of all ICOLLs (Table 2.20).

Table 2.20 Best results for Biota and Environment variable matching

No.Vars	Corr. Selections
2	0.345 4,5
3	0.344 3-5
4	0.318 1,3-5
3	0.318 1,4,5
2	0.308 3,5
1	0.308 5
3	0.288 1,3,5
2	0.288 1,5
4	0.270 3-5,7
3	0.270 4,5,7

In an attempt to interpret patterns of distribution and abundance of macrobenthic invertebrates, whilst at the same time giving consideration to environmental variables which influence these patterns, a canonical correspondence analysis (CCA) was conducted. The first CCA biplot (Figure 2.43) illustrates relationships between both macrobenthic families and complete sample-units (comprised of the abundance of all families in a particular sample) to each other and to the environmental variables (Total Nitrogen (TN), Total Phosphorous (TP), Chlorophyll *a* (Chl a), Salinity (Sal), Dissolved Oxygen (DO), Temperature (Temp), pH, Turbidity (Turb), Organic Carbon (OC), Percentage Fines (Fines), Distance from beach berm (Dist) and Foreshore Condition (FC)). The variables depth and fetch were shown to have little influence and were therefore excluded to reduce noise in the biplot (Figure 2.43). Each point represents the weighted average of the family or sample-unit (ter Braak and Verdonschot, 1995). Individual families are denoted by triangles with the name of the family abbreviated to first three letters (see Table 2.13 for full family name). The relationship between families and 12 environmental variables is significant (P-value = 0.0080 < 0.05).

The arrows point in the direction of maximum change in an environmental variable. The length of the arrow is directly proportional to the rate of change in the variable – the longer the arrow the greater the rate. In general, environmental variables with long arrows are likely to be more closely related to the pattern of variation displayed between families and sample-units than are short arrows. The combined plot of families, sample-units and environmental arrows is in fact a biplot that approximates the weighted averages with respect to the environmental variables. By projection of the sample or the family (by eye) orthogonally onto arrows corresponding to environmental variables the family/environmental relationships can be elucidated. This procedure enables identification of variables that principally influence particular families or sample-units and enables them to be ranked in terms of their response to particular variables.

The weighted averages are approximated as deviations from the mean value of each environmental variable, which is represented by the origin. Inferred weighted averages are higher than the mean when a projected point lies on the same side of the origin as an arrow-head, and are lower than average when the origin lies between a projected point and an arrow-head.

Families or sample-units that are unrelated to the environmental variables tend to be placed near the origin, and consequently are not distinguished from families or sample-units having true optima there. CCA also has the tendency to place species-poor sites which are generally environmentally impoverished sites at the end of the horizontal dimension of the biplot.

In all CCAs the beach berm samples containing the Paracalliopiidae amphipods were omitted to help spread the remaining invertebrates. It is apparent, without statistical analysis, that Paracalliopiidae is most strongly influenced by the presence of the beach berm and its presence in the biplot concentrates the other invertebrates too tightly. It can be seen in Figure 2.43 that several families are grouped tightly and are it is difficult to distinguish individual families. To clarify relationships, 2 further CCAs were undertaken, separating water quality variables from the variables related to distance from beach berm, foreshore condition and the sediment variables, organic carbon and percentage fines (Figure 2.44 and 2.45).

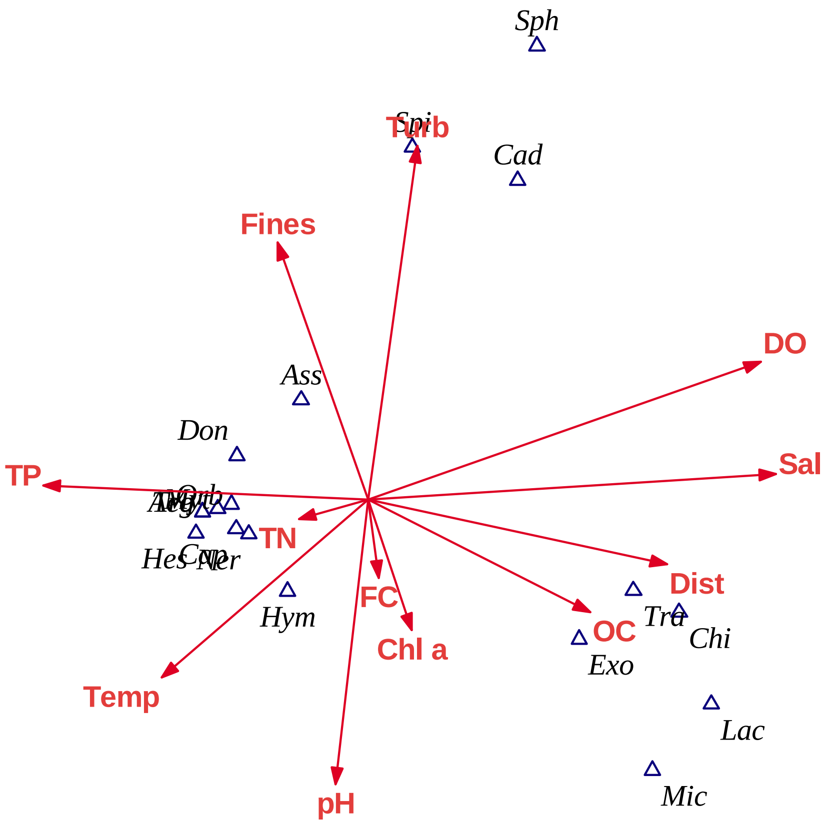


Figure 2.43 CCA Biplot with family and environmental values (Test of significance of all canonical axes: Trace = 2.459, F-ratio = 2.165, P-value = 0.0080, Goodness of fit (%): 31.6, 55.7, 69.1, 80.0) (Families: Mic, Mictyridae; Hym, Hymenosomatidae; Par, Paracalliopiidae; Exo, Exoedicerotidae; Sph, Sphaeromatidae; Aeg, Aegidae; Ner, Nereididae; Hes, Hesionidae; Spi, Spionidae; Cap, Capitellidae; Orb, Orbiniidae; Tra, Trapeziidae; Eul, Eulimidae; Tro, Trochidae; Psa, Psammobiidae; Don, Donacidae; Ass, Assiminidae; Myt, Mytilidae; Chi, Chironomidae; Lac, Lacewing larva; Cad, Caddis fly larva)

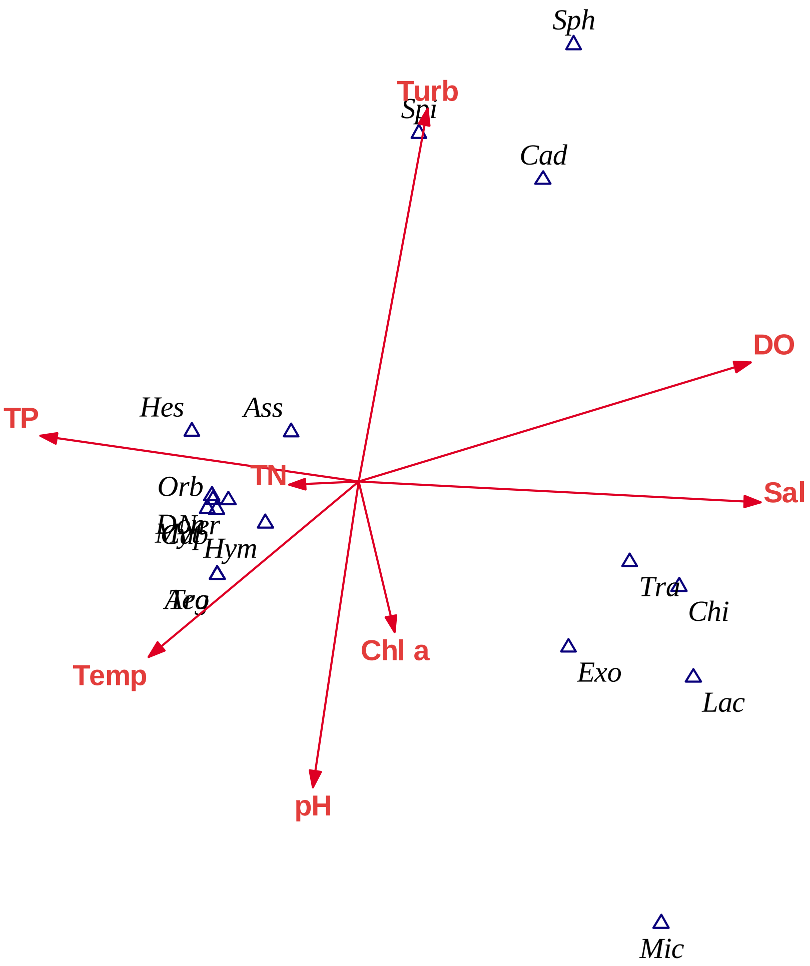


Figure 2.44 Species-Water Quality CCA Biplot with family and environmental values and without beach berm samples (Test of significance of all canonical axes: Trace = 2.155, F-ratio = 3.432, P-value = 0.0020, Goodness of fit (%): 35.4, 59.4, 74.2, 84.1) (Families: Mic, Mictyridae; Hym, Hymenosomatidae; Exo, Exoedicerotidae; Sph, Sphaeromatidae; Aeg, Aegidae; Ner, Nereididae; Hes, Hesionidae; Spi, Spionidae; Cap, Capitellidae; Orb, Orbiniidae; Tra, Trapeziidae; Eul, Eulimidae; Tro, Trochidae; Psa, Psammobiidae; Don, Donacidae; Ass, Assiminidae; Myt, Mytilidae; Chi, Chironomidae; Lac, Lacewing larva; Cad, Caddis fly larva) (499 permutations under reduced model).

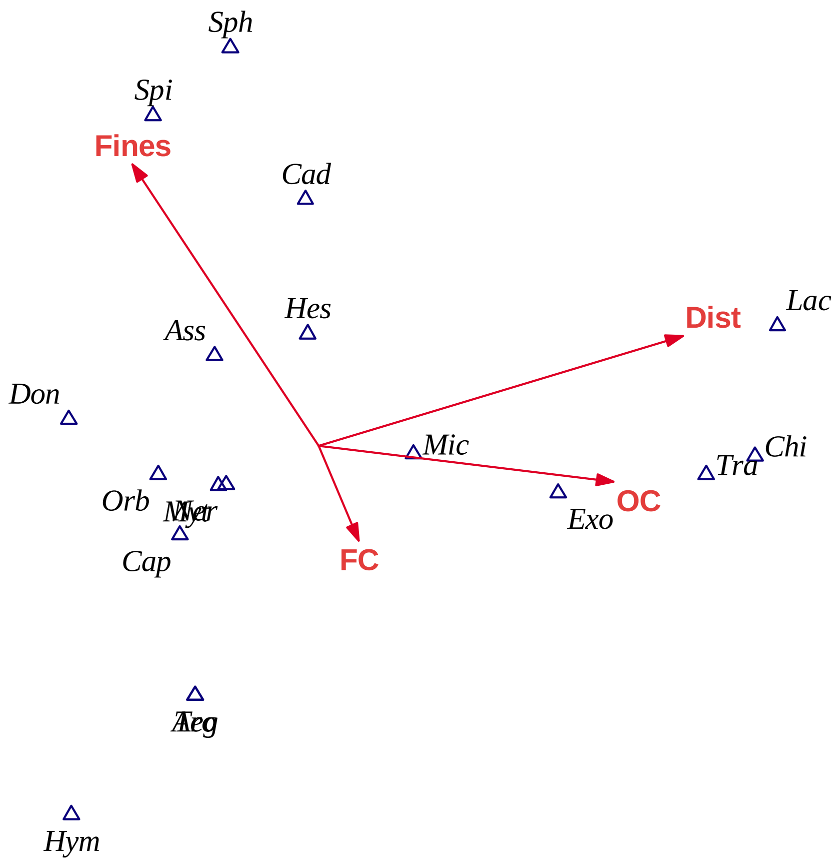


Fig 2.45 Species-sediment/distance from berm/foreshore condition CCA Biplot with family and environmental values and without beach berm samples (Test of significance of all canonical axes: Trace = 1.162, F-ratio = 1.869, P-value = 0. 0100, Goodness of fit (%): 52.8, 78.1, 94.0, 100.0) (Families: Mic, Mictyridae; Hym, Hymenosomatidae; Exo, Exoedicerotidae; Sph, Sphaeromatidae; Aeg, Aegidae; Ner, Nereididae; Hes, Hesionidae; Spi, Spionidae; Cap, Capitellidae; Orb, Orbiniidae; Tra, Trapeziidae; Eul, Eulimidae; Tro, Trochidae; Psa, Psammobiidae; Don, Donacidae; Ass, Assiminidae; Myt, Mytilidae; Chi, Chironomidae; Lac, Lacewing larva; Cad, Caddis fly larva) (499 permutations under reduced model).

Figure 2.44 suggests that in the absence of the other variables related to sediment and location, the invertebrates form 3 distinct groups. The first of these are grouped around higher nutrient values and lower salinities and lower dissolved oxygen levels. The second group are the opposite of this and the third group are associated with higher turbidity and more acidic water. This latter group include the insects, found in the creek deltas. The biplots indicate that the insects and the bivalve mollusc Trapeziidae are also influenced by distance from the beach berm and higher organic carbon content (Figure 2.45), as would be expected given the results of the previous biplot (Figure 2.44). The bulk of the remaining macrobenthos is concentrated closer to the origin and demonstrate a relationship with the finer sediments found in the basin and creek delta regions.

Multiple regression analyses indicated that there were no significant correlations between species richness or species diversity with any of the variables sampled. The strongest correlations and therefore arguably the most important variables were sediment organic carbon, sediment percentage fines and distance from beach berm. This was the case for both total abundance and diversity of species (Tables 2.21-2.22, Figures 2.46-2.51).

Table 2.21 Regression models best describing relationships between species richness and environmental parameters using multiple linear regression.

Regression Summary for Dependent Variable: Species richness						
R= 0.974 R^2= 0.949 Adjusted R^2= 0.436						
F(10,1)=1.850 p<0.521Std. Error of estimate: 35.518						
		St. Err.		St. Err.		
	BETA	of BETA	B	of B	t(1)	*p*-level
Intercept			**978.57**	**2430.18**	**0.40**	**0.76**
Organic Carbon	**0.26**	0.63	8.46	20.69	0.41	0.75
% Fines	**-1.25**	0.94	-29.94	22.36	-1.34	0.41
Distance to berm	**1.30**	0.71	24.98	13.55	1.84	0.32

Regression models are presented with standardised beta coefficients for each independent variable to assess their contributions to the overall relationship. The adjusted determination coefficient (R^2) and significant level (p) are also displayed. Independent variables were transformed (ln) prior to analysis.

Table 2.22 Regression models best describing relationships between total species abundance and environmental parameters using multiple linear regression.

Regression Summary for Dependent Variable: Species abundance						
R= 0.983 R^2= 0.967 Adjusted R^2= 0.638						
F(10,1)=2.9360 p<0.428 Std.Error of estimate: 1.680						
		St. Err.		St. Err.		
	BETA	of BETA	B	of B	t(1)	*p*-level
Intercept			-11.47	114.93	-0.10	0.94
Organic Carbon	0.13	0.50	0.25	0.98	0.26	0.84
% Fines	-0.36	0.75	-0.51	1.06	-0.48	0.72
Distance to berm	0.82	0.57	0.93	0.64	1.45	0.38

Regression models are presented with standardised beta coefficients for each independent variable to assess their contributions to the overall relationship. The adjusted determination coefficient (R^2) and significant level (p) are also displayed. Independent variables were transformed (ln) prior to analysis.

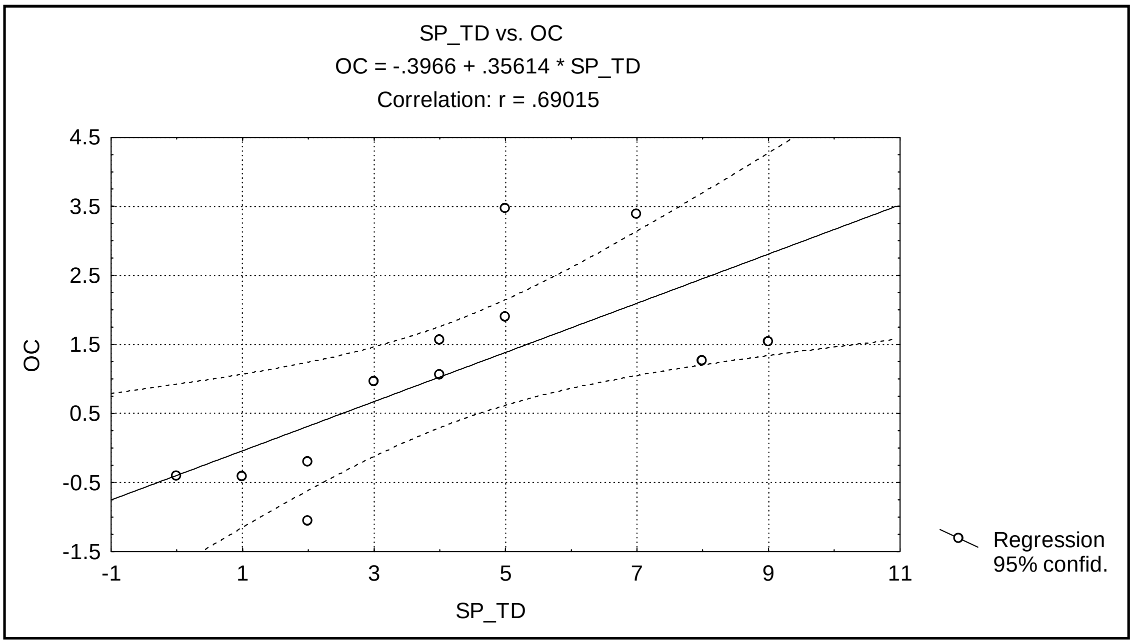


Figure 2.46 Correlation scatter plot illustrating relationship between organic carbon (OC) and total density of species (SP_TD) (r = 0.69, 95% confidence)

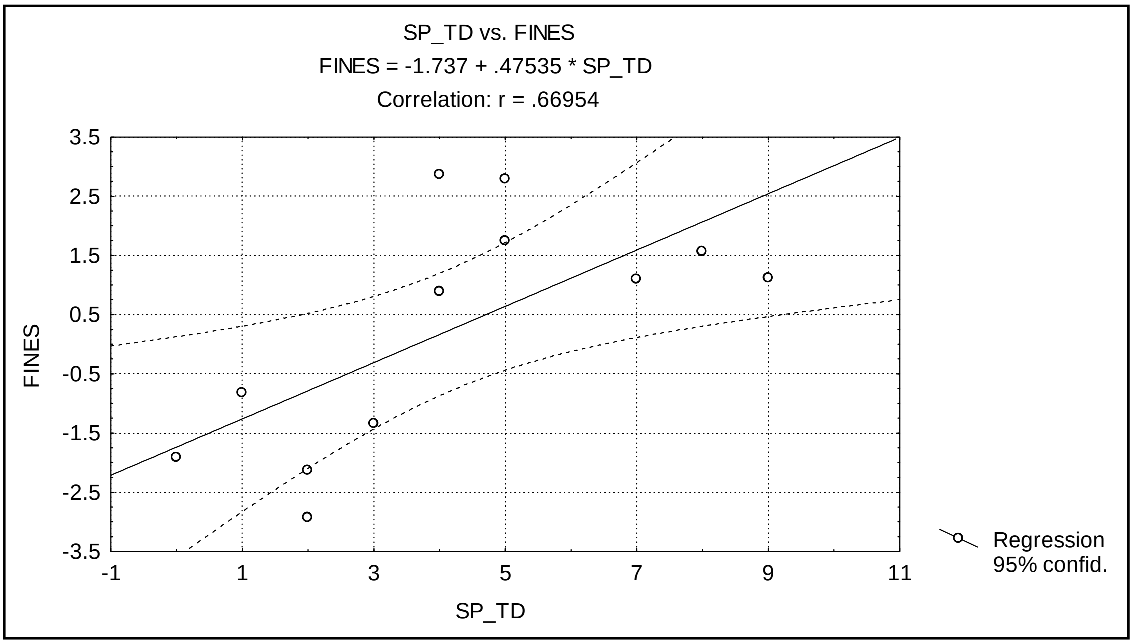


Figure 2.47 Correlation scatter plot illustrating relationship between sediment percentage fines (% < 63 µm) and total density of species (SP_TD) (r = 0.67, 95% confidence)

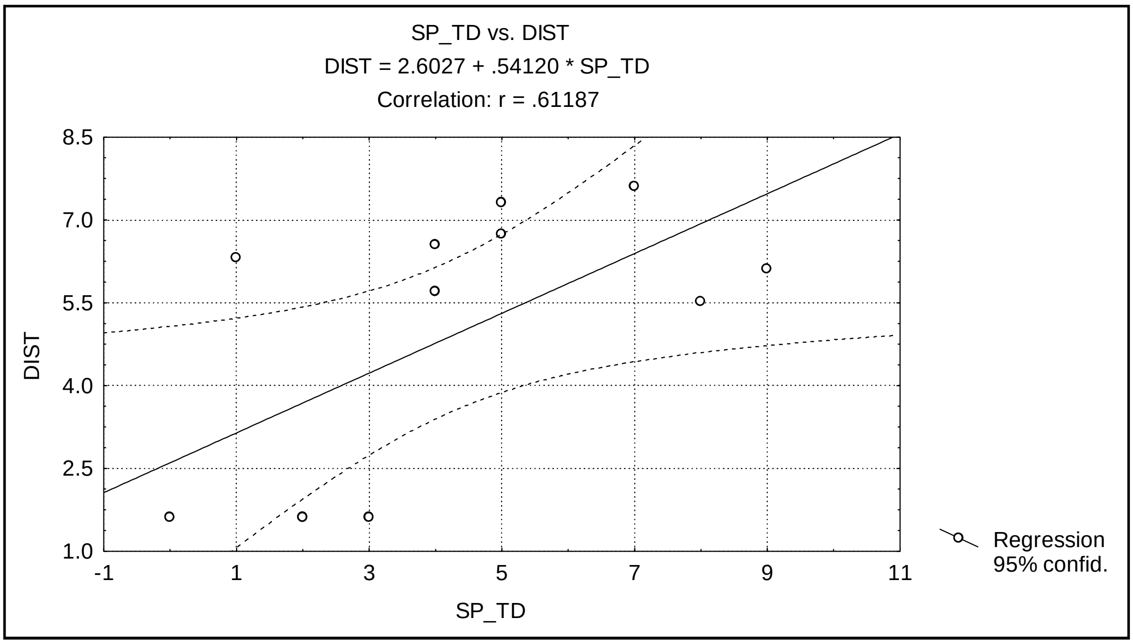


Figure 2.48 Correlation scatter plot illustrating relationship between distance from beach berm (DIST) and total density of species (SP_TD) (r = 0.61, 95% confidence)

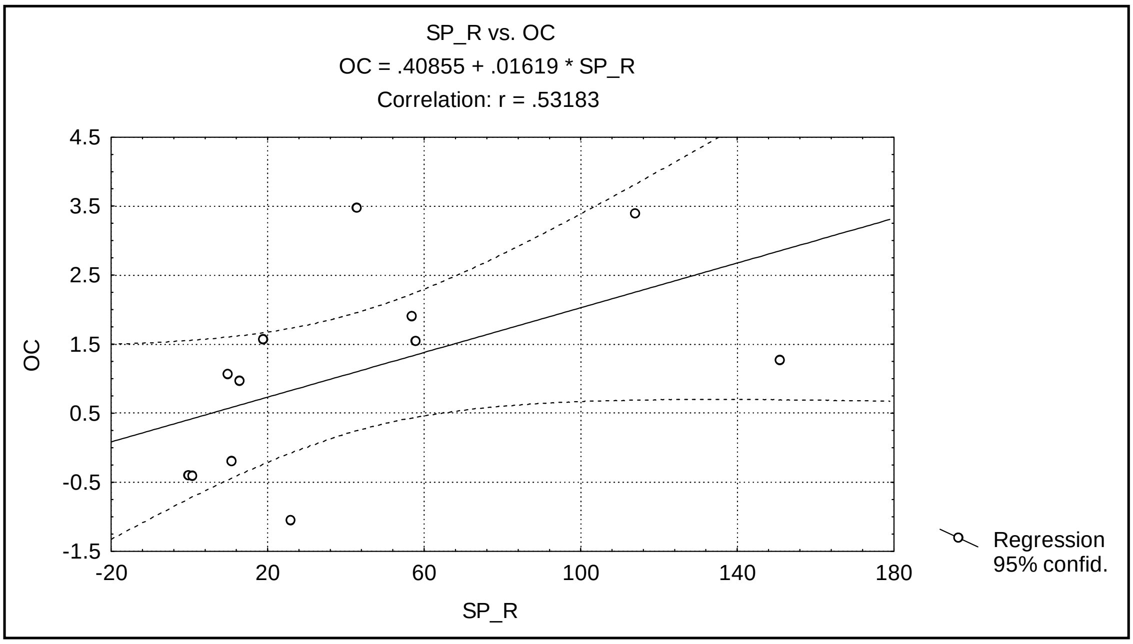


Figure 2.49 Correlation scatter plot illustrating relationship between organic carbon (OC) and species richness (SP_R) (r = 0.53, 95% confidence)

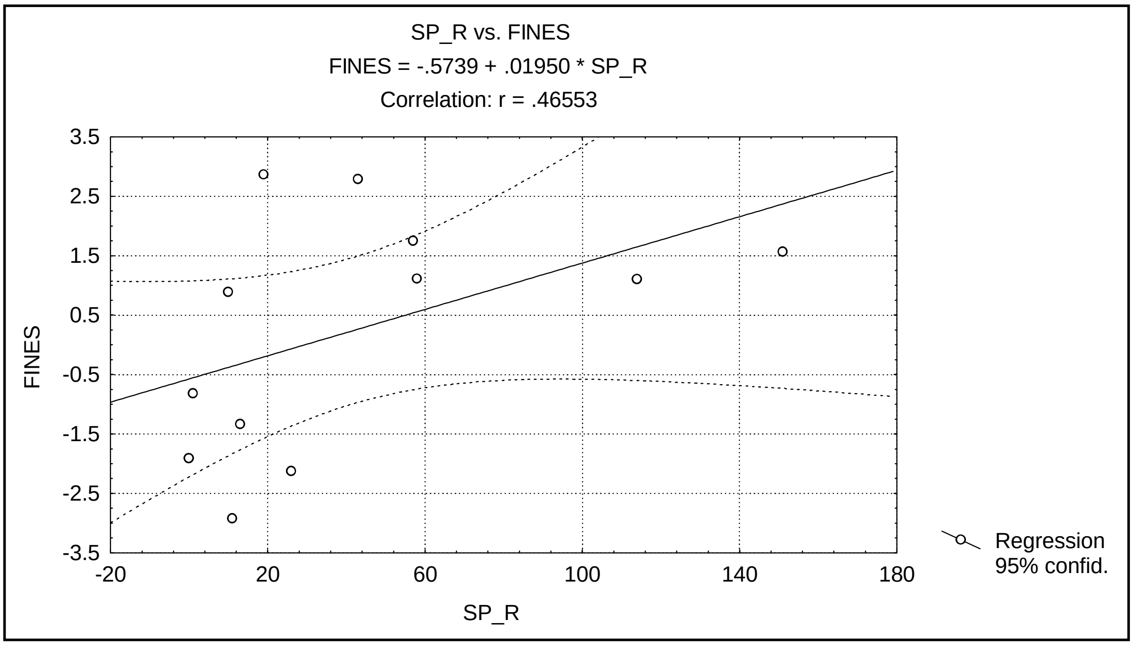


Figure 2.50 Correlation scatter plot illustrating relationship between sediment percentage fines (% < 63 µm) and species richness (SP_R) (r = 0.46, 95% confidence)

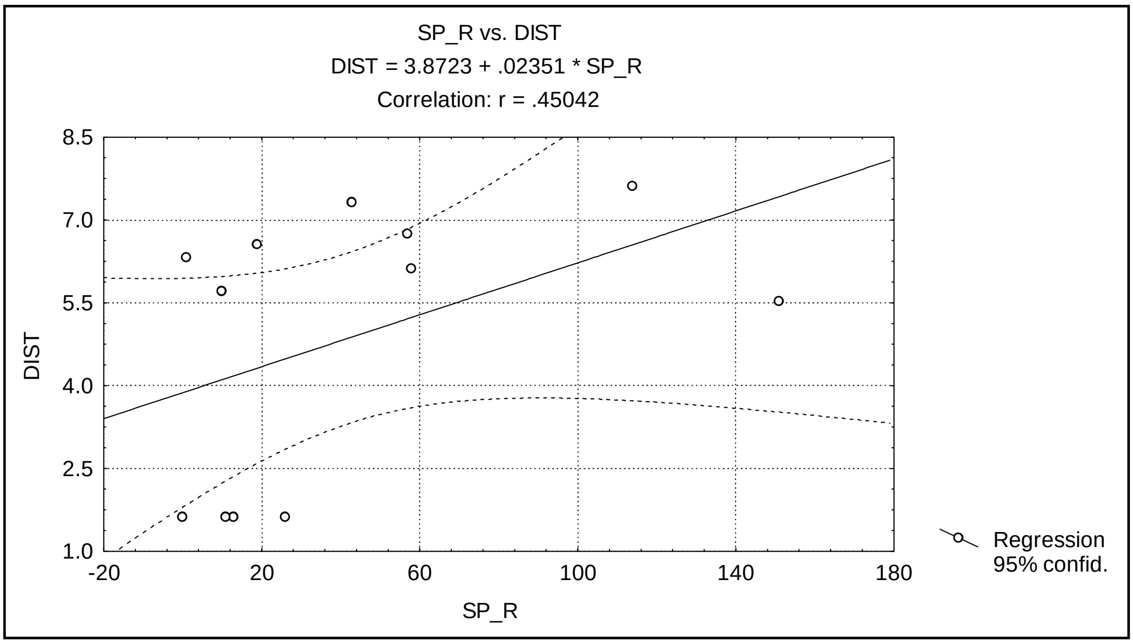


Figure 2.51 Correlation scatter plot illustrating relationship between distance from beach berm (DIST) and species richness (SP_R) (r = 0.45, 95% confidence)

2.2.4 Discussion

Aside from documenting the macrobenthos of the lagoons, the objectives of this study were to compare the benthic macroinvertebrate assemblages of different regions. This was tested by comparing the benthic macroinvertebrate abundance, diversity and assemblage structure. An additional aim of this study was to determine whether or not particular environmental variables influence patterns of distribution and abundance of benthic macroinvertebrates within these lagoons.

Numbers of families and individuals of macroinvertebrates were highest within the central mud basin region of all ICOLLs and lowest within the beach berm region of all ICOLLs. As such, the hypothesis that; the number of families and number of individuals of all families of benthic macroinvertebrates will differ among the three regions (beach berm, basin and creek), of the four ICOLLs; has been supported. Of the 22 families of macroinvertebrates, only one species of one family (Paracalliopiidae) was found within the beach berm region of Wamberal, Avoca and Cockrone lagoons. This family, however, was not found within the beach berm of Terrigal Lagoon nor any of the non-beach berm regions of any of the ICOLLs.

There was an overall significant difference in macroinvertebrate assemblages between ICOLLs regions for all ICOLLs. Generally, beach berm regions are very different from other regions, while basin and creek delta regions are similar. This was tested by two-way nested ANOSIM (with region nested within ICOLL), one-way ANOSIM (just on region) using pairwise tests and MDS ordination plots. The hypothesis that; the community composition of the benthic macroinvertebrates will differ among the three regions (beach berm, basin and creek), of the four ICOLLs; has also been supported. As family Paracalliopiidae was only found within berm regions, this taxon was the primary cause of difference between beach berm regions and others.

Regions of ICOLLs were also individually compared between ICOLLs (e.g. creek delta regions were compared between ICOLLs). However, due to insufficient samples containing counts of macroinvertebrates within berm regions (e.g. no macroinvertebrates were collected from Terrigal beach berm samples), beach berms were not compared. By conducting a one-way ANOSIM testing for differences between creek regions; there was an overall significant difference in macroinvertebrate assemblages between creek regions of all ICOLLs. Likewise, there was an overall significant difference in macroinvertebrate assemblages between basin regions of Wamberal and Terrigal, Wamberal and Avoca, Wamberal and Cockrone, and Terrigal and Cockrone ICOLLs. However, no significant differences in basin regions were found between Terrigal and Avoca, and Avoca and Cockrone ICOLLs. MDS ordination plots have supported these results. As significant differences between creek regions of all ICOLLs and between basin regions of most ICOLLs, the hypothesis that; within a particular ICOLL region, the number of families, number of individuals and community composition of benthic macroinvertebrates will differ among the four ICOLLs; has been also been supported.

Biota-environment matching analyses were conducted to compare biotic patterns of macroinvertebrate assemblages to the environmental variables using mean data for two sites within each region of all four ICOLLs. These analyses showed that with high Spearman's correlation, salinity and turbidity were the most distinguishing environmental variables to patterns and differences of macroinvertebrate assemblages between the regions of all ICOLLs. The hypothesis that; differences in environmental variables such as salinity and water temperature, percentage of silt/clay and particulate organic content in sediments among the three regions will be related to any differences in the benthic macroinvertebrates of those ICOLLs; has been supported. However, differences in sampled quality parameters may, in some instances, have been influenced by the timing of the sampling event. For example, water temperature differences may be related to the ambient temperatures throughout the day. The lower DO at Wamberal may also be related to the time of sampling as oxygen levels are likely to increase with diurnal photosynthesis processes. Similarly, the pH levels recorded for Avoca and Cockrone may also be related to increased photosynthetic activity likely to be experienced with prolonged sunshine.

Environmental influences from freshwater tributaries are known to contribute to differences of macroinvertebrate assemblages between the three regions of an estuary. With freshwater being constantly input into estuaries, variations in salinities between regions are common. Additional influences of salinity include the low berm heights of ICOLL allowing for flushing of high saline sea-water into berm regions of ICOLL. The BIO-ENV results support this reasoning. Also, a study conducted by Underwood and Anderson (1994) has shown that sedimentary characteristics of estuarine substratum can influence patterns of macroinvertebrate establishment and change. As settling velocity varies with the size, shape, volume and density of creek derived sediment (Branson *et al*, 1996), variations in water turbidity within estuaries is likewise known to influence macroinvertebrate assemblages within ICOLLs by affecting rates of dietary required algal and phytoplankton growth. Heavier sediment settles faster than finer sediment basins of the fluvial delta are typically composed of gravel and sand, while silt and clay continues to carry further into the central mud basin (Roy *et al*., 2001). Settling velocity similarly influences macroinvertebrate assemblages due to the different grain sizes being found within each sedimentary zone or ICOLL region. Each sedimentary zone has been shown to provide different benthic habitats for macroinvertebrate assemblages within ICOLLs (Etter and Grassle, 1992; Snelgrove and Butman, 1994). Finally Rainer (1981) and Horwitz and Blake (1992), refer to macroinvertebrate assemblages found within the fine sediment characteristics typical of the central mud basin as being low-grade assemblages governed by physical processes, small-scale disturbances and organic loading rather than biological processes. As a result, macroinvertebrate assemblages of the deeper basin regions can be described as having high abundances, low diversities and small size stratums (O'Conner and Lake, 1994). The results of this study support this concept.

Many issues are known to arise when measuring community structures and assemblages of macroinvertebrates. Limitations of such studies include a lack of understanding about the interactions controlling diversities of assemblages as well as the stability and resilience of ecosystems. Using species richness, diversity and measures of biomass of macroinvertebrates as indicators of ecological state can lead to problems in their interpretation. For example macroinvertebrates are spatially very variable, which requires complex sampling designs and a need for high replication. This issue had to be overcome in order to appropriately fulfil the aims of the study. Furthermore, this high variability and need for complex sampling designs also leads to the requirement of complex statistical procedures in order to detect any patterns, differences and similarities between various macroinvertebrate assemblages.

The use of Canonical Correspondence Analyses (CCA) have attempted to address this. Results of CCA biplots demonstrated significant relationships between macrobenthos communities and environmental variables, such as sediment grain size, organic carbon content of sediments, distance from beach berm and various water quality parameters. These biplots supported other analyses used here (such as SIMPER and Bio-Env) and indicated that these variables, characteristic of the different regions investigated here, are influencing patterns of distribution and abundance of macrobenthic community assemblages.

The results of multiple regression analysesalso indicate that relationships exist between species diversity and abundance, and the sediment parameters, organic carbon and percentage fines, as well as with the distance from the beach berm or ocean. Similar research by Freewater (2004) supports this model.

2.3 Influence of artificially opening lagoons on macrobenthos

2.3.1 Introduction

The material presented in Section 2.3 is a summary of work published in Gladstone et al (2006). This study assessed the impacts of artificial openings of coastal lagoons on the macroinvertebrate fauna of entrance barriers. About 45% of estuaries in south-east Australia are intermittently open lagoons (Griffiths & West, 1999) and entrance barriers, which are composed of marine sand, are a component of the habitat diversity of coastal lagoons. The macroinvertebrate fauna of entrance barriers is likely to be important in the ecological processes of these lagoons. The crustacean component of the macroinvertebrate fauna is the dominant component in the diet of estuarine fishes and almost all production of crustaceans larger than 1 mm is consumed by fishes (Edgar and Shaw 1995). Distribution and abundance of water birds in estuaries is influenced by the availability of their macroinvertebrate prey (Beukema *et al*., 1993; Moreira, 1994). This study tested the hypotheses that taxonomic richness and density of individual species were significantly reduced in the re-formed entrance barrier of opened lagoons, and that the assemblage structure of macroinvertebrates was significantly different in the re-formed entrance barriers of opened lagoons.

2.3.2 Methods

This study focused on the sedimentary in-fauna (specifically mmacroinvertebrates) occurring in the entrance barriers of lagoons. Macroinvertebrates were sampled approximately 5 m from the shoreline in water 10-15 cm deep by inserting a PVC corer into the sediment to collect a sediment core and then sieving the sediment sample through a 1 mm mesh. Ten replicate cores of dimensions 15 cm wide and 20 cm deep were sampled. The animals retained were collected, preserved in 5% formalin in seawater, and returned to the lab for identification and counting.

In addition to the sediment cores collected for macroinvertebrates, six replicate cores of sediment were collected from each lagoon on each sampling occasion. Sediment samples were oven-dried at 60^0 C for 14 days and then separated using an Endecott's EFL2000/2 vibrating shaker into the following fractions: 1 mm, 0.5 mm, 212 µm, 63 µm, and < 63 µm. The weight of each fraction was determined and expressed as a proportion of the total sample weight. Analysis was done only for the < 63 µm fraction because it has been shown to be significantly associated with variation in production of total benthos and crustaceans (Edgar and Shaw 1995).

The macroinvertebrate assemblages were sampled a total of nine times between January and March 2004. The temporal component incorporated 3 days within each of 3 periods: one before the opening of Terrigal lagoon in January and two after its subsequent closure by natural processes. Terrigal lagoon was artificially opened in January and remained opened for 11 days. After 1 sampling began 3 days after the entrance barrier had closed at Terrigal lagoon, and after 2 sampling began 42 days after the entrance barrier had closed. It was not possible to predict or control the timing of opening and therefore only one before sampling period was possible. To account for this unbalanced temporal design separate, balanced analyses were done: before vs. after 1, and before vs. after 2. A modified sampling design was used for the January-March 2004 study where small-scale spatial variability was not assessed because of the difficulty in predicting the location of the opening. Therefore, ten replicate cores (of the same dimensions as the 2003 study) were sampled across the entrance barrier.

Asymmetrical ANOVA was used to analyze the January-March 2004 data because there was only one opened lagoon and three unopened or control lagoons. The procedures used to analyze this asymmetrical design follow those outlined by Underwood (1992, 1993). Separate asymmetrical ANOVAs were done to compare before-after 1 and before-after 2 periods. The components of the asymmetrical ANOVA were constructed from the logic in Underwood (1992, 1993) by repartitioning the sums of squares from four separate orthogonal ANOVAs: (1) all data; (2) control lagoons only; (3) all lagoons in the before period; and (4) control lagoons in the before period. Period was regarded as a fixed factor and day as a random factor nested within period. Lagoons were regarded as a random factor because the lagoon that opened was not pre-determined.

The logic behind impact assessment using asymmetrical ANOVA is discussed by Underwood (1992, 1993) and summarized here (Table 2.26). Populations vary through time in different ways at different locations and therefore interactions between space and time are commonly encountered in analyses. It is usual for an impact to occur at only one location and, to address the space x time interactions that would have occurred anyway, impact assessments need to involve multiple control locations sampled at multiple times before and after the disturbance. Testing for an impact therefore involves testing for an interaction between the difference between the disturbed location and the control locations and time, and/or a change in the magnitude of this interaction. The tests used to test for an impact are outlined in Table 2.26

Data were examined for homogeneity of variances with Cochran's test (Underwood, 1981). When heterogeneous variances were detected data were transformed and homogeneity re-tested with Cochran's test. When transformation was unsuccessful the analysis was done on untransformed data because ANOVA is robust to departures from this assumption for the sample sizes used in this study (Underwood, 1997). Analyses were undertaken using GMAV5 software (Institute of Marine Ecology, University of Sydney).

The assemblage structure was investigated by multivariate statistics using Primer V6 software (Plymouth Routines in Multivariate Ecological Research 2005) (Clarke, 1993; Clarke and Warwick 2001). Differences in assemblage structure over time were visualized with non-metric multidimensional scaling ordinations based on a Bray-Curtis similarity matrix. Raw data were square-root transformed before construction of the similarity matrix because of large variation in species' abundance within and between samples (Clarke, 1993). The significance of changes in assemblage structure between periods was tested by non-parametric multivariate analysis of variance using the program NPMANOVA (Anderson 2001). Analyses were done on square-root transformed data with permutation of residuals done under the full model. Taxa contributing to dissimilarity in assemblage structure between the before and after periods were determined with the SIMPER routine in Primer V6 software (Plymouth Routines in Multivariate Ecological Research 2005).

2.3.3 Results

360 cores were collected and a total of 2,865 macroinvertebrates were sampled. Ninety cores contained no macroinvertebrates and 62 (68.9%) of these were from Terrigal lagoon. Fourteen cores from Wamberal, no cores from Avoca, and 16 cores from Cockrone contained no macroinvertebrates. Fifteen taxa of macroinvertebrates and 1 taxa representing an insect larvae were sampled (Table 2.23). Five taxa and 55 individuals were sampled at Terrigal lagoon and the most abundant taxa was the amphipod *Paracalliope australis* (n = 49). Seven taxa and 372 individuals were sampled at Wamberal lagoon and the most abundant taxa was *P. australis* (n = 275). Fifteen taxa and 1885 individuals were sampled at Avoca lagoon and the most abundant taxa were the molluscs *Aschoris victoriae* (n = 966) and *Donax deltoides* (n = 362). Five taxa and 553 individuals were sampled at Cockrone lagoon and the most abundant taxa was *A. victoriae* (n = 477).

Table 2.23 Summary of macroinvertebrate fauna sampled in each lagoon in the January-March 2004 sampling.

Taxon		Lagoon			
		Wamberal	Terrigal	Avoca	Cockrone
Polychaetes	*Simplisetia aequisetis*	9	1	180	0
	Leitoscoloplos bifurcatus	0	0	88	0
Isopods	*Pseudolana elegans*	0	2	0	0
	Family Sphaeromatidae	0	0	3	9
Amphipods	*Paracalliope australis*	275	49	14	40
Gastropod molluscs	*Aschoris victoriae*	72	2	966	477
	Salinator solida	2	0	51	0
	S. fragilis	0	0	9	0
	Tatea sp.	0	0	7	22
	Nassarius jonasii	0	0	3	0
Bivalve molluscs	*Xenostrobus securis*	12	0	143	0
	Donax deltoides	1	0	362	0
	Arthritica helmsii	0	0	12	0
	Irus crenatus	0	0	17	0
	Laternula crecina	0	0	8	0
Miscellaneous	Insect larvae	1	1	22	5

Taxonomic richness varied from 0 to 9 taxa per replicate and the greatest taxonomic richness in a single sample occurred at Avoca lagoon in the after 1 period. No macroinvertebrates were sampled at Terrigal lagoon on the first day of the before period and average taxonomic richness was always greatest at Avoca lagoon during the study period (Figure 2.52). Control lagoons did not differ in their short-term variation (i.e. between days) in taxonomic richness in the after periods and there was no short-term variation in the difference between Terrigal and the opened lagoons in the after periods (Table 2.24). The opening of Terrigal lagoon therefore had no short-term impact on taxonomic richness. There was a significant change in the differences between control lagoons from before to after the opening, as shown by the significant *F*-ratios for B x Controls/residual in Table 2.24. Average taxonomic richness was greater at Wamberal in the before period and greater at Copacabana in the after period (Figure 2.52). However, the interaction in the difference between Terrigal and the control lagoons from before to after the opening did not differ from this same interaction in the control lagoons, as shown by the non-significant *F*-ratio for B x Open / B x Controls in Table 2.24. The changes in taxonomic richness that occurred at Terrigal lagoon from before to after its opening were not different from the range of changes that occurred in the control lagoons over the same time periods.

Total density of macroinvertebrates varied from 0 to 71 macroinvertebrates per sample. Control lagoons differed in their short-term variation (i.e. between days) after the opening, as shown by the significant *F*-ratios for D(After) x Control/residual (Table 2.24). Over the three sampling days within the after 1 period total density of macroinvertebrates increased at Wamberal, increased greatly at Avoca, and decreased at Cockrone. Over the three sampling days within the after 2 period total density of macroinvertebrates increased at Wamberal, decreased at Avoca, and increased then decreased at Cockrone. The short-term variation that occurred in the re-formed entrance barrier at Terrigal lagoon did not differ significantly from the short-term variation that occurred in the entrance barriers at the control lagoons in either after period, as shown by the non-significant *F*-ratios in Table 2.4 for D(After) x Open / D(After) x Control.

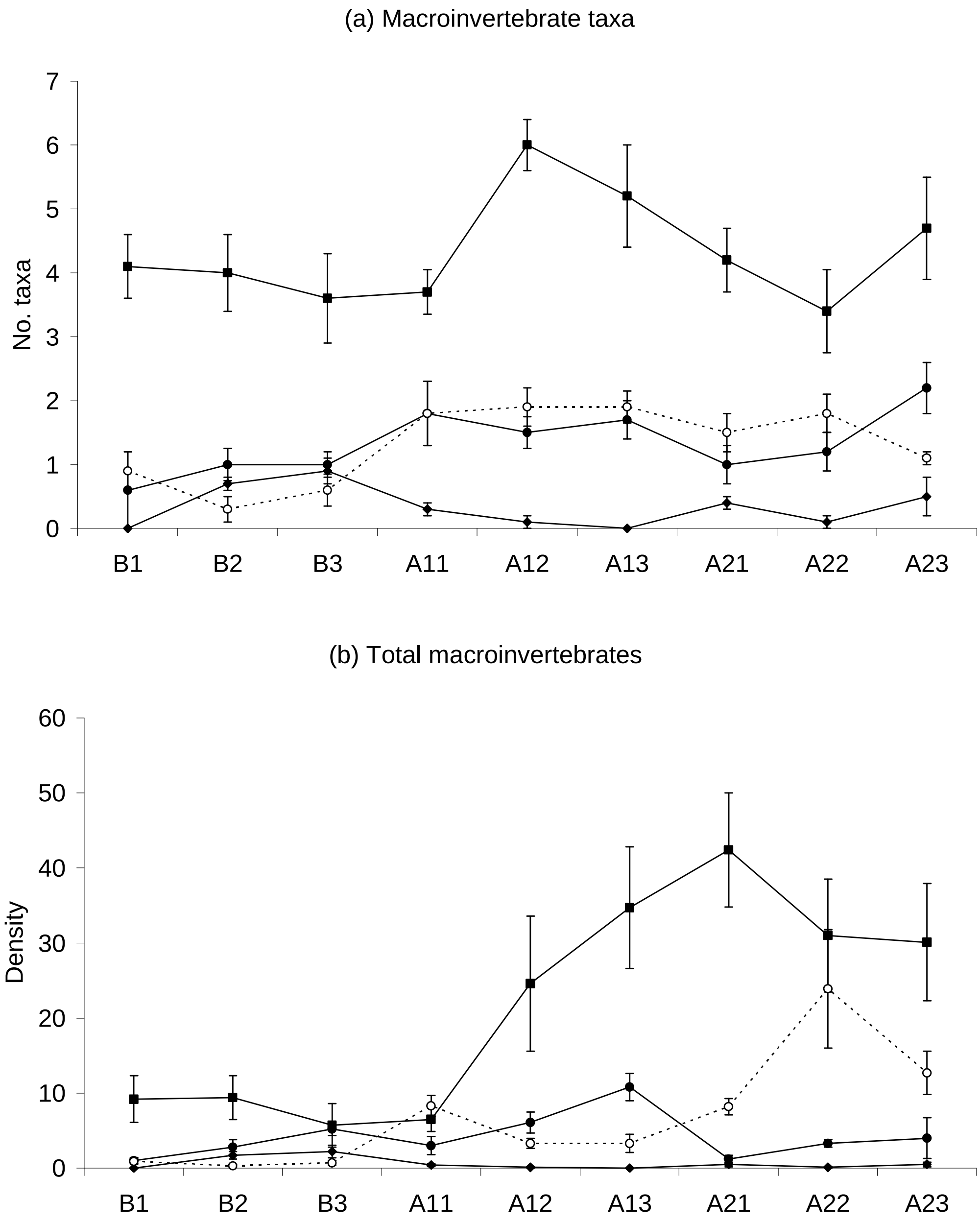
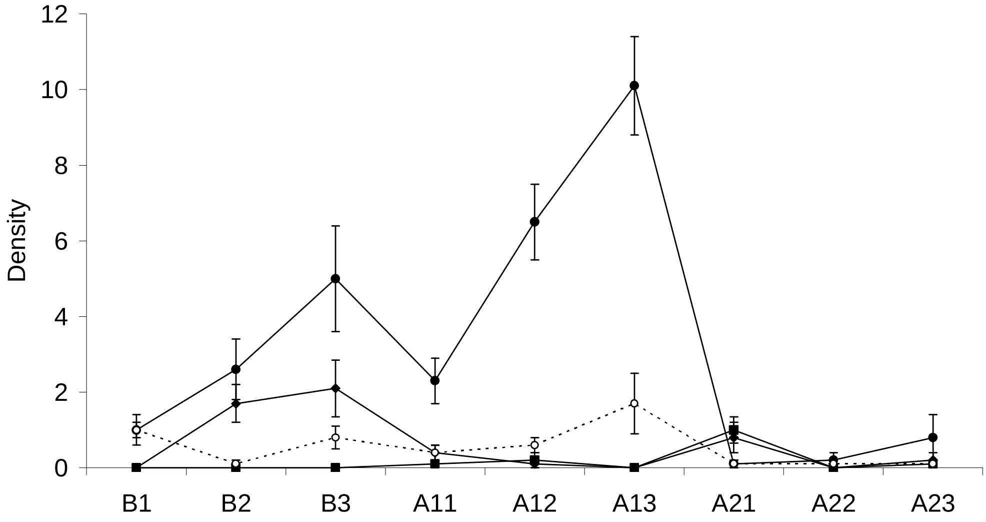


Figure 2.52 Mean number of taxa, density of selected taxa, and % sediment in 63 µm fraction from (♦) Terrigal, (•) Wamberal, (■) Avoca, and (O) Cockrone lagoons. Values shown are the mean of N = 10 replicate samples (± standard error). Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

(c) *Paracalliope australis*



(d) *Aschoris victoriae*

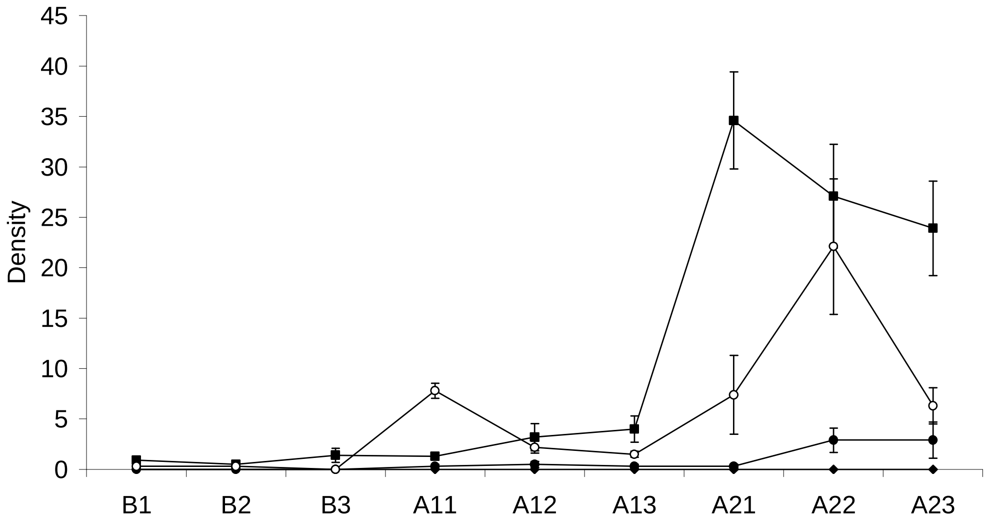
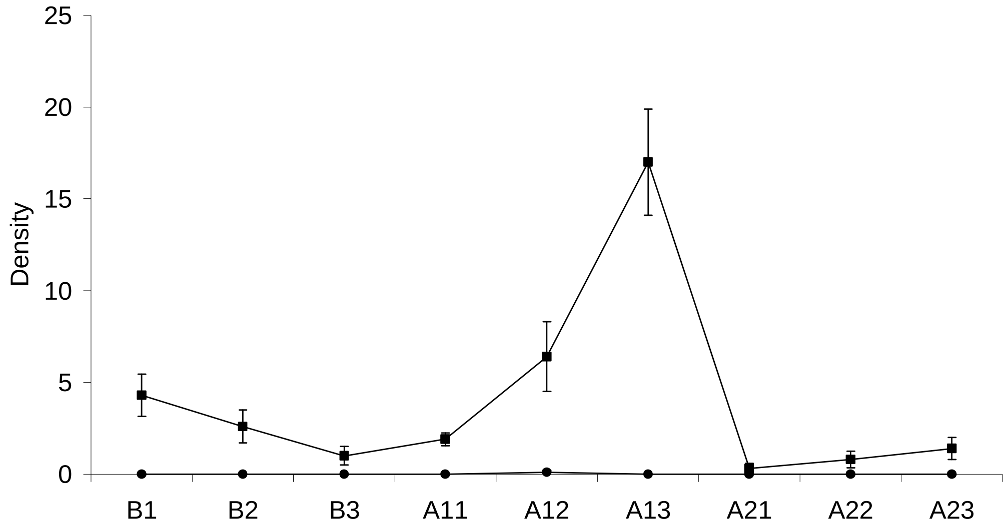


Figure 2.52 (cont.) Mean number of taxa, density of selected taxa, and % sediment in 63 µm fraction from (♦) Terrigal, (•) Wamberal, (■) Avoca, and (O) Cockrone lagoons. Values shown are the mean of N = 10 replicate samples (± standard error). Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

(e) *Donax deltoides*



(f) *Leitoscoloplos bifurcatus*

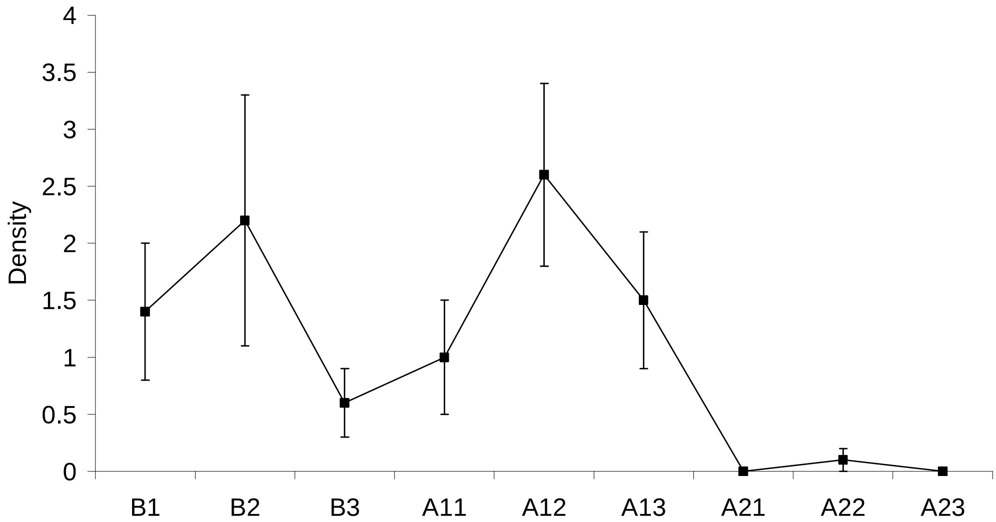
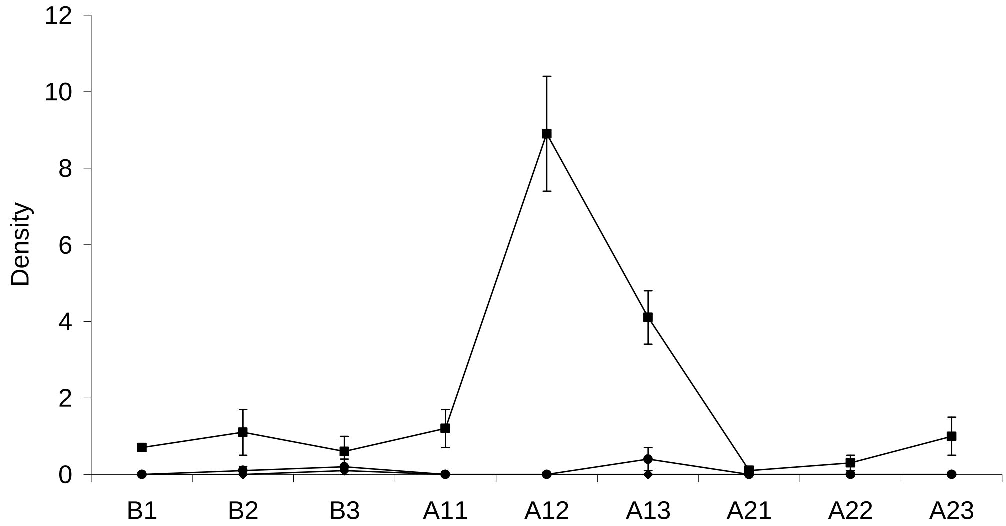


Figure 2.52 (cont) Mean number of taxa, density of selected taxa, and % sediment in 63 µm fraction from (♦) Terrigal, (•) Wamberal, (■) Avoca, and (O) Cockrone lagoons. Values shown are the mean of N = 10 replicate samples (± standard error). Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

(g) *Simplisetia aequisetis*



(h) *Tatea* sp.

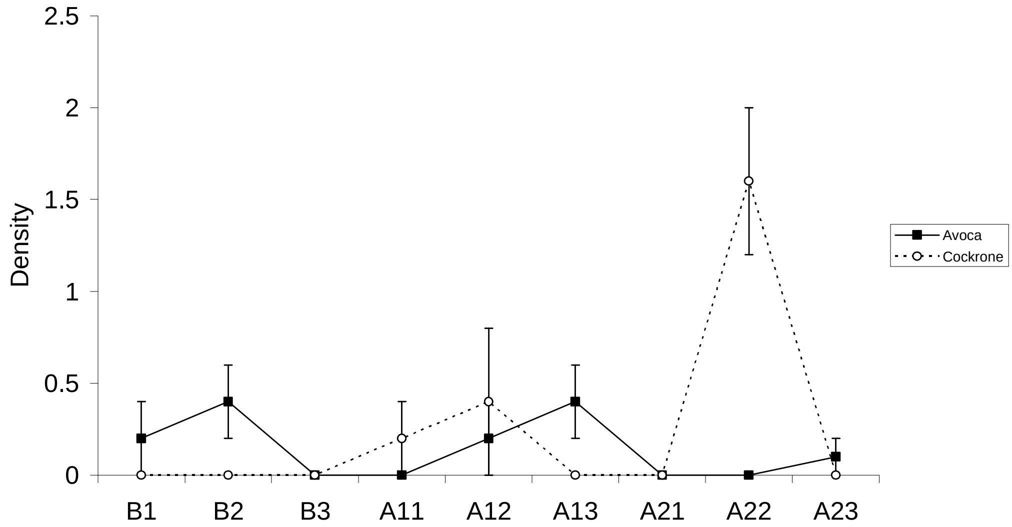
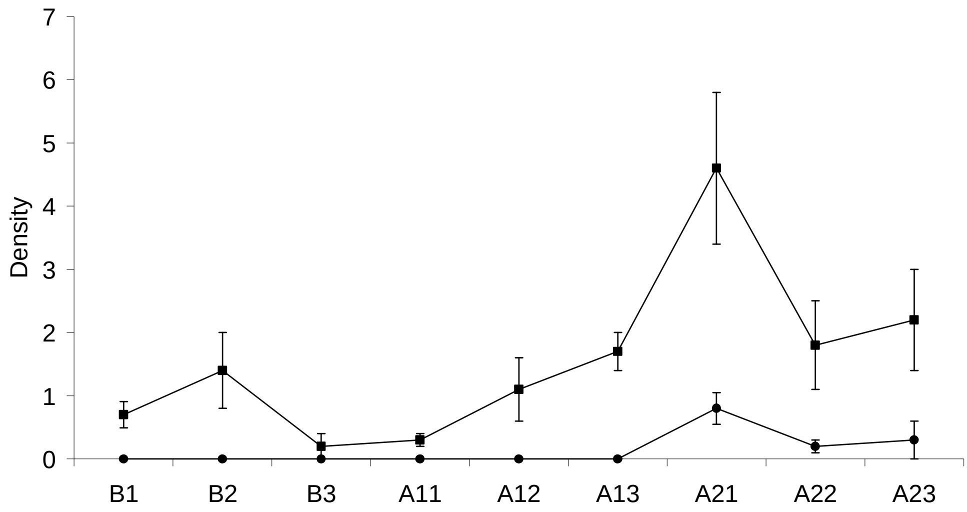


Figure 2.52 (cont.) Mean number of taxa, density of selected taxa, and % sediment in 63 µm fraction from (♦) Terrigal, (•) Wamberal, (■) Avoca, and (O) Cockrone lagoons. Values shown are the mean of N = 10 replicate samples (± standard error). Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

(i) *Xenostrobus securis*



(j) Sediment < 63 µm

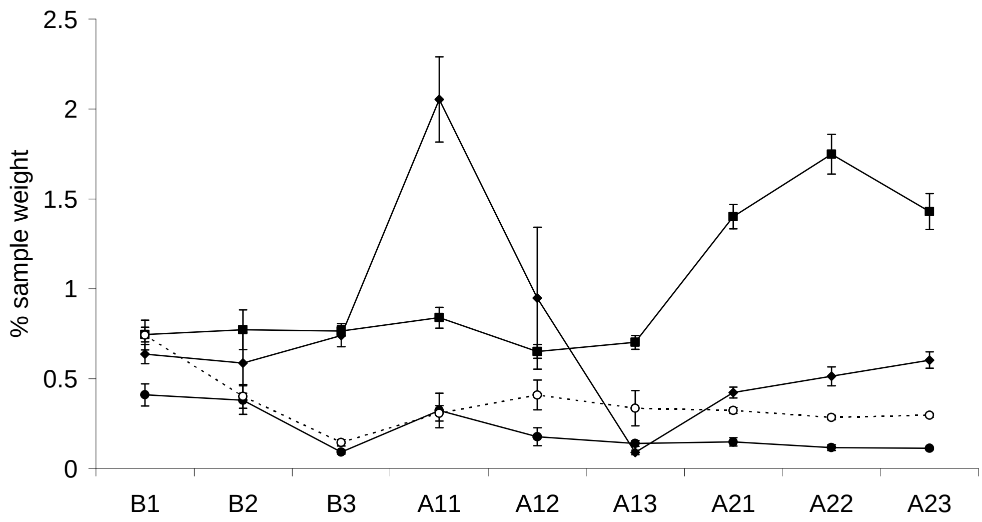


Figure 2.52 (cont.) Mean number of taxa, density of selected taxa, and % sediment in 63 µm fraction from (♦) Terrigal, (•) Wamberal, (■) Avoca, and (O) Cockrone lagoons. Values shown are the mean of N = 10 replicate samples (± standard error). Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

Density of the amphipod *Paracalliope australis* varied from 0 to 16 per sample and density was greatest at Wamberal lagoon for much of the study period (Figure 2.52). Control lagoons differed in their short-term variation (i.e. between days) after the opening, as shown by the significant *F*-ratios for D(After) x Control/residual (Table 2.24). In the after 1 period density increased greatly at Wamberal and increased at Cockrone on the third day. In the after 2 period density declined at Avoca and there were few individuals recorded at Wamberal or Copacabana. The short-term variation in density of *P. australis* in the re-formed entrance barrier of Terrigal in the after periods was not significantly different from the short-term variation that occurred in the entrance barriers at the control lagoons, as shown by the non-significant *F*-ratios in Table 2.24 for D(After) x Open / D(After) x Control.

A number of other taxa were sampled infrequently over the study period and were therefore not able to be analyzed. Density of the mollusc *Aschoris victoriae* varied from 0 to 57 per sample and average density increased in Avoca and Cockrone lagoons in the after 2 period (Figure 2.52 (d)). The pipi *Donax deltoides* (Figure 2.52 (e)) was always sampled at Avoca lagoon, occurred only in 1 sample at Wamberal lagoon and was absent from the other lagoons. The polychaete *Leitoscoloplos bifurcatus* occurred only at Avoca lagoon and its density declined considerably in the after 2 period (Figure 2.52(f)). The polychaete *Simplesetia aequisetis* was always sampled at Avoca lagoon and a short-term increase in density occurred over 2 d in the after 1 period. *S. aequisetis* was sampled in low numbers at Wamberal and Terrigal and was not sampled at Cockrone lagoon (Figure 2.52 (g)). The gastropod mollusc *Tatea sp*. was sampled only in low numbers at different times at Avoca and Cockrone lagoons (Figure 2.52 (h)). The bivalve mollusc *Xenostrobus securis* was always present at Avoca lagoon and exhibited considerable short-term changes in density, and was sampled at Wamberal lagoon in the after 2 period.

Table 2.24 Summary of results of asymmetrical ANOVA for taxonomic richness of macroinvertebrates, total density of macroinvertebrates, and density of individual species ([a] ln (x + 1) transformed, [b] untransformed, variances heterogeneous, [c] ln (x + 0.1) transformed, *** $P < 0.001$, * $P < 0.05$, ns $P > 0.05$)

(a) Before vs. after 1

Source of variation	**df**	**Richness[a]**		**Total density[b]**		***P. australis*[c]**	
		MS	***F***	**MS**	***F***	**MS**	***F***
Before vs. After: B	1	3.47		1349.00		3.83	
Days (B): D(B)	4	0.12		210.89		5.89	
Lagoons: L	3	20.84		2110.45		106.27	
Open[1]	1	29.07					
				1917.54		13.27	
Controls[1]	2	16.73					
				2206.90		152.77	
B x L	3	2.18		452.74		17.05	
B x Open[1]	1	5.17	7.49 ns	690.31			
						42.94	
B x Controls[1]	2	0.69	7.67 ***	333.95		4.10	
D(B) x L	12	0.32		232.53		4.98	
D(Before) x L[1]	6	0.47		31.61		6.43	
D(Before) x Open[1]	2	0.87		7.87			
						10.88	
D(Before) x Controls[1]	4	0.27					
				43.48		4.21	
D(After) x L[1]	6	0.18		433.45		3.53	
D(After) x Open[1]	2	0.22	2.44 ns	156.51	0.27 ns		2.07
						5.38	ns
D(After) x Controls[1,2,3]	4	0.17	1.89 ns		25.83 ***	2.6	2.63 *
				571.93			
Residual	216	0.09		22.14		0.99	

[1] Repartitioned sources of variation
[2] If D(After) x Controls / residual and D(After) x Open / residual are not significant impact occurs if B x Controls / residual and B x Open / B x Controls are significant
[3] If D(After) x Controls / residual is significant test D(After) x Open / D(After) x Controls to determine if the interaction between days of sampling and the difference between open and control lagoons after the opening is greater than the interaction between days of sampling and control lagoons after the opening

Table 2.24 (cont.) Summary of results of asymmetrical ANOVA for taxonomic richness of macroinvertebrates, total density of macroinvertebrates, and density of individual species (a ln (x + 1) transformed, b untransformed, variances heterogeneous, c ln (x + 0.1) transformed, *** P < 0.001, * P < 0.05, ns P > 0.05)

(b) Before vs. after 2

		Richness[a]		Total density[b]		*P. australis*[c]	
Source of variation	**df**	**MS**	***F***	**MS**	***F***	**MS**	***F***
Before vs. After: B	1	0.96		5273.44		34.03	
Days (B): D(B)	4	0.11		100.01		6.58	
Lagoons: L	3	17.75		5113.68		18.52	
Open[1]	1	18.54		4047.02		1.47	
Controls[1]	2	17.35		5647.01		27.05	
B x L	3	1.07		2475.68		20.49	
B x Open[1]	1	1.40	1.55 ns	2125.24		2.88	
B x Controls[1]	2	0.90	7.50 ***	2650.90		29.30	
D(B) x L	12	0.32		220.07		4.78	
D(Before) x L[1]	6	0.47		31.61		6.43	
D(Before) x Open[1]	2	0.86		7.87		10.88	
D(Before) x Controls[1]	4	0.27		43.48		4.21	
D(After) x L[1]	6	0.18		408.53		3.12	
D(After) x Open[1]	2	0.16	1.33 ns	75.36	0.13 ns	0.15	0.03 ns
D(After) x Controls[1,2,3]	4	0.19	1.58 ns	575.11	12.50 ***	4.61	4.39 *
Residual	216	0.12		46.01		1.05	

[1] Repartitioned sources of variation
[2] If D(After) x Controls / residual and D(After) x Open / residual are not significant impact occurs if B x Controls / residual and B x Open / B x Controls are significant
[3] If D(After) x Controls / residual is significant test D(After) x Open / D(After) x Controls to determine if the interaction between days of sampling and the difference between open and control lagoons after the opening is different from the interaction between days of sampling and control lagoons after the opening

There was a short-term increase in the % sediment in the < 63 μm fraction at Terrigal immediately after the opening (Figure 2.52). The significant short-term interaction between the open and control lagoons in the after 1 period (shown by the significant *F*-ratio for D(After) x Open / Residual) is not indicative of an impact of the opening because the short-term temporal interactions between the open and control lagoons did not change from before to after the opening (D(Aft) x Open / D(Bef) x Open, $F_{2,2}$ = 18.65, 2-tailed test) and because D(After) x Control was not significantly different from D(Before) x Controls ($F_{4,4}$ = 0.26, 2-tailed test) (Table 2.25). The short-term increase at Avoca in the after 2 period led to a significant, short-term interaction between the control locations (D(Aft) x Control / Residual). The changes that occurred in the opened lagoon were not significantly different from this (D(Aft) x Open / D(Aft) x Control).

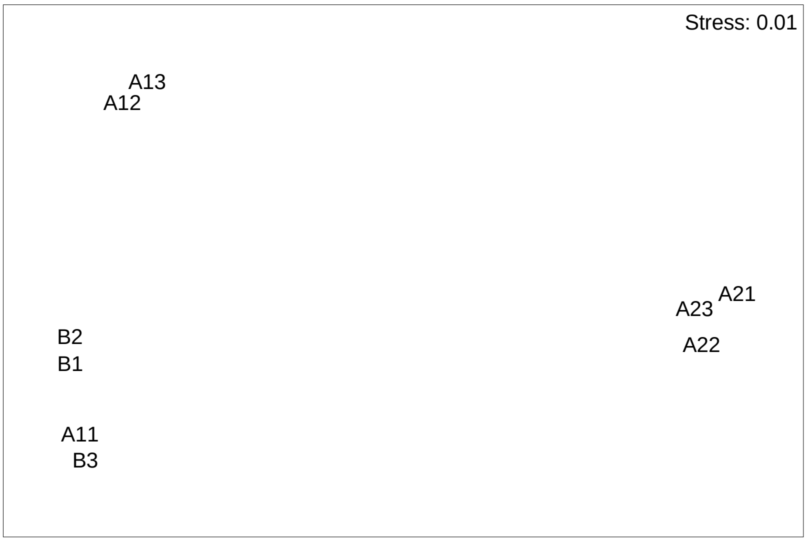
Assemblage structure at Terrigal lagoon changed after the lagoon was opened; however, the differences between the before period and each of the after periods were non significant (Table 2.26). Differences in assemblage structure between days occurred only in the before period.

Assemblage structure at Wamberal Lagoon did not change between the before and after 1 periods (Figure 2.53), although there was a significant difference between days in the after 1 period (Table 2.26). Assemblage structure changed significantly from the before to after 2 period and there was a significant difference between days in the after 2 period. Dissimilarity in assemblage structure between the before and after 2 periods was due to decreased abundance of *P. australis* and increased abundance of *A. victoriae* and the bivalve *Xenostrobus securis*.

Assemblage structure at Avoca lagoon formed three groups corresponding to the three time periods (Figure 2.53). Assemblage structure did not change significantly between the before and after 1 periods; however, there was a significant difference between days in both the before and after 1 periods (Table 2.26). Assemblage structure changed significantly from the before to after 2 period and there were significant differences between days in the after 2 period (Table 2.26). Dissimilarity in assemblage structure between the before and after 2 periods was due to increased abundance of *A. victoriae* and *X. securis* and decreased abundance of *D. deltoides, L. bifurcatus,* and *S. solida.*

Figure 2.53 Non metric multidimensional scaling ordinations of macroinvertebrate assemblage structure at each lagoon based on mean abundances of each taxon on each day of sampling. Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

(c) Avoca lagoon



(d) Cockrone lagoon

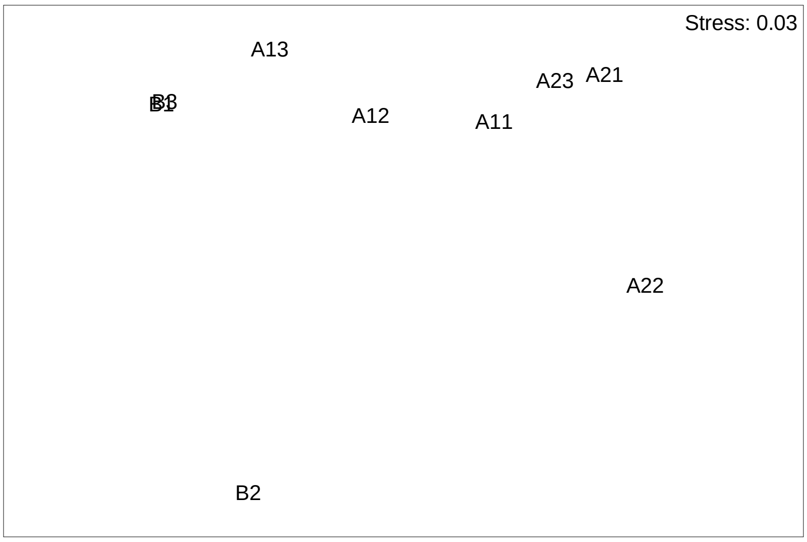


Figure 2.47 (cont'd.) Non metric multidimensional scaling ordinations of macroinvertebrate assemblage structure at each lagoon based on mean abundances of each taxon on each day of sampling. Sampling was done on three days (B1, B2, B3) in one period before Terrigal lagoon opened, on three days in one period after the opening (A11, A12, A13) and on three days in a second period after the opening (A21, A22, A23).

*Table 2.25 Summary of results of asymmetrical ANOVA for the amount of sediment in the < 63 µm fraction ([a] untransformed, variances heterogeneous, *** P < 0.001, * P < 0.05, ns P > 0.05)*

Source of variation	df	Before-after 1[a]		Before-after 2[a]	
		MS	***F***	**MS**	***F***
Before vs. After: B	1	0.08		0.24	
Days (B): D(B)	4	1.09		0.14	
Lagoons: L	3	2.85		6.01	
Open[1]	1	3.89		0.003	
Controls[1]	2	2.32		9.01	
B x L	3	0.44		1.87	
B x Open[1]	1	1.30		0.60	
B x Controls[1]	2	0.01		2.51	
D(B) x L	12	0.76		0.12	
D(Before) x L[1]	6	0.18		0.18	
D(Before) x Open[1]	2	0.21		0.21	
D(Before) x Controls[1]	4	0.16		0.16	
D(After) x L[1]	6	1.34		0.07	
D(After) x Open[1]	2	3.93	49.02 ***	0.06	0.66 ns
D(After) x Controls[1,2,3]	4	0.04	0.51 ns	0.08	3.20 *
Residual	120	0.08		0.03	

[1] Repartitioned sources of variation
[2] If D(After) x Controls / residual is not significant, impact occurs if D(After) x Open / residual is significant and if D(After) x Open is significantly different from D(Before) x Open (2-tailed test) and if D (After) x Controls and D(Before) x Controls are not significantly different (2-tailed test)
[3] If D(After) x Controls / residual is significant test D(After) x Open / D(After) x Controls to determine if temporal variation in the open lagoons is greater after the opening than temporal variation in the control lagoon

Table 2.26 Summary of NPMANOVA results comparing assemblage structure in each lagoon between before and after periods. *** P < 0.001, ** P < 0.01, * P < 0.05, ns P > 0.05.

Lagoon	Analysis	Source of variation	df	MS	*F*
Terrigal	Before-after 1	Period	1	19635.91	1.89 ns
		Days (Period)	4	10408.78	8.01 ***
		Residual	54	1299.63	
	Before-after 2	Period	1	12437.69	1.08 ns
		Days (Period)	4	11559.39	6.55 ***
		Residual	54	1764.66	
Wamberal	Before-after 1	Period	1	12053.85	4.07 ns
		Days (Period)	4	2959.52	2.13 *
		Residual	54	1390.28	
	Before-after 2	Period	1	47848.25	9.22 **
		Days (Period)	4	5187.31	2.03 *
		Residual	54	2551.04	
Avoca	Before-after 1	Period	1	11178.96	2.62 ns
		Days (Period)	4	4259.26	3.18 ***
		Residual	54	1340.10	
	Before-after 2	Period	1	61975.66	24.46 ***
		Days (Period)	4	2533.32	2.26 **
		Residual	54	1118.68	
Cockrone	Before-after 1	Period	1	48735.82	9.11 **
		Days (Period)	4	5351.89	2.85 **
		Residual	54	1877.86	
	Before-after 2	Period	1	72188.24	14.54 ***
		Days (Period)	4	4963.37	2.98 **
		Residual	54	1663.70	

Assemblage structure at Cockrone lagoon changed significantly between the before and after 1 periods and there was significant differences between days in each period (Figure 2.38, Table 2.26). Dissimilarity between the before and after 1 periods was due to increased abundance of *A. victoriae* and *P. australis* and decreased abundance of *Tatea* sp. Assemblage structure also changed significantly between the before and after 2 periods and assemblage structure differed significantly between days in the after 2 period (Table 2.28). Dissimilarity between the before and after 2 periods was due to increased abundance of *A. victoriae* and *Tatea* sp. and decreased abundance of *P. australis*.

2.3.4 Discussion

This study investigated the impacts of artificial openings of Gosford's lagoons by testing for changes in single variables and in whole assemblages of macroinvertebrates. In the 2003 openings density of only one taxa, the polychaete worm *Simplisetia aequisetis*, declined significantly in all lagoons after the openings. A number of taxa declined significantly after the openings in some lagoons but not in others and a number of taxa and variables did not change after the openings. It is not possible to draw definitive conclusions about the impacts of the 2003 openings because all lagoons opened following a period of heavy rainfall and no unopened lagoons were available as controls. The majority of the discussion of the results of this study will therefore relate to the results of the 2004 sampling because the latter study included both opened and unopened lagoons.

The entrance barriers of the opened lagoon was destroyed by the artificial opening and subsequently re-established with sand deposited by wave action from the ocean. Contrary to the proposed hypothesis, no significant effect of the opening was detected for any of the variables or assemblages tested. The absence of any effect of the artificial opening is surprising, given that loss of the entrance barrier represented a temporary but substantial loss of habitat. Short-term variability was assessed in the 2004 opening to test for the possibility of a short-term decline in the re-formed entrance barrier. However, no short-term decline was observed and the short-term variability in the re-formed entrance barrier of the opened lagoon in both the after 1 and after 2 periods was within the range of variability that occurred among the control lagoons and indicated no short-term impact of the artificial opening (Underwood 1992, 1993).

The absence of any impact could be due to migration of macroinvertebrates to the re-formed entrance barrier from surrounding portions of the sand bar that were not destroyed by the opening, and some species are known to be highly mobile (Lawrie and Raffaelli, 1998; Ford *et al*., 1999; Norderhaug *et al*., 2002). Immigration by adult macroinvertebrates has been observed in the recovery of other estuarine habitats (Lewis *et al*. 2003). Alternatively, the macroinvertebrates sampled could have migrated from the adjacent beach as sand was transported by wave action from the beach to close the entrance. Many taxa sampled in this study are represented in sandy beach fauna (Jones *et al*., 1991; Hacking, 1998). It is unlikely that the macroinvertebrates in the re-formed entrance barrier were remnants of the pre-existing barrier fauna because the artificial opening reduced the depth of sand at the opening by 1-1.5 m and pilot studies conducted at the outset of these studies found few macroinvertebrates below 20 cm sediment depth. Recovery of disturbed habitats in other estuarine systems occurs via larval settlement (Lewis *et al*. 2003). However, the sampled fauna of the re-formed entrance barrier did not appear to consist of recent recruits because, although not measured, there was no apparent difference in size of individuals after the openings.

When disturbances occur only at one location multiple control locations are required to test for any changes associated with the disturbance within the context of the range of natural variations occurring at similar, undisturbed locations (Underwood, 1992; Glasby, 1997). Interactions between time and control locations mean that an impact will only occur if it causes a change beyond the variation occurring in the controls (Underwood, 1992). Control lagoons used in this study were examples of the same habitat as the opened lagoon and were separated by 1-5 km, but different species dominated numerically in each lagoon and shared taxa varied differently through time. Under these circumstances, an impact will be a very large change at the disturbed location relative to controls. Otherwise, changes following a disturbance in such systems will be within the range of natural variations and the fauna will be resilient to changes of this type and magnitude.

Low abundance and temporal variability were features of many macroinvertebrates in this study and this has been reported previously in similar systems (Morrisey *et al*., 1992b). Temporal patchiness may be due to these species having relatively short generation times; however the sampling frequency was within the lifespan and reproductive periodicity of the organisms sampled. Amphipods breed on one to two occasions throughout the year, have life spans of 6 mo – 15 mo and are sexually mature after 1 mo (Beare and Moore, 1998; Thiel, 1998; Costa & Coasta, 1999; Cunha *et al*., 2000; Pardal *et al*., 2000; Thiel, 2000; Yu *et al*., 2002). Temporal variation in assemblage structure in both opened and control lagoons is therefore likely to be a normal feature of these assemblages in this habitat. Temporal variability in macroinvertebrate populations is known to be coupled to variations in pelagic productivity (Lehtonen and Andersin, 1998); temperature and salinity (Cunha *et al*., 2000); algal biomass (Costa and Costa, 1999); and day length (Beare and Moore, 1998). However, the temporal changes driven by these factors are likely to occur over a longer time scale than the temporal scales sampled in this study.

An alternative explanation for the observed temporal variability is that it represents instead small-scale spatial patchiness resulting from the sampling strategy. Cores were positioned haphazardly across the entrance barrier for each sampling event, and were separated by 1-2 m. The haphazard selection of core position was done to reduce the chance of the same position being sampled on consecutive occasions 2-3 d apart. Small-scale patchiness in the distribution of benthic organisms and sedimentary infauna exists in other systems (Volckaert, 1987; Barry and Dayton, 1991; Thrush, 1991; Morrisey *et al*., 1992a; Kendall & Widdicombe, 1999) and scales of spatial variation can differ between species (Morrisey *et al*., 1992a; Ysebaert & Herman, 2002). Small-scale heterogeneity in sediment type (Warwick and Davies, 1977) and density of other biota (Thrush, 1986; Morrisey *et al*., 1992a; Osterling and Pihl, 2001), and species mobility (Lawrie and Raffaelli, 1998) can underlie these patterns.

The variability observed in the present study is unlikely to be related to variability in sediment composition because lagoons differed in the ways sediment changed through time. In the 2004 opening individual taxa and assemblages varied between periods and between days within periods in both the opened and control lagoons. The % sediment < 63 µm varied significantly between days in the after 1 period only in the opened lagoon, and between days in the after 2 period only in the control lagoons. Rather than responding to the same feature (e.g. % sediment

< 63 µm) different species may be responding to different features that vary in different ways through time.

Ideally, impact studies need to be replicated spatially and temporally to account for spatial and temporal variation and to verify the generality of the results (Underwood, 1992; Glasby & Underwood, 1996; Kelaher *et al.*, 1998). This study assessed the impacts of artificial openings of coastal lagoons with multiple controls and at multiple temporal scales. The results suggest that macroinvertebrates in lagoon entrance barriers are resilient to the disturbance caused by artificial openings.

Terrigal lagoon is the most frequently opened of Gosford's lagoons. Although the species complement of Terrigal lagoon was similar to that found in the other lagoons in both the 2003 and 2004 studies, the majority of empty cores occurred at Terrigal and the smallest total number of individuals occurred at Terrigal lagoon in both studies. It is therefore possible that the more frequent openings of Terrigal lagoon may have had a cumulative impact on the macroinvertebrate assemblages of its entrance barrier or that this difference may be a result of natural differences between Terrigal lagoon and all other Gosford lagoons.

2.3.5 Recommendations for Further Work

The results of the present study suggest that impacts of lagoon openings could not be detected as significant in one component of the biodiversity of Gosford's lagoons – the macroinvertebrates of entrance barriers. Other components of the lagoons' biodiversity may be impacted by openings e.g. invertebrates < 1 mm, fishes, benthic macroinvertebrates, and habitat diversity. It is therefore recommended that the potential impacts of lagoon openings on these other components be studied. In addition, it is also recommended that process-orientated studies be undertaken and these should include trophic pathways, reproduction, recruitment, and movement of individuals to and from lagoons during openings.

The possibility that the more frequent openings of Terrigal lagoon have had a cumulative impact on the assemblages of macroinvertebrates in its entrance barrier needs to be investigated by continued long-term monitoring of all lagoons combined with manipulative field experiments to mimic artificial openings, and by comparison with other components of the biodiversity of all lagoons.

A further avenue of relevant research is the impact of lagoon openings on the biodiversity of the beach and adjacent subtidal habitats. These openings represent a sudden and dramatic physical disturbance to the beach and contribute water of uncertain quality to nearshore waters.

3.0 Assessment of the Loss of Habitat and Biodiversity

3.1 Loss of terrestrial vegetation

Gosford City currently has a rich diversity of terrestrial ecosystems, with a correspondingly high diversity of native plants and animals. The extent of national parks, state forest, nature reserves as well as large natural areas reserved for water catchment protection and Council's unique Coastal Open Space System (COSS) protect much of the natural vegetation of the area. These natural areas provide considerable benefits to Gosford City including protection of its natural biodiversity, cleaner waterways and beaches, aesthetic values and recreational opportunities. However, many areas of native vegetation, particularly in the coastal areas where development pressures are greatest and the population is predominantly located, are not protected. In addition, many plants and animals are now threatened with extinction as habitat is lost or becomes degraded through pressures such as weed and feral animal invasion.

Council commissioned city-wide vegetation community mapping in 2003 (Bell 2004) and this provides the basis for assessing the extent and significance of vegetation communities across the City. There have been few quantitative studies of the condition of native vegetation in Gosford City. A report on the COSS found that 20% of the total COSS lands (at that time 2,000 ha) were impacted by weeds (Manidis and Roberts 1992). The Gosford Rainforest Study (Payne 2002) found that lantana had increased significantly since 1987, and that where previously a few metres existed at the rainforest edge, that this was now well over 100 metres in depth in some areas. Condition mapping (i.e. extent of tracks and clearing, bush fire or other regrowth) is not available for the Gosford study at this stage, nor is there any mapping describing the extent of weed invasion.

Vegetation mapping enables an assessment to be made about the extent and proportion of native vegetation communities and their relative conservation significance, this is best done within a regional context. The Regional Biodiversity Conservation Strategy (LHCCREMS 2003) provides a conservation assessment for the region, considering national, state and local significant vegetation communities.

For national significance, no locally occurring vegetation communities have been listed so far under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. However, Environment Australia provides criteria to identify communities that could qualify under this category. The Regional Biodiversity Conservation Strategy assessed all regional vegetation communities against national criteria and identified a number of communities that would qualify for national significance. Of the communities identified, only Beach Spinifex and

Alluvial Tall Moist Forest are not now likely to be covered under the new determinations for endangered ecological communities at NSW State level.

State significant vegetation was described as those communities listed under the Threatened Species Conservation Act 1995 as being “endangered” or “vulnerable”. There are currently 9 endangered ecological communities in the Gosford LGA, six of which can be found among the riparian and floodplain regions surrounding the lagoons (see Table 3.1).

Table 3.1 List of Endangered Ecological Communities found within study area (or State Significant Vegetation) with comparative vegetation communities as mapped by Bell (2004).

ENDANGERED ECOLOGICAL COMMUNITY	**Mapped Vegetation Communities that may qualify as listed Endangered Ecological Communities**
Swamp Sclerophyll on Coastal Floodplains	Swamp Mahogany – Paperbark Forest
	Alluvial Paperbark Sedge Forest
	Coastal Sand Swamp Forest
	Narrabeen Alluvial Sedge Woodland
	Estuarine Paperbark Scrub-Forest
Freshwater Wetlands on Coastal Floodplains and Sydney Freshwater Wetlands	Phragmites Rushland
Umina Coastal Sandplain Woodland	Umina Sands Coastal Woodland
Littoral Rainforest	Coastal Sand Littoral Rainforest
Swamp Oak Floodplain Forest	Estuarine Swamp Oak Forest
	Estuarine Baumea Sedgeland,
	Estuarine Juncus Rushland
	Swamp Oak Sedge Forest
Lowland Rainforest	Coastal Warm Temperate Rainforest

For Regionally Significant Vegetation and Habitat Morison and House in LHCCREMS (2003) developed three categories for vegetation and habitat of regional significance, as follows:

- **Vulnerable Communities** that have an extant distribution of less than or equal to 30% of their pre-1750 (original) distribution (i.e. they have been heavily cleared) or less than or equal to 1000 hectares (i.e. they have a restricted distribution). This included communities that met the criteria for EPBC Act listing as endangered, vulnerable or severely restricted.

- **Specialised Communities** defined as communities that provide specialised habitat for species including rainforest, rocky complexes, riparian, aquatic and estuarine vegetation. This included communities that were often included in state legislation such as SEPPs.

- **At Risk Communities** that have an extant distribution of greater than 30% and less than or equal to 45% of their pre-1750 distribution. Also included were communities that met the criteria for EPBC Act listing as having a limited distribution. Communities in this category that are found in Gosford LGA are now listed as endangered ecological communities (Map Units 40 and 43).

A map of pre-1770 riparian and floodplain vegetation around the four coastal lagoons is provided in Figure 3.1. A comparison of Figure 3.1 with Figures 1.2 – 1.5 (Section 1.1.3.1) illustrate a significant loss or modification of foreshore riparian and floodplain habitat (> 25%) since European settlement.

Wildlife corridors are areas of habitat (such as remnant vegetation, feed or hollow bearing trees, caves, roadsides, wetlands and waterways) that form connections between larger areas of vegetation, particularly reserves and national parks. Corridors contribute to the protection of biodiversity as they aid the movement of species. They do not necessarily form linear connections but may provide "stepping stones" in an otherwise modified urban environment. Corridors enable movement and interaction of plants and animals – both on a physical and genetic level. Without these corridors some species, such as small ground dwelling mammals would be unable to move between habitat areas, particularly in the event of natural disasters such as through bushfire or flood and human disturbances.

Corridors are vital to species being able to maintain viable populations; enabling species to cross pollinat*e* or interbreed and maintain genetic diversity. Without adequate linkages species evolve in isolation, perhaps unable to breed and in the longer term are likely to become extinct in isolated areas. The long term result of not protecting linkages is that isolated patches of vegetation become 'sink habitats'. These are areas where the death rate of native species exceeds the birth rate, ultimately resulting in declining species abundance and the risk of extinction for these populations. One example of an island or sink habitat is Blackwall Mountain Reserve, which is isolated by roads and lack of connectivity to other reserves in the area.

A considerable amount has been written about the value of corridors for native animals (Saunders and Hobbs, 1993; Saunders and Hobbs, 1991; Hussey *et al.,* 1991; Lindemayer, 1994) including debate about their value (Bonner, 1994; etc).

Not all areas of native vegetation may function as a wildlife corridor and not all species will utilise the corridor in the same way. For example, Yellow-bellied Gliders (*Petaurus australis*) are likely to require a minimum of 100 metre corridors plus tall trees to enable gliding as well as adequate numbers of hollow bearing and feed trees. Studies done on invertebrates indicate that < 6 metre roads can pose a total barrier which insects and spiders will not cross (Bennett, 1990). This needs careful consideration as invertebrates are an important food source for small mammals and permanently limiting their range can limit the range of other species which depend on it.

Condition may also be a disincentive or barrier to animal movement. Small mammals may require good coverage such as a dense shrub layer before they will move across areas. A study on radiotelemetry of tagged mice (Bennett 1990) demonstrated that they preferred to move in fencerows rather than in more open landscape elements. Other studies have indicated that gaps < 10 metres can inhibit their movement. (Bennett 1990). Barnett *et al.* (1978) showed that gaps of more than 3 metres appeared to inhibit movements of Brown Antechinus and Bush Rat (Bennett 1990).

Logging and then agricultural activities (including livestock, farming and orchards) within the lagoon catchments has resulted in the loss of nutrient rich topsoil to the lagoons. This would have increased both the sediment load and the total nutrient load contained within bottom sediments. Whilst some of these sediments and associated nutrients are expelled when the lagoons are opened, most remain.

Because of development around the foreshores, the lagoons are opened at lower than natural levels to avoid flooding of foreshore properties. Such changes to the natural hydrology of the lagoons have made it more difficult for natural processes to remove sediments and reduce the impacts of stormwater pollution. Continued sedimentation has resulted in progressive changes and loss of certain vegetation communities, such as seagrasses in Terrigal Lagoon.

Other changes, including the infilling and reclamation of foreshores, such as Terrigal, the construction of seawalls, stormwater culverts, bridges, sewage pumping stations and similar have also resulted in loss of foreshore vegetation and habitat. Such changes have resulted in fragmentation of fringing wetlands and loss of connectivity between habitats. The patchiness of fringing wetland can be seen in the maps of fringing and foreshore vegetation (Figures 1.2 – 1.5, Section 1.1.3.1).

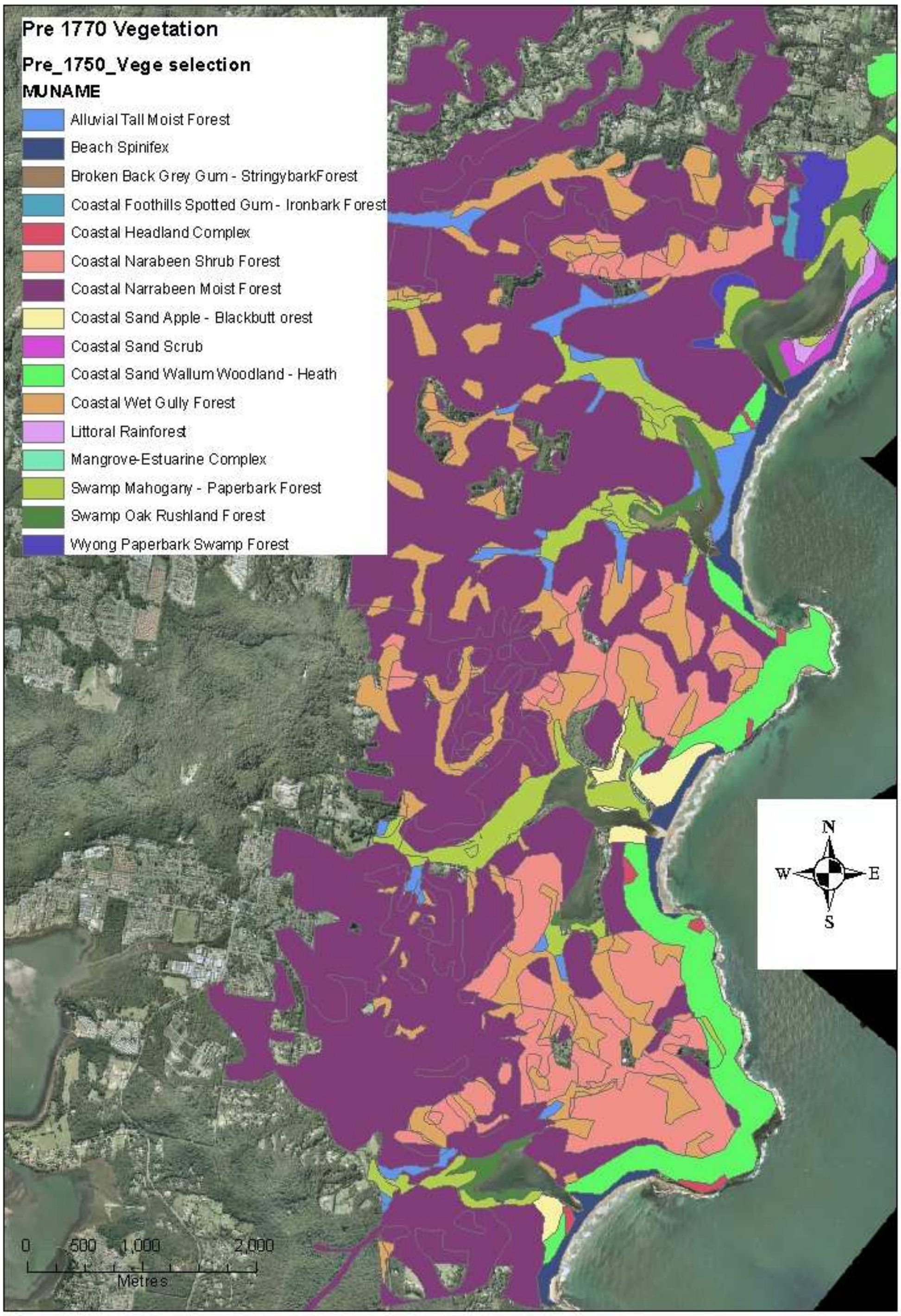


Figure 3.1 Pre-1770 Vegetation communities located among riparian or floodplain regions of the four coastal lagoons (ICOLLs)

3.2 Loss of aquatic vegetation

State Environmental Planning Policy No 14 – Coastal Wetlands (SEPP 14) applies to wetlands on the coast of NSW. The Policy is designed to protect wetlands from ad hoc clearing, draining, filling and levee construction. The areas within the four lagoons protected by SEPP 14 are illustrated in Figure 3.2. However, the SEPP 14 wetlands mapped in Figure 3.2 do not cover the complete extent of valuable wetland areas contained within and around the coastal lagoons of Gosford. Previous sections of this report (*Section 1.1 Riparian and Floodplain Vegetation* and *Section 1.2 Aquatic habitats and flora*) describe and map (Figures 1.2-1.5 and 1.22-24) fringing wetland habitats and the extent of seagrasses and macrophytes. With the exception of Terrigal Lagoon, which lacks submerged vegetation, the existing wetland habitats are in excellent condition.

Wetlands are considered to be important ecosystems for their role in providing breeding areas for fish, habitat for migratory birds and other waders and for trapping nutrients that would otherwise find their way into the adjacent waterways. All wetland communities are now all included in endangered ecological communities (EECs) listings. There are two freshwater wetland EECs listed, these are Freshwater Wetlands on Coastal Floodplains and Sydney Freshwater Wetlands. Swamp Forest is also associated with wetland communities and in the Gosford LGA many swamp forest contain the winter flowering swamp mahogany (*Eucalyptus robusta*) that is a critical resource for native animals. Sydney Coastal Estuary Swamp Forest has now been replaced by a newer determination, Swamp Sclerophyll on Coastal Floodplain. Forest Oak is now also listed and is found on higher ground fringing wetland areas.

The importance of riparian vegetation is also well documented, for example it contributes significantly to riverbank stability by "affecting resistance to flow, bank strength, sediment storage, bed stability and stream morphology and is important for aquatic ecosystem function". (Webb and Erskine, 2003). Creeklines, gullies and other water sources are considered to be very important for native animals. A targeted biodiversity study undertaken on behalf of Council (Conacher Travers, 2001) found that moist environments contained the greatest species diversity. Protection of native vegetation along watercourses will assist native species by providing movement wildlife corridors and also protect water quality and bank stability.

Figure 3.2 State Environmental Planning Policy No 14 – Coastal Wetlands (SEPP 14) areas within the coastal lagoons

A report by the Wentworth Group of Concerned Scientists (2003) recommended that standards be adopted that aimed to conserve riparian vegetation 50 to 100 metres on either side of major rivers and wetlands, 20 – 50 metres on either side of creeks and 10 – 20 metres on either side of streams for water quality purposes.

Whilst riparian vegetation can directly affect the water quality of streams, the streams themselves are generally conduits for stormwater pollution entering wetlands. Together with stormwater outlets, they contribute the bulk of waterborne pollutants to coastal lagoons. Urban stormwater runoff is recognised as a major source of a wide variety of pollutants to coastal waters. Several studies have inquired into the nature of stormwater pollution in an attempt to qualify or quantify the composition of pollutants discharged into the receiving waters. Freewater (2004) reviewed the effects of heavy metals in urban runoff and suggested that there are three main inputs within the urban catchment; wet and dry atmospheric deposition, urban surfaces, and sub-surface deposition (including in-pipe deposition and stormwater drain accumulation). In his review of the impacts of stormwater on estuarine environments in NSW, Freewater (2004) indicates that:

- The urban street surface is probably the most important source of contaminants;
- most pollutants are sediment associated;
- metals and nutrients are largely associated with finely graded inorganic particles (< 125 μm);
- over 70% of oil and polycyclic aromatic hydrocarbons (PAHs) in stormwater are associated with organic solids; and
- some PAH's are carcinogens and are readily released from road surfaces and appear to make up a significant proportion of the pollution load of urban runoff.

Freewater (2004) concluded that the urbanisation of coastal catchments threaten the ecological integrity of the receiving waters into which they drain and that ameliorating the impact of urban runoff is one of the greatest challenges of contemporary catchment management objectives. Therefore, it is not surprising that considerable research has focused on attempts to quantify pollutant loads in urban runoff.

The streams and stormwater inputs to each of the coastal lagoons were mapped together with the 2 m contours for the adjacent land draining to each lagoon (Figures 3.3-3.6). It can be seen that stormwater often enters directly through some wetland vegetation communities.

Figure 3.3 Stormwater input map of Wamberal Lagoon showing wetland communities, stormwater pipes (red) streams (blue) and 2 m contour lines (green)

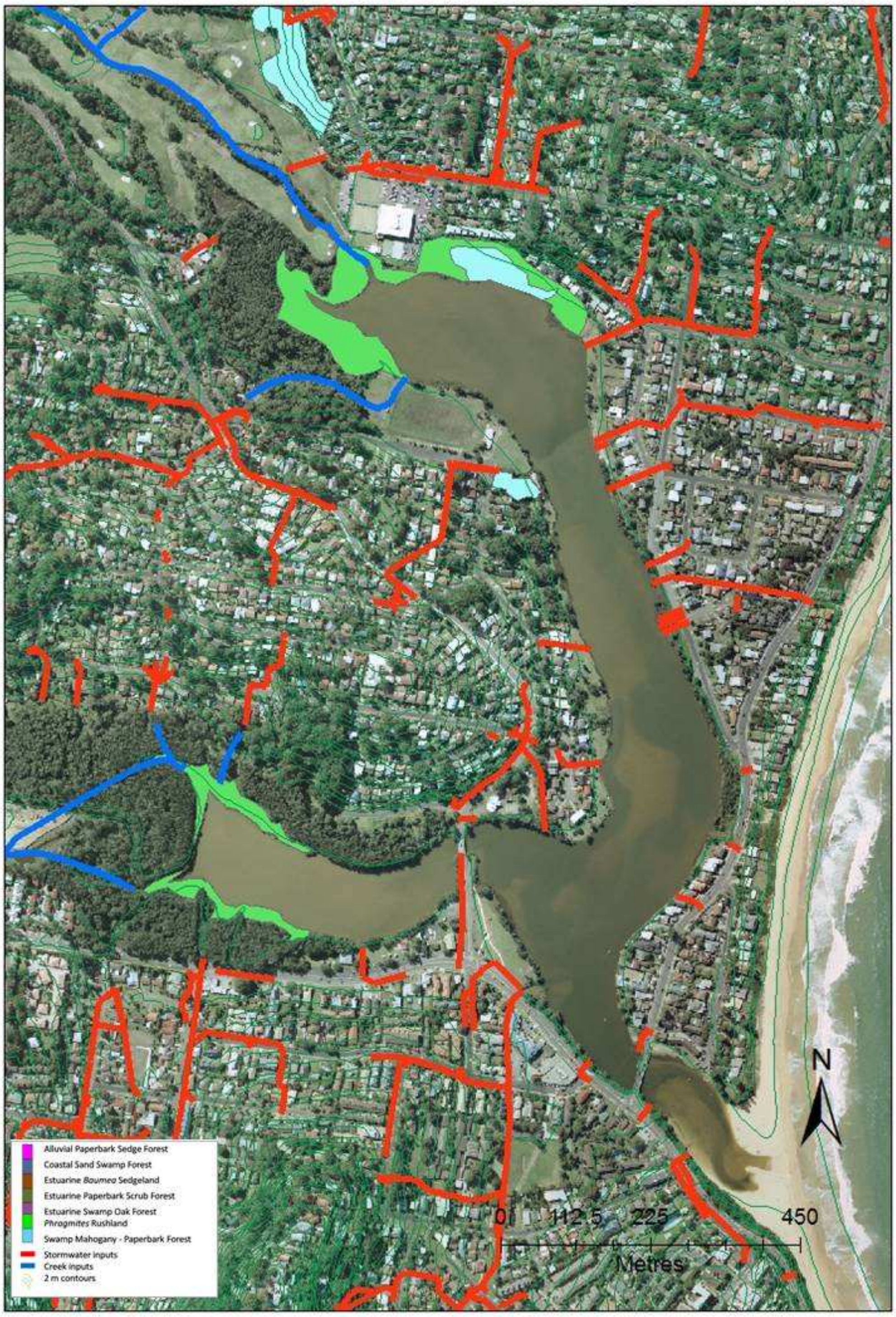


Figure 3.4 Stormwater input map of Terrigal Lagoon showing wetland communities, stormwater pipes (red) streams (blue) and 2 m contour lines (green)

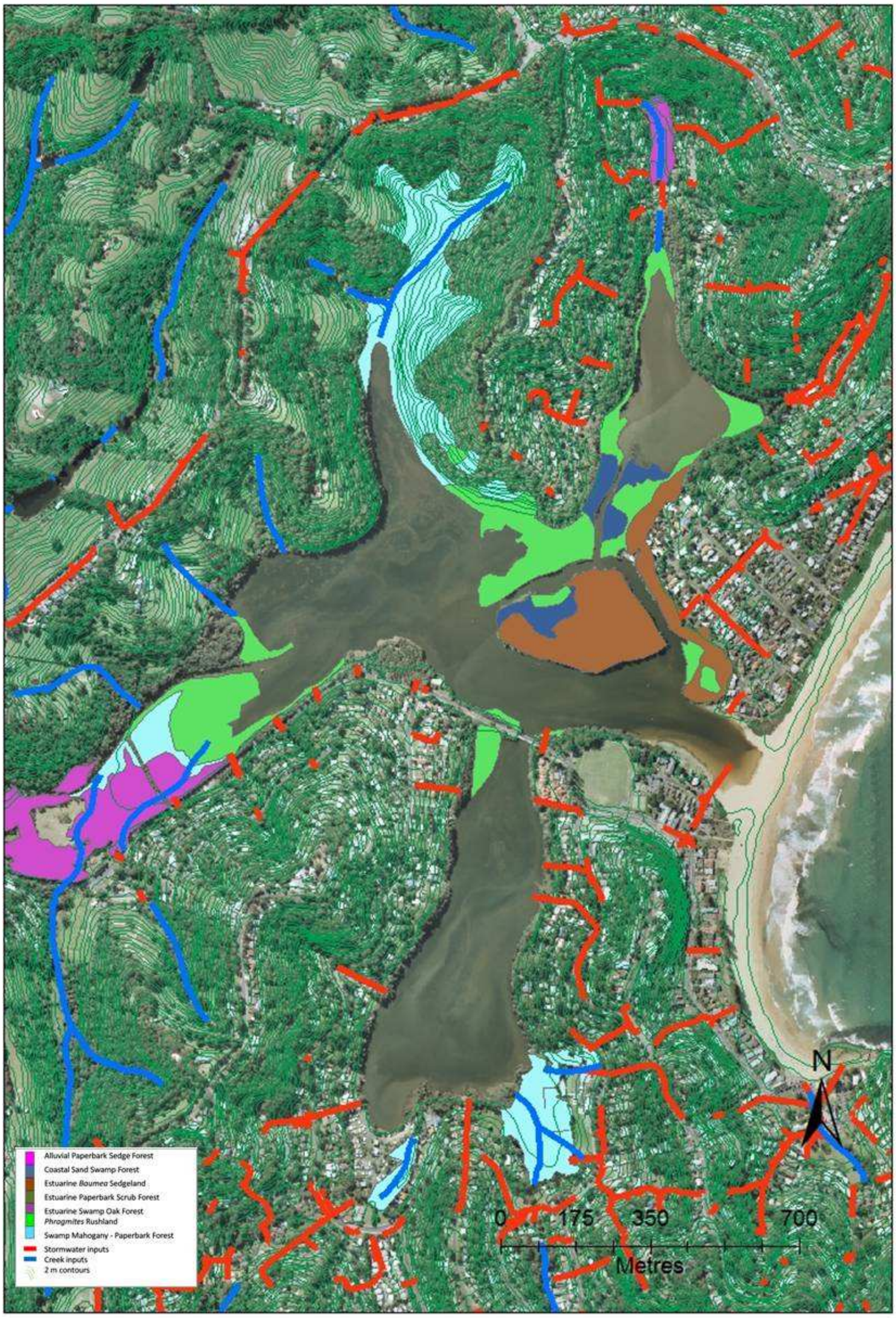


Figure 3.5 Stormwater input map of Avoca Lagoon showing wetland communities, stormwater pipes (red) streams (blue) and 2 m contour lines (green)

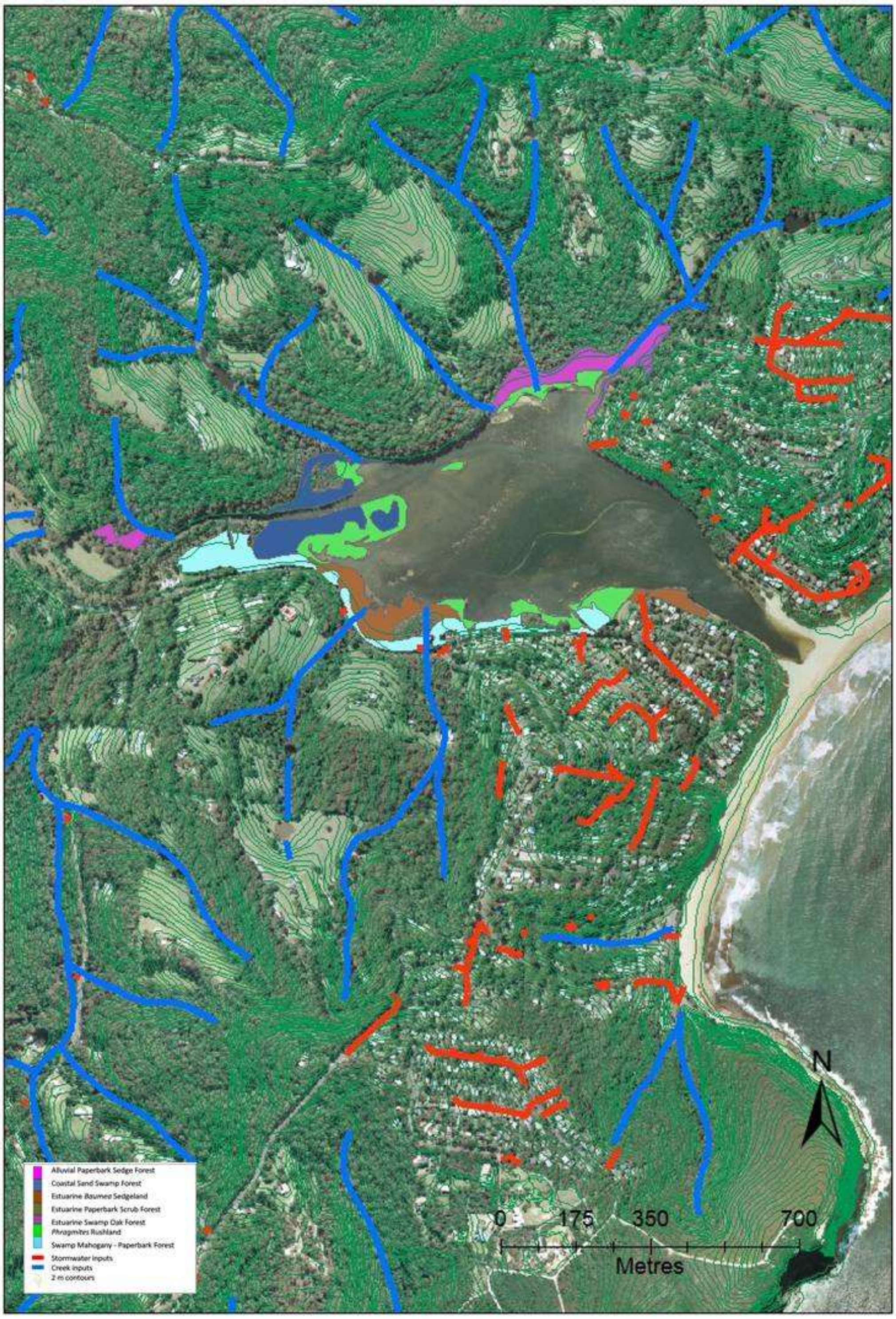


Figure 3.6 Stormwater input map of Cockrone Lagoon showing wetland communities, stormwater pipes (red) streams (blue) and 2 m contour lines (green)

Aside from the pollutants associated with sediments entering the lagoons through stormwater pipes and streams, the sediments themselves impact upon habitat both through the physical smothering of vegetation and attenuation of light caused by high levels of turbidity.

Stormwater input resulting in sedimentation at Wamberal (left) and Terrigal Lagoon (right)

Stormwater outlets at Avoca (left) and Cockrone Lagoon (right)

Anecdotal evidence from previous surveys and reports on aquatic vegetation suggest significant losses, however, the authors are reluctant to put a figure on losses because of reservations about the accuracy of previous surveys. The aquatic vegetation has been described in section 1.2. Historical assessments of benthic habitats of Gosford's Coastal Lagoons have been done by West *et al.* (1985) and Williams *et al.* (2006).

The results of surveys done for this present study are greatly different. The roughly 94% cover of *Ruppia megacarpa* in Wamberal Lagoon (Figure 3.7) reported by Williams *et al.* (2006) was recorded in this survey to be less than 60%. Similarly, Williams *et al.* (2006) indicates the cover of *Ruppia megacarpa* at Cockrone Lagoon to be approximately 84% (Figure 3.8), whilst the results of the present study indicate the cover to be closer to 20%. West *et al.* (1985) do not report any seagrasses for Cockrone Lagoon and neither do WMA (1995).

WMA (1995) indicate that *Z. capricorni* was present in Terrigal and that it had decreased from 15% cover in 1984 to 1% cover in 1991. Williams *et al.* (2006) recorded no seagrasses Terrigal and none were found during this study. However, Williams *et al.* (2006) recorded the presence of Mangroves at Terrigal (Figure 3.8). Mangroves are an opportunistic species not historically associated with Gosford's lagoons. It is likely that changes in salinity, a possible consequence of more frequent openings, has seen facilitated the arrival mangroves, which have displaced the other vegetation communities such as *Baumea* Sedgeland or *Phragmites australis*.

According to West *et al.* (1985) Avoca Lagoon supported large meadows of *Ruppia spiralis* (26% of total lagoon surface area, 16 Ha) and a fringe of eel grass, *Zostera capricorni* occurred along the northern side of the entrance channel. However, by 1991 there was no *Ruppia spp.*, very little to no macro-algae and only a small fringe of *Zostera sp.* (< 1 Ha) near the entrance (WMA, 1995). Then in 1993, cover of *Ruppia spp.* and *Zostera sp.* were similar to the early 1980's again (WMA, 1995). A maximum distribution of seagrasses was mapped for the Avoca Lagoon Estuary Processes Study (Figure 3.9). Williams *et al.* (2006) do not show records for any seagrasses in Avoca. This study indicates the cover of *Ruppia megacarpa* at Avoca Lagoon to be approximately 8 %.

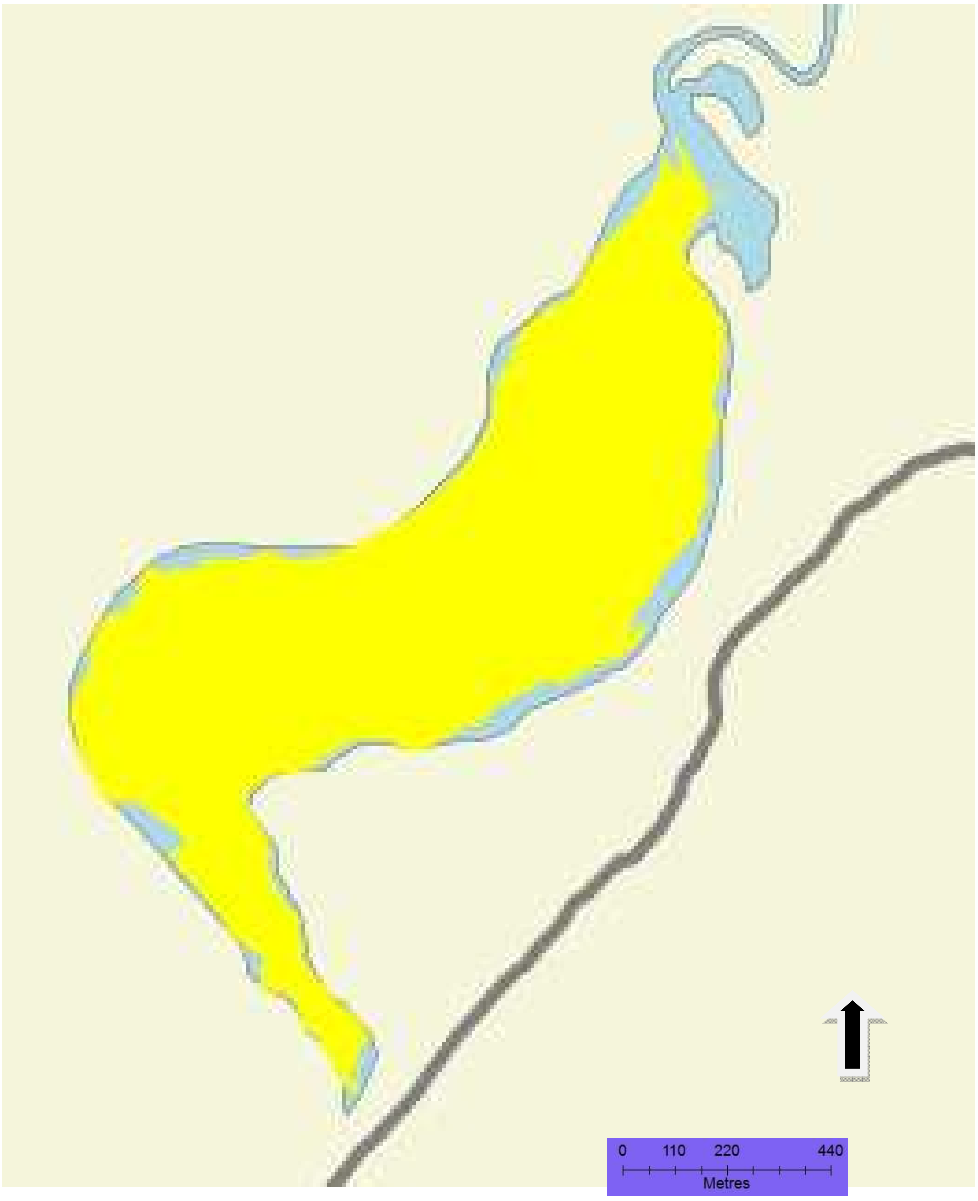


Figure 3.7 Seagrass (*Ruppia megacarpa*) 43.6 ha or 94% cover reported for Wamberal Lagoon by NSW Fisheries in 2006 (LPI 1:25000 map layers) (after DECC, 2009)

Figure 3.8 Mangroves 0.1 ha reported for Terrigal Lagoon by NSW Fisheries in 2006 (LPI 1:25000 map layers) (after DECC, 2009)

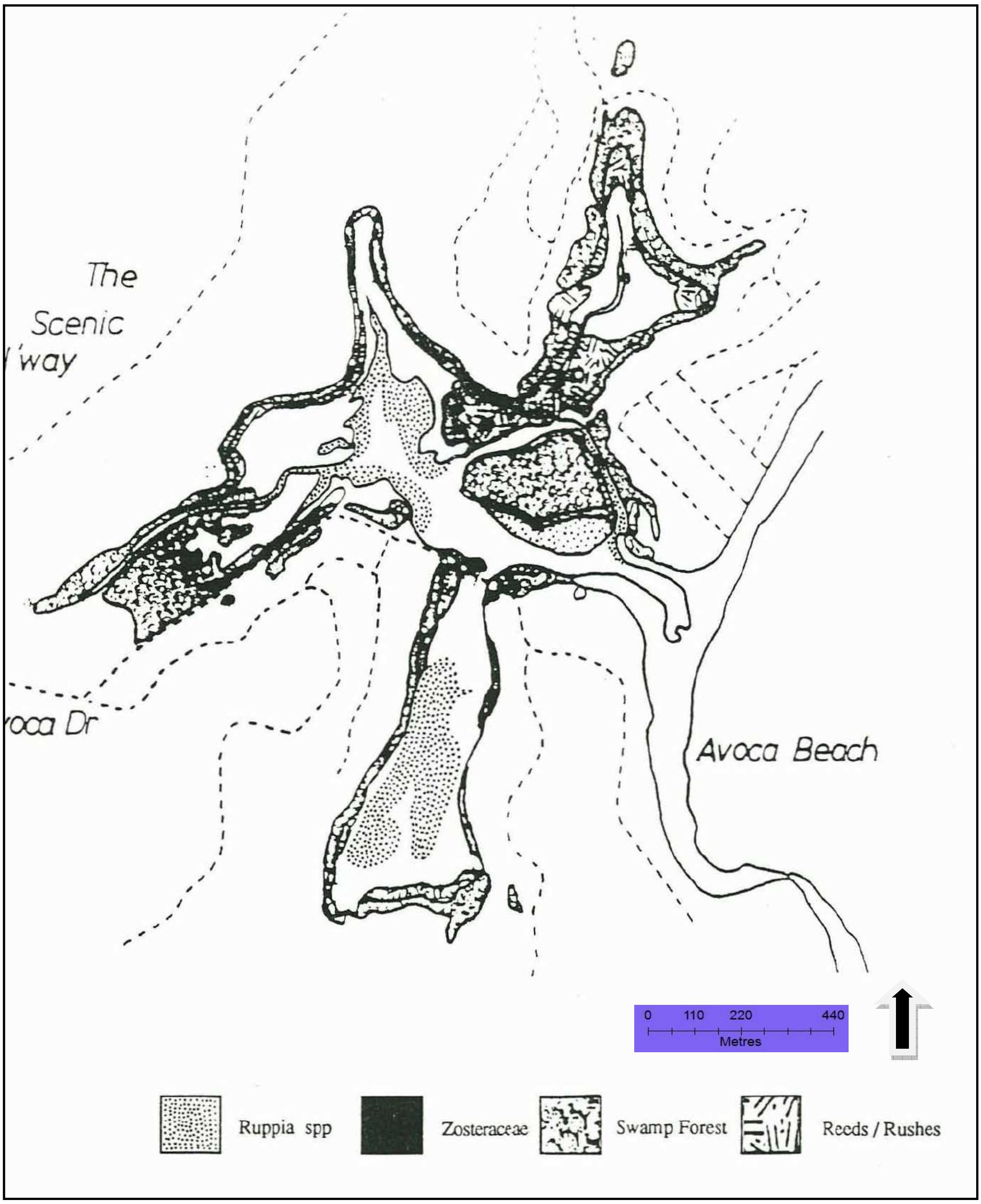


Figure 3.9 *Ruppia spp.* (16 Ha) and *Zostera spp.* (fringing northern shore of entrance) in Estuary Processes Study (after WMA, 1995).

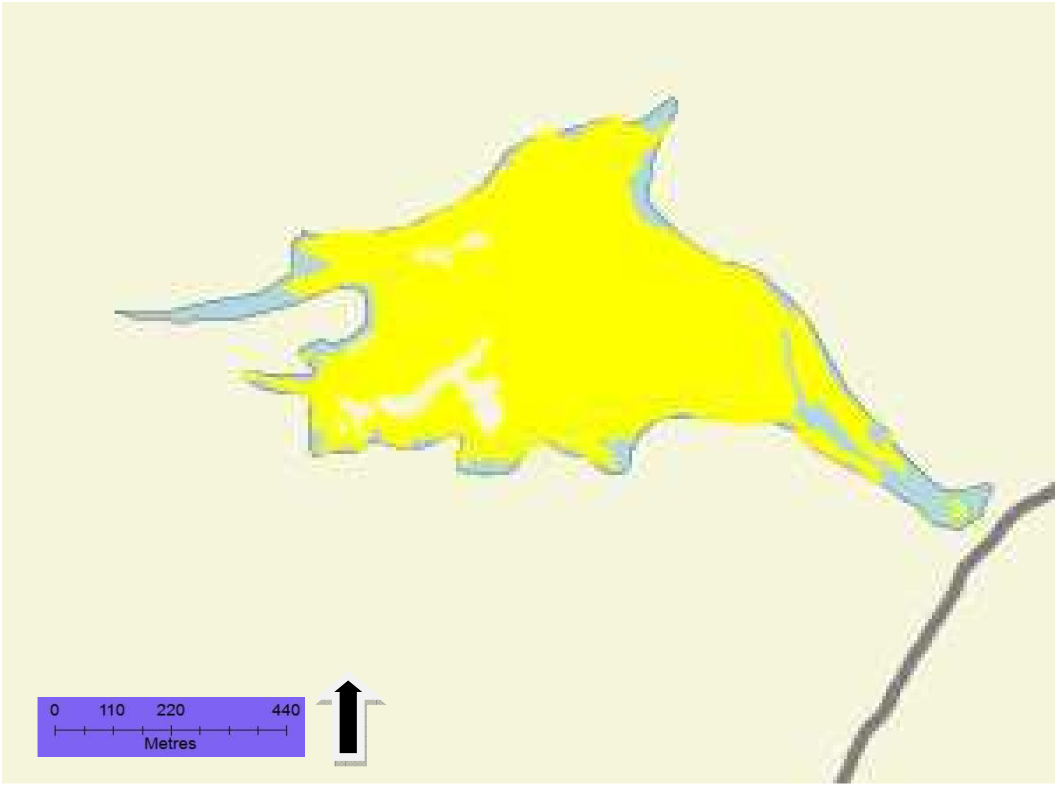


Figure 3.10 Seagrass (*Ruppia megacarpa*) 28.9 ha or 94% cover reported for Cockrone Lagoon by NSW Fisheries in 2006 (LPI 1:25000 map layers) (after DECC, 2009)

It may be that the distribution of aquatic flora in coastal lagoons is dynamic and linked to hydraulic, hydrological and seasonal factors, as concluded by WMA (1995). This may explain the extreme variation in percentage cover of *Ruppia spp.* However, it is possible that some previous reports of seagrass cover in the coastal lagoons were simply inaccurate.

High nutrient loads from stormwater pollution to Avoca and Cockrone Lagoons result in an annual spring outbreak of filamentous algae that form large mats that anchor to the shallow substratum. The algal mats are made up of a few species of filamentous algae, mostly *Enteromorpha intestinalis* and *Chaetomorpha linum*. The mats impact on the aesthetic appeal of the lagoon but they are also an environmental concern:

- the mats block sunlight and prevent the growth of seagrasses and other vegetation;
- when they die bacteria feeding on them strip the water of oxygen resulting in the deaths of native fauna;
- they limit the production of dinoflagellates that would otherwise absorb nitrogen from the water and release it as nitrogen gas at the sediment water interface when they die (this process is believed to be the major pathway for nitrogen removal in coastal lagoons);

- the mats act as a nutrient sink, trapping nutrients in the system and causing them to continuously cycle without release;
- the rotting mats form anoxic sludge which limits colonisation by bio-turbacious infauna; and
- the mats reduce wind-induced circulation currents that would limit stratification of the lagoon.

Boating activities can also be damaging to the environment. Powered boats can have a significant impact on enclosed waters such as Gosford's lagoons; leaking fuel, bilge wastes, dragging of anchors, moorings and the grounding of vessels in seagrass habitats all cause significant impacts. Powered boats are prohibited on the lagoons though unpowered watercraft such as canoes and small paddle boats are allowed and commercial operations hiring these watercraft exist at Terrigal and Avoca. However, the impact of unpowered watercraft on habitat is considered to be minimal.

3.3 Assessment of Biodiversity Loss

Biodiversity or biological diversity is defined as:

The variety of life forms, the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity.

The NPWS Biodiversity Strategy further describes these levels (NPWS 1999):

- **Genetic diversity** is the variety of genetic information contained in all individual plants, animals and micro-organisms.
- **Species diversity** is the variety of species on earth, usually a measure of the number of species (richness) and their relative abundances for a given area at a given point in time.
- **Ecosystem diversity** is the variety of habitats, biotic communities and ecological processes. An ecosystem consists of plant, animal, fungal and micro-organism communities and the associated non-living environment interacting as an ecological community.

These three levels of diversity are interrelated and interdependent as described in the NSW State of the Environment 2000 (EPA 2000). For example, increasing loss of vegetation across the landscape leads to the declining health of ecosystems and results in decreasing population sizes and genetic variability. This eventually results in species extinctions.

There have also been many fauna surveys for specific sites and areas of interest. However, few that provide systematic data that enable a comparison of fauna composition over time. Many threatened species are hard to survey for and, for many, little is known about them. In addition fungi, invertebrates and micro-organisms have not been well studied and remain poorly understood.

Survey data for lagoon fishes and crustaceans (presented in section 2.1) suggests a general reduction in both diversity and abundance of this biota since 1986. These data suggest that both diversity and abundance decreased between 1987 and 2002 and then slightly increased in 2008. However, as discussed in section 2.1, because of the differing sampling methods and effort used between 1986 and 2008, no valid conclusions can be made regarding real losses in biodiversity or fish stocks. Further, there is little scientific evidence to link any real or perceived demise in diversity or abundance to any anthropogenic process. For example, research presented did not demonstrate any impacts on fishes (section 2.1) or macrobenthic communities (section 2.3) caused by the mechanical openings of the lagoons.

There is, however, a concern that frequent lagoon openings may be resulting in a reduction in the extent of floodplain forest communities. These communities need to be inundated occasionally in order for new seedlings to emerge. The lagoon water levels are currently managed to be maintained at lower levels than have occurred naturally in the past. Advice from local bush regenerator volunteers is that few seedlings are emerging and the older trees that have died are not being replaced.

There are many threats to biodiversity values in forest communities surrounding the lagoons. Major threats include land clearing, fragmentation of native vegetation, introduced plants and animals, degradation and pollution of waterways, recreational and commercial use of natural resources and climate change. Almost 30 key threatening processes have been identified at a State level that are relevant to Gosford City. These threats continue to increase in the area although early detection and action (particularly for feral animals and weeds) may reduce the severity of future impacts.

Increasing fragmentation and loss of remaining bushland areas increases the pressure on native species. Underscrubbing and clearing for tracks and roads, new developments and for bushfire protection also leads to declining health of remnant vegetation through impacts such as edge effects and increased weed invasion. Weeds out-compete with native species and alter the composition of vegetation communities, altering their ecology and reducing habitat for native species. Introduced and feral animals species not only impact native wildlife through predation, but also through competition (for food and habitat) and spread of diseases. Companion animals such as dogs and cats also impact on native species through predation, or death as a result of injuries, infection and shock.

Although bushfires are considered to be a natural part of the Australian environment, fires that occur in the area are predominately arson related increasing fire frequency and have initiated alterations in the floristic composition and structure of some of the vegetation communities in Council’s natural area reserves. Inappropriate fire regimes can also threaten the ecological integrity of the bushland. These changes, if allowed to continue, will significantly reduce the natural integrity, conservation and recreation values of the COSS reserves.

A review of the terrestrial fauna classes (Amphibia, Reptilia, Aves and Mammalia) sighted in the near vicinity of the coastal lagoons was undertaken. However, the only source of data that provided reliable reference to location of the sighting was GCC's own georeferenced database. This database was interrogated to list fauna within a 50 m buffer of each lagoon. The results are tabulated below (Tables 3.2-3.5) providing the Class, Family, Scientific name, common name and the conservation status of each species (i.e. vulnerable, threatened or endangered – all native species are protected).

Table 3.2 Terrestrial Fauna of Wamberal Lagoon

CLASS	FAMILY	SCIENTIFIC NAME	COMMON NAME
Amphibia	Myobatrachidae	*Crinia signifera*	Common Eastern Froglet
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Striped Marsh Frog
Amphibia	Hylidae	*Litoria dentata*	Keferstein's Tree Frog
Amphibia	Hylidae	*Litoria peronii*	Peron's Tree Frog
Reptilia	Cheloniidae	*Chelonia mydas*	Green Turtle[V]
Reptilia	Agamidae	*Physignathus lesueurii*	Eastern Water Dragon
Aves	Anatidae	*Anas superciliosa*	Pacific Black Duck
Aves	Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant
Aves	Falconidae	*Falco cenchroides*	Nankeen Kestrel
Aves	Anatidae	*Anas castanea*	Chestnut Teal
Aves	Anatidae	*Anas gracilis*	Grey Teal
Aves	Anatidae	*Cygnus atratus*	Black Swan
Aves	Spheniscidae	*Eudyptula minor*	Little Penguin
Aves	Procellariidae	*Puffinus pacificus*	Wedge-tailed Shearwater
Aves	Sulidae	*Morus serrator*	Australasian Gannet
Aves	Anhingidae	*Anhinga melanogaster*	Darter
Aves	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant
Aves	Phalacrocoracidae	*Phalacrocorax melanoleucos*	Little Pied Cormorant
Aves	Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican
Aves	Ardeidae	*Ardea alba*	Great Egret
Aves	Ardeidae	*Egretta garzetta*	Little Egret
Aves	Ardeidae	*Egretta novaehollandiae*	White-faced Heron
Aves	Threskiornithidae	*Platalea regia*	Royal Spoonbill
Aves	Laridae	*Larus novaehollandiae*	Silver Gull
Aves	Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle
Aves	Accipitridae	*Haliastur sphenurus*	Whistling Kite
Aves	Accipitridae	*Pandion haliaetus*	Osprey[V]
Aves	Laridae	*Sterna bergii*	Crested Tern
Aves	Laridae	*Sterna fuscata*	Sooty Tern[V]

Aves	Laridae	*Sterna striata*	White-fronted Tern
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing
Aves	Laridae	*Chlidonias hybridus*	Whiskered Tern
Aves	Laridae	*Larus novaehollandiae*	Silver Gull
Aves	Columbidae	*Geopelia humeralis*	Bar-shouldered Dove
Aves	Columbidae	*Ocyphaps lophotes*	Crested Pigeon
Aves	Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo
Aves	Cacatuidae	*Eolophus roseicapillus*	Galah
Aves	Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet
Aves	Cuculidae	*Eudynamys orientalis*	Pacific Koel
Aves	Centropodidae	*Centropus phasianinus*	Pheasant Coucal
Aves	Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra
Aves	Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher
Aves	Maluridae	*Malurus cyaneus*	Superb Fairy-wren
Aves	Maluridae	*Malurus lamberti*	Variegated Fairy-wren
Aves	Acanthizidae	*Acanthiza nana*	Yellow Thornbill
Aves	Acanthizidae	*Acanthiza pusilla*	Brown Thornbill
Aves	Acanthizidae	*Sericornis frontalis*	White-browed Scrubwren
Aves	Meliphagidae	*Anthochaera chrysoptera*	Little Wattlebird
Aves	Meliphagidae	*Lichenostomus chrysops*	Yellow-faced Honeyeater
Aves	Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater
Aves	Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater
Aves	Meliphagidae	*Phylidonyris novaehollandiae*	New Holland Honeyeater
Aves	Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin
Aves	Eupetidae	*Psophodes olivaceus*	Eastern Whipbird
Aves	Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler
Aves	Dicruridae	*Dicrurus bracteatus*	Spangled Drongo
Aves	Artamidae	*Artamus leucorynchus*	White-breasted Woodswallow
Aves	Artamidae	*Gymnorhina tibicen*	Australian Magpie
Aves	Corvidae	*Corvus coronoides*	Australian Raven
Aves	Ptilonorhynchidae	*Ptilonorhynchus violaceus*	Satin Bowerbird
Aves	Estrildidae	*Neochmia temporalis*	Red-browed Finch
Aves	Zosteropidae	*Zosterops lateralis*	Silvereye
Mammalia	Dasyuridae	*Antechinus stuartii*	Brown Antechinus
Mammalia	Molossidae	*Mormopterus sp 1*	undescribed mastiff-bat
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat
Mammalia	Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat
Mammalia	Muridae	*Rattus fuscipes*	Bush Rat
Mammalia	Leporidae	*Oryctolagus cuniculus*	Rabbit

V = Vulnerable, E = Endangered

Table 3.3 Terrestrial Fauna of Terrigal Lagoon

CLASS	FAMILY	SCIENTIFIC NAME	COMMON NAME
Aves	Accipitridae	*Pandion haliaetus*	Osprey[V]
Aves	Cacatuidae	*Calyptorhynchus lathami*	Glossy Black-Cockatoo[V]
Mammalia	Peramelidae	*Isoodon macrourus*	Northern Brown Bandicoot

V = Vulnerable, E = Endangered

Table 3.4 Terrestrial Fauna of Avoca Lagoon

CLASS	FAMILY	SCIENTIFIC NAME	COMMON NAME
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Striped Marsh Frog
Amphibia	Hylidae	*Litoria aurea*	Green and Golden Bell Frog[E]
Amphibia	Hylidae	*Litoria dentata*	Keferstein's Tree Frog
Aves	Anatidae	*Anas superciliosa*	Pacific Black Duck
Aves	Anatidae	*Anas castanea*	Chestnut Teal
Aves	Rallidae	*Gallinula tenebrosa*	Dusky Moorhen
Aves	Laridae	*Gygis alba*	White Tern[V]
Aves	Laridae	*Larus novaehollandiae*	Silver Gull
Aves	Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo
Aves	Cacatuidae	*Cacatua tenuirostris*	Long-billed Corella
Aves	Meliphagidae	*Manorina melanocephala*	Noisy Miner
Aves	Dicruridae	*Grallina cyanoleuca*	Magpie-lark
Mammalia	Vespertilionidae	*Myotis adversus*	Large-footed Myotis[V]

V = Vulnerable, E = Endangered

Table 3.5 Terrestrial Fauna of Cockrone Lagoon

CLASS	FAMILY	SCIENTIFIC NAME	COMMON NAME
Amphibia	Myobatrachidae	*Crinia signifera*	Common Eastern Froglet
Amphibia	Myobatrachidae	*Limnodynastes dumerilii*	Bullfrog
Amphibia	Hylidae	*Litoria verreauxii*	Verreaux's Tree Frog
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Striped Marsh Frog
Amphibia	Hylidae	*Litoria dentata*	Keferstein's Tree Frog
Amphibia	Hylidae	*Litoria phyllochroa*	Green Stream Frog
Amphibia	Hylidae	*Litoria tyleri*	Tyler's Tree Frog
Reptilia	Gekkonidae	*Phyllurus platurus*	Broad-tailed Gecko
Reptilia	Scincidae	*Lampropholis delicata*	Dark-flecked Garden Sunskink
Reptilia	Scincidae	*Saiphos equalis*	Yellow-bellied Three-toed Skink
Aves	Megapodiidae	*Alectura lathami*	Australian Brush-turkey
Aves	Anatidae	*Chenonetta jubata*	Australian Wood Duck
Aves	Anatidae	*Cygnus atratus*	Black Swan
Aves	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe

Aves	Phalacrocoracidae	*Phalacrocorax melanoleucos*	Little Pied Cormorant
Aves	Ardeidae	*Ardea alba*	Great Egret
Aves	Ardeidae	*Egretta garzetta*	Little Egret
Aves	Ardeidae	*Egretta novaehollandiae*	White-faced Heron
Aves	Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing
Aves	Columbidae	*Macropygia amboinensis*	Brown Cuckoo-Dove
Aves	Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo
Aves	Psittacidae	*Alisterus scapularis*	Australian King-Parrot
Aves	Psittacidae	*Platycercus adscitus eximius*	Eastern Rosella
Aves	Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet
Aves	Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo
Aves	Podargidae	*Podargus strigoides*	Tawny Frogmouth
Aves	Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra
Aves	Coraciidae	*Eurystomus orientalis*	Dollarbird
Aves	Climacteridae	*Cormobates leucophaeus*	White-throated Treecreeper
Aves	Maluridae	*Malurus cyaneus*	Superb Fairy-wren
Aves	Acanthizidae	*Acanthiza pusilla*	Brown Thornbill
Aves	Acanthizidae	*Acanthiza reguloides*	Buff-rumped Thornbill
Aves	Acanthizidae	*Gerygone mouki*	Brown Gerygone
Aves	Acanthizidae	*Sericornis frontalis*	White-browed Scrubwren
Aves	Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill
Aves	Meliphagidae	*Anthochaera carunculata*	Red Wattlebird
Aves	Meliphagidae	*Anthochaera chrysoptera*	Little Wattlebird
Aves	Meliphagidae	*Manorina melanocephala*	Noisy Miner
Aves	Meliphagidae	*Manorina melanophrys*	Bell Miner
Aves	Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater
Aves	Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin
Aves	Eupetidae	*Psophodes olivaceus*	Eastern Whipbird
Aves	Dicruridae	*Grallina cyanoleuca*	Magpie-lark
Aves	Dicruridae	*Monarcha melanopsis*	Black-faced Monarch
Aves	Dicruridae	*Rhipidura albiscapa*	Grey Fantail
Aves	Dicruridae	*Rhipidura leucophrys*	Willie Wagtail
Aves	Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike
Aves	Artamidae	*Gymnorhina tibicen*	Australian Magpie
Aves	Artamidae	*Strepera graculina*	Pied Currawong
Aves	Corvidae	*Corvus coronoides*	Australian Raven
Aves	Ptilonorhynchidae	*Ptilonorhynchus violaceus*	Satin Bowerbird
Aves	Estrildidae	*Neochmia temporalis*	Red-browed Finch
Aves	Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird
Aves	Hirundinidae	*Petrochelidon nigricans*	Tree Martin
Mammalia	Dasyuridae	*Antechinus sp.*	Unidentified Antechinus
Mammalia	Dasyuridae	*Antechinus stuartii*	Brown Antechinus

Mammalia	Petauridae	*Petaurus australis*	Yellow-bellied Glider[V]
Mammalia	Petauridae	*Petaurus breviceps*	Sugar Glider
Mammalia	Pseudocheiridae	*Petauroides volans*	Greater Glider
Mammalia	Pseudocheiridae	*Pseudocheirus peregrinus*	Common Ringtail Possum
Mammalia	Acrobatidae	*Acrobates pygmaeus*	Feathertail Glider
Mammalia	Phalangeridae	*Trichosurus sp.*	brushtail possum
Mammalia	Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox[V]
Mammalia	Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat[V]
Mammalia	Molossidae	*Mormopterus norfolkensis*	Eastern Freetail-bat[V]
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat
Mammalia	Vespertilionidae	*Miniopterus australis*	Little Bentwing-bat[V]
Mammalia	Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat
Mammalia	Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat
Mammalia	Vespertilionidae	*Vespadelus pumilus*	Eastern Forest Bat
Mammalia	Muridae	*Rattus fuscipes*	Bush Rat
Mammalia	Muridae	*Rattus sp.*	rat

V = Vulnerable, E = Endangered

From the list above it is clear that the lagoons provide an important habitat for avian species. Because Wamberal Lagoon is Nature Reserve it is possible to search the NSW NPWS Wildlife Atlas for fauna species. The NSW NPWS database (NSW NPWS, 2009) has 129 species for Wamberal Nature Reserve compared with only 68 for Council's database (Appendix 2a). According to the Plan of Management for the Wamberal Nature Reserve (NSW NPWS 1993) seven species of birds identified in one or more international treaties for the protection of migratory birds and their habitat have been recorded in Wamberal Lagoon Nature Reserve (NSW NPWS 1993). These are:

- great egret (*Egretta alba*)
- Pacific golden plover (*Pluvialls fulva*)
- Latham's snipe (*Gallinago hardwickii*)
- bar-tailed godwit (*Limosa lapponica*)
- red-necked stint (*Calidris ruficollis*)
- curlew sandpiper (*Calidris ferruginea*)
- white-bellied sea eagle (*Hallaeetus leucogaster*)

One species of endangered fauna, the diamond python *(Python spilotes*), listed in Schedule 12 of the National Parks and Wildlife Act, has been recorded in the Wamberal Lagoon reserve (NPWS, 2009). However, this snake was not listed on Council's georeferenced database, though the green turtle is. This turtle must have been recorded within 50 m of the lagoon and therefore it was retained in the list.

The foreshores lagoons are also important habitats for many arboreal mammals and bats, many of which are listed as vulnerable (Schedule 2 *Threatened Species Conservation Act 1995*). Surprisingly few reptiles are listed for any of the lagoons. Advice from local residents of Avoca indicates that Bareena Island, Avoca Lagoon, is home to hundreds of black snakes. These snakes have been seen swimming to the mainland, presumably to feed on amphibians such as the Green and Golden Bellfrog (Endangered under *Schedule 1 Threatened Species Conservation Act 1995*) and the Striped Marsh Frog which have managed to sustain a viable populations on the foreshore of Avoca Lagoon. Wamberal and Cockrone lagoons also have viable amphibian populations. A complete list of the threatened species found in Gosford City as listed under the Schedules of the *Threatened Species Conservation* (TSC) *Act 1995*, *Fisheries Management* (FMA) *Act 1994* and the *Commonwealth Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999* is provided in Appendix 2b.

Creeks in Gosford for the most part have been highly impacted by urbanisation, as vegetation is replaced by impervious surfaces such as roads, pathways, buildings and car parks that increase runoff velocity and pollutant content. Other impacts include channelisation, snag removal, erosion and sedimentation, habitat modification, alteration of natural hydrology and high nutrient loads which can lead to the proliferation of exotic weeds. As mentioned previously (Section 3.2), high nutrient loads from stormwater pollution generally results in an annual outbreak of filamentous algae that form large mats that anchor to the shallow substratum. These algal mats can limit the growth of seagrasses and the diversity of invertebrates. The diversity of benthic macroinvertebrate communities was shown to be extremely low in areas dominated by macroalgae. These areas contain anoxic sediments as a result of high bacterial growth. Losses in seagrass cover would also result in losses of associated invertebrates. *Ruppia spp.* meadows are an important habitat for a variety of invertebrate species, which include insects in areas of lower salinity. The most common insect taxa include midge larvae, damselfly larvae and water boatmen (Keats and Osher, 2007). Other macroinvertebrates commonly found include water mites, amphipods, ostracods and oligochaetes (Keats and Osher, 2007). These habitats also provide shelter and a food source for larval fishes that feed on invertebrates.

As discussed in Section 3.2 above, the physical smothering of seagrasses by stormwater-borne sediments may have contributed to seagrass habitat loss and hence lead to decreases in associated biodiversity.

Changes in hydrology also impact on native vegetation communities, for example it may be responsible for the encroachment of mangroves into saltmarshes. Hydrological restrictions in waterways due to sedimentation can result in increasing spread of aquatic weeds, leading to a further degradation of the habitat.

Climate change as a result of greenhouse gas emissions is emerging as the most serious global threat facing biodiversity. Mitigation and adaptation actions such as protecting and restoring corridor linkages, improving the condition of native vegetation and waterways and controlling feral animals are recommended to manage the impacts of climate change on biodiversity.

The principle factor that influences the distribution and abundance of both terrestrial and aquatic fauna in and around the coastal lagoons of Gosford is the nature and quality of habitat. Whilst each lagoon has a variety of habitats in a variety of conditions, prior to European settlement these habitats were very similar among all lagoons. All lagoons would have contained the paperbark forests, sedgelands, rushlands and seagrass communities. As has been discussed in various sections of this report, habitat loss and degradation through urban encroachment has been the main driver of a decline in biodiversity.

In 2006 Gosford Council drafted a Biodiversity Management Plan, which provided a comprehensive list of recommendations for action under 10 headings. The Plan was not adopted, however, a summary of the recommendations relevant to biodiversity management in and around the coastal lagoons is provided in the next section (*Section 3.4 Recommendations for biodiversity management*).

3.4 Recommendations for biodiversity management

Strategic Planning

Ensure that biodiversity conservation is a critical consideration in Council's future strategic planning

- Ensure that the Comprehensive LEP includes the review of all landuse zonings and provides appropriate protection for all state and regionally significant vegetation communities, riparian vegetation, corridor linkages and lagoon catchments.
- Revise and refine the draft local wildlife corridor mapping based on ground truthing, landuse zoning and other environmental constraints and consider including as an overlay to inform Council's Comprehensive LEP with appropriate landuse provisions to ensure linkages are retained and protected.
- Include mapped estuarine habitats that are identified as critical for conservation in the Brisbane Water Estuary Processes Study, in planning instruments and provide appropriate planning controls for their protection.
- During the comprehensive LEP planning process resist zonings that compromise biodiversity values.
- Once the comprehensive LEP is complete establish criteria for future rezonings that includes biodiversity considerations and that will retain and protect native vegetation including riparian vegetation and wildlife corridors.

Development Assessment and Control

Ensure that Council's development controls identify biodiversity conservation issues and provide protection for biodiversity.

- Finalise and adopt the Vegetation and Landscape DCP.
- Provide appropriate development assessment criteria and controls to protect and restore wildlife corridors to provide connectivity to reserves, adjoining vegetation and along riparian corridors.
- Develop and monitor the effectiveness of a Quality Assurance program for development and rezoning assessments as part of Council's Integrated Management System.
- Review and continue to upgrade the environmental development assessment checklist (including for rezonings) and develop a consultant requirement's checklist to incorporate changes such as new survey requirements as a result of threatened species legislation amendments.

- Develop a procedure to monitor compliance with development consent conditions especially to ensure threatened species conservation and biodiversity objectives are met.
- Ensure that environmental impact assessment guidelines are used by environmental consultants and development assessment staff in assessing impacts of development on threatened species.
- Develop a system to track development consent conditions such as rehabilitation and bushland management plans to enable follow up and compliance.
- Provide workshops/ training for planning and development assessment staff for biodiversity related matters such as threatened species legislation and management.
- Continue to enable and support staff access GIS for development assessment activities and strategic planning.
- Include monitoring requirements on development approvals where there may be an impact on threatened species, where appropriate this should be for umbrella or indicator species such as the Large Forest Owls and Yellow Bellied-Glider.
- Review information on local species for landscaping works for BASIX approval to ensure that appropriate native species are specified.
- Ensure that stormwater drainage that discharges into natural areas is diffused, preferably over rock riffles rather than point source.
- Include a review of flooding heights in revised Coastal Lagoons Management Plan around all coastal lagoons to account for climate change predictions for sea level rise, and increasing frequency of flooding and storm events.

Council operations and procedures

Ensure Council operations and procedures include adequate biodiversity consideration and incorporate effective controls, codes of conduct and procedures.

- Review all Council policies and standard work procedures to ensure that biodiversity objectives are achieved and incorporate controls that conserve and enhance biodiversity.
- Develop an IMS program and specific standard work practices for the identification and appropriate management of invasive weed species and to limit the spread of diseases for roadside maintenance and construction, drainage reserve works and other standard council operations.
- Develop and implement assessment checklists involving clearing of vegetation for bushfire protection, vermin and other health matters and Part 5 matters.
- Map roadsides to identify high conservation zones and develop appropriate management procedures.

- Provide training and staff resources to aid the identification and management of key invasive weed species and risk of diseases such as Chytrid fungus and Phytophora.
- Provide training, audit and ensure compliance with Part 5 environmental assessments.
- Continually upgrade, enhance and make available information to assist staff in environmental assessment and management.
- Develop an IMS program and specific standard work practices to ensure that appropriate plant species are selected for replanting to ensure environmental weeds are not selected and that local native species are used wherever possible.
- Develop and conduct training on the identification and typical habitat of threatened species that are likely to be encountered during council operations.
- Develop and implement a feral and pest animal policy.
- Revise Council's Biodiversity Policy in line with State policies, standards and targets.
- Revise Council's Bushfire Policy to ensure strict controls on clearing natural area reserves for bushfire protection for new developments.
- Continue to include notification on S149 certificates for threatened species and endangered ecological communities and review information as required.
- Undertake catchment audits including compliance with site rehabilitation, threatened species and bushland management plans.

Management of Council owned land (COSS reserves, parks and foreshores)

- Manage Council owned lands to ensure that biodiversity is protected and enhanced.
- Review COSS boundaries to include consideration of wetlands, riparian habitat, foreshore reserves and vegetated corridor linkages as part of the COSS.
- Identify opportunities to enhance COSS through partnerships with private landholders to create linkages, improve management planning, practices and resourcing and prioritise and fund land acquisitions to extend into other areas in Gosford City.
- Enhance the biodiversity values of Council's bushland reserves by improved management including bush regeneration and feral and domestic animal control.
- Employ a bush regeneration team or provide recurrent funding to contract professional bush regenerators to undertake bush regeneration works in priority areas such as rainforest gullies, EECs and riparian corridors in Council reserves.
- Bush regeneration team or consultants to undertake an assessment of weed status in Council reserves to identify priority areas for bush regeneration works and management options.
- Undertake a review of COSS acquisition priorities to include consideration of the representativeness of vegetation communities with reserve status. Include consideration

of bushfire requirements for the protection of existing development adjacent to reserves.

- Complete the assessment of lands to be incorporated into Western COSS and seek funding to protect identified lands.
- Develop a priority list for COSS/natural reserve areas for future funding opportunities, bush regeneration and targeted weed works/ management, and feral animal controls.
- Develop and implement a feral animal program (to extend beyond fox control) in COSS and other reserves or natural areas.
- Develop in-house operational rules and procedures for Council's parks, reserves and land management activities to incorporate biodiversity considerations. (i.e. 'No Mow' trial, Code of practice for Endangered Ecological Communities) including strict guidelines on allowable clearing for the purpose of protection existing dwellings along the bushland interface.
- Revise and update Plans of Management for COSS reserves to include provisions to exclude domestic animals under the Companion Animals Act.
- Develop site specific Plans of Management for sites identified in Recovery Plans (such as *Prostanthera askania*) as required.
- Undertake fauna surveys within Council's COSS reserves.
- Implement a native planting program for parks and reserves, roadsides, landscaping and gardens.
- Develop mechanisms (educational/enforcement) to implement actions identified in existing Council policies and Plans of Management that affect biodiversity (e.g. dogs in COSS reserves, encroachments, weed invasion, illegal clearing associated with bushfire hazard reduction)
- Develop and provide interpretive and environmental education for COSS/natural reserves for visitors and neighbouring residents. Include bushfire hazard reduction information.
- Seek external funding for regeneration projects in priority areas such as for endangered ecological communities (such as Umina Woodland community).
- Continue to support Council's volunteer Bushcare program including workshops and training.
- Develop and implement a policy for foreshore management, to include mowing regimes, protection of foreshore vegetation including EECs, emergent macrophytes, fertiliser use, frog hygiene.
- Improve signage around foreshores to inform community regarding offences related to vegetation removal.
- Review Council's Coastal Lagoons Management Plan to incorporate climate change predictions and include a long-term goal to raise let out levels or return lagoons to natural opening regimes.

Corridors and habitat linkages

- Promote and maintain corridors as a basis for maintaining biodiversity.
- Identify important wildlife linkages throughout the City between Council's parks, reserves, Coastal Open Space System, coastal lagoons, riparian habitats, wetlands, Nature Reserves, National Parks and other private and public lands.
- Identify potential obstructions to wildlife movement both within the City and to adjoining LGAs and develop mechanisms to overcome such obstructions.
- Work with adjoining Councils and community groups to preserve biodiversity within their LGA and work towards the enhancement and preservation of wildlife corridors to and from adjoining LGAs.
- Develop and promote voluntary conservation incentives to private landholders and public land managers to encourage the retention and management of habitat for significant vegetation and species.
- Trial a program to encourage landholders to erect nest boxes (especially for threatened species such as Yellow-bellied Glider, Large Forest Owls) and to monitor species using them.

Community Participation and Education

- Educate and involve the total community in biodiversity.
- Foster public education regarding biodiversity issues through advertisements, brochures and publications and other (internet, educational displays, field days, workshops) on biodiversity issues
- Develop a Companion Animals Education Campaign particularly in relation to pets in reserves and other bushland areas.
- Encourage community involvement in biodiversity via data collection, recovery and restoration of any targeted areas.
- Undertake an environmental education program for a youth audience to encourage interest in native plants and animals and to prevent cruelty to animals.
- Undertake an educational campaign for the community on feeding of native animals.
- Continue education programs on green waste and other recycling programs
- Provide information on local native plants and environmental weeds, this may be in the form of a 'look-alike' brochure.
- Develop information brochure on wildlife corridors
- Provide information on native species that can be planted in riparian areas and for streambank stability.
- Continue the Naturewatch Diary Project and report results to the community.

- Encourage and support community monitoring programs (such as Green and Golden Bell Frog, Bush Stone-curlew, Yellow Bellied-Glider, Waterwatch, nest boxes).
- Encourage landowners, the public and other interested parties in undertaking conservation and biodiversity restoration on public and private property.
- Provide assistance, information and support to individuals and groups within the community with an interest in biodiversity through resourcing libraries, counter advice, brochure, information sheets and other appropriate means.
- Promote use of coumatetralyl-based rodenticides over brodifacouma-based rodenticides (masked owls and others susceptible to secondary poisoning).
- Undertake fire awareness community education programs such as *Fire Awareness at the Bushland Interface.* Include a variety of techniques such as fire awareness days, brochures, interpretive signage and static displays.
- Involve schools in biodiversity conservation, through integration with Schools' Environmental Management Plans and curriculum materials.
- Develop education support material and/or support for teacher in-service training
- Continue educational programs on stormwater issues, importance of foreshore and riparian vegetation for water quality, pollutant sources such as dog faeces, and aquatic biodiversity.
- Undertake integrated education program to reduce incident of foreshore mowing by residents.
- Increase the knowledge and understanding of the role of fungi in bushland ecosystems by teaching community groups to recognise and identify fungi.
- Provide fungi kits, displays, workshops and presentations to Bushcare groups.

Managing threats to biodiversity

- Support research and identify threats to biodiversity in order to develop management strategies to address threats and protect and enhance biodiversity conservation.

- Council (as a member of the Regional Vertebrate Pest Committee) to seek funding for a Pilot Program for a regional Vertebrate Pest Management Project Officer.
- Prepare the Natural Areas Bushfire Risk Analysis (including a review of planning documents such as the Gosford Bushfire Planning Review & Gosford Evacuation Plan).
- Undertake an audit of landuses in lagoon catchments (including water quality of dams, other impediments to natural flow and nutrient runoff) to include recommendations to improve quality and possibly quantity runoff to lagoon catchments.
- Prepare an annual Fuel Management Plan that incorporates biodiversity considerations.
- Engage consultants to examine the biodiversity implications of climatic change for Gosford City.
- Council bush regeneration team to target priority weeds and high conservation areas in Council reserves
- Environmental weeds list to be regularly reviewed and updated when required.
- Develop and implement strategies for the control and management of regional environmental weeds.

Threatened Species Recovery

- Recover species which have become lost to the locality, or are at dangerously low population levels.

- Implement recovery plan recommendations identified for local government and other specific actions to conserve most at risk species and communities.
- Work in cooperation with the DEC and the community to implement actions identified in recovery plans for threatened species within the City.
- Specific Projects to include the Green and Golden Bell Frog (*Litoria aurea*) and Yellow-bellied Glider *Petaurus maculatus*

Monitor and research biodiversity

- Identify and fund future biodiversity research that addresses key issues and is of particular relevance to Gosford City.
- Continue to encourage and fund both aquatic and terrestrial biodiversity scientific research projects that will benefit Council and its environmental monitoring and management decisions.
- Identify biodiversity targets and indicators and monitor the implementation of biodiversity actions.
- Continue to encourage the involvement of the Universities, other research institutions and the public and private sector into Biodiversity research.
- Undertake monitoring to assess the effectiveness of management activities on biodiversity conservation through Community Monitoring project.
- Undertake monitoring to assess the effectiveness of management activities on biodiversity conservation through targeted consultancies.
- Fund research projects that consider recommendations in recovery plans such as forest owl monitoring (nest site characteristics and radio tracking studies).
- Engage specialist consultant to undertake flora surveys in poorly defined or poorly sampled vegetation types to clarify floristic relationships between the various vegetation units within the region.
- Include fauna surveys, especially macro-invertebrate studies, and sediment quality in Council water quality monitoring programs.
- Undertake comprehensive surveys of intertidal and subtidal flora and fauna assemblages along open coast.
- Work with community groups to collect data on fungi and build a database of information on local fungi species by conducting regular surveys for fungi.

Coordination and Partnerships

Establish and maintain effective partnerships and collaborations with agencies and community groups to maximise coordination of natural resource programs and efficient use of resources.

- Work closely with the DEC to address biodiversity with respect to the Nature Reserves and National Parks within the City.
- Work closely with other relevant government authorities to maximise biodiversity conservation across the LGA.
- Work with adjoining Councils and community groups to preserve biodiversity within their Local Government Area and work towards the enhancement and preservation of wildlife corridors to and from adjoining LGAs.
- Participate in the Regional Biodiversity Conservation Strategy.
- Work closely with community groups in order to undertake investigations and implement strategies.
- Participate in State Firewise Programs
- Identify funding opportunities and apply for funding as opportunities arise.
- Develop research partnerships with academic institutions.

4.0 Consideration for Fisheries Management

Tourism can impact on coastal water bodies such as coastal lagoons through a variety of ways including:

- Trampling of foreshore habitats
- Littering
- Development of foreshore infrastructure to support visitor amenity
- Noise and other disturbances can interfere with breeding or brooding avifauna
- Increased turbidity by stirring bottom sediments

Recreational or tourist based fishing can also impact on lagoon ecosystems through:

- Over fishing
- Disturbance to foreshores through trampling
- Disturbance to sea bed and water quality through boating (e.g. anchors, spills, bilge waste)
- Bait collecting

However, the impacts of fishing and tourism are often minor compared to a variety of other anthropogenic disturbances, such as land clearing, pollution from stormwater, sewage overflows and petroleum spills, reclamation and the construction of seawalls, etc. Tourist activities that could have minor impacts if sensibly planned include:

- Foreshore picnicking (would require maintained support amenities such as toilets, barbecues, playgrounds, parking).
- Non-motorised watercraft such as sailboarding, paddleboats, canoeing, kayaking, rowing and small sailing craft activities.
- Swimming
- Walking

Powered boats are currently not permitted in the lagoons so there is little impact from boating or dangers of a boat-based petroleum spill. Fishing requires little support infrastructure and is generally compatible with all forms of recreation occurring on the coastal lagoons. There is a potential for conflict with between fishermen, non-powered watercraft and swimmers.

However, there are few fish of value to recreational fishermen. To improve the recreational value of fishing in these lagoons would require considerable effort in regard to the encouragement and the maintenance of the fish stocks. Fish stocking using fingerlings has been used as a tool to boost fish stocks in wetlands elsewhere, however, the benefit of such an investment in an ICOLL is questionable as stocks would simply be flushed out to sea with every opening. Water quality could also be an issue at present as a healthy biological community require good water quality to support the fish stocks. Wetland areas could be expanded to assist with water quality management and for fish habitat, however, that would require a complete reversal in historic trends as urbanisation anthropogenic impacts have seen these habitats diminishing.

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Appendix 1 ANOVA results for fringing vegetation

B.juncaea

Between

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	0.003225	9	0.002442	1.320819	0.314071

Within

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	0.004208333	8	0.001975	2.130802	0.174516

B. articulta

Between

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	3.33E-05	9	6.94E-05	0.48	0.633759

Within

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	8.33333E-06	8	8.33333E-05	0.1	0.957763

Apium prostratum

Between

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	0.000108	9	6.11E-05	1.772727	0.224338

Within

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	5.55556E-05	8	7.5E-05	0.740741	0.556975

Selliera radicans

Between

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	7.5E-05	9	9.44E-05	0.794118	0.481266

Within

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	6.66667E-05	8	1E-04	0.666667	0.595719

Appendix 2 NSW Fisheries data 1986-2008

Species	Common name	Wamberal					Terrigal				
		1986	1987	1988	2002	2008	1986	1987	1988	2002	2008
Acanthopagrus australis	Bream	58	174	76	0	24	33	138	36	3	31
Acentrogobius bifrenatus	Bridled goby	9	187	17	4	7	100	96	32	3	39
Acentrogobius frenatus	Half-bridled goby	0	0	0	0	0	31	37	0	0	3
Acetes sibogae australis	Sergestid shrimp	0	0	0	0	0	0	0	0	3	0
Achoerodus viridis	Eastern Blue Groper	3	0	0	0	0	0	1	0	0	0
Afurcagobius tamarensis	Tamar River goby	10	803	0	0	0	1	33	11	2	7
Ambassis jacksoniensis	Glassfish	1	6	0	0	0	1562	1785	19	464	868
Ambassis marianus	Estuary perchlet	0	0	0	0	0	0	5	0	0	5
Ammotretis rostratus	Long-Nosed Flounder	3	0	0	0	0	0	0	0	0	0
Anguilla australis	Short Finned Eel	0	0	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfinned Eel	0	0	0	0	1	0	1	0	0	0
Antennarius striatus	Striated frogfish	1	0	0	0	0	1	0	0	0	0
Arripis trutta	Eastern Australian Salmon	1	0	0	0	0	2	0	0	0	0
Atherinomorus vaigiensis	Hardyhead	0	0	0	0	0	0	0	0	0	0
Atherinosoma microstoma	Small Mouth Hardyhead	3923	4554	3023	248	976	2061	7	9	0	0
Bathygobius krefftii	Krefft's goby	0	0	0	0	0	3	0	0	0	0
Callogobius sp	Goby	0	5	0	0	0	0	0	0	0	0
Centropogon australis	Fortescue	3	1	0	0	0	35	65	25	0	0
Chelidonichthys kumu	Red Gurnard	1	0	0	0	0	0	0	0	0	0
Cryptocentrus critatus	Oyster goby	0	0	0	0	0	73	278	7	0	0
Favonigobius exquisitus	Exquisite sand-goby	29	2	0	8	0	4	5	0	2	3
Favonigobius lateralis	Goby	1	0	0	0	0	0	2	0	0	0
Gambusia affinis	Mosquitofish	1	1	6	0	0	3	1	0	0	21
Gambusia holbrooki	Eastern mosquitofish	0	0	0	0	0	0	0	0	0	2
Gerres subfasciatus	Silver Biddy	0	32	0	0	0	99	178	46	49	0
Girella tricuspidata	Luderick	0	3	0	0	0	0	23	14	0	0
Gobiopterus semivestita	Goby	0	3	9	0	0	16	79	224	0	12
Gonorynchus greyi	Beaked Salmon	1	0	0	0	0	0	0	0	0	0
Herklotsichthys castelnaui	Southern Herring	1	0	0	0	2	17	36	1	40	48
Hyperlophus vittatus	Sandy sprat	0	0	2	0	0	241	0	0	0	0
Hyporhamphus regularis ardelio	Eastern river garfish	54	68	33	6	485	11	8	12	1	1
Hypseleotris compressa	Empire gudgeon	0	0	0	0	0	0	0	0	0	0

Iso rhothophilus	Surf sardine	36	0	0	0	0	0	0	0	0	0
Leptatherina presbyteroides	Silver side	0	0	0	131	0	0	0	0	0	0
Liza argentea	Flat-tail Mullet	4	13	4	0	11	50	210	187	0	86
Macquaria colonorum	Estuary Perch	1	1	0	0	0	0	0	0	0	1
Macquaria novemaculeata	Australian Bass	0	0	0	0	0	0	0	0	0	0
Macrobrachium intermedium	Striped Shrimp	0	0	0	42	0	0	0	0	1	0
Metapenaeus macleayi	School Prawn	0	0	0	0	0	0	0	0	1	0
Meuschenia freycineti	Six-spine Leatherjacket	0	0	0	0	0	0	6	0	0	0
Meuschenia trachylepis	Yellow-finned Leatherjacket	0	0	0	0	0	5	9	9	0	0
Monacanthus chinensis	Fan-bellied Leatherjacket	0	0	0	0	0	0	1	0	0	0
Monodactylus argenteus	Fingerfish	0	0	0	0	0	0	2	38	0	0
Mugil cephalus	Flathead mullet	90	121	66	0	48	343	542	43	1	40
Mugilogobius stigmaticus	Goby	0	0	0	0	0	0	0	0	0	0
Myxus elongatus	Sand grey mullet	412	127	319	1	6	1049	1350	838	0	2
Palaemon spp.	Prawn	0	0	0	57	0	0	0	0	0	0
Parkraemeria ornata	Goby	0	1	0	0	0	0	0	0	0	0
Pelates sexlineatus	Six-lined trumpeter	0	0	0	0	0	1	0	8	0	0
Petroscirtes lupus	Brown Sabretooth Blenny	0	0	0	0	0	0	1	0	0	0
Philypnodon grandiceps	Flathead Gudgeon	227	339	93	299	65	258	541	95	7	62
Philypnodon spp.	Gudgeons	29	40	33	15	11	25	27	6	0	0
Platycephalus fuscus	Dusky Flathead	0	5	1	0	1	10	14	10	0	1
Pomatomus saltatrix	Tailor	0	1	0	0	0	0	0	1	0	0
Pseudocaranx dentex	White trevally	3	0	0	0	0	0	0	2	0	0
Pseudogobius olorum	Swan river goby	29	48	104	39	25	26	50	82	4	12
Pseudomugil signifer	Pacific Blue Eye	51	50	58	2	5	4	97	5	0	1
Pseudorhombus arsius	Large-tooth flounder	0	0	0	0	0	0	2	0	0	0
Pseudorhombus jenynsii	Small-Toothed Flounder	1	0	0	1	0	1	1	0	0	1
Redigobius macrostoma	Large-mouth Goby	0	0	0	0	0	13	1	53	0	0
Repomucenus calcaratus	Spotted stinkfish	4	0	1	0	0	0	0	0	3	3
Rhabdosargus sarba	Tarwhine	0	2	0	0	0	1	21	7	8	0
Sillago ciliata	Sand Whiting	18	55	3	11	0	160	361	50	0	13
Sillago maculata	Trumpeter Whiting	0	0	0	0	0	0	1	1	0	0

Synaptura nigra	Black sole	0	0	0	0	0	0	2	1	2	0
Terapon jarbua	Crescent Perch	1	1	0	0	0	0	0	0	0	0
Tetractenos glaber	Smooth Toadfish	2	0	0	0	1	2	1	3	0	0
Tetractenos hamiltoni	Common Toadfish	0	0	0	0	1	0	4	0	0	0
Torquigener pleurogramma	Weeping Toadfish	0	0	0	0	0	0	0	0	0	0
Trachinotus coppingeri	Swallowtail Dart	0	0	0	0	0	2	0	0	0	0
Urocampus carinirostris	Hairy Pipefish	0	1	1	0	0	3	1	5	0	0
Valamugil georgii	Silver mullet	0	0	0	0	0	7	3	1	0	0

Species	**Common name**	**Avoca**					**Cockrone**				
		1986	1987	1988	2002	2008	1986	1987	1988	2002	2008
Acanthopagrus australis	Bream	17	129	15	16	31	68	350	197	10	134
Acentrogobius bifrenatus	Bridled goby	2	7	0	0	16	0	0	5	0	0
***Acentrogobius* frenatus**	Half-bridled goby	0	0	0	2	0	0	0	0	0	0
Acetes sibogae australis	Sergestid shrimp	0	0	0	0	0	0	0	0	0	0
Achoerodus viridis	Eastern Blue Groper	1	1	0	0	0	0	2	0	0	0
Afurcagobius tamarensis	Tamar River goby	5	20	0	0	8	1	5	0	0	0
Ambassis jacksoniensis	Glassfish	71	193	0	2	0	1	631	0	0	0
Ambassis marianus	Estuary perchlet	10	0	0	0	0	0	0	0	0	0
Ammotretis rostratus	Long-Nosed Flounder	0	0	0	0	0	11	0	0	0	0
Anguilla australis	Short Finned Eel	0	0	1	1	0	0	1	0	0	0
Anguilla reinhardtii	Longfinned Eel	0	0	0	0	0	0	0	0	0	0
Antennarius striatus	Striated frogfish	0	0	0	0	0	0	1	0	0	0
Arripis trutta	Eastern Australian Salmon	2	0	0	0	0	0	1	0	0	0
Atherinomorus vaigiensis	Hardyhead	0	0	2	2	0	0	10062	2	0	0
Atherinosoma microstoma	Small Mouth Hardyhead	3492	8780	1274	1284	147	1848	0	35	2	2
Bathygobius krefftii	Krefft's goby	0	0	0	0	0	0	0	0	0	0
Callogobius sp	Goby	0	0	0	0	0	0	0	0	0	0

Centropogon australis	Fortescue	6	11	1	1	1	0	1	0	0	2
Chelidonichthys kumu	Red Gurnard	0	0	0	0	0	0	0	0	0	0
Cryptocentrus critatus	Oyster goby	0	0	0	0	0	0	0	0	0	0
Favonigobius exquisitus	Exquisite sand-goby	1	0	0	6	0	0	3	0	0	4
Favonigobius lateralis	Goby	4	1	0	3	0	0	0	0	0	0
Gambusia affinis	Mosquitofish	0	7	91	91	0	0	2	2	0	0
Gambusia holbrooki	Eastern mosquitofish	0	0	0	0	1	0	0	0	0	2
Gerres subfasciatus	Silver Biddy	0	2	0	10	0	0	0	0	0	1
Girella tricuspidata	Luderick	1	7	0	0	0	0	0	0	0	0
Gobiopterus semivestita	Goby	0	4	0	0	0	0	0	0	0	0
Gonorynchus greyi	Beaked Salmon	0	0	0	0	0	1	0	0	0	0
Herklotsichthys castelnaui	Southern Herring	0	14	33	55	114	0	4	0	0	0
Hyperlophus vittatus	Sandy sprat	0	0	0	0	7	0	4	0	0	0
Hyporhamphus regularis ardelio	Eastern river garfish	21	53	1	2	105	4	4	10	0	16
Hypseleotris compressa	Empire gudgeon	0	0	0	3	0	0	0	0	0	0
Iso rhothophilus	Surf sardine	1	0	0	0	0	0	0	0	0	0
Leptatherina presbyteroides	Silver side	0	0	0	162	0	0	0	0	178	0
Liza argentea	Flat-tail Mullet	7	18	5	5	0	0	121	0	0	0
Macquaria colonorum	Estuary Perch	0	0	0	0	0	0	0	0	0	0
Macquaria novemaculeata	Australian Bass	0	0	1	1	0	0	0	0	0	0
Macrobrachium intermedium	Striped Shrimp	0	0	0	6	0	0	0	0	0	0
Metapenaeus macleayi	School Prawn	0	0	0	0	0	0	0	0	0	0
Meuschenia freycineti	Six-spine Leatherjacket	0	0	0	0	0	0	0	0	0	0
Meuschenia trachylepis	Yellow-finned Leatherjacket	0	0	0	0	0	0	0	0	0	0
Monacanthus chinensis	Fan-bellied Leatherjacket	0	0	0	0	0	0	0	0	0	0
Monodactylus argenteus	Fingerfish	0	0	0	0	0	0	0	0	0	0
Mugil cephalus	Flathead mullet	14	43	86	86	57	46	73	2	0	7
Mugilogobius	Goby	0	1	765	0	0	2062	0	0	0	0

stigmaticus											
Myxus elongatus	Sand grey mullet	162	117	0	768	2	0	187	45	0	74
Palaemon spp.	Prawn	0	0	0	0	0	0	0	0	0	0
Parkraemeria ornata	Goby	0	0	0	0	0	0	0	0	0	0
Pelates sexlineatus	Six-lined trumpeter	5	0	0	0	0	0	0	0	0	0
Petroscirtes lupus	Brown Sabretooth Blenny	0	0	0	0	0	0	0	0	0	0
Philypnodon grandiceps	Flathead Gudgeon	121	84	25	122	468	12	209	74	151	7
Philypnodon spp.	Gudgeons	139	729	270	276	39	7	446	9	4	0
Platycephalus fuscus	Dusky Flathead	1	10	3	3	0	0	0	0	0	0
Pomatomus saltatrix	Tailor	0	0	0	0	0	0	0	0	0	0
Pseudocaranx dentex	White trevally	6	0	0	0	0	6	0	0	0	0
Pseudogobius olorum	Swan river goby	53	22	24	26	18	9	157	287	7	2
Pseudomugil signifer	Pacific Blue Eye	77	119	95	106	6	14	907	12	10	2
Pseudorhombus arsius	Large-tooth flounder	0	1	0	0	0	0	0	0	0	0
Pseudorhombus jenynsii	Small-Toothed Flounder	0	0	0	0	0	0	0	0	0	0
Redigobius macrostoma	Large-mouth Goby	0	0	0	0	0	0	0	0	0	0
Repomucenus calcaratus	Spotted stinkfish	0	2	0	0	0	1	0	0	0	0
Rhabdosargus sarba	Tarwhine	3	11	4	5	0	0	2	0	0	0
Sillago ciliata	Sand Whiting	73	24	24	63	0	16	1	142	0	51
Sillago maculata	Trumpeter Whiting	0	0	0	0	0	0	0	0	0	0
Synaptura nigra	Black sole	0	0	0	0	0	0	0	0	0	0
Terapon jarbua	Crescent Perch	1	0	0	0	0	0	0	2	0	0
Tetractenos glaber	Smooth Toadfish	0	1	0	0	1	0	0	0	0	0
Tetractenos hamiltoni	Common Toadfish	0	0	0	0	1	0	0	0	0	0
Torquigener pleurogramma	Weeping Toado	1	0	0	2	0	0	0	0	0	0
Trachinotus coppingeri	Swallowtail Dart	0	0	1	0	0	0	0	0	0	0
Urocampus carinirostris	Hairy Pipefish	4	100	0	1	0	0	2	1	0	0
Valamugil georgii	Silver mullet	0	0	0	0	0	0	0	0	0	0

Appendix 3a Fauna list for Wamberal Lagoon (NSW NPWS, 2009)

Amphibia	Map	Scientific Name	Common Name	Legal Status	Count	Info
Hylidae						
		Litoria dentata	Bleating Tree Frog	P	3	
		Litoria fallax	Eastern Dwarf Tree Frog	P	1	
		Litoria peronii	Peron's Tree Frog	P	2	
Myobatrachidae						
		Crinia signifera	Common Eastern Froglet	P	5	
		Limnodynastes peronii	Brown-striped Frog	P	3	

Aves	Map	Scientific Name	Common Name	Legal Status	Count	Info
Acanthizidae						
		Acanthiza lineata	Striated Thornbill	P	1	
		Acanthiza nana	Yellow Thornbill	P	1	
		Acanthiza pusilla	Brown Thornbill	P	2	
		Sericornis frontalis	White-browed Scrubwren	P	8	
Accipitridae						
		Accipiter novaehollandiae	Grey Goshawk	P	1	
		Haliaeetus leucogaster	White-bellied Sea-Eagle	P	4	
		Haliastur sphenurus	Whistling Kite	P	4	
		Pandion haliaetus	Osprey	V	1	i
Alcedinidae						
		Dacelo novaeguineae	Laughing Kookaburra	P	3	
		Todiramphus sanctus	Sacred Kingfisher	P	3	
Anatidae						
		Anas castanea	Chestnut Teal	P	5	
		Anas gracilis	Grey Teal	P	1	
		Anas superciliosa	Pacific Black Duck	P	2	
		Chenonetta jubata	Australian Wood Duck	P	1	
		Cygnus atratus	Black Swan	P	3	

Anhingidae				
☐	Anhinga novaehollandiae	Australasian Darter	P	1
Ardeidae				
☐	Ardea modesta	Eastern Great Egret	P	1
☐	Egretta garzetta	Little Egret	P	2
☐	Egretta novaehollandiae	White-faced Heron	P	2
Artamidae				
☐	Artamus leucorynchus	White-breasted Woodswallow	P	1
☐	Cracticus tibicen	Australian Magpie	P	5
☐	Cracticus torquatus	Grey Butcherbird	P	2
☐	Strepera graculina	Pied Currawong	P	2
Cacatuidae				
☐	Cacatua galerita	Sulphur-crested Cockatoo	P	2
☐	Cacatua tenuirostris	Long-billed Corella	P	1
☐	Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo	P	1
☐	Eolophus roseicapillus	Galah	P	2
Campephagidae				
☐	Coracina novaehollandiae	Black-faced Cuckoo-shrike	P	1
Centropodidae				
☐	Centropus phasianinus	Pheasant Coucal	P	1
Charadriidae				
☐	Vanellus miles	Masked Lapwing	P	2
Columbidae				
☐	Geopelia humeralis	Bar-shouldered Dove	P	1
☐	Ocyphaps lophotes	Crested Pigeon	P	2
☐	Streptopelia chinensis*	Spotted Turtle-Dove	U	2
Corcoracidae				
☐	Corcorax melanorhamphos	White-winged Chough	P	1
Corvidae				
☐	Corvus coronoides	Australian Raven	P	5
Cuculidae				
☐	Eudynamys orientalis	Eastern Koel	P	1

	Scythrops novaehollandiae	Channel-billed Cuckoo	P	1
Dicruridae				
	Dicrurus bracteatus	Spangled Drongo	P	1
Estrildidae				
	Neochmia temporalis	Red-browed Finch	P	3
Falconidae				
	Falco cenchroides	Nankeen Kestrel	P	1
Hirundinidae				
	Hirundo neoxena	Welcome Swallow	P	2
Laridae				
	Chlidonias hybrida	Whiskered Tern	P	1
	Chroicocephalus novaehollandiae	Silver Gull	P	11
	Sterna fuscata	Sooty Tern	V	1
	Sterna hirundo	Common Tern	P	1
	Sterna striata	White-fronted Tern	P	1
	Thalasseus bergii	Crested Tern	P	8
Maluridae				
	Malurus cyaneus	Superb Fairy-wren	P	8
	Malurus lamberti	Variegated Fairy-wren	P	4
Megapodiidae				
	Alectura lathami	Australian Brush-turkey	P	5
Meliphagidae				
	Acanthorhynchus tenuirostris	Eastern Spinebill	P	1
	Anthochaera carunculata	Red Wattlebird	P	5
	Anthochaera chrysoptera	Little Wattlebird	P	9
	Lichenostomus chrysops	Yellow-faced Honeyeater	P	1
	Manorina melanocephala	Noisy Miner	P	3
	Meliphaga lewinii	Lewin's Honeyeater	P	14
	Melithreptus lunatus	White-naped Honeyeater	P	1
	Phylidonyris niger	White-cheeked Honeyeater	P	10
	Phylidonyris novaehollandiae	New Holland Honeyeater	P	3

Monarchidae				
☐	Grallina cyanoleuca	Magpie-lark	P	1
Oriolidae				
☐	Sphecotheres vieilloti	Australasian Figbird	P	1
Pachycephalidae				
☐	Colluricincla harmonica	Grey Shrike-thrush	P	1
☐	Pachycephala pectoralis	Golden Whistler	P	1
Pardalotidae				
☐	Pardalotus punctatus	Spotted Pardalote	P	3
Pelecanidae				
☐	Pelecanus conspicillatus	Australian Pelican	P	2
Petroicidae				
☐	Eopsaltria australis	Eastern Yellow Robin	P	2
Phalacrocoracidae				
☐	Microcarbo melanoleucos	Little Pied Cormorant	P	5
☐	Phalacrocorax carbo	Great Cormorant	P	5
☐	Phalacrocorax sulcirostris	Little Black Cormorant	P	4
Podargidae				
☐	Podargus strigoides	Tawny Frogmouth	P	1
Procellariidae				
☐	Ardenna grisea	Sooty Shearwater	P	1
☐	Ardenna pacificus	Wedge-tailed Shearwater	P	4
☐	Ardenna tenuirostris	Short-tailed Shearwater	P	1
Psittacidae				
☐	Platycercus elegans	Crimson Rosella	P	1
☐	Trichoglossus haematodus	Rainbow Lorikeet	P	6
Psophodidae				
☐	Psophodes olivaceus	Eastern Whipbird	P	9
Ptilonorhynchidae				
☐	Ptilonorhynchus violaceus	Satin Bowerbird	P	4
Pycnonotidae				
☐	Pycnonotus jocosus*	Red-whiskered Bulbul	U	2

Rallidae					
		Gallinula tenebrosa	Dusky Moorhen	P	1
		Porphyrio porphyrio	Purple Swamphen	P	1
Rhipiduridae					
		Rhipidura albiscapa	Grey Fantail	P	1
		Rhipidura leucophrys	Willie Wagtail	P	2
		Rhipidura rufifrons	Rufous Fantail	P	1
Spheniscidae					
		Eudyptula minor	Little Penguin	P	1
Sturnidae					
		Sturnus tristis*	Common Myna	U	1
		Sturnus vulgaris*	Common Starling	U	1
Sulidae					
		Morus serrator	Australasian Gannet	P	5
Threskiornithidae					
		Platalea regia	Royal Spoonbill	P	2
Timaliidae					
		Zosterops lateralis	Silvereye	P	7

Mammalia	Map	Scientific Name	Common Name	Legal Status	Count Info
Canidae					
		Canis lupus familiaris*	Dog	U	1
Dasyuridae					
		Antechinus stuartii	Brown Antechinus	P	4
Felidae					
		Felis catus*	Cat	U	1
Leporidae					
		Oryctolagus cuniculus*	Rabbit	U	1
Macropodidae					
		Wallabia bicolor	Swamp Wallaby	P	6
Molossidae					
		Mormopterus "Species 2"	Undescribed Freetail Bat	P	2
		Tadarida australis	White-striped Freetail-bat	P	1
Muridae					
		Rattus fuscipes	Bush Rat	P	9

		Rattus lutreolus	Swamp Rat	P	1	
		Rattus rattus*	Black Rat	U	2	
Otariidae						
		Arctocephalus tropicalis	Subantarctic Fur-seal	P	1	
Phalangeridae						
		Trichosurus vulpecula	Common Brushtail Possum	P	1	
Phocidae						
		Hydrurga leptonyx	Leopard Seal	P	2	
Pseudocheiridae						
		Pseudocheirus peregrinus	Common Ringtail Possum	P	4	
Tachyglossidae						
		Tachyglossus aculeatus	Short-beaked Echidna	P	2	
Vespertilionidae						
		Chalinolobus gouldii	Gould's Wattled Bat	P	2	
		Chalinolobus morio	Chocolate Wattled Bat	P	1	
		Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	1	
		Nyctophilus gouldi	Gould's Long-eared Bat	P	1	
		Vespadelus darlingtoni	Large Forest Bat	P	2	
		Vespadelus vulturnus	Little Forest Bat	P	1	

Reptilia	Map	Scientific Name	Common Name	Legal Status	Count	Info
Agamidae						
		Amphibolurus muricatus	Jacky Lizard	P	1	
		Physignathus lesueurii	Eastern Water Dragon	P	2	
		Rankinia diemensis	Mountain Dragon	P	1	
Boidae						
		Morelia spilota	Carpet & Diamond Pythons	P	1	
		Morelia spilota spilota	Diamond Python	P	1	
Elapidae						
		Cacophis krefftii	Southern Dwarf Crowned Snake	P	1	

	☐ Demansia psammophis	Yellow-faced Whip Snake	P	1
	☐ Pseudechis porphyriacus	Red-bellied Black Snake	P	1
Pygopodidae				
	☐ Pygopus lepidopodus	Common Scaly-foot	P	1
Scincidae				
	☐ Bellatorias major	Land Mullet	P	2
	☐ Ctenotus robustus	Robust Ctenotus	P	1
	☐ Lampropholis delicata	Dark-flecked Garden Sunskink	P	1
	☐ Lampropholis guichenoti	Pale-flecked Garden Sunskink	P	1
	☐ Tiliqua scincoides	Eastern Blue-tongue	P	1

Appendix 3b Threatened species

The following is a list of the threatened species found in Gosford City as listed under the Schedules of the *Threatened Species Conservation* (TSC) *Act 1995*, *Fisheries Management* (FMA) *Act 1994* and the *Commonwealth Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999.*

ENDANGERED SPECIES			
Schedule 1 *Threatened Species Conservation Act 1995*	**TSC ***	**FMA ****	**EPBC*****
Amphibians			
Green & Golden Bell Frog (*Litoria aurea*)	√	----	√ **(as Vulnerable)**
Giant Barred Frog (*Mixophyes iteratus*)		----	----
Stuttering Frog (*Mixophyes balbus*)	√	----	√ **(as Vulnerable)**
Birds			
Black-necked Stork (*Ephippiorhynchus asiaticus*)	√	----	----
Bush Stone-curlew (*Burhinus grallarius*)	√	----	----
Flock Bronzewing (*Phaps histrionica*)	√	----	----
Gould's Petrel (*Pterodroma leucoptera leucoptera*)	√	----	√ **(as Endangered)**
Little Tern (*Sterna albifrons*)	√	----	----
Regent Honeyeater (*Xanthomyza phrygia*)	√	----	√ **(as Endangered)**
Swift Parrot (*Lathamus discolor*)	√	----	√ **(as Endangered)**
Wandering Albatross (*Diomedea exulaus*)	√	----	√ **(as Vulnerable)**
Southern Giant Petrel (*Macronectes giganteus*)	√	----	√ **(as Endangered)**
Mammals (terrestrial)			
Eastern Quoll (*Dasyurus viverrinus*)	√	----	----
Southern Brown Bandicoot (*Isoodon obesulus*)	√	----	√ **(as Endangered)**
Reptiles			
Broad-headed Snake (*Hoplocephalus bungaroides*)	√	----	√ **(as Vulnerable)**
Invertebrates			
None			
Flora			
Acacia bynoeana Benth.	√	----	√ **(as Vulnerable)**
Chamaesyce psammogeton (P.S. Green) P.I. Forster and R.J. Henderson	√	----	√ **(as Endangered)**
Dendrobium melaleucaphilum M.A. Clem. & D.L. Jones'	√	----	----
Hibbertia procumbens (Labill.) DC.	√	----	----
Hibbertia puberula Toelken			
Persoonia hirsuta Pers. (new subspecies recorded in Yengo NP)	√	----	√ **(as Endangered)**
Prostanthera askania B J Conn (=Strickland SF)	√	----	√ **(as Endangered)**
Prostanthera junonis (=sp. Somersby)	√	----	√ **(as Endangered)**
Endangered Populations (Fauna)			
None			

VULNERABLE SPECIES			
Schedule 2 *Threatened Species Conservation Act 1995*	*TSC **	*FMA ***	*EPBC****
Amphibians			
Giant Burrowing Frog (*Heleioporus australiacus*)	√	----	√ (as Vulnerable)
Green Thighed Frog (*Litoria brevipalmata*)	√	----	----
Heath Frog (*Litoria littlejohni)*)	√	----	----
Red-crowned Toadlet (*Pseudophryne australis*)	√	----	----
Wallum Froglet (*Crinia tinnula)*	√	----	----
Birds			
Antipodean Albatross (*Diomedea antipodensis*)	√	----	√ (as Vulnerable)
Australasian Bittern (*Botaurus poiciloptilus*)	√	----	----
Barking Owl (*Ninox connivens*)	√	----	----
Black Bittern (*Ixobrychus flavicollis*)	√	----	----
Black-breasted Buzzard (*Hamirostra melanosternon*)	√	----	----
Black-chinned Honeyeater (eastern species) *Melithreptus gularis gularis*	√		
Black-tailed Godwit (*Limosa limosa*)	√	----	----
Black-winged Petrel (*Pterodroma nigripennis*)	√	----	----
Black-browed Albatross (*Diomedea melanophrys*)	√	----	----
Broad-billed Sandpiper (*Limicola falcinellus)*	√	----	----
Brown Treecreeper (eastern species) *Climacteris picumnus victoriae*	√	----	----
Comb-crested Jacana (*Irediparra gallinacea*)	√	----	----
Diamond Firetail (*Stagonopleura guttata*)	√	----	----
Flesh-footed Shearwater (*Puffinus carneipes*)	√	----	----
Gibson's Albatross (*Diomedea gibsoni*)	√	----	√ (as Vulnerable)
Glossy Black Cockatoo (*Calyptorhychus lathami*)	√	----	----
Great Knot (*Calidris tenuirostris*)	√	----	----
Greater Sand Plover (*Charadrius leschenaulti)*	√	----	----
Grey-crowned Babbler (eastern subsp.) (*Pomatostomus temporalis temporalis)*	√	----	----
Hooded Robin (eastern subsp.) (*Melanodryas cucullata cucullata)*	√	----	----
Kermandec Petrel (*Pterodroma neglecta)*	√	----	----
Lesser Sand Plover (*Charadrius mongolus*)	√	----	----
Little Shearwater (*Puffinus assimilus*)	√	----	----
Magpie Goose (*Anseranas semipalmata*)	√	----	----
Masked Owl (*Tyto novaehollandiae*)	√	----	----
Osprey (*Pandion haliaetus*)	√	----	----
Painted snipe (*Rostratula benghalensis)*	√	----	----
Pied Oystercatcher (*Haematopus longirostris*)	√	----	----
Powerful Owl (*Ninon strenua*)	√	----	----
Providence Petrel (*Pterodroma solandri*)	√	----	----
Red-tailed Tropicbird (*Phaethon rubricauda*)	√	----	----
Rose-crowned Fruit-Dove (*Ptilinopus regina*)	√	----	----
Sanderling (*Calidris alba)*	√	----	----
Sooty Owl (*Tyto tenebricosa*)	√	----	----
Sooty Oystercatcher (*Haematopus fuliginosus*)	√	----	----
Sooty Tern (*Sterna fuscata*)	√	----	----
Speckled Warbler (*Pyrrholaemus sagittata)*	√		
Superb Fruit-Dove (*Ptilinopus superbus*)	√	----	----
Terek Sandpiper (*Xenus cinereus*)	√	----	----
Turquoise Parrot (*Neophema pulchella*)	√	----	----
White Tern (*Gygis alba*)	√	----	----
Wompoo Fruit-Dove (*Ptilinopus magnificus*)	√	----	----

VULNERABLE SPECIES			
Schedule 2 *Threatened Species Conservation Act 1995*	*TSC **	*FMA ***	*EPBC****
Mammals (terrestrial)			
Brush-tailed Phascogale (*Phascogale tapoatafa*)	√	----	----
Brush-tailed Rock-wallaby (*Petrogale pencillata*)	√	----	√ (as Vulnerable)
Common Bent-wing Bat (*Miniopterus schreibersii*)	√	----	----
East Coast Freetail bat (*Mormopterus norfolkensis)*	√	----	----
Eastern Cave Bat (*Vespadelus troughtoni*)	√	----	----
Eastern Chestnut Mouse (*Pseudomys gracilicaudatus*)	√	----	----
Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)	√	----	----
Eastern Freetail-bat (*Mormopterus sp*)	√	----	----
Eastern Horsehoe-Bat (*Rhinolophus megaphyllus*)	√	----	----
Eastern Little Mastiff-bat (*Hormopterus norfolcensis*)	√	----	----
Eastern Pygmy Possum (*Cercartetus nanus)*	√	----	----
Golden-tipped Bat (*Kerivoula papuensis*)	√	----	----
Greater Broad-nosed Bat (*Scoteanax reuppellii*)	√	----	----
Greater Long-eared Bat (*Nyctophilus timoriensii)*	√	----	----
Grey-headed Flying Fox (*Pteropus poliocephalus*)	√	----	√ (as Vulnerable)
Koala (*Phascolarctos cinereus*)	√	----	----
Large-eared Pied Bat (*Chalinolobus dwyeri*)	√	----	----
Large-footed Mouse-eared Bat / Myotis (*Myotis adversus*)	√	----	----
Little Bent-wing Bat (*Miniopterus australis*)	√	----	----
Long-nosed Potoroo (*Potorous tridactylus*)	√	----	√ (as Vulnerable)
Parma Wallaby (*Macropus parma*)	√	----	----
Spotted-tailed Quoll (*Dasyurus maculatus*)	√	----	√ (as Vulnerable)
Squirrel Glider (*Petaurus norfolcensis*)	√	----	----
Yellow-bellied Glider (*Petaurus australis*)	√	----	----
Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*)	√	----	----
Reptiles			
Green Turtle (*Chelonia mydas*)	√	----	√ (as Vulnerable)
Leathery Turtle (*Dermochelys coriacea)*	√	----	√ (as Vulnerable)
Stephen's Banded Snake (*Hoplocephalus stephensii*)	√	----	----
Rosenberg's Goanna (Heath Monitor)(*Varanus rosenbergi*)	√	----	----
White-crowned Snake (*Cacophis harriettae*)	√	----	----
Invertebrates			
Adams Emerald Dragonfly (*Archaeophya adamsi)*	----	√	----

Appendix E

Catchment Modelling Report

Cardno LawsonTreloar

Shaping the Future

Gosford Coastal Lagoons Processes Study

Appendix E – Catchment Modelling

LJ2713/R2657

Prepared for Gosford City Council

July 2010

Cardno (NSW/ACT) Pty Ltd
Trading as Cardno Lawson Treloar Pty Ltd
ABN 95 001 145 035
Level 2, 910 Pacific Highway
Gordon NSW 2072
Australia
Telephone: 02 9499 3000
Facsimile: 02 9499 3033
International: +61 2 9499 3000
www.cardno.com.au

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Glossary and Abbreviations

MUSIC	Model for Urban Stormwater Improvement Conceptualisation
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids

1 Introduction

When rain falls on the catchment, a range of pollutants may become entrained in the flow of stormwater and make their way into the lagoons via tributary creeks and drainage lines. Typical pollutants found in urban stormwater runoff may include:

- Gross pollutants (e.g. rubbish, grass clippings, etc.),
- Sediments, and
- Nutrients (including nitrogen and phosphorous).

The amount (or loadings) of these different pollutants will vary depending upon the specific characteristics of each catchment. For developed catchments, such as those of the four lagoons, the loadings of each of these types of pollutants in stormwater will typically be higher than would have been the case prior to development of the catchment. Depending upon the characteristics of the receiving waterbody, this may result in impacts on estuarine processes such as estuarine siltation and sedimentation, or algal blooms due to high nutrient concentrations.

Computer modelling of stormwater runoff was undertaken for the four lagoon catchments in order to estimate the typical pollutant loadings flowing into each of the lagoons. The modelling utilised the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software.

A MUSIC model was established to estimate pollutant loads of total nitrogen (TN), total phosphorous (TP) and total suspended solids (TSS) for each of the lagoon catchments. These pollutants represent key stressors for aquatic habitat values. A variety of catchment parameters, such as land-use, impervious area and soil properties, were incorporated into these MUSIC models. In order to fully represent weather conditions of the study area, specific yearly rainfall data for an average year, wet year (above average annual rainfall) and dry year (below average annual rainfall) were used to run the models.

The model setup and parameters established for this study are based on the MUSIC modelling undertaken for the *Brisbane Water Estuary Processes Study* (Cardno, 2008b). The Brisbane Water catchment is directly adjacent to the Gosford coastal lagoons catchments and the catchment characteristics are similar.

2 Model Development

2.1 Catchment Delineation

The larger study area encompasses four discrete catchments, each of which drains to one of the four lagoons. These catchments are delineated in Figure 3.1 of the main Gosford Coastal Lagoons Processes Study report. For the purposes of the catchment modelling, each of these four catchments were delineated into sub-catchments on the basis of topographic features (using 2m contour data), aerial photography and the likely flowpaths. Land use categories were then assigned to each of the sub-catchments based on a review of the aerial photography, as illustrated in Figure 3.3 of the main report. Further details are provided in **Table 2.1**.

The percentage of impervious ground for agricultural and forest land use types was assumed to be 5% across all sub-catchments. The impervious fraction for urban areas of each sub-catchment varied based on aerial photograph interpretation and the adopted values for the relevant sub-catchments are shown in the final column of **Table 2.1**.

Table 2.1: Sub-Catchment Details

Catchment	Sub-Catchment ID	Total Area (ha)	Land Use Type; Area (ha)				% Impervious
			Urban	Agricultural	Forest	Water	
Wamberal Lagoon	W1	116.52	39.23	61.84	15.45		50
	W10	61.06	0.00	0.00	0.00	61.06	-
	W2	67.25	0.00	67.25	0.00		-
	W3	32.78	32.78	0.00	0.00		50
	W4	75.08	0.00	0.00	75.08		-
	W5	107.59	0.00	107.59	0.00		-
	W6	35.03	5.30	0.00	29.73		50
	W7	62.74	41.20	0.00	21.54		45
	W8	53.71	41.41	0.00	12.30		50
	W9	43.01	43.01	0.00	0.00		50
	Total	**654.77**	**202.93**	**236.68**	**154.1**	**61.06**	
	Proportion of Total		**31%**	**36%**	**24%**	**9%**	
Terrigal Lagoon	T1	49.58	49.58	0.00	0.00		50
	T10	37.69	0.00	0.00	0.00	37.69	-
	T2	67.16	43.42	16.73	7.01		45
	T3	189.91	0.00	131.45	58.46		-
	T4	127.31	0.00	127.31	0.00		-
	T5	280.07	106.67	117.06	56.34		50
	T6	43.98	43.80	0.00	0.18		50
	T7	64.09	63.95	0.00	0.14		50
	T8	32.52	15.30	0.00	17.22		50
	T9	36.86	31.04	0.00	5.82		50
	Total	**892.31**	**322.72**	**392.55**	**139.35**	**37.69**	
	Proportion of total		**36%**	**44%**	**16%**	**4%**	
Avoca Lagoon	A1	75.04	75.04	0.00	0.00		35
	A10	102.67	0.00	0.00	0.00	102.67	-
	A11	42.80	42.80	0.00	0.00		45
	A2	66.84	0.00	0.00	66.84		-
	A3	408.12	0.00	211.48	196.64		-
	A4	154.96	0.00	33.84	121.12		-
	A5	119.63	67.00	0.00	52.63		40

Catchment	Sub-Catchment ID	Total Area (ha)	Land Use Type; Area (ha)				% Impervious
			Urban	Agricultural	Forest	Water	
	A6	62.76	52.68	0.00	10.08		40
	A7	18.63	18.63	0.00	0.00		40
	A8	24.10	24.10	0.00	0.00		40
	A9	111.08	17.08	0.00	94.00		40
	Total	**1186.6**	**297.33**	**245.32**	**541.31**	**102.67**	
	Proportion of total		**25%**	**21%**	**46%**	**9%**	
Cockrone Lagoon	C1	78.97	33.94	2.49	42.54		40
	C2	83.78	0.00	22.24	61.54		-
	C3	190.78	0.00	31.97	158.81		-
	C4	229.56	0.00	24.00	205.56		-
	C5	59.70	0.00	32.47	27.23		-
	C6	32.91	32.91	0.00	0.00		35
	C7	46.59	0.00	0.00	0.00	46.59	-
	Total	**722.29**	**66.85**	**113.17**	**495.68**	**46.59**	
	Proportion of total		**9%**	**16%**	**69%**	**6%**	

The sub-catchment layout is illustrated in **Figure 2.1**.

The MUSIC model layout for each lagoon catchment is shown in **Figures 2.2-2.5**. It is noted that the MUSIC models assumed no pollution generation within the lagoon waterbodies, as represented by sub-catchments W10, T10, A10 and C7.

2.2 Soil and Groundwater Storage Parameters

The soil parameters were based on the *Brisbane Water Estuary Processes Study* (Cardno, 2008b). The adopted parameters for soil and groundwater storage are shown in **Tables 2.2 and 2.3** respectively.

Table 2.2: Soil Storage Parameters

Parameter	Urban	Agricultural	Forest
Soil Storage Capacity (mm)	120	120	120
Initial Storage (% of Capacity)	30	30	30
Field Capacity (mm)	80	80	80
Infiltration Capacity Coefficient – a	200	200	200
Infiltration Capacity Coefficient – b	1	1	1

Table 2.3: Groundwater Storage Parameters

Parameter	Urban	Agricultural	Forest
Initial Depth (mm)	10	10	10
Daily Recharge Rate (%)	25	25	25
Daily Baseflow Rate (%)	5	5	5
Daily Deep Seepage Rate (%)	0	5	5
Initial Depth (mm)	10	10	10

2.3 Water Quality Parameters

Three types of pollutants were modelled in MUSIC:

- Total Suspended Solids (TSS)
- Total Nitrogen (TN)
- Total Phosphorous (TP).

The water quality parameters were adopted based on the requirements of this project and are consistent with those modelled for the *Brisbane Water Estuary Processes Study* (Cardno, 2008b). The adopted parameters are shown in **Table 2.4**.

Table 2.4: Adopted Runoff and Baseflow Mean Pollutant Concentrations

Catchment Type	Runoff Concentrations (mg/L)			Baseflow Concentrations (mg/L)		
	TSS	TN	TP	TSS	TN	TP
Rural	141	2.75	0.40	12.6	0.76	0.10
Residential	110	2.04	0.21	25.1	1.0	0.13
Forest	40.7	0.84	0.08	7.94	0.65	0.03

2.4 Rainfall Data

A detailed rainfall analysis can be found in the *Brisbane Water Estuary Processes Study* (Cardno, 2008b). The following analysis is based on that report, as the Brisbane Water Catchment is in close proximity to the Gosford Lagoons catchments.

2.4.1 Rain Gauges

Rainfall information was obtained from Manly Hydraulic Laboratory (MHL) and Bureau of Meteorology (BoM) as a part of the *Brisbane Water Estuary Processes Study* (Cardno, 2008b). The following table shows the gauges that were used in the assessment. These gauges were selected based on their proximity to the catchment and their period of operation.

Table 2.5: Rainfall Gauges

Gauge	Gauge ID	Operator	Type	Data Available
Woy Woy	61318	BoM	Daily	1/12/1964 – 29/2/2004
Gosford North	61319	BoM	Daily	1/12/1971 – 23/3/2004
Marlow Creek	61354	BoM	Daily	1/1/1986 – 28/2/2002
Avoca Beach	61294	BoM	Daily	1/5/1970 – 29/2/2004
Gosford (Narara)	61087	BoM	Daily	1/7/1917 – 23/3/2004
Peats Ridge	61351	BoM	Pluvio	1/11/1996 – 6/4/2003
Wyoming	None	MHL	Pluvio	1/7/1993 – 31/12/2003
Narara	None	MHL	Pluvio	1/7/1993 – 31/12/2003
Lisarow	None	MHL	Pluvio	1/7/1993 – 31/12/2003
Kincumber	None	MHL	Pluvio	1/7/1993 – 31/12/2003

2.4.2 Long Term Analysis of Rainfall Data

The daily historical data from Woy Woy, Gosford (Narara) and Avoca Beach were used to determine long term annual rainfall depths. These daily rainfall gauges had both a reasonable length of record and a good spatial coverage of the catchment. These were then used to determine years of average (50 percentile), dry (lower 10 percentile) and wet (upper 10 percentile) rainfall. Details of the method of this analysis are provided in Cardno (2008b).

The following table shows the results of this analysis. It shows the year of record and corresponding annual rainfall depth for the average, wet and dry years for the three gauges. The average value shown gives an indicative value. The pluviometer data obtained covers the period from 1993 onwards. The average value was used to determine years from this record that represent dry, wet and average years.

Table 2.6: Analysis of Rainfall Data

Station	Top 10%		50%		Bottom 10%	
	Rainfall (mm)	Year	Rainfall (mm)	Year	Rainfall (mm)	Year
Gosford (Narara)	1743	1931	1265	1946	909	1939
Avoca	1876	1988	1292	1981	998	1991
Woy Woy	1790	1989	1164	1986	811	1979
Average	**1803**		**1240**		**906**	

2.4.3 Pluviometer Data for MUSIC

Of the pluviometer data available, the MHL gauges are the closest to the catchment. The Peats Ridge data was not use due to its distance from the catchment.

The following table shows the annual rainfall recorded at each gauge. Values with 'na' are years in which there are a significant number of missing records and hence do not provide a reasonable representation of annual rainfall.

Table 2.7: Analysis of Pluviometer Data

Year	MHL Pluvio Gauge				BoM Daily Gauge		
	Kincumber	Lisarow	Narara	Wyoming	Avoca	Woy Woy	Gosford (Narara)
1994	955	1141.5	1023.5	908.5	981.9	914.6	1036.9
1995	1111.5	1280.5	1232	1188.5	na	1159.8	1311.3
1996	1073	943.5	986	1084	na	1121.2	1192
1997	1187.5	1108.5	na	969.5	981	1004.6	1404.3
1998	1700.5	na	1581	na	1604.2	1604.6	1937.3

1999	1488	1321	1552	1357	1669.6	1448.2	1571.4
2000	844.5	859	857.5	777	na	738.3	1082.9
2001	1309.5	na	1311.5	na	1185	1126.8	1403.1
2002	832	767	1320	918	1229.6	1114.5	1084.4
2003	1197.5	1207	1292.5	1023.5	1350	1100.3	1282.2

There are some spatial variations in the data, as would be expected. MUSIC is only capable of one rainfall input, and therefore representative rainfall needs to be applied to the model. The chosen gauge depends upon the modelling period.

From the above information, the following years were chosen as representative of a wet, dry and average rainfall. The gauge used to represent the catchment is also shown. Gauges were chosen if they represented an average rainfall for the catchment for the period and also if they contained a minimal number of missing records for the chosen period.

Table 2.8: Representative Rainfall Years

Type	Percentile	Year	Gauge
Average	50%	2003	Lisarow
Wet	Upper 10%	1998	Kincumber
Dry	Lower 10%	2000	Narara

2.4.4 Evapotranspiration

Daily evaporation data was collected as a part of the *Brisbane Water Estuary Processes Study* (Cardno Lawson Treloar, 2008b) for the Peats Ridge gauge from 10 March 1981 through to 23 March 2004. This data was converted to monthly data, and the average for the period was determined. These averages were then compared to monthly areal potential evapotranspiration, taken from the *Climatic Atlas of Australia* (BOM, 2003). The following table shows this comparison.

Table 2.9: Comparision of Potential Evaporation with Areal Potential Evapotranspiration

Month	Peats Ridge Potential Evaporation (mm)	Monthly Areal Potential Evapotranspiration (mm)
January	143	179
February	116	142
March	101	139
April	76	91
May	57	57
June	48	44

July	53	47
August	77	62
September	103	89
October	127	130
November	132	153
December	148	164
Annual	**1113**	**1297**

The purpose of this comparison was to establish factors for the conversion of potential evaporation data into potential evapotranspiration data. However, the above comparison shows periods in which the potential evaporation is higher than that of the potential evapotranspiration.

Due to this inconsistency, and due to the distance of the Peats Ridge gauge from the catchment, it was decided to use the monthly areal potential evapotranspiration rates from the *Climatic Atlas of Australia* (BOM, 2003) as representative of the catchment.

3 Model Results

The annual loads and annual flows experienced under the representative year of 1995, 1998 and 2000 are shown in **Tables 3.1, 3.2** and **3.3** respectively.

Table 3.1: Annual Pollutant Loads for the Representative Average Year (1995)

Lagoon	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Pollutant Loads (kg/yr)		
				TSS	TP	TN
Wamberal Lagoon	594	2,180	0.29	228,000	614	4,600
Terrigal Lagoon	892	3,500	0.31	387,000	1,050	7,770
Avoca Lagoon	1,084	3,420	0.25	297,000	791	6,140
Cockrone Lagoon	676	1,740	0.20	101,000	252	2,230
Total Study Area	***3,246***	***10,840***	***0.26***	***1,013,000***	***2,707***	***20,740***

Table 3.2: Annual Pollutant Loads for the Representative Wet Year (1998)

Lagoon	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Pollutant Loads (kg/yr)		
				TSS	TP	TN
Wamberal Lagoon	594	5,200	0.51	453,000	1,190	9,440
Terrigal Lagoon	892	7,970	0.53	752,000	2,000	15,500
Avoca Lagoon	1,084	9,050	0.49	633,000	1,650	13,700
Cockrone Lagoon	676	5,340	0.46	260,000	627	6,000
Total Study Area	***3,246***	***27,560***	***0.50***	***2,098,000***	***5,467***	***44,640***

Table 3.3: Annual Pollutant Loads for the Representative Dry Year (2000)

Lagoon	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Pollutant Loads (kg/yr)		
				TSS	TP	TN
Wamberal Lagoon	594	1,230	0.24	148,000	386	2,880
Terrigal Lagoon	892	1,990	0.26	252,000	663	4,890
Avoca Lagoon	1,084	1,850	0.20	193,000	497	3,770
Cockrone Lagoon	676	879	0.15	65,900	154	1,300
Total Study Area	***3,246***	***5,949***	***0.21***	***658,900***	***1,700***	***12,840***

4 Key Outcomes of the Catchment Modelling

In developed catchments with a higher proportion of hard surfaces, less runoff may be absorbed into the soil and therefore the net volume of annual runoff will be higher. In addition, runoff from developed areas will tend to be higher in pollutants. In contrast, in forested catchments some proportion of rainfall will be absorbed into the soil and both water and nutrients will be taken up by vegetation. Vegetation can also catch suspended sediments in runoff. Hence, a highly developed catchment will typically generate higher pollutant loadings than a less developed catchment with larger areas of natural vegetation.

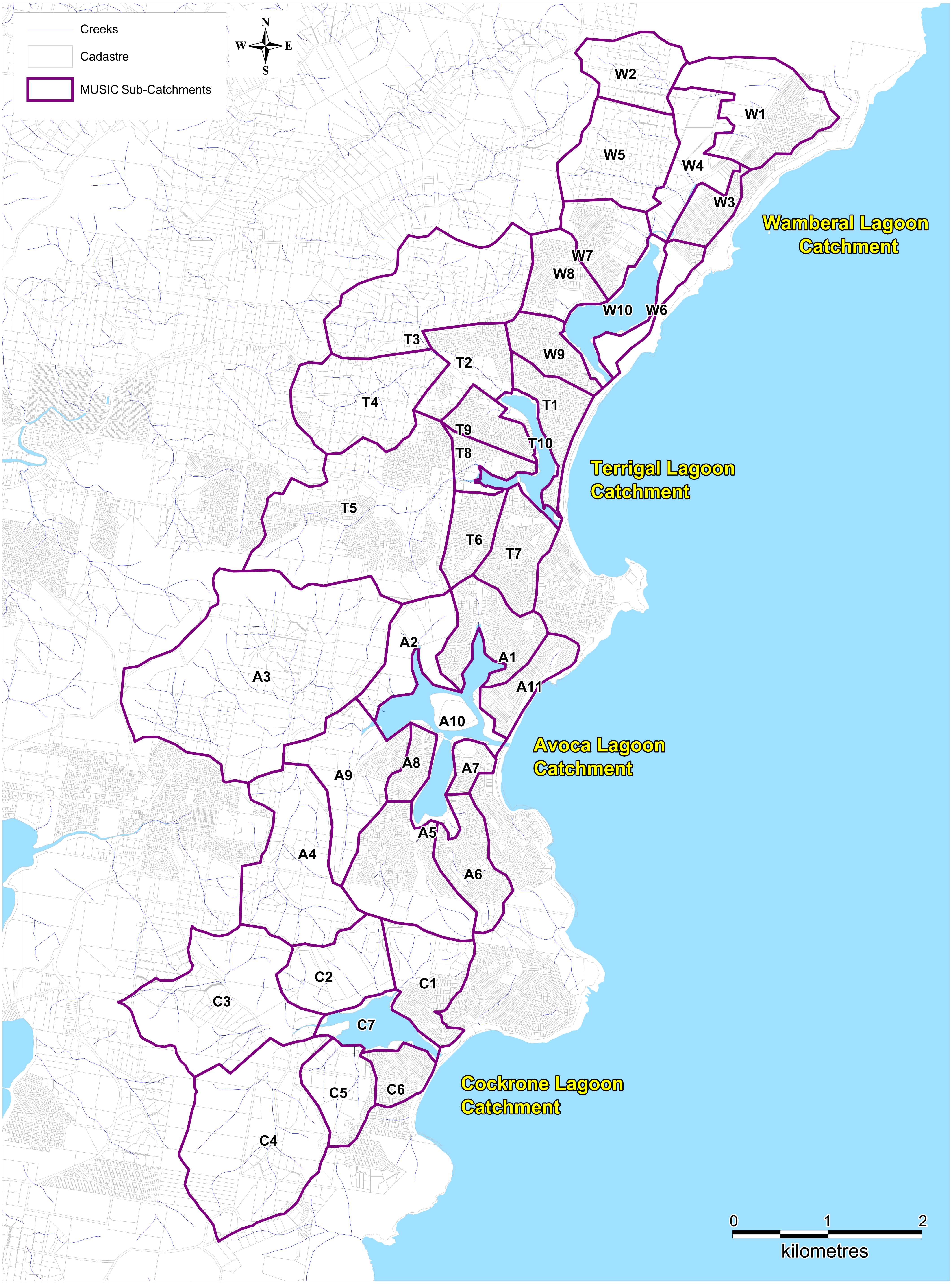
Comparing the four lagoons, the highest pollutant loadings are generated in the Terrigal Lagoon catchment. This is due to the large size of the catchment (being the second largest) and the degree of development of the catchment, with 80% of the catchment being developed for urban or rural land uses (**Table 2.1**). It is noted that the lagoon waterway comprises only 4% of the total catchment area, which in combination with the generally high pollutant loadings, indicates a high potential for water quality issues to occur in the lagoon.

While Wamberal Lagoon catchment is the smallest in size, a number of the sub-catchments have been developed (67% of the total catchment area). As such, there is a higher proportion of impervious areas and hence a greater volume of runoff and associated pollutant loads flowing into the lagoon. Despite having a catchment almost twice the size of the Wamberal Lagoon catchment, the Avoca Lagoon catchment contributes pollutant loads not dissimilar to those modelled for Wamberal Lagoon. This is due to the high proportion of forested land (46%) and lower proportion of urban land use (25%).

The Cockrone Lagoon catchment generates lower pollutant loads than all other catchments. This is due to the small catchment size and the low percentage of impervious area. In addition, the Cockrone Lagoon catchment has a high proportion of forested land (69%), which generates lower pollutant concentrations.

The modelling also provides information about how pollutant loadings to the lagoons may change under different climatic conditions. It is noted that the total pollutant loadings entering the lagoons were higher in a wet year and lower in a dry year.

Figures



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Gosford Coastal Lagoons
Processes Study

FIGURE 2.1
MUSIC MODEL
SUB-CATCHMENTS

LJ2713/R2657/V1
July 2010

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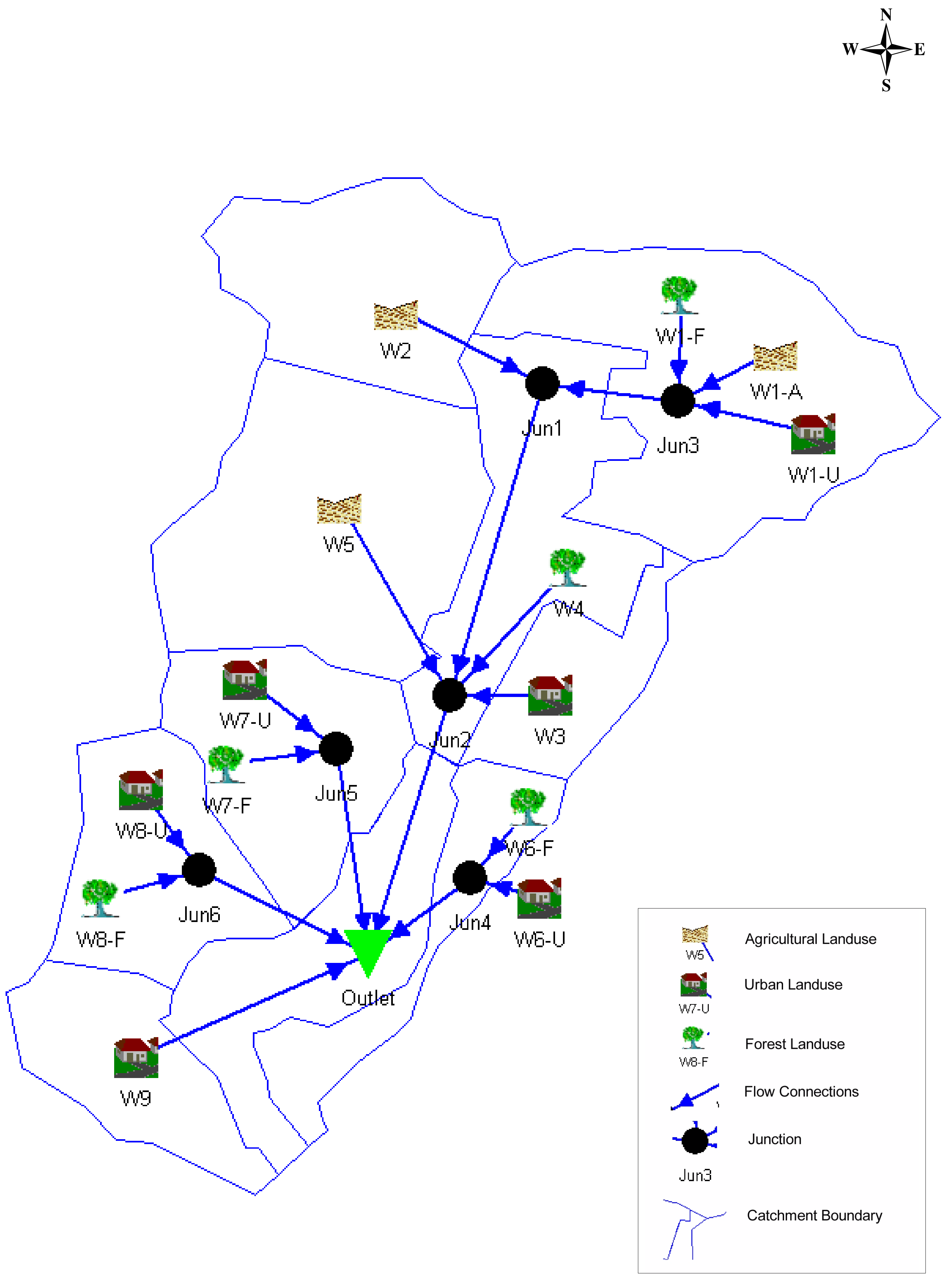
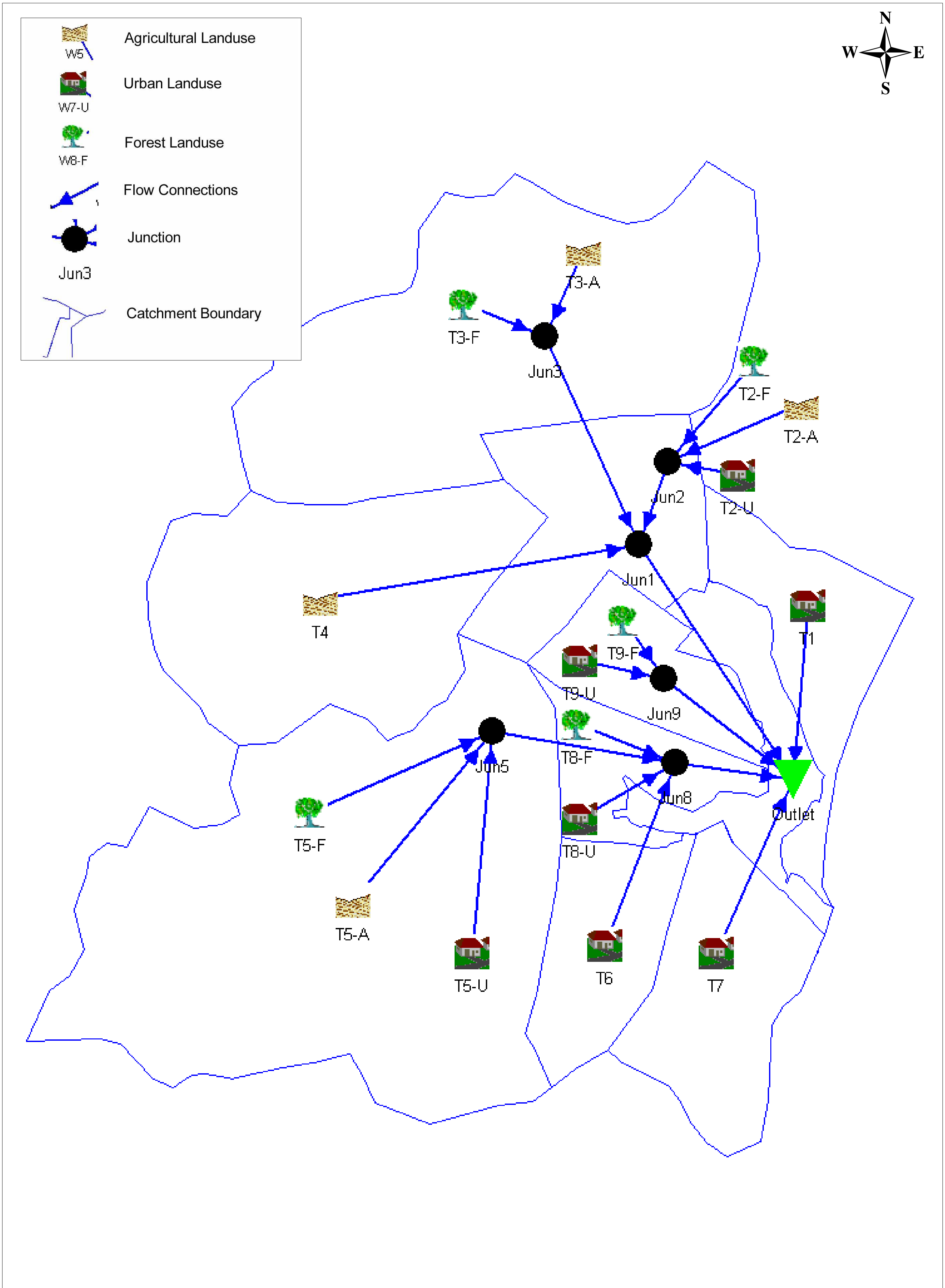


FIGURE 2.2
MUSIC MODEL LAYOUT
- WAMBERAL LAGOON



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Processes Study

FIGURE 2.3
MUSIC MODEL LAYOUT
- TERRIGAL LAGOON

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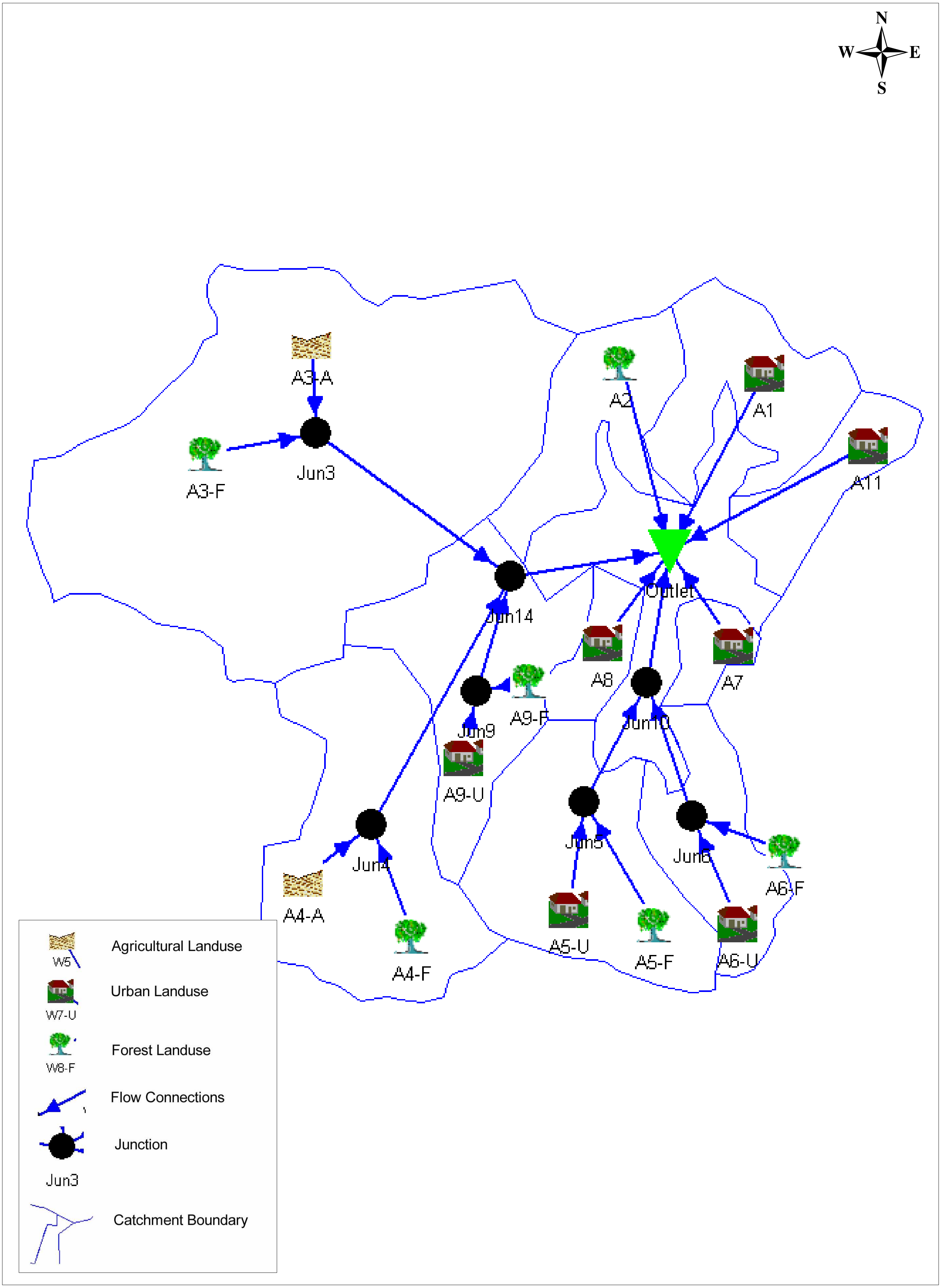

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Processes Study

FIGURE 2.4
MUSIC MODEL LAYOUT
- AVOCA LAGOON

LJ2713/R2657/V1
July 2010

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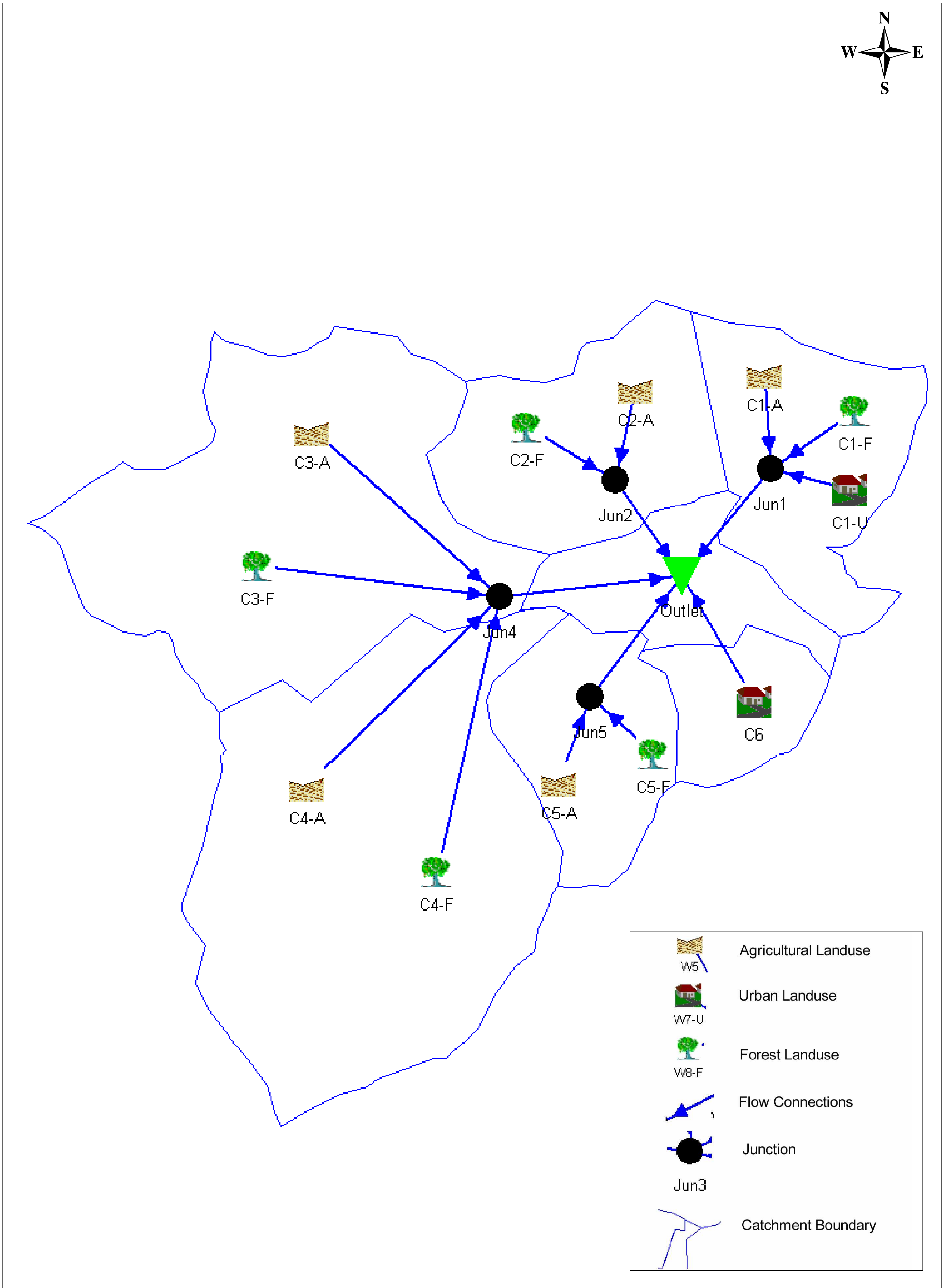

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FIGURE 2.5
MUSIC MODEL LAYOUT
- COCKRONE LAGOON

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Appendix F

Physical Processes Report

Appendix G

Foreshore Database

Zone ID[1]	Bank Stability Index[2]	Significant Wave Height[3]	
		100 Year ARI	5 Year ARI
A1	3	0.31	0.26
A2	1	0.30	0.25
A3	1	0.33	0.28
A4	5	0.35	0.30
A5	1	0.38	0.32
A6	1	0.40	0.33
A7	1	0.42	0.34
A8	2	0.43	0.34
A9	3	0.33	0.27
A10	4	0.29	0.26
A11	3	0.37	0.29
A12	3	0.42	0.32
A13	4	0.42	0.33
A14	3	0.45	0.35
A15	1	0.45	0.35
A16	2	0.38	0.30
A17	2	0.39	0.31
A18	2	0.39	0.32
A19	2	0.37	0.29
A20	2	0.50	0.39
A21	3	0.52	0.41
A22	4	0.48	0.40
A23	3	0.44	0.36
A24	4	0.45	0.37
A25	3	0.33	0.27
A26	4	0.33	0.26
A27	4	0.37	0.29
A28	4	0.31	0.25
A29	3	0.34	0.28
A30	3	0.34	0.28
A31	4	0.39	0.32
A32	4	0.39	0.32
A33	4	0.37	0.31
A34	3	0.34	0.28
C1	1	0.23	0.20
C2	5	0.26	0.22
C3	4	0.33	0.28
C4	3	0.32	0.27
C5	3	0.33	0.28
C6	3	0.28	0.25
C7	3	0.32	0.26
C8	3	0.38	0.30
C9	3	0.43	0.34
C10	4	0.40	0.33
C11	5	0.46	0.37
C12	5	0.39	0.31
C13	4	0.37	0.30

Zone ID[1]	Bank Stability Index[2]	Significant Wave Height[3]	
		100 Year ARI	5 Year ARI
C14	3	0.27	0.23
T1	3	0.25	0.21
T2	1	0.25	0.22
T3	3	0.39	0.30
T4	5	0.35	0.27
T5	1	0.35	0.28
T6	5	0.30	0.24
T7	3	0.29	0.23
T8	3	0.32	0.25
T9	1	0.35	0.28
T10	4	0.40	0.32
T11	3	0.40	0.32
T12	3	0.33	0.27
T13	3	0.42	0.34
T14	4	0.39	0.32
T15	3	0.43	0.34
T16	5	0.44	0.35
T17	3	0.44	0.35
T18	1	0.35	0.29
T19	2	0.31	0.27
T20	3	0.30	0.26
T21	1	0.30	0.26
T22	2	0.26	0.22
T23	1	0.26	0.21
T24	3	0.28	0.23
W1	3	0.22	0.29
W2	4	0.26	0.30
W3	3	0.28	0.39
W4	3	0.32	0.44
W5	3	0.35	0.49
W6	3	0.35	0.50
W7	3	0.37	0.51
W8	3	0.35	0.46
W9	3	0.31	0.40
W10	3	0.31	0.41
W11	3	0.26	0.36
W12	3	0.26	0.36

[1] Zone locations shown on Figure E1

[2] Foreshore Stability Index descriptions provided in Table 4.8

[3] Wave height calculations provided in Appendix D

Appendix H

Water Quality Data

Terrigal Lagoon

Date	-	12-Jan-06	14-Feb-06	17-Mar-06	19-Apr-06	30-Jun-06	10-Aug-06	13-Sep-06	16-Oct-06	24-Nov-06	11-Dec-06	8-Jan-07	6-Feb-07	12-Mar-07	2-Apr-07	4-May-07	24-Jun-07	1-Jul-07	1-Aug-07	16-Jan-08	25-Feb-08	31-Mar-08	18-Apr-08	26-May-08	19-Jun-08	4-Jul-08	4-Aug-08	2-Sep-08	1-Oct-08	3-Nov-08	12-Dec-08
Ammonia Nitrogen as N	mg/L	0.01	0.06	0.08	0.06	0.005	0.005	0.06	0.11	0.01	0.01	0.01	0.06	0.09	0.04	0.03	0.09	0.005	0.03	0.08	0.04	0.02	0.04	0.03	0.04	0.03	0.02	0.01	0.005	0.06	0.07
Chlorophyll a	µg/L	4	3	2	6	0.5	25	0.5	0.5	2	5	0.5	3	4	0.5	1	0.5	0.5	0.5	1	3	3	2	0.5	1	1	0.5	1	2	1	0.5
NOx	mg/L	0.005	0.01	0.03	0.03	0.06	0.07	0.37	0.03	0.01	0.01	0.005	0.03	0.04	0.03	0.06	0.2	0.03	0.005	0.02	0.005	0.01	0.01	0.025	0.1	0.04	0.01	0.04	0.05	0.02	0.03
Ortho-Phosphate (as P)	mg/L	0.01	0.02	0.03	0.01	0.005	0.005	0.01	0.01	0.005	0.005	0.005	0.02	0.02	0.01	0.005	0.01	0.005	0.005	0.01	0.01	0.02	0.025	0.02	0.035	0.035	0.015	0.015	0.005	0.015	0.005
Total Nitrogen as N (TKN + NOx)	mg/L	0.05	0.4	0.1	0.05	0.8	0.7	0.9	0.4	0.2	0.3	0.4	0.4	0.05	0.1	0.6	0.6	0.05	0.05	0.3	0.6	0.4	0.4	0.4	0.6	0.2	0.3	0.3	0.2	0.4	0.1
Total Phosphorus	mg/L	0.005	0.04	0.03	0.03	0.03	0.02	0.05	0.03	0.01	0.03	0.02	0.03	0.03	0.03	0.07	0.03	0.005	0.005	0.02	0.02	0.03	0.025	0.025	0.035	0.035	0.015	0.015	0.02	0.015	0.005
Dissolved Oxygen/1	mg/L	4.3	4.8	4.8	5.8	9.1	10.2	9.5	6.9	5.7	6.5	5.9	5.7	5.1	6.7	6.9	6.8	7.4	6.7	4.7	5.8	6.9	6.9	7	7.9	8.3	10.5	8.9	6.4	7.4	9.9
Dissolved Oxygen/2	mg/L	4.4	4.9	4.8	5.8	8.7	9.1		5.9	5.3	6.3	5.8	5.5		5.9	6.2	6.5	7.2	6.5												
Dissolved Oxygen/3	mg/L																														
Turbidity/1	NTU	4	11.6	10.3	6.6	29.3	6.1	18.3	8.9	7.6	32.6	9.3	9.7	20.9	19.4	17	11.9	1.9	1.8	9.8	1	27.7	13.3	19.7	23	3.7	17.1	19.7	4.4	10.9	3.1
Turbidity/2	NTU	25.9	12	5.3	19	28.1	8.1		10	7.3	65.2	8.3	11		18.8	21	12.2	1.5	2.1												
Turbidity/3	NTU																														
BOD(5-Day)	mg/L																			1	1	1	1	1	1	1	1	1	1	1	1
EntranceCondition	-																			Closed	Closed	Closed	Closed	Closed	Closed	Closed	Nodata	Closed	Closed	Closed	Open
FaecalStreptococci	cfu/100mL																			40	81	5	153	27	145						
SuspendedSolids(Total@105C)	mg/L																			12	8	9	8	10	3	22	14	11.1	21.4	18.3	14.9
Tide Mark	m																														
TotalBlueGreenAlgae	cells/mL																			0	0	0	80	320	139500						
TotalKjeldahlNitrogen	mg/L																			0.3	0.6	0.4	0.4	0.4	0.5	0.2	0.3	0.3	0.1	0.4	0.1
Conductivity	mS/cm																			35.1	19	17.7	13.7	25.2	27.6	35.6	23.5	18.9	34.2	29.6	24.7
Depth	m																			0.1	0.1	0.1	0.1	0.1	0.1						0.1
pH	-																			7.6	8.2	7.9	8	8.3	7.4	7.5	7.8	8.1	7.7	7.7	7.6
Salinity	PSS																			22.2	11.2	10.4	7.8	15.1	16.8	22	14	11.1	21.4	18.3	14.9
Temperature	℃																			29.6	23.1	20.7	18.8	16.6	15.4	12.8	13.4	16.3	22.4	25	19.5
ThermotolerantColiforms	CFU/100mL																									5	36	11	7	3	48
Enterococci	CFU/100mL																									91	1	18	5	1	43

Wamberal Lagoon

Date	-	12-Jan-06	14-Feb-06	17-Mar-06	19-Apr-06	30-Jun-06	10-Aug-06	13-Sep-06	16-Oct-06	24-Nov-06	11-Dec-06	8-Jan-07	6-Feb-07	12-Mar-07	2-Apr-07	4-May-07	24-Jun-07	1-Jul-07	1-Aug-07	16-Jan-08	25-Feb-08	31-Mar-08	18-Apr-08	26-May-08	19-Jun-08	4-Jul-08	4-Aug-08	2-Sep-08	1-Oct-08	3-Nov-08	12-Dec-08
Ammonia Nitrogen as N	mg/L	0.01	0.005	0.01	0.02	0.005	0.03	0.005	0.02	0.06	0.03	0.005	0.12	0.03	0.08	0.41	0.14	0.07	0.14	0.005	0.25	0.04	0.04	0.06	0.19						
Chlorophyll a	µg/L	2	0.5	2	1	0.5	2	1	0.5	2	1	1	9	8	7	3	3	5	1	1	2	2	1	0.5	7						
NOx	mg/L	0.005	0.005	0.02	0.01	0.005	0.01	0.05	0.005	0.02	0.01	0.005	0.01	0.02	0.005	0.13	0.05	0.03	0.05	0.005	0.02	0.02	0.005	0.01	0.15						
Ortho-Phosphate (as P)	mg/L	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.01	0.005	0.025	0.035						
Total Nitrogen as N (TKN + NOx)	mg/L	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.3	0.6	0.5	1	1	0.7	1.1	1.1	0.3	0.5	0.5	0.5	1.1	0.7	0.6	0.5	1.1						
Total Phosphorus	mg/L	0.005	0.01	0.005	0.02	0.005	0.02	0.05	0.02	0.02	0.04	0.08	0.06	0.02	0.04	0.04	0.005	0.005	0.005	0.03	0.02	0.01	0.01	0.025	0.035						
Dissolved Oxygen/1	mg/L	6.3	7.8	3.1	8.6	8.9	8.7	8.2	8.7	6	6.3	7.1	5.2	6.5	6.4	7.1	7.2	7.8	7.1	6	5.2	7.7	8.9	8.4	10.4						
Dissolved Oxygen/2	mg/L	6.5	7.6	3	8.6	8.9	8.3					7.1																			
Dissolved Oxygen/3	mg/L	6.3	7.7	2.7	8.6	6.7	7.6					7.1																			
Turbidity/1	NTU	0.7	1	2.8	0.2	1.9	6.1	30.3	3.5	0.1	14.5	29.5	12.3	12.9	19.8	9.5	8.9	4	3.4	20.3	1.4	32.2	6.4	17.3	33						
Turbidity/2	NTU	1	1.5	3	0.3	2.2	5.6					29.5																			
Turbidity/3	NTU	15	13	7	1.3	5.3	4.7					29.5																			
BOD(5-Day)	mg/L																			1	1	1	1	1	1						
EntranceCondition	-																			Closed	Closed	Closed	Closed	Closed	Closed						
FaecalStreptococci	cfu/100mL																			970	189	5	36	9	100						
SuspendedSolids(Total@105C)	mg/L																			22	4	2	3	5	5						
Tide Mark	m																			1.45	2.5	2	2.5	0.5	2.3						
TotalBlueGreenAlgae	cells/mL																														
TotalKjeldahlNitrogen	mg/L																			0.5	1.1	0.7	0.6	0.5	0.9						
Conductivity	mS/cm																			13.6	8.82	8.48	8.3	35	10.1						
Depth	m																			0.1	0.1	0.1	0.1	0.1	0.1						
pH	-																			8.1	7.9	7.9	8.1	8.4	7.3						
Salinity	PSS																			7.9	4.9	4.7	4.6	21.7	5.6						
Temperature	℃																			31	23.8	21.1	18.4	16.3	15.5						
Thermotolerant Coliforms	CFU/100mL																														
Enterococci	CFU/100mL																														

Avoca Lagoon

Date	-	12-Jan-06	14-Feb-06	17-Mar-06	19-Apr-06	30-Jun-06	10-Aug-06	13-Sep-06	16-Oct-06	24-Nov-06	11-Dec-06	8-Jan-07	6-Feb-07	12-Mar-07	2-Apr-07	4-May-07	24-Jun-07	1-Jul-07	1-Aug-07	16-Jan-08	25-Feb-08	31-Mar-08	18-Apr-08	26-May-08	19-Jun-08	4-Jul-08	4-Aug-08	2-Sep-08	1-Oct-08	3-Nov-08	12-Dec-08
Ammonia Nitrogen as N	mg/L	0.01	0.08	0.44	0.1	0.01	0.04	0.15	0.07	0.14	0.03	0.16	0.34	0.16	0.38	1	0.17	0.13	0.19	0.1	0.06	0.06	0.08	0.11	0.17	0.07	0.05	0.06	0.06	0.08	0.08
Chlorophyll a	µg/L	23	16	9	9	2	2	0.5	0.5	5	8	0.5	5	18	2	2	0.5	2	1	3	1	2	1	1	0.5	1	0.5	0.5	1	1	0.5
NOx	mg/L	0.005	0.005	0.04	0.05	0.005	0.03	0.08	0.005	0.01	0.005	0.01	0.09	0.05	0.05	0.11	0.09	0.1	10	0.03	0.005	0.02	0.005	0.04	0.1	0.04	0.02	0.02	0.04	0.005	0.005
Ortho-Phosphate (as P)	mg/L	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.02	0.02	0.005	0.005	0.005	0.005	0.07	0.01	0.005	0.005	0.005	0.025	0.015	0.015	0.005	0.015	0.005	0.01	0.005
Total Nitrogen as N (TKN + NOx)	mg/L	1	1.2	0.3	1	0.7	0.5	0.6	0.3	0.5	0.6	1	1.1	1.4	1.3	1.2	0.4	0.6	0.5	0.8	0.9	0.8	0.8	0.5	0.1	0.2	0.1	0.2	0.4	0.6	0.4
Total Phosphorus	mg/L	0.08	0.06	0.03	0.03	0.01	0.005	0.02	0.07	0.04	0.05	0.04	0.04	0.06	0.03	0.04	0.005	0.01	0.005	0.02	0.02	0.02	0.005	0.025	0.015	0.015	0.005	0.015	0.01	0.01	0.005
Dissolved Oxygen/1	mg/L	2.6	4.6	4.1	6.6	8.8	7.9	7.5	8.4	5	5.8	7.6	6.4	6.4	6.6	6.8	7.8	8.7	7.1	6.8	5.1	6.7	8.7	10.2	5.6	7.4	11.3	8.3	4.7	6.7	6.9
Dissolved Oxygen/2	mg/L	2.6	4.5	4	6.8	8.1	8.3	7.5	8.3	4.4	5.6	7.2	6.4	6.1	6.5	5.2	7.7	8.4	6.8												
Dissolved Oxygen/3	mg/L	1	4.1	3.1	6.4	6.4	7.7	7.5	7.9	4	5.2	6	6.4	5.8	6.4	4.8	7.5	8.6	6.5												
Turbidity/1	NTU	4.3	0.9	1.8	1.3	1.8	3	6	0.5	2	1	3.7	1.3	8.1	4.1	5.5	14.2	5.1	2.1	0.3	1	19	3.4	31.3	14.1	18.9	19.1	19	2	14.4	7.9
Turbidity/2	NTU	4.5	2	1.3	2.2	1.3	3.1		0.5	2.4	1.6	3.3	1.5	8	4	5.2	14.4	5.3	2.5												
Turbidity/3	NTU	8	26.6	6.3	2.4	1.2	3.2		12	2.5	1.8	3.1	1.1	8.9	3.9	5.1	14	8	4												
BOD(5-Day)	mg/L																			1	1	1	1	1	1	1	1	1	1	1	1
EntranceCondition	-																			Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
FaecalStreptococci	cfu/100mL																			5	5	5	9	27	55						
SuspendedSolids(Total@105C)	mg/L																			4	4	2	4	6	8	3	4	5	1	21	2
Tide Mark	m																														
TotalBlueGreenAlgae	cells/mL																														
TotalKjeldahlNitrogen	mg/L																			0.8	0.9	0.8	0.8	0.5	0.05	0.2	0.1	0.2	0.4	0.6	0.4
Conductivity	mS/cm																			25.3	16.3	15.4	14.9	35	50.4	50.4	41.8	37.5	26.1	25.5	25.2
Depth	m																			0.1	0.1	0.1	0.1	0.1	0.1						0.1
pH	-																			8.1	8.2	8	8.3	8.7	7.9	7.8	8	8.3	7.4	7.8	7.8
Salinity	PSS																			15.5	9.5	8.9	8.6	21.7	32.5	32.4	26.3	23.5	15.9	15.5	15.2
Temperature	℃																			29.8	24.3	21.5	19	15.9	16.6	12	12.5	16.3	21.6	23.3	22.7
ThermotolerantColiforms	CFU/100mL																									5	5	2	1	10	25
Enterococci	CFU/100mL																									100	27	7	7	34	79

Cockrone Lagoon

Date	-	12-Jan-06	14-Feb-06	17-Mar-06	19-Apr-06	30-Jun-06	10-Aug-06	13-Sep-06	16-Oct-06	24-Nov-06	11-Dec-06	8-Jan-07	6-Feb-07	12-Mar-07	2-Apr-07	4-May-07	Jun-07	Jul-07	Aug-07	16-Jan-08	25-Feb-08	31-Mar-08	18-Apr-08	26-May-08	19-Jun-08	4-Jul-08	4-Aug-08	2-Sep-08	1-Oct-08	3-Nov-08	12-Dec-08
Ammonia Nitrogen as N	mg/L	0.01	0.01	0.03	0.03	0.005	0.005	0.83	0.25	0.1	0.02	0.005	0.03	0.71	2	0.73	0.25	0.18	0.27	0.08	0.06	0.02	0.03	0.18	0.23	0.07	0.02	0.03	0.005	0.02	0.03
Chlorophyll a	µg/L	1	1	0.5	0.5	1	7	0.5	0.5	0.5	0.5	0.5	2	0.5	2	0.5	0.5	0.5	0.5	6	1	0.5	0.5	0.5	1	1	0.5	0.5	1	1	0.5
NOx	mg/L	0.005	0.005	0.005	0.01	0.005	0.03	0.05	0.005	0.03	0.01	0.005	0.005	0.04	0.11	0.09	0.07	0.05	0.03	0.005	0.005	0.005	0.005	0.02	0.07	0.04	0.02	0.01	0.03	0.005	0.005
Ortho-Phosphate (as P)	mg/L	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.035	0.005	0.005	0.015	0.005	0.015	0.005
Total Nitrogen as N (TKN + NOx)	mg/L	0.7	0.7	0.7	1	0.3	0.7	1.3	1	0.9	0.6	0.8	1.2	1.9	2.6	1.1	0.6	0.6	0.5	1	0.9	0.6	0.6	0.6	0.8	0.5	0.3	0.3	0.5	0.5	0.3
Total Phosphorus	mg/L	0.005	0.005	0.005	0.005	0.02	0.01	0.08	0.05	0.02	0.02	0.01	0.02	0.01	0.01	0.03	0.03	0.005	0.005	0.04	0.02	0.005	0.005	0.005	0.035	0.005	0.005	0.015	0.01	0.015	0.005
Dissolved Oxygen/1	mg/L	6.1	6.5	3.9	8.6	9.5	8.8	5	8.4	6.2	9.1	7.8	5.7	5.2	5.6	6.1	7.1	8.1	8.1	4.9	5.9	9.2	9.3	5.3	8.8	8.2	11.7	10.5	7.5	9	8.3
Dissolved Oxygen/2	mg/L	6.1	6.5	3.8	8.5	9.4	8.7	5	8.4			7.8																			
Dissolved Oxygen/3	mg/L	6.2	6.5	4.8	8.6	9.2	8.8	5	8.4			7.8																			
Turbidity/1	NTU	0.6	0.7	0.1	0.2	2.5	3.8	20.2	0.5	0	0.5	0	0	2.3	0.7	11	6.5	4.1	4.1	0.5	1	7.5	11.5	34.4	31.4	46.4	30.2	12.3	2.1	24.3	2.2
Turbidity/2	NTU	0.8	2	0.1	2	2.2	3.6	20.2	0.5			0																			
Turbidity/3	NTU	12	12	55.7	20.1	2	3.5	20.2	0.5			0																			
BOD(5-Day)	mg/L																			4	1	1	1	1	1	1	1	1	1	1	1
EntranceCondition	-																			Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
FaecalStreptococci	cfu/100mL																			5	27	5	90	252	118						
SuspendedSolids(Total@105C)	mg/L																			9	2	13	2	7	6	7	4	4	2	2	2
Tide Mark	m																			1	1.7	1.7	1.8	1	1.9						0.1
TotalBlueGreenAlgae	cells/mL																			0	0	600	80	320	80						
TotalKjeldahlNitrogen	mg/L																			1	0.9	0.6	0.6	0.6	0.7	0.5	0.3	0.3	0.5	0.5	0.3
Conductivity	mS/cm																			53.8	22.1	21.6	19.5	49.7	30.2	48	41.5	37	26.6	25.9	25.5
Depth	m																			0.1	0.1	0.1	0.1	0.1	0.1						0.1
pH	-																			7.7	8.4	9.6	9.8	8.2	7.6	7.9	8	9.2	8.9	9.5	9.3
Salinity	PSS																			35.8	13.3	12.9	11.5	32	18.5	30.7	26	23.1	16.2	15.8	15.5
Temperature	℃																			29	24	20.6	18.3	15.6	15.6	12.6	13.2	16.9	21.6	23.7	21.7
ThermotolerantColiforms	CFU/100mL																									5	9	1	2	1	1
Enterococci	CFU/100mL																									9	64	36	164	100	4

Blank cells represent instances of no data.
Cells shaded yellow represent non-detect samples. The value shown is half the original non-detect value.

INSUFF >50% of samples for the parameter were non-detect samples
NS No samples were taken for the parameter (parameter left in for completeness)

Terrigal Lagoon

Parameter	Units	Number of Samples	Number of Non-Detect Samples	Mean	Median	90th Percentile	10th Percentile
Ammonia Nitrogen as N	mg/L	30	4	0.04	0.04	0.08	0.01
Chlorophyll a	µg/L	30	11	2.52	1.00	4.10	0.50
NOx	mg/L	30	5	0.05	0.03	0.07	0.01
Ortho-Phosphate (as P)	mg/L	30	16	INSUFF	INSUFF	INSUFF	INSUFF
Total Nitrogen as N (TKN + NOx)	mg/L	30	6	0.35	0.35	0.61	0.05
Total Phosphorus	mg/L	30	11	0.03	0.03	0.04	0.01
Dissolved Oxygen/1	mg/L	30	0	6.98	6.85	9.54	4.80
Dissolved Oxygen/2	mg/L	16	0	6.18	5.90	7.95	4.85
Dissolved Oxygen/3	mg/L	0	0	NS	NS	NS	NS
Turbidity/1	NTU	30	0	12.69	10.60	23.47	2.98
Turbidity/2	NTU	16	0	15.99	11.50	27.00	3.70
Turbidity/3	NTU	0	0	NS	NS	NS	NS
BOD(5-Day)	mg/L	12	12	1.00	1.00	1.00	1.00
EntranceCondition	-	10	0	NS	NS	NS	NS
FaecalStreptococci	cfu/100mL	6	1	75.17	60.50	149.00	16.00
SuspendedSolids(Total@105C)	mg/L	12	0	12.64	11.55	21.09	8.00
Tide Mark	m	0	0	NS	NS	NS	NS
TotalBlueGreenAlgae	cells/mL	6	0	23316.67	40.00	69910.00	0.00
TotalKjeldahlNitrogen	mg/L	12	0	0.33	0.35	0.49	0.11
Conductivity	mS/cm	12	0	25.40	24.95	35.01	17.82
Depth	m	7	0	0.10	0.10	0.10	0.10
pH	-	12	0	7.82	7.75	8.19	7.51
Salinity	PSS	12	0	15.43	15.00	21.94	10.47
Temperature	°C	12	0	19.47	19.15	24.81	13.60
ThermotolerantColiforms	CFU/100m	6	1	18.33	9.00	42.00	4.00
Enterococci	CFU/100m	6	2	26.50	11.50	67.00	1.00

Wamberal Lagoon

Parameter	Units	Number of Samples	Number of Non-Detect Samples	Mean	Median	90th Percentile	10th Percentile
Ammonia Nitrogen as N	mg/L	24	5	0.07	0.04	0.18	0.01
Chlorophyll a	µg/L	24	5	2.63	2.00	7.00	0.50
NOx	mg/L	24	8	0.03	0.01	0.05	0.01
Ortho-Phosphate (as P)	mg/L	24	20	INSUFF	INSUFF	INSUFF	INSUFF
Total Nitrogen as N (TKN + NOx)	mg/L	24	0	0.68	0.60	1.10	0.50
Total Phosphorus	mg/L	24	9	0.02	0.02	0.05	0.01
Dissolved Oxygen/1	mg/L	24	0	7.23	7.15	8.84	5.44
Dissolved Oxygen/2	mg/L	7	0	7.14	7.60	8.72	5.10
Dissolved Oxygen/3	mg/L	7	0	6.67	7.10	8.06	4.86
Turbidity/1	NTU	24	0	11.33	7.65	30.06	0.79
Turbidity/2	NTU	7	0	6.16	2.20	15.16	0.72
Turbidity/3	NTU	7	0	10.83	7.00	20.80	3.34
BOD(5-Day)	mg/L	6	6	1.00	1.00	1.00	1.00
EntranceCondition	-	6	0	NS	NS	NS	NS
FaecalStreptococci	cfu/100mL	6	1	218.17	68.00	579.50	7.00
SuspendedSolids(Total@105C)	mg/L	6	0	6.83	4.50	13.50	2.50
Tide Mark	m	6	0	1.88	2.15	2.50	0.98
TotalBlueGreenAlgae	cells/mL	0	0	NS	NS	NS	NS
TotalKjeldahlNitrogen	mg/L	6	0	0.72	0.65	1.00	0.50
Conductivity	mS/cm	6	0	14.05	9.46	24.30	8.39
Depth	m	6	0	0.10	0.10	0.10	0.10
pH	-	6	0	7.95	8.00	8.25	7.60
Salinity	PSS	6	0	8.23	5.25	14.80	4.65
Temperature	°C	6	0	21.02	19.75	27.40	15.90
Thermotolerant Coliforms	CFU/100m	0	0	NS	NS	NS	NS
Enterococci	CFU/100m	0	0	NS	NS	NS	NS

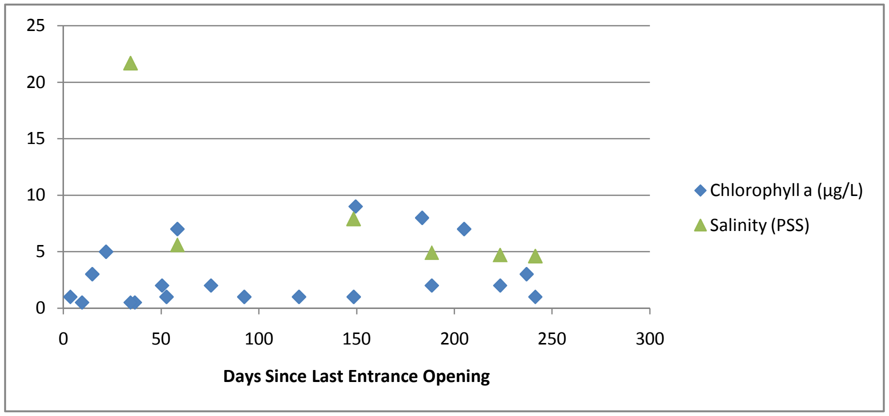
Avoca Lagoon

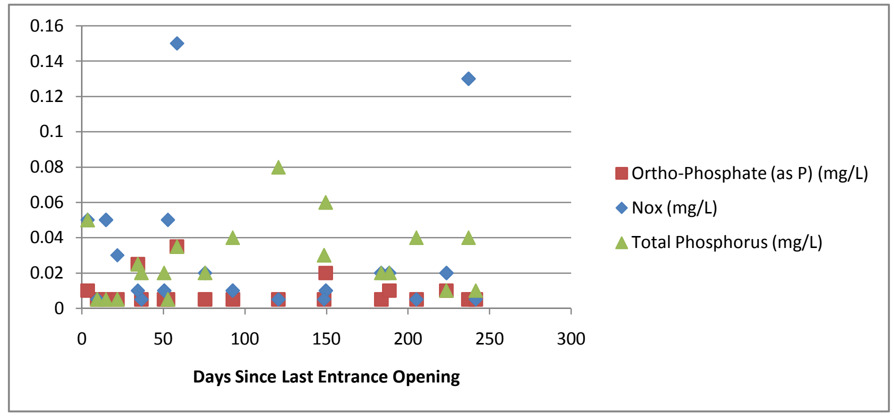
Parameter	Units	Number of Samples	Number of Non-Detect Samples	Mean	Median	90th Percentile	10th Percentile
Ammonia Nitrogen as N	mg/L	30	0	0.15	0.09	0.34	0.04
Chlorophyll a	µg/L	30	8	3.97	1.50	9.70	0.50
NOx	mg/L	30	9	0.37	0.03	0.10	0.01
Ortho-Phosphate (as P)	mg/L	30	24	INSUFF	INSUFF	INSUFF	INSUFF
Total Nitrogen as N (TKN + NOx)	mg/L	30	0	0.67	0.60	1.20	0.20
Total Phosphorus	mg/L	30	11	0.03	0.02	0.06	0.01
Dissolved Oxygen/1	mg/L	30	0	6.90	6.80	8.71	4.69
Dissolved Oxygen/2	mg/L	18	0	6.36	6.65	8.30	4.28
Dissolved Oxygen/3	mg/L	18	0	5.85	6.40	7.76	3.73
Turbidity/1	NTU	30	0	7.24	3.90	19.00	0.99
Turbidity/2	NTU	17	0	3.71	2.50	6.38	1.30
Turbidity/3	NTU	17	0	6.59	4.00	12.80	1.56
BOD(5-Day)	mg/L	12	12	1.00	1.00	1.00	1.00
EntranceCondition	-	12	0	NS	NS	NS	NS
FaecalStreptococci	cfu/100mL	6	3	17.67	7.00	41.00	5.00
SuspendedSolids(Total@105C)	mg/L	12	0	5.33	4.00	7.80	2.00
Tide Mark	m	0	0	NS	NS	NS	NS
TotalBlueGreenAlgae	cells/mL	0	0	NS	NS	NS	NS
TotalKjeldahlNitrogen	mg/L	12	1	0.48	0.45	0.80	0.11
Conductivity	mS/cm	12	0	30.32	25.80	49.54	15.49
Depth	m	7	0	0.10	0.10	0.10	0.10
pH	-	12	0	8.03	8.00	8.30	7.80
Salinity	PSS	12	0	18.79	15.70	31.79	8.96
Temperature	°C	12	0	19.63	20.25	24.20	12.84
ThermotolerantColiforms	CFU/100m	6	3	8.00	5.00	17.50	1.50
Enterococci	CFU/100m	6	0	42.33	30.50	89.50	7.00

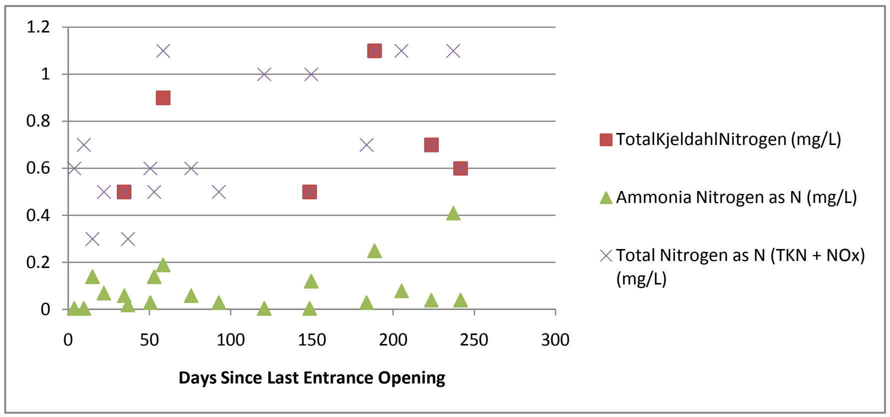
Cockrone Lagoon

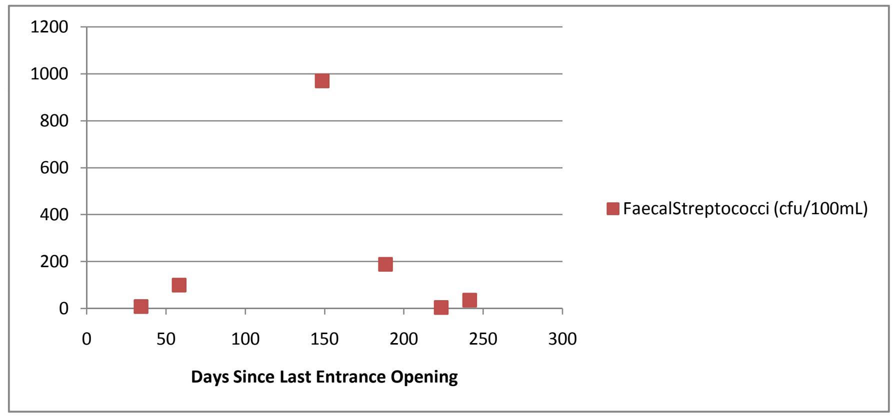
Parameter	Units	Number of Samples	Number of Non-Detect Samples	Mean	Median	90th Percentile	10th Percentile
Ammonia Nitrogen as N	mg/L	30	4	0.21	0.03	0.71	0.01
Chlorophyll a	µg/L	30	18	INSUFF	INSUFF	INSUFF	INSUFF
NOx	mg/L	30	13	0.03	0.01	0.07	0.01
Ortho-Phosphate (as P)	mg/L	30	27	INSUFF	INSUFF	INSUFF	INSUFF
Total Nitrogen as N (TKN + NOx)	mg/L	30	0	0.80	0.70	1.21	0.30
Total Phosphorus	mg/L	30	15	INSUFF	INSUFF	INSUFF	INSUFF
Dissolved Oxygen/1	mg/L	30	0	7.48	7.95	9.32	5.18
Dissolved Oxygen/2	mg/L	9	0	7.13	7.80	8.84	4.76
Dissolved Oxygen/3	mg/L	9	0	7.26	7.80	8.88	4.96
Turbidity/1	NTU	30	0	8.72	2.40	30.32	0.09
Turbidity/2	NTU	9	0	3.49	2.00	6.92	0.08
Turbidity/3	NTU	9	0	14.00	12.00	27.30	0.40
BOD(5-Day)	mg/L	12	11	1.25	1.00	1.00	1.00
EntranceCondition	-	12	0	NS	NS	NS	NS
FaecalStreptococci	cfu/100mL	6	2	82.83	58.50	185.00	5.00
SuspendedSolids(Total@105C)	mg/L	12	0	5.00	4.00	8.80	2.00
Tide Mark	m	7	0	1.31	1.70	1.84	0.64
TotalBlueGreenAlgae	cells/mL	6	0	180.00	80.00	460.00	0.00
TotalKjeldahlNitrogen	mg/L	12	0	0.57	0.55	0.88	0.30
Conductivity	mS/cm	12	0	33.45	28.40	49.53	21.65
Depth	m	7	0	0.10	0.10	0.10	0.10
pH	-	12	0	8.68	8.65	9.59	7.72
Salinity	PSS	12	0	20.94	17.35	31.87	12.94
Temperature	°C	12	0	19.40	19.45	23.97	13.44
ThermotolerantColiforms	CFU/100m	6	4	3.17	1.50	7.00	1.00
Enterococci	CFU/100m	6	0	62.83	50.00	132.00	6.50

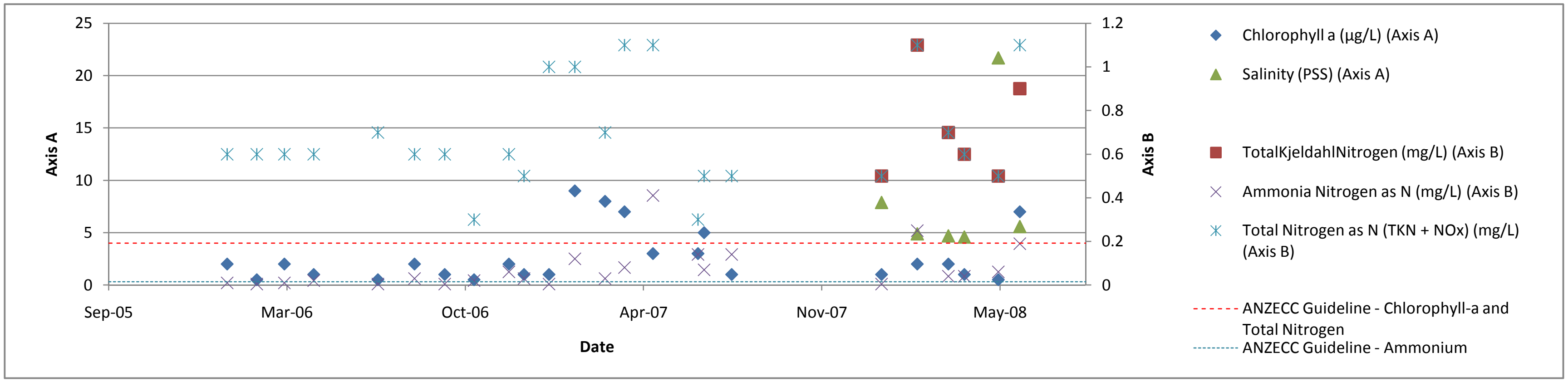
WAMBERAL

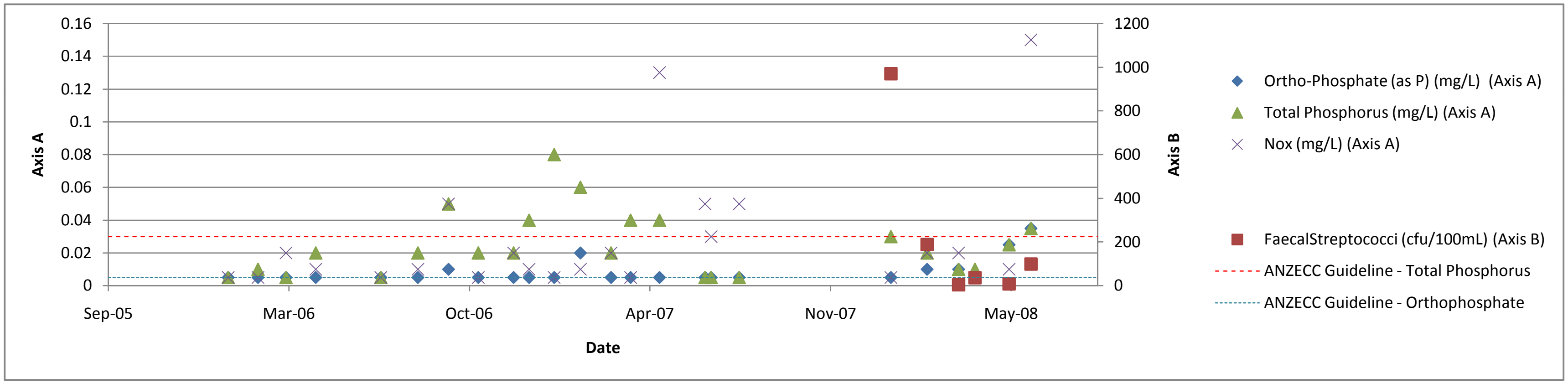

25
20
15
10
5
0
0
50
100
150
200
250
300
Days Since Last Entrance Opening
Chlorophyll a (µg/L)
Salinity (PSS)


0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
Days Since Last Entrance Opening
Ortho-Phosphate (as P) (mg/L)
Nox (mg/L)
Total Phosphorus (mg/L)

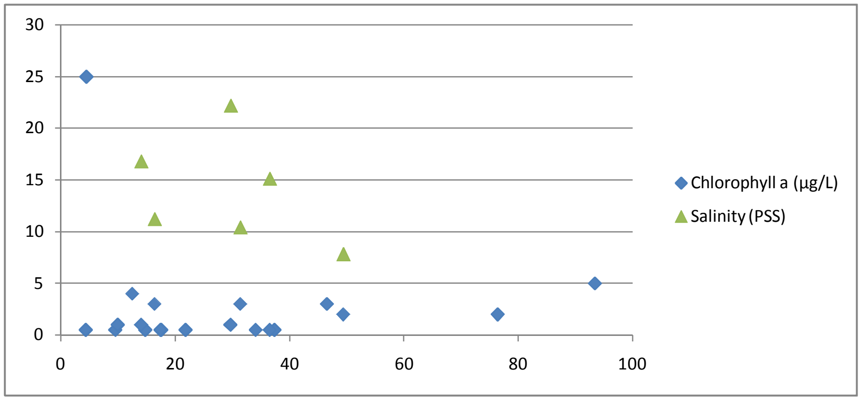

1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
Days Since Last Entrance Opening
TotalKjeldahlNitrogen (mg/L)
Ammonia Nitrogen as N (mg/L)
Total Nitrogen as N (TKN + NOx) (mg/L)


1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
Days Since Last Entrance Opening
FaecalStreptococci (cfu/100mL)


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Chlorophyll a (µg/L) (Axis A)
Salinity (PSS) (Axis A)
TotalKjeldahlNitrogen (mg/L) (Axis B)
Ammonia Nitrogen as N (mg/L) (Axis B)
Total Nitrogen as N (TKN + NOx) (mg/L) (Axis B)
ANZECC Guideline - Chlorophyll-a and Total Nitrogen
ANZECC Guideline - Ammonium


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Ortho-Phosphate (as P) (mg/L) (Axis A)
Total Phosphorus (mg/L) (Axis A)
Nox (mg/L) (Axis A)
FaecalStreptococci (cfu/100mL) (Axis B)
ANZECC Guideline - Total Phosphorus
ANZECC Guideline - Orthophosphate

TERRIGAL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25
20
15
10
5
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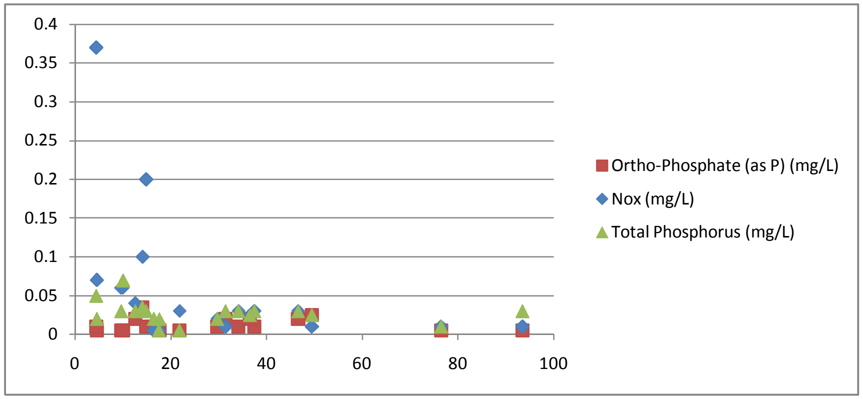
0
20
40
60
80
100
Chlorophyll a (µg/L)
Salinity (PSS)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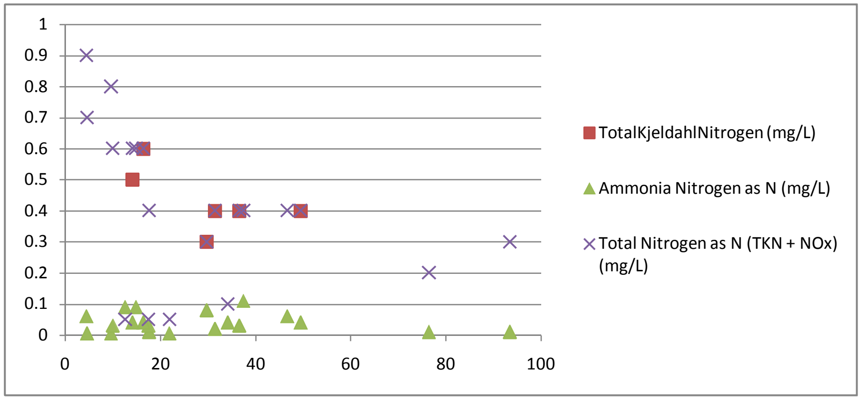
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
Ortho-Phosphate (as P) (mg/L)
Nox (mg/L)
Total Phosphorus (mg/L)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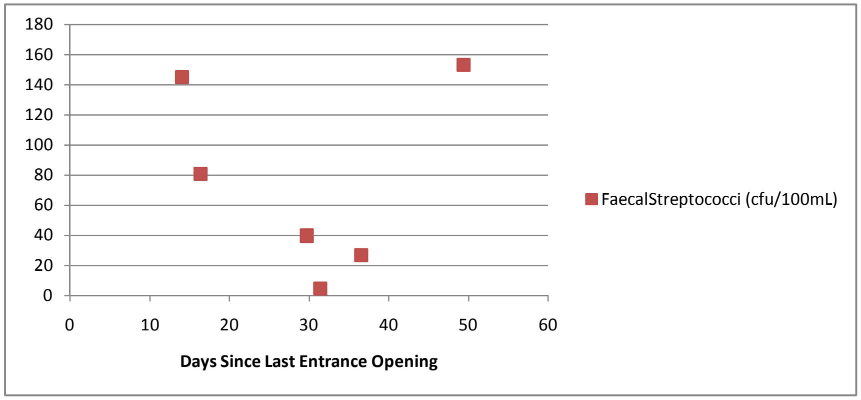
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
TotalKjeldahlNitrogen (mg/L)
Ammonia Nitrogen as N (mg/L)
Total Nitrogen as N (TKN + NOx) (mg/L)


180
160
140
120
100
80
60
40
20
0
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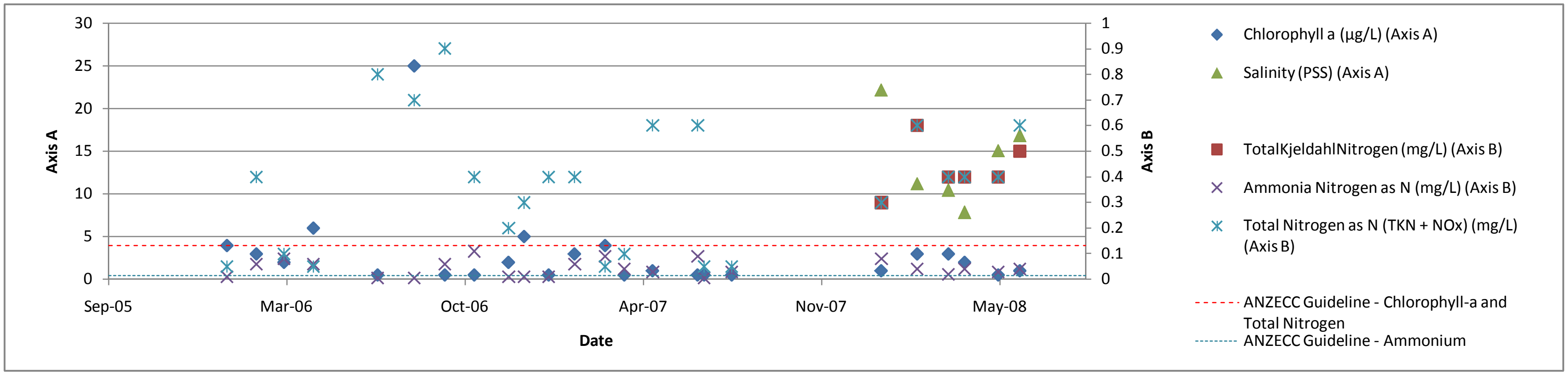
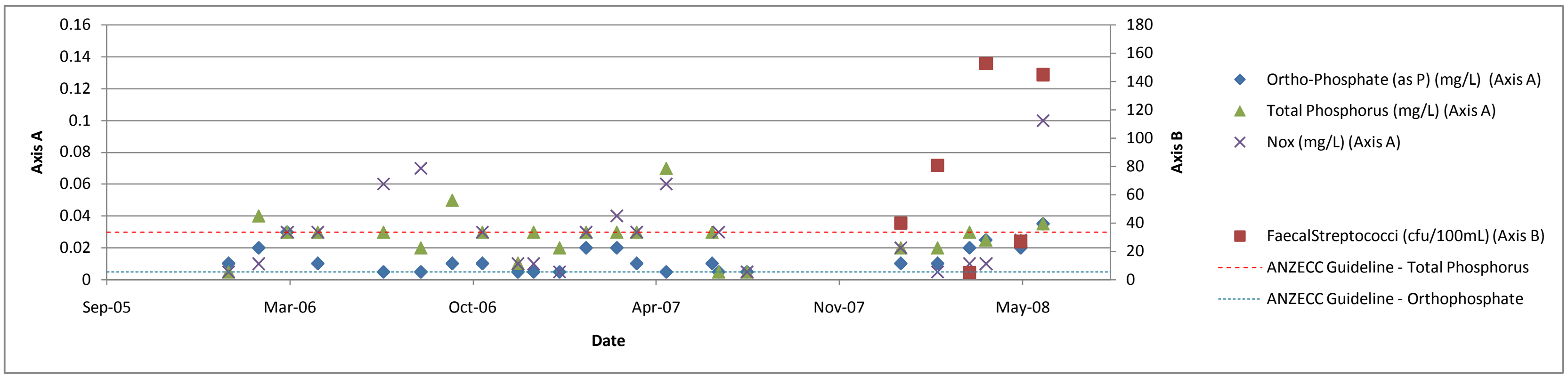
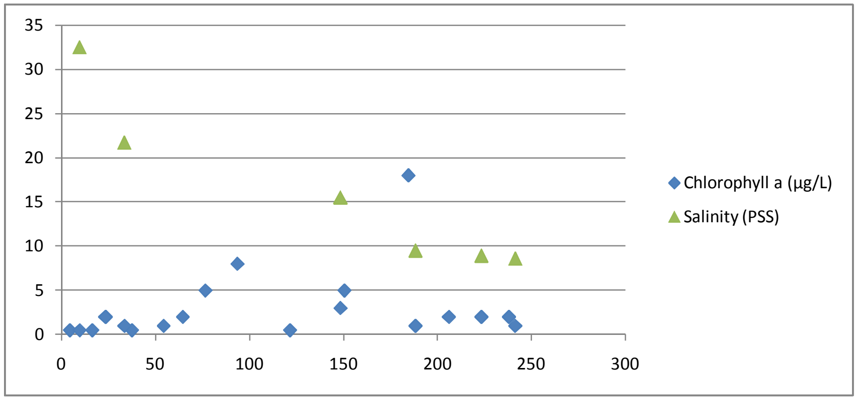
10
20
30
40
50
60
Days Since Last Entrance Opening
FaecalStreptococci (cfu/100mL)


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Chlorophyll a (µg/L) (Axis A)
Salinity (PSS) (Axis A)
TotalKjeldahlNitrogen (mg/L) (Axis B)
Ammonia Nitrogen as N (mg/L) (Axis B)
Total Nitrogen as N (TKN + NOx) (mg/L) (Axis B)
ANZECC Guideline - Chlorophyll-a and Total Nitrogen
ANZECC Guideline - Ammonium


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Ortho-Phosphate (as P) (mg/L) (Axis A)
Total Phosphorus (mg/L) (Axis A)
Nox (mg/L) (Axis A)
FaecalStreptococci (cfu/100mL) (Axis B)
ANZECC Guideline - Total Phosphorus
ANZECC Guideline - Orthophosphate

AVOCA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25
20
15
10
5
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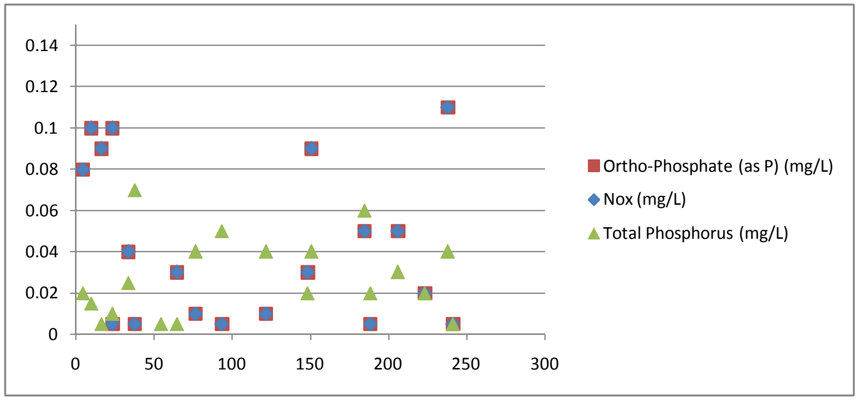
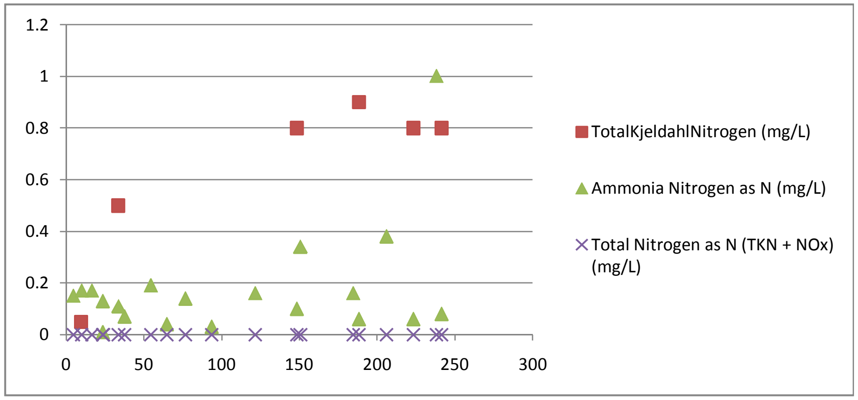
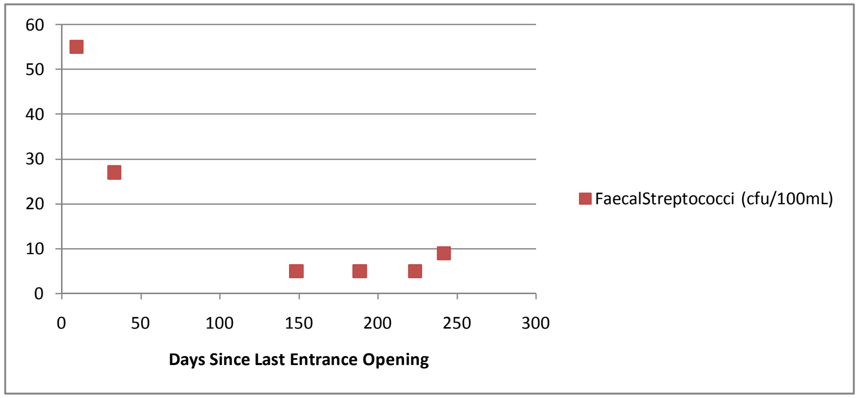
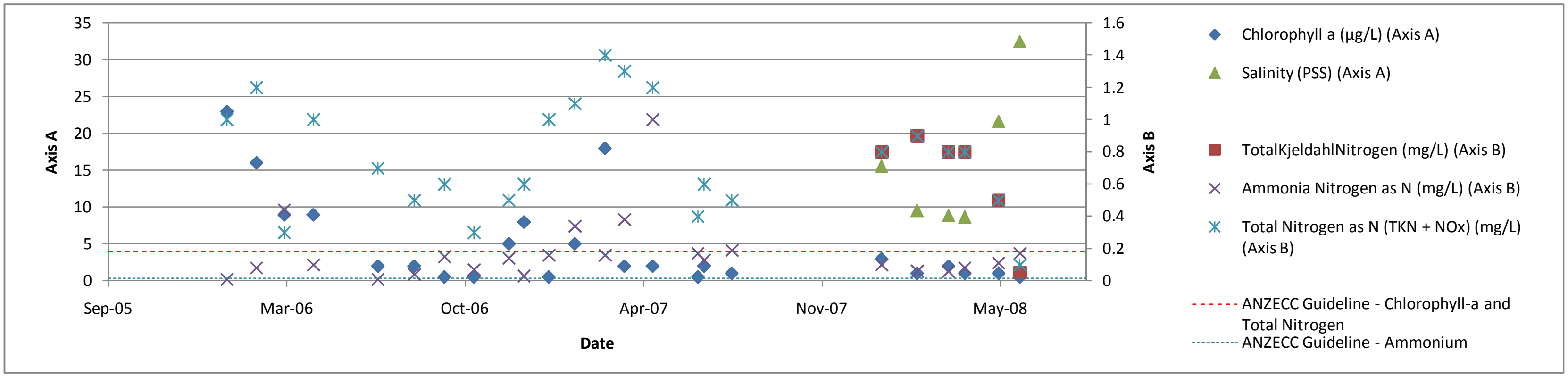
50
100
150
200
250
300
Chlorophyll a (µg/L)
Salinity (PSS)


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
Ortho-Phosphate (as P) (mg/L)
Nox (mg/L)
Total Phosphorus (mg/L)


1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
TotalKjeldahlNitrogen (mg/L)
Ammonia Nitrogen as N (mg/L)
Total Nitrogen as N (TKN + NOx) (mg/L)


60
50
40
30
20
10
0
0
50
100
150
200
250
300
Days Since Last Entrance Opening
FaecalStreptococci (cfu/100mL)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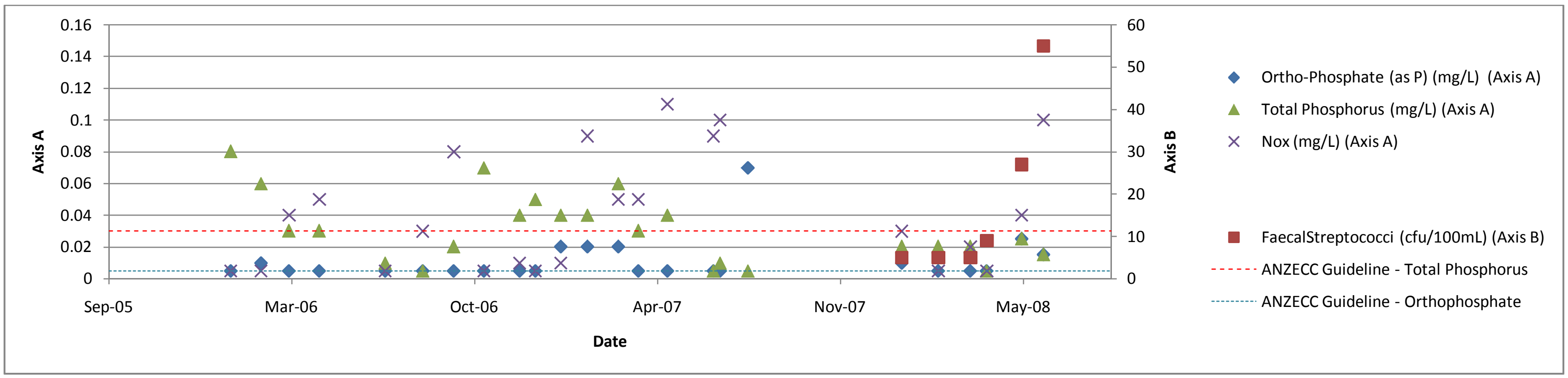
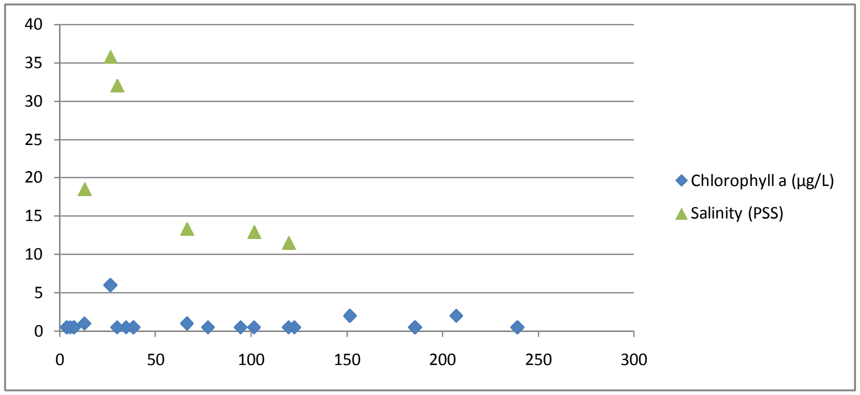
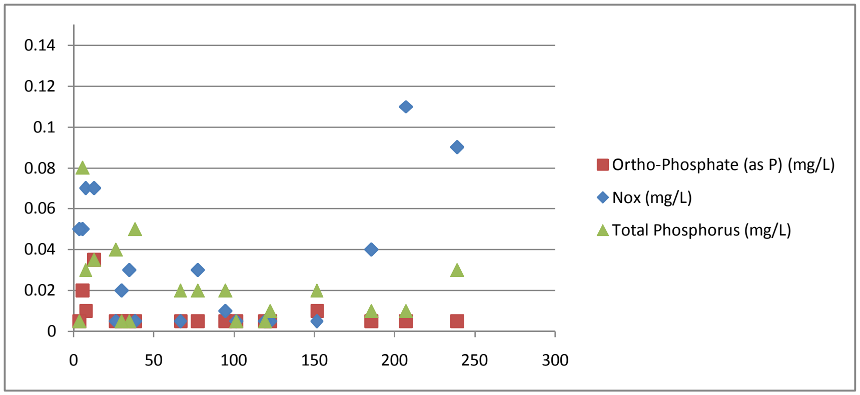
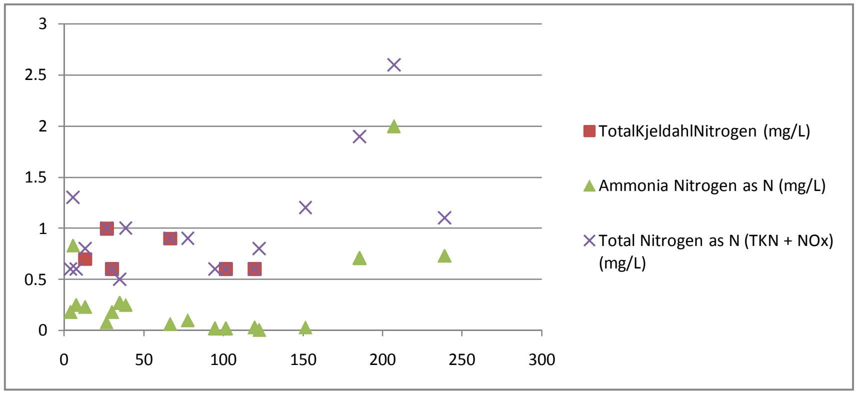
30
25
20
15
10
5
0
Axis A
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Axis B
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Date
Chlorophyll a (µg/L) (Axis A)
Salinity (PSS) (Axis A)
TotalKjeldahlNitrogen (mg/L) (Axis B)
Ammonia Nitrogen as N (mg/L) (Axis B)
Total Nitrogen as N (TKN + NOx) (mg/L) (Axis B)
ANZECC Guideline - Chlorophyll-a and Total Nitrogen
ANZECC Guideline - Ammonium

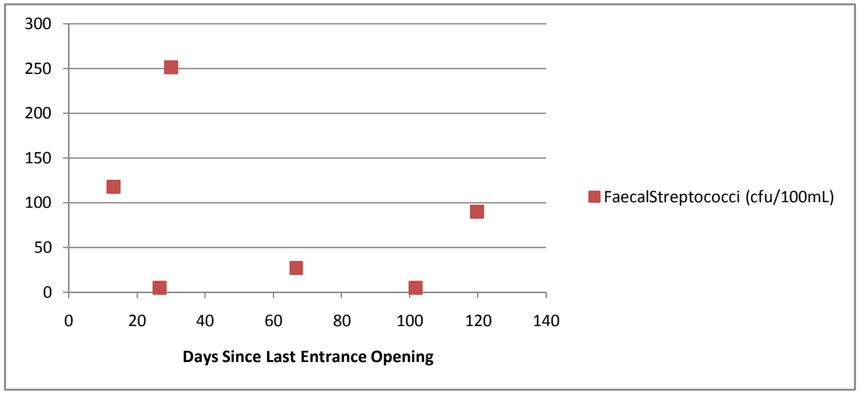

0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Axis A
60
50
40
30
20
10
0
Axis B
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Date
Ortho-Phosphate (as P) (mg/L) (Axis A)
Total Phosphorus (mg/L) (Axis A)
Nox (mg/L) (Axis A)
FaecalStreptococci (cfu/100mL) (Axis B)
ANZECC Guideline - Total Phosphorus
ANZECC Guideline - Orthophosphate

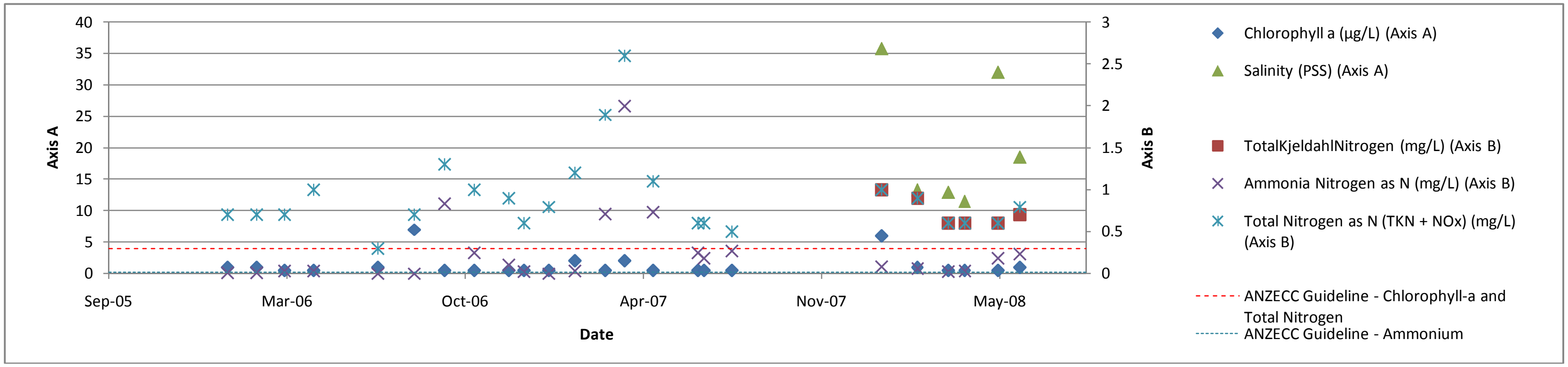
COCKRONE

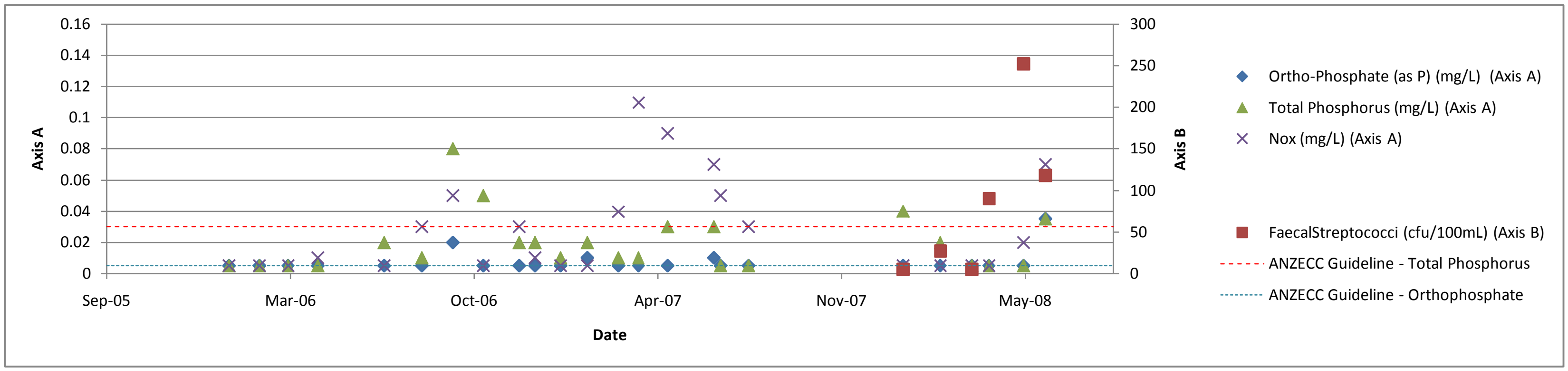

40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
Chlorophyll a (µg/L)
Salinity (PSS)


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
Ortho-Phosphate (as P) (mg/L)
Nox (mg/L)
Total Phosphorus (mg/L)


3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
TotalKjeldahlNitrogen (mg/L)
Ammonia Nitrogen as N (mg/L)
Total Nitrogen as N (TKN + NOx) (mg/L)


300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Days Since Last Entrance Opening
FaecalStreptococci (cfu/100mL)


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Chlorophyll a (µg/L) (Axis A)
Salinity (PSS) (Axis A)
TotalKjeldahlNitrogen (mg/L) (Axis B)
Ammonia Nitrogen as N (mg/L) (Axis B)
Total Nitrogen as N (TKN + NOx) (mg/L) (Axis B)
ANZECC Guideline - Chlorophyll-a and Total Nitrogen
ANZECC Guideline - Ammonium


Axis A
Axis B
Date
Sep-05
Mar-06
Oct-06
Apr-07
Nov-07
May-08
Ortho-Phosphate (as P) (mg/L) (Axis A)
Total Phosphorus (mg/L) (Axis A)
Nox (mg/L) (Axis A)
FaecalStreptococci (cfu/100mL) (Axis B)
ANZECC Guideline - Total Phosphorus
ANZECC Guideline - Orthophosphate

Appendix I

Threatened Species Records

Australian Government
Department of the Environment, Water, Heritage and the Arts

Environmental Reporting Tool

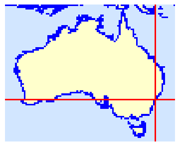
You are here: Environment Home > ERIN > ERT

25 January 2010 16:27

Database Report

This report includes places of national environmental significance that are registered in the Department of the Environment and Water Resources' databases, for the selected area. The information presented here has been provided by a range of groups across Australia, and the accuracy and resolution varies.

Search Type:	Area
Buffer:	1 km
Coordinates:	-33.3944,151.4891, -33.3944,151.3828, -33.5093,151.3828, -33.5093,151.4891



Report Contents: Summary >> Details >> Caveat >> Acknowledgment

Biodiversity

Threatened Species:	48
Migratory Species:	69
Listed Marine Species:	96
Invasive Species:	17
Whales and Other Cetaceans:	13
Threatened Ecological Communities:	None

Heritage

World Heritage Properties:	None
Australian Heritage Sites:	4

Wetlands

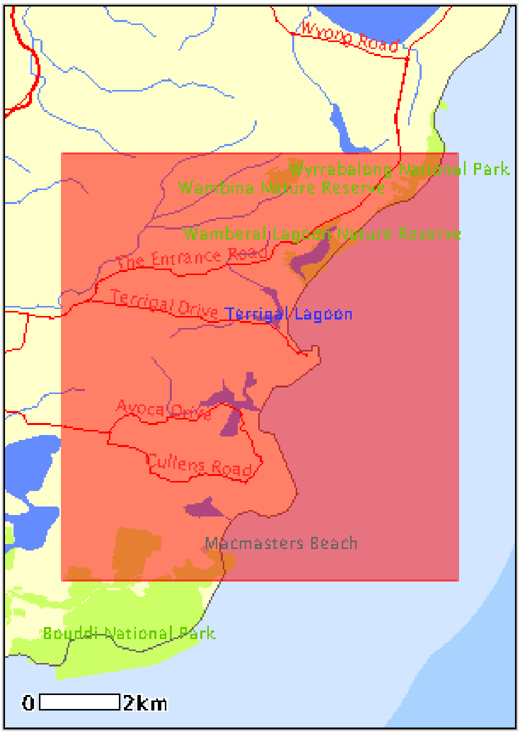
Ramsar sites: (Internationally important)	None
Nationally Important Wetlands:	5

National Pollutant Inventory

Reporting Facilities:	1
Airsheds:	1
Catchments:	None

Protected Areas

Reserves and Conservation Areas:	4
Regional Forest Agreements:	1



This map may contain data which are
© Commonwealth of Australia (Geoscience Australia)
© PSMA Australia Limited

Biodiversity

Threatened Species [Dataset Information]	Status	Comments
Birds		
Anthochaera phrygia Regent Honeyeater	Endangered	Species or species habitat likely to occur within area
Diomedea exulans (sensu lato) Wandering Albatross	Vulnerable	Species or species habitat may occur within area
Diomedea exulans amsterdamensis Amsterdam Albatross	Endangered	Species or species habitat may occur within area
Diomedea exulans antipodensis	Vulnerable	Species or species habitat may occur

Antipodean Albatross		within area
Diomedea exulans exulans Tristan Albatross	Endangered	Foraging, feeding or related behaviour may occur within area
Diomedea exulans gibsoni Gibson's Albatross	Vulnerable	Species or species habitat may occur within area
Lathamus discolor Swift Parrot	Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Vulnerable	Species or species habitat may occur within area
Pterodroma leucoptera leucoptera Gould's Petrel	Endangered	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western)	Vulnerable	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe	Vulnerable	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta salvini Salvin's Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris impavida Campbell Albatross	Vulnerable	Species or species habitat may occur within area
Frogs		
Heleioporus australiacus Giant Burrowing Frog	Vulnerable	Species or species habitat likely to occur within area
Litoria aurea Green and Golden Bell Frog	Vulnerable	Species or species habitat known to occur within area
Litoria littlejohni Littlejohn's Tree Frog, Heath Frog	Vulnerable	Species or species habitat may occur within area
Mixophyes balbus Stuttering Frog, Southern Barred Frog (in Victoria)	Vulnerable	Species or species habitat likely to occur within area
Mixophyes iteratus Southern Barred Frog, Giant Barred Frog	Endangered	Species or species habitat likely to occur within area
Mammals		
Balaenoptera musculus Blue Whale	Endangered	Species or species habitat may occur within area
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat	Vulnerable	Species or species habitat may occur within area
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population)	Endangered	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale	Vulnerable	Species or species habitat known to occur within area
Potorous tridactylus tridactylus Long-nosed Potoroo (SE mainland)	Vulnerable	Species or species habitat may occur within area
Pteropus poliocephalus	Vulnerable	Roosting known to occur within area

Grey-headed Flying-fox		
Ray-finned fishes		
Macquaria australasica Macquarie Perch	Endangered	Species or species habitat may occur within area
Prototroctes maraena Australian Grayling	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Chelonia mydas Green Turtle	Vulnerable	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Endangered	Species or species habitat may occur within area
Hoplocephalus bungaroides Broad-headed Snake	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharias taurus (east coast population) Grey Nurse Shark (east coast population)	Critically Endangered	Species or species habitat may occur within area
Carcharodon carcharias Great White Shark	Vulnerable	Species or species habitat may occur within area
Galeorhinus galeus School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark	Conservation Dependent	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark	Vulnerable	Species or species habitat may occur within area
Plants		
Acacia bynoeana Bynoe's Wattle, Tiny Wattle	Vulnerable	Species or species habitat likely to occur within area
Apatophyllum constablei	Endangered	Species or species habitat may occur within area
Caladenia tessellata Thick-lipped Spider-orchid, Daddy Long-legs	Vulnerable	Species or species habitat likely to occur within area
Cryptostylis hunteriana Leafless Tongue-orchid	Vulnerable	Species or species habitat may occur within area
Eucalyptus camfieldii Camfield's Stringybark	Vulnerable	Species or species habitat likely to occur within area
Melaleuca biconvexa Biconvex Paperbark	Vulnerable	Species or species habitat known to occur within area
Rhizanthella slateri Eastern Underground Orchid	Endangered	Species or species habitat may occur within area
Syzygium paniculatum Magenta Lilly Pilly, Magenta Cherry, Pocket-less Brush Cherry, Scrub Cherry, Creek Lilly Pilly, Brush Cherry	Vulnerable	Species or species habitat likely to occur within area
Migratory Species [Dataset Information]	Status	Comments
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail	Migratory	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch	Migratory	Breeding may occur within area
Myiagra cyanoleuca	Migratory	Breeding likely to occur within area

Satin Flycatcher		
Rhipidura rufifrons Rufous Fantail	Migratory	Breeding may occur within area
Xanthomyza phrygia Regent Honeyeater	Migratory	Species or species habitat likely to occur within area

Migratory Wetland Species

Birds

Actitis hypoleucos Common Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris alba Sanderling	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris canutus Red Knot, Knot	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris ferruginea Curlew Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris ruficollis Red-necked Stint	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris tenuirostris Great Knot	Migratory	Foraging, feeding or related behaviour likely to occur within area
Charadrius bicinctus Double-banded Plover	Migratory	Foraging, feeding or related behaviour known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Migratory	Foraging, feeding or related behaviour likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Migratory	Foraging, feeding or related behaviour likely to occur within area
Glareola maldivarum Oriental Pratincole	Migratory	Foraging, feeding or related behaviour likely to occur within area
Heteroscelus brevipes Grey-tailed Tattler	Migratory	Foraging, feeding or related behaviour known to occur within area
Limicola falcinellus Broad-billed Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Limosa lapponica Bar-tailed Godwit	Migratory	Foraging, feeding or related behaviour known to occur within area
Limosa limosa Black-tailed Godwit	Migratory	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew	Migratory	Foraging, feeding or related behaviour known to occur within area
Numenius minutus Little Curlew, Little Whimbrel	Migratory	Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel	Migratory	Foraging, feeding or related behaviour known to occur within area
Pluvialis fulva Pacific Golden Plover	Migratory	Foraging, feeding or related behaviour known to occur within area

Pluvialis squatarola Grey Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area
Rostratula benghalensis s. lat. Painted Snipe	Migratory	Species or species habitat may occur within area
Tringa glareola Wood Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Tringa nebularia Common Greenshank, Greenshank	Migratory	Foraging, feeding or related behaviour likely to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank	Migratory	Foraging, feeding or related behaviour likely to occur within area
Xenus cinereus Terek Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater	Migratory	Species or species habitat may occur within area
Diomedea amsterdamensis Amsterdam Albatross	Migratory	Species or species habitat may occur within area
Diomedea antipodensis Antipodean Albatross	Migratory	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross	Migratory	Foraging, feeding or related behaviour may occur within area
Diomedea exulans (sensu lato) Wandering Albatross	Migratory	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Migratory	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Migratory	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Migratory	Species or species habitat may occur within area
Pterodroma leucoptera leucoptera Gould's Petrel	Migratory	Species or species habitat may occur within area
Puffinus leucomelas Streaked Shearwater	Migratory	Species or species habitat may occur within area
Sterna albifrons Little Tern	Migratory	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Migratory	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross	Migratory	Species or species habitat may occur within area
Thalassarche chlororhynchos Yellow-nosed Albatross, Atlantic Yellow-nosed Albatross	Migratory	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Migratory	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Migratory	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross	Migratory	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross	Migratory	Species or species habitat may occur within area

Migratory Marine Species

Mammals

Balaenoptera edeni Bryde's Whale	Migratory	Species or species habitat may occur within area
Balaenoptera musculus Blue Whale	Migratory	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale	Migratory	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Migratory	Species or species habitat likely to occur within area
Lagenorhynchus obscurus Dusky Dolphin	Migratory	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Migratory	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca	Migratory	Species or species habitat may occur within area
Reptiles		
Chelonia mydas Green Turtle	Migratory	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Migratory	Species or species habitat may occur within area
Sharks		
Carcharodon carcharias Great White Shark	Migratory	Species or species habitat may occur within area
Rhincodon typus Whale Shark	Migratory	Species or species habitat may occur within area
Listed Marine Species [Dataset Information]	Status	Comments
Birds		
Actitis hypoleucos Common Sandpiper	Listed	Foraging, feeding or related behaviour likely to occur within area
Apus pacificus Fork-tailed Swift	Listed - overfly marine area	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Listed - overfly marine area	Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone	Listed	Foraging, feeding or related behaviour likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper	Listed	Foraging, feeding or related behaviour likely to occur within area
Calidris alba Sanderling	Listed	Foraging, feeding or related behaviour likely to occur within area
Calidris canutus Red Knot, Knot	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris ferruginea Curlew Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris melanotos Pectoral Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris ruficollis Red-necked Stint	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris subminuta Long-toed Stint	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris tenuirostris Great Knot	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calonectris leucomelas	Listed	Species or species habitat may occur

Streaked Shearwater		within area
Catharacta skua Great Skua	Listed	Species or species habitat may occur within area
Charadrius bicinctus Double-banded Plover	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Charadrius dubius Little Ringed Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover	Listed	Foraging, feeding or related behaviour likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover	Listed	Foraging, feeding or related behaviour likely to occur within area
Charadrius ruficapillus Red-capped Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Diomedea amsterdamensis Amsterdam Albatross	Listed	Species or species habitat may occur within area
Diomedea antipodensis Antipodean Albatross	Listed	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross	Listed	Foraging, feeding or related behaviour may occur within area
Diomedea exulans (sensu lato) Wandering Albatross	Listed	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Listed	Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Gallinago megala Swinhoe's Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Gallinago stenura Pin-tailed Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Glareola maldivarum Oriental Pratincole	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle	Listed	Species or species habitat likely to occur within area
Heteroscelus brevipes Grey-tailed Tattler	Listed	Foraging, feeding or related behaviour known to occur within area
Heteroscelus incanus Wandering Tattler	Listed	Foraging, feeding or related behaviour likely to occur within area
Himantopus himantopus Black-winged Stilt	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Hirundapus caudacutus White-throated Needletail	Listed - overfly marine area	Species or species habitat may occur within area
Lathamus discolor Swift Parrot	Listed - overfly marine area	Species or species habitat likely to occur within area
Limicola falcinellus Broad-billed Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Limnodromus semipalmatus Asian Dowitcher	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Limosa lapponica Bar-tailed Godwit	Listed	Foraging, feeding or related behaviour known to occur within area
Limosa limosa Black-tailed Godwit	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Macronectes giganteus Southern Giant-Petrel	Listed	Species or species habitat may occur within area
Macronectes halli	Listed	Species or species habitat may occur

Northern Giant-Petrel		within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch	Listed - overfly marine area	Breeding may occur within area
Myiagra cyanoleuca Satin Flycatcher	Listed - overfly marine area	Breeding likely to occur within area
Numenius madagascariensis Eastern Curlew	Listed	Foraging, feeding or related behaviour known to occur within area
Numenius minutus Little Curlew, Little Whimbrel	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel	Listed	Foraging, feeding or related behaviour known to occur within area
Phalaropus lobatus Red-necked Phalarope	Listed	Foraging, feeding or related behaviour likely to occur within area
Philomachus pugnax Ruff (Reeve)	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Pluvialis fulva Pacific Golden Plover	Listed	Foraging, feeding or related behaviour known to occur within area
Pluvialis squatarola Grey Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Rhipidura rufifrons Rufous Fantail	Listed - overfly marine area	Breeding may occur within area
Rostratula benghalensis s. lat. Painted Snipe	Listed - overfly marine area	Species or species habitat may occur within area
Sterna albifrons Little Tern	Listed	Species or species habitat may occur within area
Stiltia isabella Australian Pratincole	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Thalassarche bulleri Buller's Albatross	Listed	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross	Listed	Species or species habitat may occur within area
Thalassarche chlororhynchos Yellow-nosed Albatross, Atlantic Yellow-nosed Albatross	Listed	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Listed	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Listed	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross	Listed	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross	Listed	Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa glareola Wood Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa nebularia Common Greenshank, Greenshank	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa totanus Common Redshank, Redshank	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area

Xenus cinereus Terek Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Mammals		
Arctocephalus forsteri New Zealand Fur-seal	Listed	Species or species habitat may occur within area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal	Listed	Species or species habitat may occur within area
Ray-finned fishes		
Acentronura tentaculata Hairy Pygmy Pipehorse	Listed	Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish	Listed	Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish	Listed	Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish	Listed	Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish	Listed	Species or species habitat may occur within area
Hippocampus abdominalis Eastern Potbelly Seahorse, New Zealand Potbelly, Seahorse, Bigbelly Seahorse	Listed	Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse	Listed	Species or species habitat may occur within area
Histiogamphelus briggsii Briggs' Crested Pipefish, Briggs' Pipefish	Listed	Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish	Listed	Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish	Listed	Species or species habitat may occur within area
Notiocampus ruber Red Pipefish	Listed	Species or species habitat may occur within area
Phyllopteryx taeniolatus Weedy Seadragon, Common Seadragon	Listed	Species or species habitat may occur within area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse	Listed	Species or species habitat may occur within area
Solenostomus cyanopterus Blue-finned Ghost Pipefish, Robust Ghost Pipefish	Listed	Species or species habitat may occur within area
Solenostomus paradoxus Harlequin Ghost Pipefish, Ornate Ghost Pipefish	Listed	Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish	Listed	Species or species habitat may occur within area
Stigmatopora nigra Wide-bodied Pipefish, Black Pipefish	Listed	Species or species habitat may occur within area
Syngnathoides biaculeatus Double-ended Pipehorse, Alligator Pipefish	Listed	Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bend Stick Pipefish, Short-tailed Pipefish	Listed	Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish	Listed	Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish	Listed	Species or species habitat may occur within area
Reptiles		
Chelonia mydas Green Turtle	Listed	Species or species habitat may occur within area
Dermochelys coriacea	Listed	Species or species habitat may occur

Leatherback Turtle, Leathery Turtle, Luth		within area
Pelamis platurus Yellow-bellied Seasnake	Listed	Species or species habitat may occur within area
Invasive Species [Dataset Information]	Status	Comments
Selected Invasive Species: Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.		
Mammals		
Capra hircus Goat	Feral	Species or species habitat may occur within area
Felis catus Cat, House Cat, Domestic Cat	Feral	Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit	Feral	Species or species habitat likely to occur within area
Sus scrofa Pig	Feral	Species or species habitat may occur within area
Vulpes vulpes Red Fox, Fox	Feral	Species or species habitat likely to occur within area
Plants		
Alternanthera philoxeroides Alligator Weed	WoNS	Species or species habitat may occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus	WoNS	Species or species habitat may occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed	WoNS	Species or species habitat may occur within area
Genista sp. X Genista monspessulana Broom	Invasive	Species or species habitat may occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage	WoNS	Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn	Invasive	Species or species habitat may occur within area
Nassella trichotoma Serrated Tussock, Yass River Tussock, Yass Tussock, Nassella Tussock (NZ)	WoNS	Species or species habitat may occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine	Invasive	Species or species habitat may occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry	WoNS	Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtiji Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow	WoNS	Species or species habitat may occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed	WoNS	Species or species habitat may occur within area
Ulex europaeus Gorse, Furze	WoNS	Species or species habitat may occur within area
Whales and Other Cetaceans [Dataset Information]	Status	Comments
Balaenoptera acutorostrata	Cetacean	Species or species habitat may occur

Minke Whale		within area
Balaenoptera edeni Bryde's Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera musculus Blue Whale	Cetacean	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale	Cetacean	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin	Cetacean	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Cetacean	Species or species habitat likely to occur within area
Grampus griseus Risso's Dolphin, Grampus	Cetacean	Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin	Cetacean	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Cetacean	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca	Cetacean	Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin	Cetacean	Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin	Cetacean	Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin	Cetacean	Species or species habitat may occur within area

Heritage

Australian Heritage Sites [Dataset Information]
Note that not all Indigenous sites may be listed.

Historic

Holy Cross Catholic Church and Graveyard NSW

St Pauls Anglican Church NSW

Natural

Bouddi National Park (1981 boundary) NSW

Wamberal Lagoon Nature Reserve NSW

Wetlands

Nationally Important Wetland Sites [Dataset Information]

Avoca Lagoon, NSW

Brisbane Water Estuary, NSW

Cockrone Lagoon, NSW

Terrigal Lagoon, NSW

Wamberal Lagoon, NSW

National Pollutant Inventory

NPI Location Report

Reporting Facility [Dataset Information]	Top Substance	Source
Substance emissions are ranked on a scale of 1-100: 1=lowest; 100=highest. Rankings are shown as: =0-25; =26-50; =51-75; =76-100.		
Gosford City Council (Kincumber Sewage Treatment Plant, Kincumber NSW)	Total Phosphorus [Low]	Wastewater treatment, using preliminary treatment, primary and secondary treatment, and anaerobic sludge digestion.

Airshed [Dataset Information]	Substances	Sources
Greater Sydney Newcastle & Wollongong Regions	73	23

(GMR), NSW

Other

Reserves and Conservation Areas [Dataset Information]

Bouddi National Park, NSW

Wamberal Lagoon Nature Reserve, NSW

Wambina Nature Reserve, NSW

Wyrrabalong National Park, NSW

Regional Forest Agreements [Dataset Information]
Note that all RFA areas including those still under consideration have been included.

Lower North East NSW RFA, New South Wales

Caveat

The information presented here has been drawn from a range of sources, compiled for a variety of purposes. Details of the coverage of each dataset are included in the metadata [Dataset Information] links above.

Acknowledgment

This database has been compiled from a range of data sources. The Department acknowledges the following custodians who have contributed valuable data and advice:

- New South Wales National Parks and Wildlife Service
- Department of Sustainability and Environment, Victoria
- Department of Primary Industries, Water and Environment, Tasmania
- Department of Environment and Heritage, South Australia Planning SA
- Parks and Wildlife Commission of the Northern Territory
- Environmental Protection Agency, Queensland
- Birds Australia
- Australian Bird and Bat Banding Scheme
- Australian National Wildlife Collection
- Natural history museums of Australia
- Queensland Herbarium
- National Herbarium of NSW
- Royal Botanic Gardens and National Herbarium of Victoria
- Tasmanian Herbarium
- State Herbarium of South Australia
- Northern Territory Herbarium
- Western Australian Herbarium
- Australian National Herbarium, Atherton and Canberra
- University of New England
- Other groups and individuals

ANUCliM Version 1.8, Centre for Resource and Environmental Studies, Australian National University was used extensively for the production of draft maps of species distribution. The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Wyong CMA sub-region

Below is a list of the 120 threatened species found in the Wyong sub-region. You can also see a list of:

- threatened algae
- threatened animals
- threatened communities
- threatened fungi
- threatened plants
- see this complete list categorised by vegetation type

Threatened species known or predicted to occur in the Wyong CMA sub-region Export this list

Scientific Name	Common Name	Type of species	Level of Threat	Known or Predicted to occur
Acacia bynoeana	Bynoe's Wattle	Plant > Shrubs	Endangered	Known
Angophora inopina	Charmhaven Apple	Plant > Trees	Vulnerable	Known
Anseranas semipalmata	Magpie Goose	Animal > Birds	Vulnerable	Known
Astrotricha crassifolia	Thick-leaf Star-hair	Plant > Shrubs	Vulnerable	Predicted
Baloskion longipes	Dense Cord-rush	Plant > Herbs and Forbs	Vulnerable	Predicted
Botaurus poiciloptilus	Australasian Bittern	Animal > Birds	Vulnerable	Known
Burhinus grallarius	Bush Stone-curlew	Animal > Birds	Endangered	Known
Caladenia porphyrea	Caladenia porphyrea	Plant > Orchids	Endangered	Known
Caladenia tessellata	Tessellated Spider Orchid	Plant > Orchids	Endangered	Known
Calidris alba	Sanderling	Animal > Birds	Vulnerable	Known
Calidris tenuirostris	Great Knot	Animal > Birds	Vulnerable	Known
Callistemon linearifolius	Netted Bottle Brush	Plant > Shrubs	Vulnerable	Known
Callocephalon fimbriatum	Gang-gang Cockatoo	Animal > Birds	Vulnerable	Known
Calyptorhynchus lathami	Glossy Black-cockatoo	Animal > Birds	Vulnerable	Known
Caretta caretta	Loggerhead Turtle	Animal > Reptiles	Endangered	Known
Cercartetus nanus	Eastern Pygmy-possum	Animal > Marsupials	Vulnerable	Known
Chalinolobus dwyeri	Large-eared Pied Bat	Animal > Bats	Vulnerable	Known
Chamaesyce psammogeton	Sand Spurge	Plant > Herbs and Forbs	Endangered	Known
Charadrius leschenaultii	Greater Sand-plover	Animal > Birds	Vulnerable	Known
Charadrius mongolus	Lesser Sand-plover	Animal > Birds	Vulnerable	Known
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	Animal > Birds	Vulnerable	Known
Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Community > Threatened Ecological Communities	Endangered Ecological Community	Predicted
Crinia tinnula	Wallum Froglet	Animal > Amphibians	Vulnerable	Known
Cryptostylis hunteriana	Leafless Tongue Orchid	Plant > Orchids	Vulnerable	Known
Cynanchum elegans	White-flowered Wax Plant	Plant > Epiphytes and climbers	Endangered	Known
Darwinia glaucophylla	*Darwinia glaucophylla*	Plant > Shrubs	Vulnerable	Known
Dasyurus maculatus	Spotted-tailed Quoll	Animal > Marsupials	Vulnerable	Known
Dermochelys coriacea	Leathery Turtle	Animal > Reptiles	Vulnerable	Known
Diuris bracteata	*Diuris bracteata*	Plant > Orchids	Endangered	Known
Diuris praecox	Rough Double Tail	Plant > Orchids	Vulnerable	Known
Epacris purpurascens var. purpurascens	*Epacris purpurascens var. purpurascens*	Plant > Shrubs	Vulnerable	Known

Ephippiorhynchus asiaticus	Black-necked Stork	Animal > Birds	Endangered	Known
Eucalyptus camfieldii	Camfield's Stringybark	Plant > Mallees	Vulnerable	Known
Eucalyptus oblonga - endangered population	*Eucalyptus oblonga* (Narrow-leaved Stringybark) population at Bateau Bay	Plant > Endangered Populations	Endangered Population	Known
Eucalyptus parramattensis subsp. decadens	*Eucalyptus parramattensis* subsp. *decadens*	Plant > Trees	Vulnerable	Known
Eucalyptus parramattensis subsp. parramattensis - endangered population	*Eucalyptus parramattensis* subsp. *parramattensis* population in the Wyong and Lake Macquarie LGAs	Plant > Endangered Populations	Endangered Population	Known
Falsistrellus tasmaniensis	Eastern False Pipistrelle	Animal > Bats	Vulnerable	Known
Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Freshwater wetlands on coastal floodplains	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Genoplesium insignis	Variable Midge Orchid	Plant > Orchids	Endangered	Known
Grantiella picta	Painted Honeyeater	Animal > Birds	Vulnerable	Known
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	Plant > Shrubs	Vulnerable	Known
Haematopus fuliginosus	Sooty Oystercatcher	Animal > Birds	Vulnerable	Known
Haematopus longirostris	Pied Oystercatcher	Animal > Birds	Vulnerable	Known
Heleioporus australiacus	Giant Burrowing Frog	Animal > Amphibians	Vulnerable	Known
Hibbertia procumbens	Spreading Guinea Flower	Plant > Shrubs	Endangered	Known
Hoplocephalus bitorquatus	Pale-headed Snake	Animal > Reptiles	Vulnerable	Known
Hoplocephalus bungaroides	Broad-headed Snake	Animal > Reptiles	Endangered	Known
Hoplocephalus stephensii	Stephens' Banded Snake	Animal > Reptiles	Vulnerable	Known
Hunter Lowland Redgum Forest in the Sydney Basin and NSW North Coast Bioregions	Hunter Lowland Redgum Forest in the Sydney Basin and NSW North Coast Bioregions	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Irediparra gallinacea	Comb-crested Jacana	Animal > Birds	Vulnerable	Known
Ixobrychus flavicollis	Black Bittern	Animal > Birds	Vulnerable	Known
Kerivoula papuensis	Golden-tipped Bat	Animal > Bats	Vulnerable	Known
Kincumber Scribbly Gum Forest in the Sydney Basin bioregion	Kincumber Scribbly Gum Forest	Community > Threatened Ecological Communities	Critically Endangered Ecological Community	Known
Lathamus discolor	Swift Parrot	Animal > Birds	Endangered	Known
Limicola falcinellus	Broad-billed Sandpiper	Animal > Birds	Vulnerable	Known
Limosa limosa	Black-tailed Godwit	Animal > Birds	Vulnerable	Known
Litoria aurea	Green and Golden Bell Frog	Animal > Amphibians	Endangered	Known
Litoria brevipalmata	Green-thighed Frog	Animal > Amphibians	Vulnerable	Known
Litoria littlejohni	Littlejohn's Tree Frog	Animal > Amphibians	Vulnerable	Known
Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Community > Threatened Ecological Communities	Endangered Ecological Community	Predicted
Lophoictinia isura	Square-tailed Kite	Animal > Birds	Vulnerable	Predicted
Low woodland with heathland on indurated sand at Norah Head	Low woodland with heathland on indurated sand at Norah Head	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Lower Hunter Spotted Gum - Ironbark Forest in the Sydney Basin Bioregion	Lower Hunter Spotted Gum - Ironbark Forest	Community > Threatened Ecological Communities	Endangered Ecological Community	Known

Macropus parma	Parma Wallaby	Animal > Marsupials	Vulnerable	Known
Maundia triglochinoides	*Maundia triglochinoides*	Plant > Herbs and Forbs	Vulnerable	Known
Melaleuca biconvexa	Biconvex Paperbark	Plant > Trees	Vulnerable	Known
Melaleuca groveana	Grove's Paperbark	Plant > Shrubs	Vulnerable	Predicted
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	Animal > Birds	Vulnerable	Known
Miniopterus australis	Little Bentwing-bat	Animal > Bats	Vulnerable	Known
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	Animal > Bats	Vulnerable	Known
Mixophyes balbus	Stuttering Barrred Frog	Animal > Amphibians	Endangered	Known
Mixophyes iteratus	Giant Barred Frog	Animal > Amphibians	Endangered	Known
Mormopterus norfolkensis	Eastern Freetail-bat	Animal > Bats	Vulnerable	Known
Myotis macropus (formally Myotis adversus)	Large-footed Myotis	Animal > Bats	Vulnerable	Known
Neophema pulchella	Turquoise Parrot	Animal > Birds	Vulnerable	Known
Nettapus coromandelianus	Cotton Pygmy-goose	Animal > Birds	Endangered	Known
Ninox connivens	Barking Owl	Animal > Birds	Vulnerable	Known
Ninox strenua	Powerful Owl	Animal > Birds	Vulnerable	Known
Oxyura australis	Blue-billed Duck	Animal > Birds	Vulnerable	Known
Pandion haliaetus	Osprey	Animal > Birds	Vulnerable	Known
Petaurus australis	Yellow-bellied Glider	Animal > Marsupials	Vulnerable	Known
Petaurus norfolcensis	Squirrel Glider	Animal > Marsupials	Vulnerable	Known
Petrogale penicillata	Brush-tailed Rock-wallaby	Animal > Marsupials	Endangered	Known
Phascolarctos cinereus	Koala	Animal > Marsupials	Vulnerable	Known
Planigale maculata	Common Planigale	Animal > Marsupials	Vulnerable	Known
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	Animal > Birds	Vulnerable	Known
Potorous tridactylus	Long-nosed Potoroo	Animal > Marsupials	Vulnerable	Known
Prostanthera askania	Cut-leaf Mint-bush	Plant > Shrubs	Endangered	Known
Prostanthera junonis	Somersby Mintbush	Plant > Shrubs	Endangered	Known
Pseudomys gracilicaudatus	Eastern Chestnut Mouse	Animal > Rodents	Vulnerable	Known
Pseudophryne australis	Red-crowned Toadlet	Animal > Amphibians	Vulnerable	Known
Pteropus poliocephalus	Grey-headed Flying-fox	Animal > Bats	Vulnerable	Known
Ptilinopus magnificus	Wompoo Fruit-dove	Animal > Birds	Vulnerable	Known
Ptilinopus regina	Rose-crowned Fruit-dove	Animal > Birds	Vulnerable	Known
Ptilinopus superbus	Superb Fruit-dove	Animal > Birds	Vulnerable	Known
Pyrrholaemus saggitatus	Speckled Warbler	Animal > Birds	Vulnerable	Known
Quorrobolong Scribbly Gum Woodland in the Sydney Basin Bioregion	Quorrobolong Scribbly Gum Woodland in the Sydney Basin Bioregion	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	River-Flat Eucalypt Forest on Coastal Floodplains	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Rostratula benghalensis	Painted Snipe	Animal > Birds	Endangered	Predicted
Rutidosis heterogama	Heath Wrinklewort	Plant > Herbs and Forbs	Vulnerable	Known
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	Animal > Bats	Vulnerable	Known
Scoteanax rueppellii	Greater Broad-nosed Bat	Animal > Bats	Vulnerable	Known
Senecio spathulatus	Coast Groundsel	Plant > Herbs and Forbs	Endangered	Known
Stagonopleura guttata	Diamond Firetail	Animal > Birds	Vulnerable	Known

Sterna albifrons	Little Tern	Animal > Birds	Endangered	Known
Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions	Swamp oak floodplain forest	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Swamp sclerophyll forest on coastal floodplains	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Sydney Freshwater Wetlands in the Sydney Basin Bioregion	Sydney Freshwater Wetlands in the Sydney Basin Bioregion	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Syzygium paniculatum	Magenta Lilly Pilly	Plant > Trees	Endangered	Known
Tetratheca glandulosa	*Tetratheca glandulosa*	Plant > Shrubs	Vulnerable	Known
Tetratheca juncea	Black-eyed Susan	Plant > Shrubs	Vulnerable	Known
Thylogale stigmatica	Red-legged Pademelon	Animal > Marsupials	Vulnerable	Predicted
Tyto novaehollandiae	Masked Owl	Animal > Birds	Vulnerable	Known
Tyto tenebricosa	Sooty Owl	Animal > Birds	Vulnerable	Known
Umina Coastal Sandplain Woodland in the Sydney Basin Bioregion	Umina Coastal Sandplain Woodland in the Sydney Basin Bioregion	Community > Threatened Ecological Communities	Endangered Ecological Community	Known
Varanus rosenbergi	Rosenberg's Goanna	Animal > Reptiles	Vulnerable	Known
Vespadelus troughtoni	Eastern Cave Bat	Animal > Bats	Vulnerable	Known
Xanthomyza phrygia	Regent Honeyeater	Animal > Birds	Endangered	Known
Xenus cinereus	Terek Sandpiper	Animal > Birds	Vulnerable	Known
Zannichellia palustris	*Zannichellia palustris*	Plant > Aquatic plants	Endangered	Known

 Last updated: 01/09/2005

Combined geographic and habitat search results

Your search returned **40** results. You searched for the following information:

- geographic region: **Hunter/Central Rivers > Hunter/Central Rivers - marine zone**
- vegetation type: **all**
- type: **all**

Search Results

Scientific Name	Common Name	Level of Threat
Diomedea antipodensis	Antipodean Albatross	Vulnerable
Arctocephalus pusillus doriferus	Australian Fur-seal	Vulnerable
Esacus neglectus	Beach Stone-curlew	Critically Endangered
Thalassarche melanophris	Black-browed Albatross	Vulnerable
Limosa limosa	Black-tailed Godwit	Vulnerable
Pterodroma nigripennis	Black-winged Petrel	Vulnerable
Balaenoptera musculus	Blue Whale	Endangered
Limicola falcinellus	Broad-billed Sandpiper	Vulnerable
Dugong dugon	Dugong	Endangered
Puffinus carneipes	Flesh-footed Shearwater	Vulnerable
Diomedea gibsoni	Gibson's Albatross	Vulnerable
Pterodroma leucoptera leucoptera	Gould's Petrel	Vulnerable
Calidris tenuirostris	Great Knot	Vulnerable
Charadrius leschenaultii	Greater Sand-plover	Vulnerable
Chelonia mydas	Green Turtle	Vulnerable
Procelsterna cerulea	Grey Ternlet	Vulnerable
Megaptera novaeangliae	Humpback Whale	Vulnerable
Pterodroma neglecta	Kermadec Petrel	Vulnerable
Dermochelys coriacea	Leathery Turtle	Vulnerable
Charadrius mongolus	Lesser Sand-plover	Vulnerable
Puffinus assimilis	Little Shearwater	Vulnerable
Sterna albifrons	Little Tern	Endangered
Caretta caretta	Loggerhead Turtle	Endangered
Arctocephalus forsteri	New Zealand Fur-seal	Vulnerable
Macronectes halli	Northern Giant-Petrel	Vulnerable
Pandion haliaetus	Osprey	Vulnerable
Haematopus longirostris	Pied Oystercatcher	Vulnerable
Pterodroma solandri	Providence Petrel	Vulnerable
Calidris alba	Sanderling	Vulnerable
Thalassarche cauta	Shy Albatross	Vulnerable
Phoebetria fusca	Sooty Albatross	Vulnerable
Haematopus fuliginosus	Sooty Oystercatcher	Vulnerable
Sterna fuscata	Sooty Tern	Vulnerable
Macronectes giganteus	Southern Giant-Petrel	Endangered
Eubalaena australis	Southern Right Whale	Vulnerable
Physeter macrocephalus	Sperm Whale	Vulnerable
Xenus cinereus	Terek Sandpiper	Vulnerable
Diomedea exulans	Wandering Albatross	Endangered
Gygis alba	White Tern	Vulnerable
Fregetta grallaria	White-bellied Storm-petrel	Vulnerable

search & map species | taxonomic search | feedback

Bio

Add species to map groups

Selected Area: User Defined - 151.384429,-33.512804,151.484429,-33.394902
Search Type: Fauna
Agencies: NSW Fisheries
Threatened Status: E1,E4,FE,FV,V
Search Term: Search All Records

You can now determine which species you would like to map. You do this by adding the species y map group. There are five map groups. The species allocated to each map group are displayed or symbol.

By default only the first 500 species found are displayed. If your search produces more results th choose "Next 500" to view the next five hundred search results, or choose "Show All" to view all r results).

Note that a MAXIMUM total of 20 species can be assigned to Map Groups.

Matching Records: 1 (Showing: 1 - 1)

Auto assign to Group 1 | Next Step

Order	Family	Sci Name	Common Name	Agency	Threat	Cou
FISH						
Lamniformes			Mackeral sharks and allies			
	Odontaspididae		Grey Nurse sharks			
		Carcharias taurus		FishPub	FE	

Auto assign to Group 1 | Next Step

NEW SOUTH WALES FLORA ONLINE

Search Result

Click on a name to see the page for that taxon.
* denotes an introduced species; + denotes an endangered species; ‡ denotes a gazetted weed.
Terrigal
151.44999,-33.45

Acanthaceae	*Hypoestes*	**aristata*
Amaranthaceae	*Guilleminea*	**densa*
Araceae	*Arum*	**italicum*
	Zantedeschia	**aethiopica*
Asparagaceae	*Asparagus*	**aethiopicus*
Asphodelaceae	*Trachyandra*	**divaricata*
Asteraceae	*Ageratina*	**riparia*
	Ambrosia	**psilostachya*
	Anthemis	**cotula*
	Cosmos	**bipinnatus*
	Erechtites	**valerianifolia*
	Erigeron	**karvinskianus*
	Gamochaeta	**antillana*
	Tagetes	**minuta*
Bignoniaceae	*Tecoma*	**stans*
Boraginaceae	*Echium*	**plantagineum*
Buddlejaceae	*Buddleja*	**dysophylla*
Cannaceae	*Canna*	**indica*
Caprifoliaceae	*Lonicera*	**japonica*
Chenopodiaceae	*Chenopodium*	**album*
Convolvulaceae	*Ipomoea*	**cairica*
		**indica*
Fabaceae - Caesalpinioideae	*Senna*	**pendula var. glabrata*
		**septemtrionalis*
Fabaceae - Faboideae	*Lotus*	**subbiflorus*
		**uliginosus*
	Tephrosia	**grandiflora*
	Ulex	**europaeus*
Iridaceae	*Gladiolus*	**carneus*
Juncaceae	*Juncus*	**cognatus*
Oleaceae	*Ligustrum*	**sinense*
Oxalidaceae	*Oxalis*	**articulata*
		**pes-caprae*
Poaceae	*Aira*	**cupaniana*
	Briza	**maxima*
	Echinochloa	**crus-galli*
	Eleusine	**indica*
	Paspalum	**wettsteinii*
	Pennisetum	**macrourum*
	Phalaris	**canariensis*
	Setaria	**pumila*
Polygonaceae	*Acetosa*	**sagittata*
Ranunculaceae	*Ranunculus*	**repens*
Rosaceae	*Rubus*	**polyanthemus*
Rubiaceae	*Richardia*	**brasiliensis*
Salviniaceae	*Salvinia*	**molesta*
Verbenaceae	*Verbena*	**rigida*

Birds Australia Database Records
Searched 7/12/2009

Species order	Atlas Number	Common Name	Scientific Name	NSW LISTINGS	Jamba	Camba	ROKAMBA	EPBC marine
6	8	Australian Brush-turkey	Alectura lathami					
11	9	Stubble Quail	Coturnix pectoralis					marine
12	11	Brown Quail	Coturnix ypsilophora					
14	903	Indian Peafowl	Pavo cristatus					
26	203	Black Swan	Cygnus atratus					
32	202	Australian Wood Duck	Chenonetta jubata					
37	212	Australasian Shoveler	Anas rhynchotis					
39	211	Grey Teal	Anas gracilis					
40	210	Chestnut Teal	Anas castanea					
43	948	Northern Mallard	Anas platyrhynchos					
44	208	Pacific Black Duck	Anas superciliosa					
45	215	Hardhead	Aythya australis					
49	61	Australasian Grebe	Tachybaptus novaehollandiae					
54	957	Rock Dove	Columba livia					
56	28	White-headed Pigeon	Columba leucomela					
60	989	Spotted Dove	Streptopelia chinensis					
61	29	Brown Cuckoo-Dove	Macropygia amboinensis					
62	33	Emerald Dove	Chalcophaps indica					
63	34	Common Bronzewing	Phaps chalcoptera					
66	43	Crested Pigeon	Ocyphaps lophotes					
73	30	Peaceful Dove	Geopelia striata					
74	32	Bar-shouldered Dove	Geopelia humeralis					
75	44	Wonga Pigeon	Leucosarcia picata					
86	27	Topknot Pigeon	Lopholaimus antarcticus					
88	313	Tawny Frogmouth	Podargus strigoides					
101	334	White-throated Needletail	Hirundapus caudacutus		J	C	R	marine
117	88	Black-browed Albatross	Thalassarche melanophris	VU				marine
143	69	Wedge-tailed Shearwater	Ardenna pacifica		J			marine
148	70	Sooty Shearwater	Ardenna grisea		J	C		marine
149	71	Short-tailed Shearwater	Ardenna tenuirostris		J		R	marine
185	5	Little Penguin	Eudyptula minor					marine
192	104	Australasian Gannet	Morus serrator					marine
196	101	Australasian Darter	Anhinga novaehollandiae					
197	100	Little Pied Cormorant	Microcarbo melanoleucos					
198	96	Great Cormorant	Phalacrocorax carbo					
199	97	Little Black Cormorant	Phalacrocorax sulcirostris					
200	99	Pied Cormorant	Phalacrocorax varius					
204	106	Australian Pelican	Pelecanus conspicillatus					marine
206	197	Australasian Bittern	Botaurus poiciloptilus	VU				
211	196	Black Bittern	Ixobrychus flavicollis	VU				
213	189	White-necked Heron	Ardea pacifica					
214	187	Eastern Great Egret	Ardea modesta		J	C		marine
215	186	Intermediate Egret	Ardea intermedia					marine
217	977	Cattle Egret	Ardea ibis		J	C		marine
218	193	Striated Heron	Butorides striata					
222	188	White-faced Heron	Egretta novaehollandiae					
223	185	Little Egret	Egretta garzetta					marine
224	191	Eastern Reef Egret	Egretta sacra			C		marine
226	192	Nankeen Night-Heron	Nycticorax caledonicus					marine
229	179	Australian White Ibis	Threskiornis molucca					marine
230	180	Straw-necked Ibis	Threskiornis spinicollis					marine
231	181	Royal Spoonbill	Platalea regia					
233	241	Eastern Osprey	Pandion cristatus	VU				marine
234	232	Black-shouldered Kite	Elanus axillaris					
236	230	Square-tailed Kite	Lophoictinia isura	VU				
239	234	Pacific Baza	Aviceda subcristata					
240	226	White-bellied Sea-Eagle	Haliaeetus leucogaster			C		marine
241	228	Whistling Kite	Haliastur sphenurus					marine
244	221	Brown Goshawk	Accipiter fasciatus					marine
245	222	Collared Sparrowhawk	Accipiter cirrocephalus					
247	220	Grey Goshawk	Accipiter novaehollandiae					
249	219	Swamp Harrier	Circus approximans					marine
254	240	Nankeen Kestrel	Falco cenchroides					marine
255	239	Brown Falcon	Falco berigora					
256	235	Australian Hobby	Falco longipennis					
259	237	Peregrine Falcon	Falco peregrinus					
262	58	Purple Swamphen	Porphyrio porphyrio					marine

Birds Australia Database Records
Searched 7/12/2009

Species order	Atlas Number	Common Name	Scientific Name	NSW LISTINGS	Jamba	Camba	ROKAMBA	EPBC marine
268	46	Buff-banded Rail	Gallirallus philippensis					marine
281	56	Dusky Moorhen	Gallinula tenebrosa					
282	59	Eurasian Coot	Fulica atra					
285	174	Bush Stone-curlew	Burhinus grallarius	EN				
288	130	Australian Pied Oystercatcher	Haematopus longirostris	VU				
289	131	Sooty Oystercatcher	Haematopus fuliginosus	VU				
290	146	Black-winged Stilt	Himantopus himantopus					marine
292	147	Banded Stilt	Cladorhynchus leucocephalus					
293	137	Pacific Golden Plover	Pluvialis fulva		J	C	R	marine
299	143	Red-capped Plover	Charadrius ruficapillus					marine
306	144	Black-fronted Dotterel	Elseyornis melanops					
308	132	Red-kneed Dotterel	Erythrogonys cinctus					
309	135	Banded Lapwing	Vanellus tricolor					
310	133	Masked Lapwing	Vanellus miles					
316	168	Latham's Snipe	Gallinago hardwickii		J	C	R	marine
321	153	Bar-tailed Godwit	Limosa lapponica		J	C	R	marine
342	164	Red Knot	Calidris canutus		J	C	R	marine
345	162	Red-necked Stint	Calidris ruficollis		J	C	R	marine
350	163	Sharp-tailed Sandpiper	Calidris acuminata		J	C	R	marine
352	161	Curlew Sandpiper	Calidris ferruginea		J	C	R	marine
356	934	Ruff	Philomachus pugnax		J	C	R	marine
381	117	Little Tern	Sternula albifrons	EN	J	C	R	marine
384	112	Caspian Tern	Hydroprogne caspia			C		marine
389	114	White-fronted Tern	Sterna striata					marine
391	953	Common Tern	Sterna hirundo		J	C	R	marine
395	115	Crested Tern	Thalasseus bergii		J			marine
396	126	Pacific Gull	Larus pacificus					marine
403	125	Silver Gull	Chroicocephalus novaehollandiae					marine
409	265	Glossy Black-Cockatoo	Calyptorhynchus lathami	VU				
410	267	Yellow-tailed Black-Cockatoo	Calyptorhynchus funereus					
413	268	Gang-gang Cockatoo	Callocephalon fimbriatum	VU				
415	273	Galah	Eolophus roseicapillus					
416	272	Long-billed Corella	Cacatua tenuirostris					
418	271	Little Corella	Cacatua sanguinea					
419	269	Sulphur-crested Cockatoo	Cacatua galerita					
420	274	Cockatiel	Nymphicus hollandicus					
421	254	Rainbow Lorikeet	Trichoglossus haematodus					
422	256	Scaly-breasted Lorikeet	Trichoglossus chlorolepidotus					
424	258	Musk Lorikeet	Glossopsitta concinna					
425	260	Little Lorikeet	Glossopsitta pusilla					
430	281	Australian King-Parrot	Alisterus scapularis					
436	282	Crimson Rosella	Platycercus elegans					
437	288	Eastern Rosella	Platycercus eximius					
444	309	Swift Parrot	Lathamus discolor	EN				marine
463	349	Pheasant Coucal	Centropus phasianinus					
465	347	Eastern Koel	Eudynamys orientalis					marine
467	348	Channel-billed Cuckoo	Scythrops novaehollandiae					marine
468	342	Horsfield's Bronze-Cuckoo	Chalcites basalis					marine
470	344	Shining Bronze-Cuckoo	Chalcites lucidus					marine
472	337	Pallid Cuckoo	Cacomantis pallidus					marine
474	338	Fan-tailed Cuckoo	Cacomantis flabelliformis					marine
475	339	Brush Cuckoo	Cacomantis variolosus					
478	248	Powerful Owl	Ninox strenua	VU				
480	246	Barking Owl	Ninox connivens	VU				
481	242	Southern Boobook	Ninox novaeseelandiae					marine
485	253	Sooty Owl	Tyto tenebricosa	VU				
486	250	Masked Owl	Tyto novaehollandiae	VU				
490	319	Azure Kingfisher	Ceyx azureus					
493	322	Laughing Kookaburra	Dacelo novaeguineae					
498	326	Sacred Kingfisher	Todiramphus sanctus					marine
502	318	Dollarbird	Eurystomus orientalis					marine
508	350	Superb Lyrebird	Menura novaehollandiae					
511	558	White-throated Treecreeper	Cormobates leucophaea					
518	676	Green Catbird	Ailuroedus crassirostris					
521	684	Regent Bowerbird	Sericulus chrysocephalus					
522	679	Satin Bowerbird	Ptilonorhynchus violaceus					
527	529	Superb Fairy-wren	Malurus cyaneus					

Birds Australia Database Records
Searched 7/12/2009

Species order	Atlas Number	Common Name	Scientific Name	NSW LISTINGS	Jamba	Camba	ROKAMBA	EPBC marine
532	536	Variegated Fairy-wren	Malurus lamberti					
555	493	Yellow-throated Scrubwren	Sericornis citreogularis					
556	488	White-browed Scrubwren	Sericornis frontalis					
559	494	Large-billed Scrubwren	Sericornis magnirostra					
569	454	Brown Gerygone	Gerygone mouki					
580	470	Striated Thornbill	Acanthiza lineata					
581	471	Yellow Thornbill	Acanthiza nana					
582	486	Yellow-rumped Thornbill	Acanthiza chrysorrhoa					
584	484	Buff-rumped Thornbill	Acanthiza reguloides					
589	475	Brown Thornbill	Acanthiza pusilla					
594	565	Spotted Pardalote	Pardalotus punctatus					
597	976	Striated Pardalote	Pardalotus striatus					
598	591	Eastern Spinebill	Acanthorhynchus tenuirostris					
601	605	Lewin's Honeyeater	Meliphaga lewinii					
608	614	Yellow-faced Honeyeater	Lichenostomus chrysops					
614	617	White-eared Honeyeater	Lichenostomus leucotis					
621	613	Fuscous Honeyeater	Lichenostomus fuscus					
625	633	Bell Miner	Manorina melanophrys					
626	634	Noisy Miner	Manorina melanocephala					
631	712	Little Wattlebird	Anthochaera chrysoptera					
633	638	Red Wattlebird	Anthochaera carunculata					
648	586	Scarlet Honeyeater	Myzomela sanguinolenta					
654	631	New Holland Honeyeater	Phylidonyris novaehollandiae					
655	632	White-cheeked Honeyeater	Phylidonyris niger					
661	578	White-naped Honeyeater	Melithreptus lunatus					
666	645	Noisy Friarbird	Philemon corniculatus					
670	585	Striped Honeyeater	Plectorhyncha lanceolata					
682	421	Eastern Whipbird	Psophodes olivaceus					
686	549	Varied Sittella	Daphoenositta chrysoptera					
688	424	Black-faced Cuckoo-shrike	Coracina novaehollandiae					marine
691	429	Cicadabird	Coracina tenuirostris					marine
695	416	Crested Shrike-tit	Falcunculus frontatus					
699	398	Golden Whistler	Pachycephala pectoralis					
702	401	Rufous Whistler	Pachycephala rufiventris					
707	408	Grey Shrike-thrush	Colluricincla harmonica					
709	432	Australasian Figbird	Sphecotheres vieilloti					
711	671	Olive-backed Oriole	Oriolus sagittatus					
712	543	White-breasted Woodswallow	Artamus leucorynchus					
719	702	Grey Butcherbird	Cracticus torquatus					
721	700	Pied Butcherbird	Cracticus nigrogularis					
722	705	Australian Magpie	Cracticus tibicen					
723	694	Pied Currawong	Strepera graculina					
726	673	Spangled Drongo	Dicrurus bracteatus					marine
727	362	Rufous Fantail	Rhipidura rufifrons					marine
730	361	Grey Fantail	Rhipidura albiscapa					
733	364	Willie Wagtail	Rhipidura leucophrys					
737	930	Australian Raven	Corvus coronoides					
744	365	Leaden Flycatcher	Myiagra rubecula					
747	728	Restless Flycatcher	Myiagra inquieta					
749	373	Black-faced Monarch	Monarcha melanopsis					marine
752	375	Spectacled Monarch	Symposiarchus trivirgatus					marine
753	415	Magpie-lark	Grallina cyanoleuca					marine
763	377	Jacky Winter	Microeca fascinans					
770	384	Rose Robin	Petroica rosea					
776	392	Eastern Yellow Robin	Eopsaltria australis					
789	524	Australian Reed-Warbler	Acrocephalus australis					marine
799	574	Silvereye	Zosterops lateralis					marine
806	357	Welcome Swallow	Hirundo neoxena					marine
808	359	Tree Martin	Petrochelidon nigricans					marine
811	990	Red-whiskered Bulbul	Pycnonotus jocosus					
816	779	Bassian Thrush	Zoothera lunulata					
824	999	Common Starling	Sturnus vulgaris					
827	998	Common Myna	Sturnus tristis					
829	564	Mistletoebird	Dicaeum hirundinaceum					
832	655	Double-barred Finch	Taeniopygia bichenovii					
839	662	Red-browed Finch	Neochmia temporalis					
852	995	House Sparrow	Passer domesticus					

Birds Australia Database Records
Searched 7/12/2009

Species order	Atlas Number	Common Name	Scientific Name	NSW LISTINGS	Jamba	Camba	ROKAMBA	EPBC marine
854	647	Australasian Pipit	Anthus novaeseelandiae					marine
871	818	Corella species						
874	837	Crow & Raven species						
875	838	Domestic Goose						
877	2507	Domestic Goose						