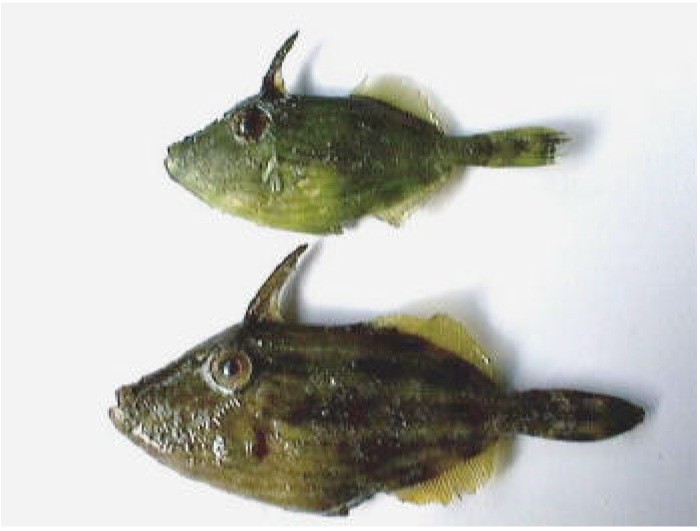
University of Wollongong

FRDC Project 97/204:
Shallow Water Fish Communities of New South Wales South Coast Estuaries

R.J. West and M.V. Jones



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HISTORICAL NOTE

Extracts from H.C. Dannevig (1906):

"Correlation between our Home Fisheries and the Salt Water Lakes on the South Coast"

"When visiting the Lakes district on the South Coast some little time ago, in company with the Hon. J.H. Want, a member of the Board, I had an opportunity of inspecting the principal nurseries from which our fish mainly migrate, and we also got a fair insight into the manner in which these waters are being worked. There are over forty salt-water lakes from St. Georges Basin to the border, with an area each of 30 acres or more, the total expanse being about 32,000 acres. Some of these waters are constantly open to the sea, others occasionally closed, while a few are only connected to the sea for a few weeks at a time, and then only at long intervals. It follows that the first-mentioned only are available to their full extent as natural nurseries, and the others with a closing entrance are more or less handicapped."

Shallow water fishing method.

Citation:

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FRDC 97/204: **Shallow Water Fish Communities of New South Wales South Coast Estuaries**

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Objectives:

1. Examine variability in the diversity and abundance of fishes within and between selected estuaries, coastal lakes and lagoons in southern NSW, including fished and non-fished areas.
2. Provide the first set of comparative data for the south coast region of NSW on the recruitment intensity for a large selection of economically important estuarine fish species.
3. Investigate the usefulness of these data as indicators of biodiversity and sustainability, and possible inclusion as performance indicators in management of estuaries.
4. Provide a comprehensive set of environmental data relating to each sampling location, including water quality and habitat quality parameters.

Non-Technical Summary:

There are over 60 estuaries in southeastern Australia between Sydney (NSW) and the Victorian border, over 40 of which are intermittently closed and open lakes and lagoons (ICOLLs). These estuaries have been long recognised as important natural assets requiring careful management, yet despite over a century of concern, there has been little information available on the fish and fish communities in this region.

While commercial catch statistics are available for some of the economically important fish species, no data has been collected for the fish communities for the vast majority of these estuaries. In recent years, the adoption of the principles of Ecologically Sustainable Development (ESD) to fisheries and estuary management, has meant that much a greater level of information concerning biodiversity of fish in these estuaries is now required.

In this three-year study, information has been collected on the shallow water fishes in 24 NSW south coast estuaries at three spatial and temporal scales. Shallow water fish sampling is a convenient and relatively quick method of collecting useful information on fish found in one of the key habitats in estuaries, the seagrasses. Sampling seagrass fish yields information not only on permanent residents in these areas, but also on many of the economically important species that recruit to these sites as juveniles. This sampling program probably represents the largest systematic sampling of fish communities undertaken in the coastal region in NSW.

Prior to sampling, a pilot study was conducted to optimise the number of replicates. During each sampling occasion, four replicate hauls of a small seine net were carried out in shallow seagrass dominated sites, and a wide range of water quality data was collected. Low intensity sampling consisted of one July and one December sampling near the entrance of 18 estuaries. Medium intensity sampling involved collecting information at three locations within each of seven estuaries, four times a year for the three-year period. High intensity sampling consisted of sampling 4 locations within 8 regions of two estuaries, every 4-6 weeks for 12 months. Locations sampled included estuaries and sites that were open and closed to many forms commercial fishing, particularly fin-fish netting.

Overall, 289 160 fish comprising over 100 species were collected, identified and recorded. Voucher specimens of each species were kept for lodgment with the Australian Museum. The vast majority of fish were released unharmed. For many of the economically important species, data on recruitment intensity was also collected.

This report presents a summary of these data. In addition, some very preliminary analyses have been carried out. For example, multivariate analyses of the data collected from the medium intensity sampling program indicated that fish communities in the seven lakes sampled were very similar, except for those in Coila Lake which had been closed to the sea for several years prior to sampling. Further analyses of these data are to be carried out over the next few months. While the impact of fishing was not specifically studied, no obvious differences were detected between locations subject to fishing activities (such as netting) and those closed to fishing. Major differences between fish communities at various sites and between estuaries appeared to be more related to environmental and physical factors associated with each sample location.

This study has demonstrated that the sampling of shallow water fish communities in southeastern Australian estuaries, particularly those fishes inhabiting seagrass beds, provides extremely useful information on biodiversity of fish and on recruitment of many economically important species. This type of sampling is relatively easy to carry out, provides statistically robust data and can give information that is of interest to the public, community groups and scientists. As such, the methodology provides data that would be very useful as an "environmental indicator" of estuary and estuarine fisheries "health".

Already, the information collected in this study has been used widely by Local Councils in the region and by agencies in the NSW State Government. The data has been summarised in management plans, state of the environment reports and used in developing marine conservation policies.

KEYWORDS:

estuaries, shallow water, fish, fish communities, fishing, recruitment, biodiversity

1 INTRODUCTION

1.1 Background

This report presents an overview and summary of a major fisheries research program carried out to provide information on the diversity and abundance of shallow water fishes in New South Wales (NSW) south coast estuaries (Figure 1.1). Between July 1997 and July 2000, fish inhabiting shallow waters in 24 estuaries between Wollongong and Eden (NSW) were sampled using three spatial and temporal scales. As such, the information compiled during this samping program represents the largest systematic collection of fish biodiversity data in NSW estuaries, and includes data for many locations previously not sampled.

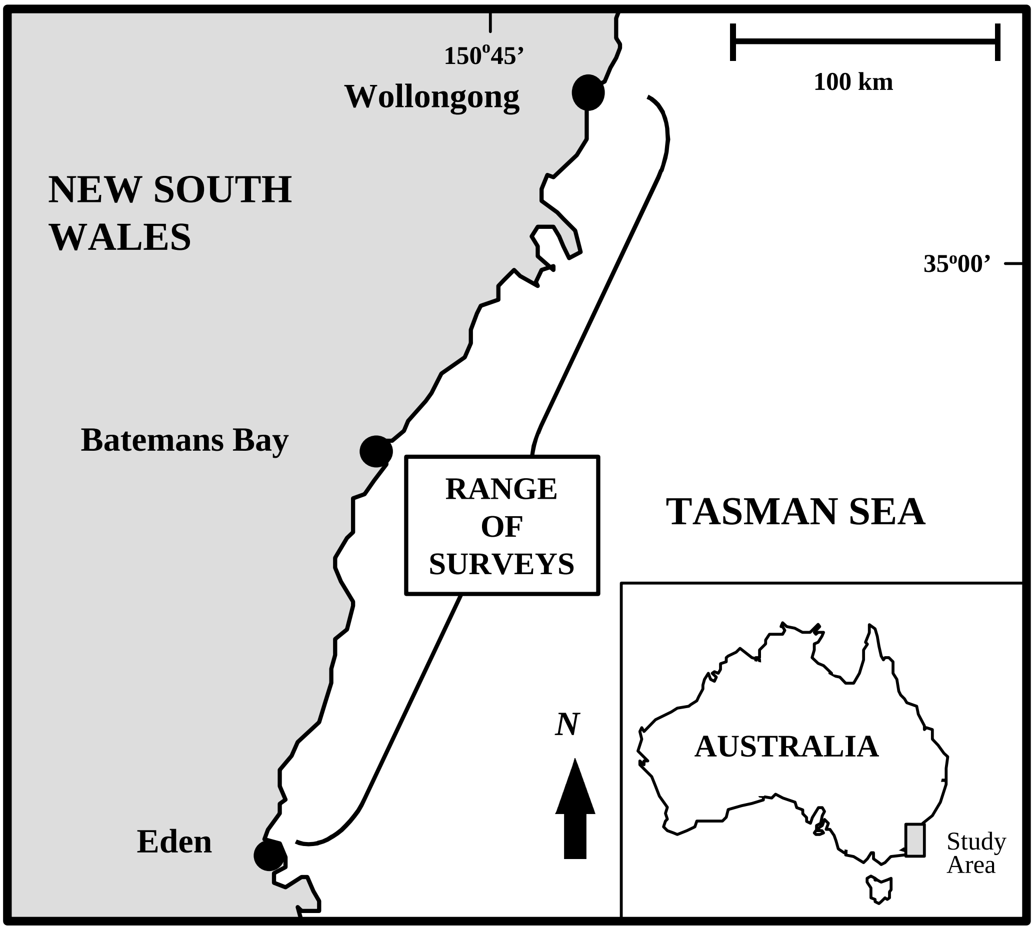
Shallow waters in NSW estuaries provide an important habitat for a variety of commercial fish species (see references below). These environments are particularly important as recruitment sites for many economically important fish species, such as yellowfin bream (*Acanthopagrus australis*), black bream (*Acanthopagrus butcherii*), sea mullet (*Mugil cephalus*), flat-tail mullet (*Liza argentes*), luderick (*Girella tricuspidata*), silver biddies (*Gerres subfasciatus*), eastern garfish (*Hyporhampus australis*), snapper (*Chrysophrys auratus*) and sand whiting (*Sillago ciliata*). Juveniles of many of these species recruit to seagrass and sand habitats in the shallow waters, moving to deeper waters as they age. Species recruiting to these shallow waters make up a large percentage of the commercial fisheries catches in NSW estuaries and have a market value of up to $20 million per year. They also comprise the majority of the recreational catch in NSW waters.

Several completed research projects have demonstrated the importance of shallow water environments to estuarine fish communities (Burchmore et al., 1984; Middleton et al., 1984; Bell and Pollard, 1989; McNeill et al., 1992; Worthington et al., 1992), however almost all of these studies have been within the Sydney Region. Prior to this study, there was almost no data for NSW coastal areas south of Sydney, a region that has more than 40 estuaries, over 20 of which are commercially productive in terms of fisheries. The area surveyed covers approximately 30% of the NSW coast. The estuaries in this region range from permanently open urbanised lakes and rivers (eg. Lakes Illawarra and Merimbula) to small intermittently-open pristine lagoons (eg. Nelson and Nadgee Lagoons).

A number of studies by NSW Fisheries have been carried out in Jervis Bay (Ferrell and Bell, 1991; Bell et al., 1992; Ferrell et al., 1993; McNeill and Fairweather, 1993) and Pollard (1994) described the fish communities in Lake Conjola, Swan Lake and Lake Wollumboola. More recently, some work has been carried out in the Shoalhaven River and St Georges Basin (unpublished FRDC Funded Project). However, there is little information about the estuarine fish communities of any other NSW south coast estuary. For the vast majority of these estuaries (>30), no fisheries research studies have ever been carried out and fisheries data is restricted to the availability and reliability of commercial fisheries statistics. No information exists concerning biodiversity of fish communities and no useful information exists which will lead to the development of indicators of sustainability.

In this report data from the surveys are summarised and some initial analyses has been carried out to describe some of the major findings. Over the next six to twelve months, these data will be analysed further and prepared for publication in a variety of public, technical and scientific formats.

Figure 1.1: Map showing the South Coast of New South Wales. Twenty-four estuaries were sampled during this study, located between Wollongong and Eden (see map).



1.2 Need

Major structural changes are occurring in several natural resource industries as the principles of Ecological Sustainable Development (ESD), Biodiversity Conservation and National Competition Policy are being implemented. These principles are having a significant and fundamental impact on natural resource management, at all levels of Government and in several primary industry areas, including forestry, agriculture, water and, more recently, the fishing industry.

The forestry industry, which bears closest parallels with the fishing industry, has undergone major restructuring due to these policy changes. For example, in NSW the implementation of Biodiversity Conservation principles has led to the reservation of areas traditionally harvested by industry and implementation of ESD principles has led to the need to prepare forestry management plans, incorporating indicators of sustainability. A major problem in reforming NSW forestry has been the lack of useful forestry data relating to biodiversity and overall sustainability (eg. faunal components of forests).

A parallel situation now exists in fisheries where, in general, very little data has been collected on the diversity of fish communities in the vast majority of areas that are presently being fished. Data collected during this study has provided information on the diversity of fish communities and the recruitment of many economically important fish species, across a large number of NSW South Coast estuaries.

1.3 Project Objectives

This project had the following broad objectives, to:

a) Examine variability in the diversity and abundance of fishes within and between selected estuaries, coastal lakes and lagoons in southern NSW, including fished and non-fished areas.
b) Provide the first set of comparative data for the south coast region of NSW on the recruitment intensity for a large selection of economically important estuarine fish species.
c) Investigate the usefulness of these data as indicators of biodiversity and sustainability, and possible inclusion as performance indicators in management of estuaries.
d) Provide a comprehensive set of environmental data relating to each sampling location, including water quality and habitat quality parameters.

These objectives have been met through the large-scale structured fish-sampling program, which included collection of environmental data. Objectives (a), (b) and (d) are met through the presentation of data for the 24 estuaries sampled, in Section 4 of this report. Objective (c) is met in Section 5 through a discussion of the usefulness of these data as an “indicator” of the state of the fish populations and of estuaries, in general.

1.4 Transfer of Information

During the course of this project, information has already been provided for use in a wide variety of management plans and reports prepared by both community groups and Government, including fisheries management plans, estuary management plans, catchment management plans and state of the environment reporting.

The inclusion of fisheries information in these reporting mechanisms has raised the profile of fisheries issues with these bodies and allowed a better appreciation of the present state of estuarine fisheries resources.

2 STUDY AREA

This study sampled shallow water fish inhabiting estuaries on the NSW south coast between Wollongong and Eden. This region has at least 69 “recognised” estuaries (West et al., 1985) and more than a hundred smaller water bodies and streams (Williams, Watford and Taylor, 1996).

The present study used three levels of sampling intensity (see Method and Materials) to provide information of 24 of these estuaries (Table 2.1, Figure 2.1).

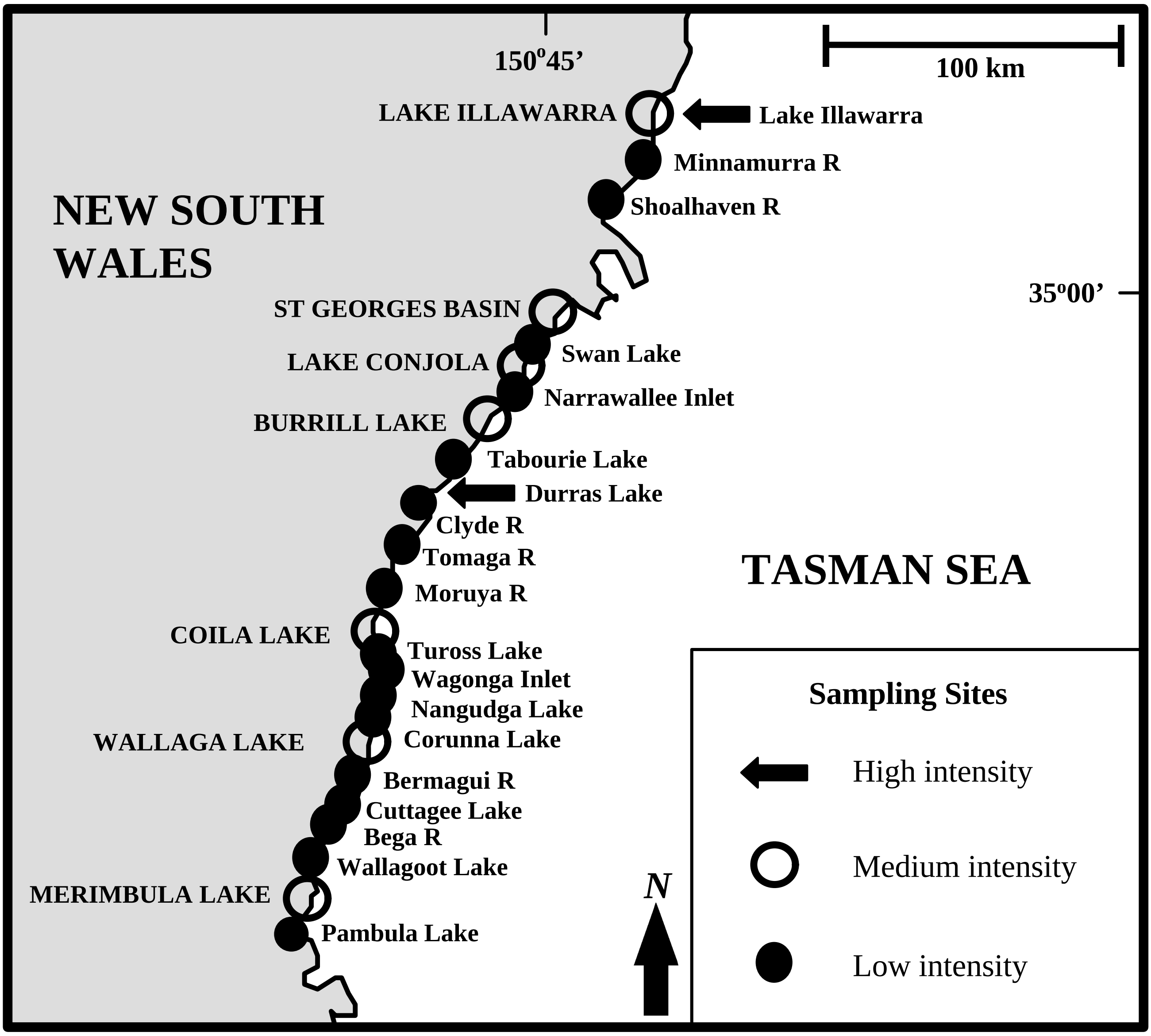
Table 2.1: List of estuaries along NSW south coast showing areas sampled as part of this study. Note that this list does not include many smaller water bodies (see also Method and Materials).

Estuary Name	Latitude	Longitude	Area (km^2)	Low Intensity Sampling	Medium Intensity Sampling	High Intensity Sampling
Bellambi Lagoon	34° 22’E	150° 55’S	1.0			
Towradgi Creek	34° 25’E	150° 55’S	0.1			
Port Kembla Harbour	34° 28’E	150° 54’S	0.1			
Lake Illawarra	34° 33’E	150° 52’S	35.0		*	*
Bensons Creek	34° 34’E	150° 52’S	0.1			
Minnamurra River	34° 38’E	150° 52’S	1.3	*		
Werri Lagoon	34° 44’E	150° 50’S	0.1			
Crooked River	34° 46’E	150° 49’S	0.4			
Shoalhaven River	34° 52’E	150° 45’S	12.9	*		
Crookhaven River	34° 54’E	150° 46’S	8.0			
Lake Wollumboola	34° 57’E	150° 46’S	9.0			
Jervis Bay	35° 06’E	150° 47’S	102.0			
St Georges Basin	35° 11’E	150° 36’S	39.0		*	
Swan Lake	35° 11’E	150° 33’S	4.1			
Berrara Creek	35° 12’E	150° 32’S	0.2			
Nerrindillah Creek	35° 14’E	150° 32’S	0.1			
Lake Conjola	35° 16’E	150° 30’S	5.8		*	
Narrawallee Inlet	35° 18’E	150° 28’S	0.5	*		
Ulladulla Harbour	35° 22’E	150° 29’S	0.1			
Burrill Lake	35° 24’E	150° 27’S	4.1		*	
Tabourie Lake	35° 27’E	150° 25’S	1.4	*		
Termeil Lake	35° 28’E	150° 23’S	0.6			
Meroo Lake	35° 29’E	150° 23’S	0.6			
Willinga Lake	35° 30’E	150° 23’S	0.5			
Kioloa Lagoon	35° 33’E	150° 23’S	0.4			
Durras Lake	35° 38’E	150° 18’S	3.2	*		*
Clyde River	35° 42’E	150° 10’S	20.0	*		
Cullendulla Creek	35° 42’E	150° 13’S	0.3			
Batemans Bay	35° 43’E	150° 13’S	30.0			
Tomaga River	35° 50’E	150° 11’S	1.6	*		
Candlagan Creek	35° 51’E	150° 11’S	0.1			
Moruya River	35° 55’E	150° 09’S	3.7	*		
Congo Creek	35° 57’E	150° 09’S	0.2			
Meringo Creek	35° 59’E	150° 09’S	0.1			

Table 2.1 Continued

Estuary Name	**Latitude**	**Longitude**	**Area (km^2)**	**Low Intensity Sampling**	**Medium Intensity Sampling**	**High Intensity Sampling**
Coila Lake	36 ° 02'E	150 ° 08'S	9.0		*	
Tuross Lake	36 ° 04'E	150 ° 08'S	20.0	*		
Lake Brunderee	36 ° 05'E	150 ° 07'S	0.2			
Lake Brou	36 ° 08'E	150 ° 07'S	1.7			
Lake Dalmeny	36 ° 10'E	150 ° 07'S	1.4			
Kianga Lake	36 ° 12'E	150 ° 08'S	0.2			
Wagonga Inlet	36 ° 13'E	150 ° 08'S	6.3	*		
Nangudga Lake	36 ° 15'E	150 ° 09'S	0.5	*		
Corunna Lake	36 ° 17'E	150 ° 08'S	2.8	*		
Tilba Tilba Lake	36 ° 20'E	150 ° 06'S	0.9			
Little Lake	36 ° 21'E	150 ° 07'S	0.1			
Wallaga Lake	36 ° 22'E	150 ° 05'S	8.4		*	
Bermagui River	36 ° 26'E	150 ° 04'S	2.7	*		
Barragoot Lake	36 ° 28'E	150 ° 04'S	0.7			
Cuttagee Lake	36 ° 29'E	150 ° 03'S	1.5	*		
Murrah Lagoon	36 ° 32'E	150 ° 03'S	1.0			
Bunga Lagoon	36 ° 33'E	150 ° 03'S	0.2			
Wapengo Lagoon	36 ° 38'E	150 ° 01'S	3.6			
Middle Lagoon	36 ° 39'E	150 ° 00'S	0.4			
Nelson Lagoon	36 ° 41'E	150 ° 00'S	0.7			
Bega River	36 ° 42'E	149 ° 59'S	3.4	*		
Wallagoot Lake	36 ° 47'E	148 ° 57'S	4.0	*		
Bournda Lagoon	36 ° 50'E	149 ° 56'S	0.6			
Back Lagoon	36 ° 53'E	149 ° 56'S	0.8			
Merimbula Lake	36 ° 54'E	149 ° 55'S	4.5		*	
Pambula Lake	36 ° 57'E	149 ° 55'S	4.0	*		
Curalo Lagoon	37 ° 03'E	149 ° 55'S	0.9			
Nullica River	37 ° 05'E	149 ° 53'S	0.5			
Twofold Bay	37 ° 05'E	149 ° 55'S	35.0			
Towamba River	37 ° 06'E	149 ° 54'S	6.9			
Fisheries Creek	37 ° 07'E	149 ° 55'S	0.0			
Wonboyn River	37 ° 17'E	149 ° 57'S	6.0			
Merrica River	37 ° 18'E	149 ° 56'S	0.3			
Nadgee River	37 ° 20'E	149 ° 56'S	0.9			
Nadgee Lake	37 ° 28'E	149 ° 58'S	1.2			

Figure 2.1: Map showing the South Coast of New South Wales with location of estuaries sampled for shallow water fish communities, as part of this project (see also Table 2.1)



3 METHOD AND MATERIALS

Sampling of fish in shallow waters is a useful method of providing information on a range of economically important fish that recruit to these habitats as juveniles. It also provides important information on the biodiversity of one of the key habitats in estuaries, the seagrass beds.

Prior to this research project a number of possible methods of sampling shallow waters were trialled in Lake Illawarra, including the use of traps and various nets. These trials helped in the initial selection of the type of sampling gear to be used, but not the level of replication.

As part of the planning for the main sampling program, a short pilot study was also carried out to help in optimising statistical power. In the following sections, details of the experimental design, net selection and pilot study have been outlined, followed by a description of Method and Materials used in the main sampling program.

3.1 Experimental Design

In order to provide information on fish communities over the widest possible area of the NSW south coast, the experimental design involved sampling at three levels of "intensity" which are outlined below.

3.1.1 Low Intensity Sampling

Low intensity sampling had the objective of providing very basic information on a large number of estuaries between Wollongong and Eden. For the vast majority of these estuaries, no previous data had been collected on fish communities. For each estuary, shallow water fish communities were sampled during the Summer and Winter period of one year, at sites located near the entrance (whether open or closed). Basic water quality parameters (temperature, salinity, conductivity, pH, water depth, seagrass type and % cover) were collected.

The following estuaries were sampled using low intensity sampling:

- Minnamurra River* #
- Shoalhaven River*
- Swan Lake*
- Narawallee Inlet*
- Tabourie Lake*
- Durras Lake*
- Clyde River*
- Tomaga River*
- Moruya River*
- Tuross Lake*
- Wagonga Inlet* #
- Nangudga Lake*
- Corunna Lake*
- Bermagui River*
- Cuttagee Lake*
- Bega River*
- Wallagoot Lake*
- Pambula Lake*

NB: # Closed to commercial fish nets
* Closed areas within estuary

3.1.2 Medium Intensity Sampling

Medium intensity sampling had the objective of providing detailed spatial and temporal information on fish communities and water quality parameters for six large estuarine lakes over the entire three-year period. The number of estuaries sampled was expanded to seven in the second and third year. These estuaries were sampled four times each year over the entire three-year period (July 1997 to July 2000). Each lake was sampled at three shoreline locations, sited near the entrance, in central basin region and along the western shoreline. Sampling sites were chosen haphazardly within each location.

The following estuaries were sampled using medium intensity sampling:

- Lake Illawarra*
- St Georges Basin*
- Lake Conjola*
- Burrill Lake*
- Coila Lake
- Wallaga Lake*
- Merimbula Lake* # (2nd and 3rd yr)

NB: # Closed to commercial fish nets
* Closed areas within estuary

3.1.3 High Intensity Sampling

During the second and third year, high intensity sampling was carried out in two estuaries, with the objective of determining small-scale differences in shallow water fish communities. These estuaries were sampled approximately every 4 to 6 weeks between early May 1999 and late May 2000.

The following two estuaries were sampled using high intensity sampling:

- Lake Illawarra*
- Durras Lake*

NB: * closed areas within estuary

3.2 Net Selection and Use

The net selected for the sampling program was a fine mesh seine net about 12 m long and 2 m high, very similar to the design used in studies carried out over the past decade (Ferrell and Bell, 1991, McNeill et al., 1992; West and King, 1996; Gray et al., 1996). This mesh size of this net is approximately 6 mm when stretched. The net is lightly weighted and has a series of floats along the headrope. When in use, it encircles a standard area of about 25 m^2.

The net was set from a plastic fish box by hauling it to form a large circle surrounding the area to be sampled. The ends are then brought together and the net carefully retrieved into the fish box. Care needs to be taken so that the bottom of the net does not roll, especially in seagrass areas. The net is then passed over a second fish box to remove the fish, the vast majority of which are kept alive and released (see below).

Figure 3.1: Photographs of sampling procedure and some typical fish species captured by shallow water seining.

3.3 Pilot Study to Determine Sampling Method

3.3.1 Background

Previous studies of shallow water fish that have sampled habitats with fine mesh seine nets have used between two and four replicates per sample (Gray et al., 1996; Ferrell and Bell, 1991; McNeill et al., 1992; West and King, 1996). In order to optimise the number of replicates used in this research, a small-scale pilot study was undertaken. The importance of optimising the replication and ensuring suitable statistical power is achieved is now recognised as an important step in the planning stages of any sampling program (Gerrodette, 1987; Green, 1989; Peterman, 1990; Taylor and Gerrodette, 1993).

For the pilot study, a simple benefit-cost analysis was adopted. Benefit was considered to be the gain statistical power in a two-sample comparison. Cost was considered to be the increase in resources required for each additional replicate, using a fixed cost per replicate.

3.3.2 Sampling

Ten replicate hauls of the seine net were carried out during September 1997 near the entrance channel of Lake Illawarra to provide the data for the benefit-cost analysis. All species captured were identified to species level and counted. Numbers of species and numbers of individual fish captured per haul were recorded. The data for the ten hauls were arranged in a spreadsheet and then duplicated to provide allow a two sample comparison Analysis of Variance (ANOVA) to be carried out (n=20). Prior to analysis, abundance data were transformed using $log_{10}(x+1)$ to assist in stabilising variances. This procedure is recommended by Lester et al. (1996) and is used widely in similar fisheries data (West and King, 1996; Gray et al., 1996).

Power analysis was then used to calculate the least number of replicates which provided a significant result ($p=0.05$) for differences of between 10%, 20%, 30% … up to 100% in the mean number of individuals and the mean number of fish species. This has been termed the least significant number (LSN) of replicates for each effect size. Since it was considered that between two and six replicates at each site was possible within the time and resource constraints, these options were investigated in more detail, particularly in terms of their power to detect a specified effect.

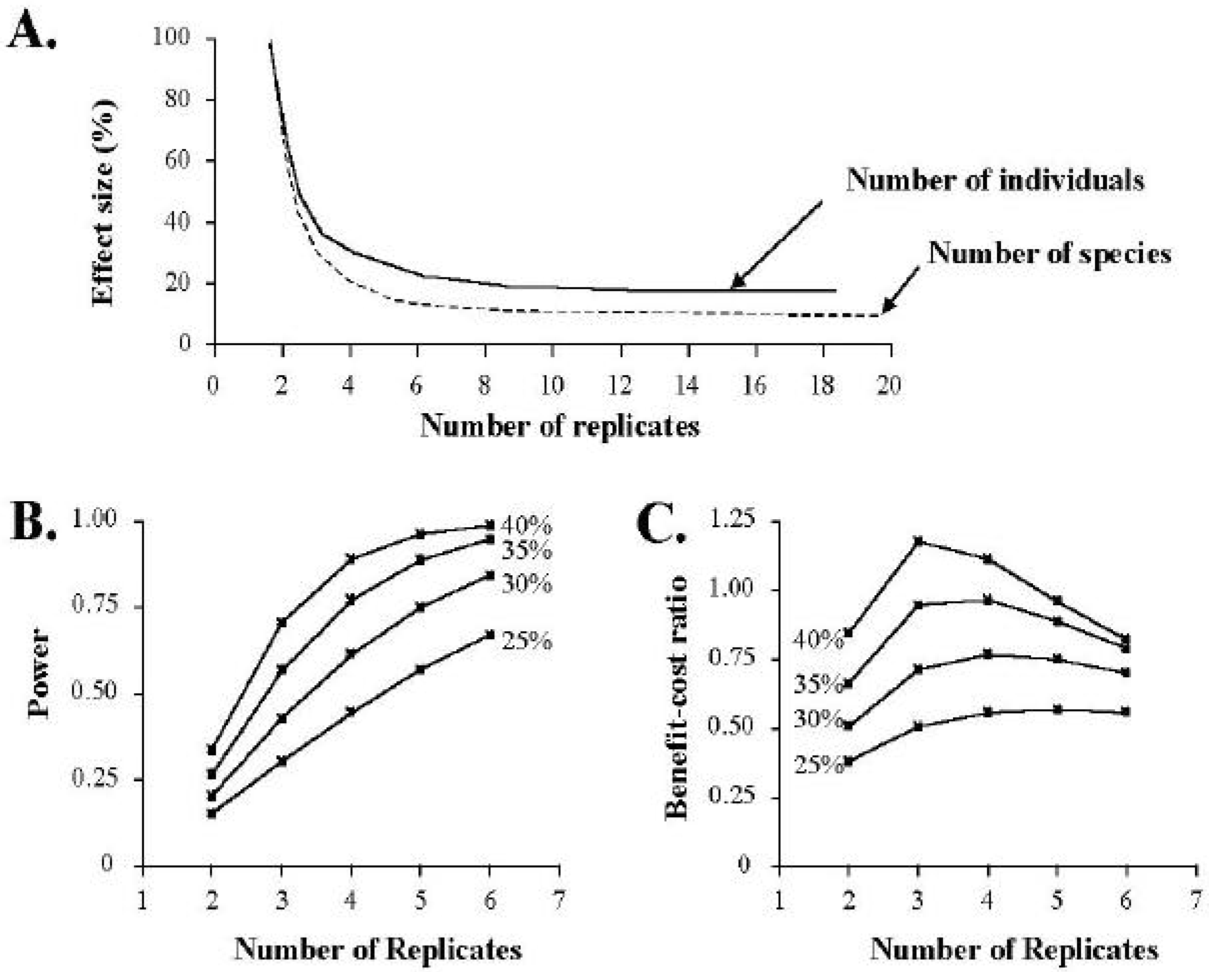
3.3.3 Results

The relationship between LSN of replicates and “effect size” has been shown for both number of individuals and for numbers of species (Figure 3A). Numbers of individual fish in replicates is larger and fluctuates more than numbers of fish species. For numbers of individuals, these data indicated that in a two-sample test, three replicates should detect an effect size of about 40% (that is, difference in means) and four replicates should detect an effect size of about 30%. Increasing the number of replicates above four provides little in additional power (Figure 3A).

Figure 3B uses only data on numbers of individual fish and demonstrates the increase in statistical power with increasing number of replicates, for specified effect sizes. Generally a power of >0.7 is considered acceptable (Lester et al., 1996). Using the pilot study data, only effect sizes of over 30% could be determined with acceptable power and this required more than three replicates. The benefit-cost analysis indicated that for effect sizes of between 25% and 35%, the best ratio of statistical power to cost was obtained using four replicates (Figure 3C).

On the basis of these results, it was considered that four replicates was the optimum number of replicates to be collected as a site sample.

Figure 3.2: Relationship between number of replicates and minimum detectable effect size (A), statistical power (B) and benefit-cost ratio (C). These relationships were determined from ANOVA of data collected during repetitive sampling in Lake Illawarra (see Method). Figure 3A shows data for numbers of individual fish and numbers of fish species whereas Figure 3B and 3C show data for numbers of individuals only.



3.4 Field Sampling

Field sampling involved the collection of water quality data and information on fish communities at each selected site.

3.4.1 Water quality

Physiochemical water quality data that might be expected to influence the shallow water fish assemblages were collected at each site during field sampling.

Water temperature (^{o}C), conductivity (µHMOS) and salinity (‰) were measured at mid-depth, with a handheld meter (TPS MC-84 Conductivity-Salinity-Temperature Meter). A handheld meter (Whitman Waterproof pH Meter) was used to determine surface water pH. A water sample was collected at each location and turbidity (Nephlemetric Turbidity Units, NTU) measured in the laboratory (Jenway Model 6035 Turbidimeter).

During the final year of sampling, water samples (1 litre) were also collected for the "core" estuaries and kept frozen for later chemical analysis. Nutrient analyses for total nitrogen, soluble nitrogen and phosphorus were carried out on these water samples by the NSW Environment Protection Authority (NSW EPA).

3.4.2 Fish sampling

Four replicate hauls of the seine net were used to sample fish at each of the selected sites. Fishing was carried out under the conditions set by the NSW Fisheries Scientific Permit (F96/294). The majority of fish identification and sorting was carried out in the field to reduce fish mortality, as permitted by Animal Ethics Permit AE 96/18.

In general, fish were identified to species and counted before they are returned to the water near where they were captured. The fork length (FL) was measured to the nearest millimetre for fish considered to be of economic importance or of particular interest. Individual fish requiring closer examination or to be collected as voucher specimens were humanely killed by placing on ice and preserved in a mixture of 70% ethanol. A reference collection, cross-checked with the Australian Museum (Sydney, Australia) was established.

3.5 Data Analysis

All data were entered into a specially designed database (Claris Filemaker Pro & Microsift Access) at the end of the sampling period and manually crosschecked for elimination of errors. In this preliminary analysis of the data, fish community structure has been investigated and hypothesis related to the spatial and temporal variability fish diversity and abundance have been tested.

Table 3.1 outlines the data analyses carried out for the preparation of this report.

Table 3.1: Data analyses carried out for this report on the shallow water fish communities in NSW south coast estuaries.

Low Intensity Sampling	• Summary of environmental data for each estuary • Summary of abundance of fish species for each estuary
Medium Intensity Sampling	• Summary of environmental data for each estuary • Summary of abundance of fish species for each estuary • Analysis of variance to test for significant differences between sampling event and location in numbers of fish and numbers of fish species, carried out separately for each estuary • Multivariate analyses of fish community structure for each estuary • Summary of comparison in fish communities between different estuaries • Summary of length frequencies for some selected species of economic importance
High Intensity Sampling	• Summary of abundance of fish species for each estuary

3.5.1 Summary of Environmental Data and Fish Abundance Data

Water quality data has been summarised for each location and sampling event within each estuary. Summary tables indicating overall abundance by each fish species captured have also been compiled for each location and for each sampling event.

3.5.2 Abundance and Diversity of Shallow Water Fishes

Analysis of Variance (ANOVA) were used to test for significant differences ($p=0.05$) in abundance and diversity of shallow water fishes between locations within estuaries (fixed factor) and between sampling events (random factor). Prior to ANOVA, abundance data were transformed using $\log_{10}(x+1)$, as this helps to stabilise heterogeneity of the data. In some cases, this transformation did not produce homogeneous variances, however ANOVA is still considered quite robust under these conditions, when sample sizes are equal (Underwood, 1981).

Where ANOVA indicated significant differences among means, the Student Newman Keuls (SNK) test was used for *post-hoc* comparison of means.

3.5.3 Fish Community Structure

Community structure was examined using multivariate techniques with the aid of the PRIMER 4.0 Software package (Plymouth Marine Laboratory, United Kingdom). Classification and ordination methods were employed to investigate patterns in the structure of the fish community data (Clarke 1993). For reasons outlined by Tonn et al. (1990), rarely captured species ($n \leq 10$ summed over 3 years) were removed before analyses. Replicate data were pooled and a transformation ($x^{0.25}$) used which emphasised the contribution of less common species in the analyses. Similarity matrices based on the Bray-Curtis similarity measure (Bray and Curtis, 1957) were generated. Data were subjected to cluster analyses using a group average linking to construct hierarchical agglomerative dendograms. In order to view spatial relationships, ordinations employing non-metric multidimensional scaling were performed to generate two dimensional ordination plots of the data. Where required, three-dimensional plots were constructed.

3.5.4 Length Frequency Histograms

Length frequency histograms were used to investigate the time of recruitment and growth of some of the economically important fish species. Numbers of fish less than 50 mm fork length were pooled by species and estuary. This meant that data were summed over replicates and locations within each estuary, for each sampling event.

3.5.5 Sampling of fished and unfished areas and estuaries

During the course of the research program, shallow water sites were sampled in locations and estuaries that were open and closed to most commercial fishing activities. Where possible, differences between these sites have been assessed. It should be noted however that it is not possible to study the impacts of commercial fishing activities without an experimental design that incorporates a range of controlled fishing closures, so that a Before, After, Control, Impact (BACI) experiment can be carried out.

4 RESULTS

A species list of scientific and common names has been included as Appendix 3.

4.1 Low Intensity Sampling

4.1.1 Introduction

Low intensity sampling was carried out in 18 estuaries with the objective of providing some basic information concerning the environment of these estuaries and their shallow water fish communities. Each site was sampled during the summer and winter period of one year at four sites and a complete listing of fish captured is contained in Appendix 1. This section summarises information collected for each of these estuaries, including data from Bell and Edwards (1980) and West et al. (1985).

4.1.2 Minnamurra River

The Minnamurra River (34^{o}38'S, 150^{o} 52'E) is a mature barrier estuary with a permanently open entrance to the sea. It has a catchment area of 142 km^2 and a water area of 1.3 km^2. The estuary has a seagrass area of approximately 0.232 km^2, with only *Zostera* spp. recorded. Two mangrove species, *Avicennia marina* and *Aegiceras corniculatum* form patchy stands that cover an area of approximately 0.484 km^2. The area of saltmarsh associated with the estuary is relatively small, covering an area of approximately 0.197 km^2. The land-use surrounding the Minnamurra River is principally disturbed freehold land and urban development. According to Bell and Edwards (1980), 50-70% of the catchment has been cleared with shoreline development in the same range. A number of rare and endangered plant species exist in patches of rainforest near Minnamurra Falls. The Minnamurra River does not support any significant commercial fishing.

Twenty-five species were captured in the Minnamurra River in the 8 seine hauls, taken in winter and summer 1998. Glassy perchlet (*Ambassis jacksoniensis*) and Gobies dominated the shallow seagrass areas (Table 4.1). The main economically important fish species captured during the surveys were mullet species, particularly flat-tail mullet (*Liza argentea*).

4.1.3 Shoalhaven River

The Shoalhaven River (34^{o}52'S, 150^{o} 45'E) is a large barrier estuary with an intermittently open entrance to the sea. The estuary has a catchment area of 7500 km^2 and a water area of 12.9 km^2. Seagrass beds cover an area of approximately 0.340 km^2 and represent *Zostera* spp. and *Halophila* spp. Mangroves stands are comprised of the species *Avicennia marina* and *Aegiceras corniculatum* and cover an area of 0.670 km^2. The area of saltmarsh associated with the estuary is patchy in distribution, covering approximately 0.146 km^2. Between 50-75% of the shoreline has been developed along the Shoalhaven River and 25-50% of the catchment cleared. The dominant land-use in the catchment is disturbed freehold land. Five sewage treatment works discharge directly into the Shoalhaven River and/or its tributaries, with a limestone mine also affecting water quality (Saenger and Bucher, 1989). A flood frequency of 1 flood per 6.1 years (Saenger and Bucher, 1989) has resulted in major flood mitigation works within the catchment (Bell and Edwards, 1980).

Table 4.1: Total number of fish caught by each species, at the entrance of Minnamurra River during February and July 1998.

Family *Species*	**Number Caught**
Clupeidae	
*Hyperlophus vittatus**	17
Syngnathidae	
Urocampus carinirostiis	2
Vanacampus poecilolaemus	1
Scorpaenidae	
Centropogon australis	5
Ambassidae	
Ambassis jacksoniensis	868
Teraponidae	
Pelates quadrilineatus	34
Pomatomidae	
*Pomatomus saltator**	1
Mullidae	
Parupeneus signatus	1
Girellidae	
*Girella tricuspidata**	18
Enoplosidae	
Enoplosus armatus	1
Mugilidae	
*Liza argentea**	62
*Mugil cephalus**	2
*Myxus elongatus**	5
Labridae	
*Achoerodus viridis**	1
Blennidae	
Petroscirtes lupus	11
Gobiidae	
Afurcagobius tamarensis	29
Favonigobius lateralis	1
Gobiopterus semivestitus	1
Pseudogobius olorum	4
Redigobius macrostoma	28
Siganidae	
Siganus nebulosus	1
Monacanthidae	
*Meuschenia freycineti**	12
*Meuschenia trachylepis**	20
*Monacanthus chinensis**	1
Tetraodontidae	
Tetractenos glaber	4
TOTAL (nos of species = 25)	**1130**

Table 4.2: Total number of fish caught by each species, at the entrance of Shoalhaven River during February and July 1998.

Family *Species*	**Number caught**
Hemiramphidae	
*Hyporhamphus australis**	5
Atherinidae	
Atherinosoma microstoma	2
Pseudomugilidae	
Pseudomugil signifer	7
Syngnathidae	
Urocampus carinirostiis	18
Scorpaenidae	
Centropogon australis	24
Ambassidae	
Ambassis jacksoniensis	817
Teraponidae	
Pelates quadrilineatus	51
Sillaginidae	
*Sillago ciliata**	1
Pomatomidae	
*Pomatomus saltator**	2
Sparidae	
*Acanthopagrus australis**	8
*Chrysophrys auratus**	1
*Rhabdosargus sarba**	21
Gerreidae	
*Gerres subfasciata**	21
Monodactylidae	
*Monadactylus argentus**	4
Girellidae	
*Girella tricuspidata**	48
Mugilidae	
*Mugil cephalus**	4
*Myxus elongatus**	17
Blennidae	
Petroscirtes lupus	1
Gobiidae	
Afurcagobius tamarensis	57
Gobiopterus semivestitus	78
Philypnodon grandiceps	3
Pseudogobius olorum	54
Redigobius macrostoma	24
Monacanthidae	
*Meuschenia freycineti**	3
*Meuschenia trachylepis**	32
Diodontidae	
Dicotylichthys punctulatus	14
TOTAL (nos. of species = 26)	1317

The Shoalhaven River supports a substantial commercial fishery producing mainly finfish, prawns and oysters. The commercial fisheries production for the period 1995/6 was 133 612 kg/yr. A total of 1334 individuals were caught in the months of February and July 1998, representing twenty-six fish species of which twelve species are considered of importance to commercial and recreational fisheries. Glassy perchlet (*Ambassis jacksoniensis*) dominated the seagrass fauna, followed by members of the Gobiidae family (Table 4.2). The main economically important species caught in Shoalhaven River were the yellow-finned leatherjacket (*Meuschenia trachylepis*), luderick (*Girella tricuspidata*) and tarwhine (*Rhabdosargus sarba*).

4.1.4 Swan Lake

Swan Lake (35°11'S, 150° 33'E) is a barrier estuary connected to the ocean via an intermittently open entrance. The lake has a catchment area of 32 km^2 and a water area of 4.082 km^2. Seagrass beds consisting of *Ruppia* spp. cover an area of approximately 0.070 km^2. There are very few mangrove trees and little saltmarsh associated with the estuary. Swan Lake and the surrounding catchment remain relatively undisturbed with a small amount of agriculture and urban development. Bell and Edwards (1980) estimated that 10-25% of the catchment had been cleared with shoreline development in the same range. Swan Lake supports some commercial fishing that produces mostly finfish. The commercial fisheries production for the period 1995/6 was 6 028 kg/yr.

Table 4.3: Total number of fish caught by each species, at the entrance of Swan Lake during February and July 1998.

Family *Species*	**Number caught**
Hemiramphidae	
*Hyporhamphus australis**	24
Atherinidae	
Atherinosoma microstoma	431
Pseudomugilidae	
Pseudomugil signifer	67
Sparidae	
*Acanthopagrus australis**	5
Gobiidae	
Philypnodon grandiceps	471
Pseudogobius olorum	6
Redigobius macrostoma	2
TOTAL (nos. of species = 7)	**1006**

The eight seine hauls taken in Swan Lake during February and July 1998 yielded 1006 individuals (Table 4.3). This represented seven species of which only two commercial fish species, sea garfish (*Hyporhamphus australis*) and yellowfin bream (*Acanthopagrus australis*) were caught. The flat-headed gudgeon (*Philypnodon grandiceps*), and the small mouth hardyhead (*Atherinosoma microstoma*) dominated the seagrass fish fauna.

4.1.5 Narrawallee Inlet

Narrawallee Inlet (35°18'S, 150° 28'E) is a mature barrier estuary with an intermittently open entrance to the sea. It has a catchment area of 85 km^2 and a water area of 0.456 km^2. The area of seagrass within the estuary is small (0.014 km^2) with *Zostera capricorni* and *Ruppia* spp. recorded. Stands of *Avicennia marina* and *Aegiceras corniculatum* are patchy in distribution and cover an area of approximately 0.378 km^2. The area of saltmarsh associated with the estuary is relatively small, covering approximately 0.091 km^2. Approximately 50-75% of the Narrawallee Inlet catchment has been cleared with disturbed freehold land the dominant land-use (Bell and Edwards 1980). No substantial wetland areas are associated with the estuary, nor are any other features of conservation significance. Narrawallee Inlet does not support any commercial fishing. Sampling was undertaken in Narrawallee Inlet during February and July 1999, and from the eight seine hauls 375 individuals were caught. A total of sixteen fish species was found of which six species are economically important (Table 4.4). Glassy perchlet (*Ambassis jacksoniensis*), dominated the assemblage. Low numbers of the commercial species were found, but the main species were luderick (*Girella tricuspidata*) and the mullet species.

Table 4.4: Total number of fish caught by each species, at the entrance of Narrawallee Inlet during February and July 1999.

Family *Species*	**Number Caught**
Scorpaenidae	
Centropogon australis	8
Ambassidae	
Ambassis jacksoniensis	313
Terapontidae	
Pelates quadrilineatus	23
Pomatomidae	
*Pomatomus saltator**	1
Sparidae	
*Acanthopagrus australis**	2
Girellidae	
*Girella tricuspidata**	6
Mugilidae	
*Mugil cephalus**	6
*Myxus elongatus**	3
Labridae	
*Achoerodus viridis**	1
Blennidae	
Petroscirtes lupus	2
Gobiidae	
Favonigobius lateralis	4
Favonigobius exquisites	2
Gobiopterus semivestitus	1
Siganidae	
Siganus nebulosus	1
Monacanthidae	
Meuschenia species	1
Tetradontidae	
Tetractenos glaber	1
TOTAL (nos. species = 16)	**375**

4.1.6 Tabourie Lake

Tabourie Lake (35°27'S, 150° 25'E) is a small intermittently open lagoon with a catchment area of 48 km^2 and a water area of 1.380 km^2. Species of seagrass include *Zosteraceae* spp. *Halophila* spp. and *Ruppia* spp., which cover an area of 1.199 km^2. A small area (0.010 km^2) of saltmarsh has also been recorded. The estuary and catchment are relatively undisturbed with 10-25% of the catchment cleared and only a small amount of shoreline development (Bell and Edwards 1980). The dominant land-use includes State Forest/Timber Reserve and freehold (Bell and Edwards 1980). Toubourie Lake does not support any commercial fishing activity. A total of 96 fish were caught in Lake Tabourie during February and July 1999. This represented 22 fish species of which 10 were considered of commerical importance (Table 4.5).

Table 4.5: Total number of fish caught by each species, at the entrance of Lake Tabourie during February and July 1999.

Family *Species*	**Number Caught**
Hemiramphidae	
*Hyporhamphus australis**	1
Syngnathidae	
Urocampus carinirostris	2
Vanacampus poecilolaemus	1
Scorpaenidae	
Centropogon australis	8
Terapontidae	
Pelates quadrilineatus	12
Pomatomidae	
*Pomatomus saltator**	1
Sparidae	
*Acanthopagrus australis**	2
*Rhabdosargus sarba**	2
*Chrysophrys auratus**	1
Gerreidae	
*Gerres subfasciatus**	10
Girellidae	
*Girella tricuspidata**	15
Mugilidae	
*Mugil cephalus**	1
Labridae	
*Achoerodus viridis**	4
Gobiidae	
Subfamily Eleotridinae	
Philypnodon grandiceps	2
Gobiidae	
Favonigobius lateralis	10
Favonigobius exquisites	7
Bathygobius kreffti	1
Afurcagobius tamarensis	4
Pseudogobius olorum	1
Gobiopterus semivestitus	5
Monacanthidae	
*Meuschenia trachylepis**	4
Meuschenia species	2
TOTAL (nos. species = 22)	**96**

4.1.7 Durras Lake

Durras Lake (35°38'S, 150° 18'E) is a small intermittently open lagoon with a catchment area of 63 km^2 and water area of 3.214 km^2. The estuary has a seagrass area of 0.509 km^2 comprised of *Zosteraceae* spp. and *Halophila* spp. No mangroves occur within the lake; however, a small area (0.046 km^2) of saltmarsh exists.

The shoreline and catchment surrounding Durras Lake are relatively undisturbed with 10-25% of the catchment cleared and shoreline development in the same range (Bell and Edwards 1980). The dominant land-use within the catchment is State Forest/Timber Reserve and a nature reserve exists on the northern side of the entrance (Bell and Edwards 1980). A small commercial fishery operates within Durras Lake producing finfish and prawns. The commercial fisheries production for the period 1995/6 was 9 723 kg/yr.

Durras Lake was sampled during February and July 1999 and the eight seine hauls yielded 3206 individuals. Twenty-four species were found and nine of these species are considered to be of economic importance (Table 4.6). High numbers of glassy perchlet (*Ambassis jacksoniensis*) dominated the seagrass fauna. The main economically important species captured was luderick (*Girella tricuspidata*).

Table 4.6: Total number of fish caught by each species, at the entrance of Durras Lake during February and July 1999

Family *Species*	**Number Caught**
Syngnathidae	
Vanacampus poecilolaemus	9
Urocampus carinirostris	3
Stigmatopora nigra	2
Scorpaenidae	
Centopogon australis	17
Ambassidae	
Ambassis jacksoniensis	3086
Terapontidae	
Pelates quadrilineatus	10
Sillaginidae	
*Sillago ciliata**	1
Sparidae	
*Acanthopagrus australis**	2
*Rhabdosargus sarba**	2
Gerridae	
*Gerres subfasciatus**	2
Mullidae	
Parapeneus signatus	2
Girellidae	
*Girella tricuspidata**	17
Mugilidae	
*Liza argentea**	2
Blennidae	
Petroscirtes lupus	21
Eleotrididae	
Phylipnodon grandiceps	6

Table 4.6 Continued

Gobiidae	
Favonigobius lateralis	4
Amoya frenatus	1
Afurcagobius tamarensis	7
Redigobius macrostoma	3
Gobiopterus semivestitus	2
Siganidae	
Siganus nebulosus	1
Pleuronectidae	
*Ammmotretis rostratus**	1
Monacanthidae	
*Monacanthus chinesis**	2
*Meuschenia freycineti**	3
TOTAL (nos. species = 24)	**3206**

4.1.8 Clyde River

The Clyde River (35°42'S, 150° 10'E) is a permanently open coastal river with very little infilling. It has a catchment area of 1791 km^2 and a water area of 19.898 km^2. The area of seagrass associated with the estuary covers approximately 0.092 km^2 consisting of *Zosteraceae* spp. *Halophila* spp. and *Posidonia australis*. Mangrove stands representing the species *Avicennia marina* and *Aegiceras corniculatum* comprise an area of approximately 2.318 km^2. Patchy areas of saltmarsh are associated with the estuary and cover an area of approximately 1.017 km^2.

Batemans Bay is a popular holiday and tourist resort, and the entrance to the Clyde River is consequently surrounded by urban and industrial land-uses. However, most of the catchment is still under natural forest with 10-25% of the catchment cleared (Bell and Edwards 1980). Due to the absences of major weirs and blocking structures in the lower reaches of the Clyde (Bell and Edwards 1980), the estuary is the best remaining habitat of the rare and endangered fish species, Australian grayling (*Prototrocetes maraena*) and contains good populations of Australian bass (*Macquarie novemaculatus*). The Clyde River also supports a substantial commercial fishery producing finfish, prawns, crabs and oysters. The commercial fisheries production for the period 1995/6 was 388 859 kg/yr.

Table 4.7: Total number of fish caught by each species, at the entrance of Clyde River during February and July 1998.

Family *Species*	**Number caught**
Syngnathidae	
Stigmatophora argus	2
Urocampus carinirostiis	14
Vanacampus poecilolaemus	218
Ambassidae	
Ambassis jacksoniensis	11
Teraponidae	
Pelates quadrilineatus	50

Table 4.7 Continued

Mullidae	
Parupeneus signatus	1
Girellidae	
*Girella tricuspidata**	61
Mugilidae	
*Liza argentea**	1
*Myxus elongatus**	4
Blennidae	
Petroscirtes lupus	2
Gobiidae	
Afurcagobius tamarensis	395
Amoya frenatus	13
Pseudogobius olorum	9
Redigobius macrostoma	8
Siganidae	
Siganus nebulosus	2
Bothidae	
*Pseudorhombus arsius**	1
Monacanthidae	
*Monacanthus chinensis**	2
Nelusetta ayraudi	4
Tetraodontidae	
Tetractenos hamiltoni	1
Diodontidae	
Dicotylichthys punctulatus	1
TOTAL (nos. of species = 20)	**800**

A total of 800 fish were caught in the Clyde River during February and July 1998. Twenty fish species were found and five of these species were of economic importance (Table 4.7). The Tamar River goby (*Afurcagobius tamarensis*) and the long snout pipefish (*Vanacampus poecilolaemus*) dominated the shallow seagrass fish fauna. In terms of commercially and recreationally important fish species, high numbers of luderick (*Girella tricuspidata*) were caught.

4.1.9 Tomaga River

The Tomaga River (35^{o}50’S, 150^{o} 11’E) is a permanently open barrier estuary at a mature stage of infilling. It has a catchment area of 98 km^2 and a water area of 1.214 km^2. The estuary has approximately 0.527 km^2 of seagrass representing *Zosteraceae* species. Mangroves cover an area of approximately 0.210 km^2 and include the species *Avicennia marina* and *Aegiceras corniculatum*. The area of saltmarsh associated with the estuary is patchy in its distribution and is approximately 0.351 km^2 in area.

Bell and Edwards (1980) estimated that 25-50% of the catchment had been cleared with shoreline development in the range 50-75%. Land-use in the catchment includes freehold land and State Forest. A small commercial fishery operates within the estuary and fisheries production for the period 1995/6 was 3 752 kg/yr.

The Tomaga River was sampled during February and July 1998, and the eight seine samples yielded 667 individuals. A total of twenty-one fish species were caught and six of these species are considered economically important (Table 4.8). Glassy perchlet (*Ambassis jacksoniensis*) dominated the seagrass fish fauna. The main economically important fish species caught were the fan-belly leatherjacket (*Monacanthus chinesis*) and luderick (*Girella tricuspidata*).

Table 4.8: Total number of fish caught by each species, at the entrance of Tomaga River during February and July 1998.

Family *Species*	**Number caught**
Syngnathidae	
Stigmatophora argus	1
Syngnathoides biaculeatus	2
Urocampus carinirostiis	5
Vanacampus phillipi	7
Vanacampus poecilolaemus	86
Ambassidae	
Ambassis jacksoniensis	337
Teraponidae	
Pelates quadrilineatus	101
Girellidae	
*Girella tricuspidata**	34
Mugilidae	
*Liza argentea**	2
*Myxus elongatus**	16
Blennidae	
Petroscirtes lupus	7
Gobiidae	
Afurcagobius tamarensis	2
Philypnodon grandiceps	1
Pseudogobius olorum	1
Redigobius macrostoma	4
Siganidae	
Siganus nebulosus	1
Monacanthidae	
*Meuschenia freycineti**	15
*Meuschenia trachylepis**	2
*Monacanthus chinensis**	38
Nelusetta ayraudi	2
Tetraodontidae	
Tetractenos glaber	3
TOTAL (nos. of species = 21)	**667**

4.1.10 Moruya River

The Moruya River has a catchment area of 1445 km^2 and a water area of 4.222 km^2. It is classified as a mature estuary with a permanent opening to the sea. The estuary has a seagrass area of approximately 0.644 km^2 that is comprised of *Zosteraceae* spp. and *Halophila* spp. Extensive mangrove stands consisting of *Avicennia marina* and *Aegiceras corniculatum* species cover an area of approximately 0.380 km^2. The area of saltmarsh associated with the estuary covers approximately 0.674 km^2. The town of Moruya is a popular holiday and tourist resort. A significant proportion of the Moruya River catchment is protected in the Deua National Park; however, other land-uses include freehold land and State Forest (Bell and Edwards 1980). Bell and Edwards (1980) estimated that 10-25% of the catchment had been cleared with shoreline development in the range of 50-75%. The Moruya River is one of the few remaining habitats of the protected Australian grayling (*Prototrocetes maraena*) and has good populations of Australian bass (*Macquarie novemaculatus*) (Bell and Edwards 1980). The Moruya River estuary supports some commercial fishing, producing finfish, prawns and oysters. The commercial fisheries production for the period 1995/6 was 41 641 kg/yr.

A total of 1414 fish were caught in the Moruya River during February and July 1998. Eleven fish species were found, of which three species are of economic importance, (*Hyperlophus vittatus*), tarwhine (*Rhabdosargus sarba*) and luderick (*Girella tricuspidataI*). In terms of abundance, the seagrass fish fauna was dominated by high numbers of glassy perchlet (*Ambassis jacksoniensis*) and the blue-spotted goby (*Pseudogobius olorum*) (Table 4.9).

Table 4.9: Total number of fish caught by each species, at the entrance of Moruya River during February and July 1998.

Family *Species*	**Number caught**
Clupeidae	
*Hyperlophus vittatus**	4
Scorpaenidae	
Centropogon australis	16
Ambassidae	
Ambassis jacksoniensis	1075
Teraponidae	
Pelates quadrilineatus	13
Sparidae	
*Rhabdosargus sarba**	6
Girellidae	
*Girella tricuspidata**	44
Gobiidae	
Afurcagobius tamarensis	13
Amoya frenatus	8
Philypnodon grandiceps	18
Pseudogobius olorum	209
Redigobius macrostoma	8
TOTAL (nos. of species = 11)	**1414**

4.1.11 Tuross Lake

Tuross Lake (36°04'S, 150° 08'E) is a permanently open barrier estuary that has a catchment area of 1816 km^2 and a water area of 13.299 km^2. Seagrass beds composed of *Zosteraceae species*, *Halophila* spp. and *Posidonia australis* cover an area of approximately 0.452 km^2. Mangrove stands consisting of *Avicennia marina* and *Aegiceras corniculatum* species cover an area of 0.566 km^2. The area of saltmarsh associated with the estuary covers approximately 0.401 km^2. The holiday resort of Tuross heads is close to the entrance of Tuross Lake and is a popular recreational area in the summer months. The land-use surrounding the rest of the lake is dominated by freehold land and State Forest (Bell and Edwards 1980). According to Bell and Edwards (1980) 25-50% of the catchment had been cleared with shoreline development in the range of 50-75%. Tuross Lake supports some commercial fishing producing finfish, crabs and oysters. For the period 1995/6, commercial fisheries production was 109 759 kg/yr.

1558 fish were caught in Tuross Lake during February and July 1998. This represented twenty-four fish species of which seven species are of economic importance (Table 4.10). In terms of abundance, high numbers of glassy perchlet, (*Ambassis jacksoniensis*) dominated the assemblage. The main economically important fish species caught were the sand mullet (*Myxus elongatus*) and species from the Monacanthidae family, particularly the six-spined leatherjacket (*Meuschenia freycineti*) and bridled leatherjacket (*Acanthalures spilomelanurus*).

Table 4.10: Total number of fish caught by each species, at the entrance of Tuross Lake during February and July 1998.

Family *Species*	**Number caught**
Atherinidae	
Atherinosoma microstoma	11
Syngnathidae	
Stigmatophora argus	1
Stigmatophora nigra	3
Urocampus carinirostiis	1
Vanacampus phillipi	1
Vanacampus poecilolaemus	49
Scorpaenidae	
Centropogon australis	11
Ambassidae	
Ambassis jacksoniensis	1214
Teraponidae	
Pelates quadrilineatus	63
Pomatomidae	
*Pomatomus saltator**	5
Sparidae	
*Acanthopagrus australis**	3
Girellidae	
*Girella tricuspidata**	15

Table 4.10 Continued

Enoplosidae	
Enoplosus armatus	5
Mugilidae	
*Myxus elongatus**	26
Blennidae	
Petroscirtes lupus	19
Gobiidae	
Afurcagobius tamarensis	35
Amoya frenatus	2
Philypnodon grandiceps	1
Redigobius macrostoma	3
Monacanthidae	
Acanthaluteres spilomelanurus	28
*Meuschenia freycineti**	44
*Meuschenia trachylepis**	8
*Monacanthus chinensis**	4
Tetraodontidae	
Tetractenos glaber	6
TOTAL (nos. of species = 24)	**1558**

4.1.12 Wagonga Inlet

Wagonga Inlet (36°13'S, 150° 08'E) is a large barrier estuary with a permanently open entrance to the sea. It has a catchment area of 97 km^2 and a water area of 6.276 km^2. Seagrass beds are patchy in distribution and cover an area of approximately 1.484 km^2. *Zosteraceae* species and *Posidonia australis* seagrasses have been recorded. Patchy stands of mangroves (0.249 km^2) consisting of the species *Avicennia marina* are associated with the estuary. Saltmarsh covers an area of 0.056 km^2 and is patchy in its distribution.

The town of Narooma is located at the mouth of Wagonga Inlet and is a popular tourist and holiday resort. Bell and Edwards (1980) estimated shoreline development to be in the range of 50-75% with 25-50% of the catchment cleared. The dominant land-use in the catchment is State Forest/Timber Reserve. Wagonga Inlet supports significant oyster production as well as some finfish and prawns.

Sampling of Wagonga Inlet occurred during February and July 1999, and the eight seine hauls caught 956 fish. Twenty-six species were found and eleven of these species were considered to of importance to commercial and recreational fisheries (Table 4.11). The most abundant species caught were sea mullet (*Mugil cephalus*) small mouth hardyhead (*Atherina microstoma*) and glassy perchlet (*Ambassis jacksoniensis*). The main economically important species caught were from the mullet family and tailor (*Pomatomus saltator*).

Table 4.11: Total number of fish caught by each species, at the entrance of Wagonga Inlet during February and July 1999.

Family *Species*	**Number Caught**
Clupeidae	
Spratelloides robustus	19
Atherinidae	
Atherinosoma microstoma	205
Syngnathidae	
Urocampus carinirostris	4
Vanacampus phillipi	5
Stigmatopora nigra	1
Stigmatophora argus	17
Vanacampus poelcilolaemus	31
Scorpaenidae	
Centopogon australis	1
Ambassidae	
Ambassis jacksoniensis	146
Sillaginidae	
*Sillago cilliata**	1
Pomatomidae	
*Pomatomus saltator**	86
Sparidae	
*Acanthopagrus australis**	7
Gerreidae	
*Gerres subfasciatus**	1
Girellidae	
*Girella tricuspidata**	5
Mugilidae	
*Mugil cephalus**	341
*Myxus elongatus**	38
Labridae	
*Achoerodus viridis**	2
Blennidae	
Petroscirtes lupus	15
Clinidae	
Cristiceps australis	1
Gobiidae	
Favonigobius lateralis	7
Afurcagobius tamarensis	1
Monacanthidae	
*Meuschenia freycineti**	4
*Meuschenia trachylepis**	2
*Monacanthus chinesis**	10
Tetradontidae	
Tetractenos glaber	1
TOTAL (nos. species = 26)	**956**

4.1.13 Nangudga Lake

Nangudga Lake (36°15'S, 150° 09'E) is an intermittently open lagoon with a catchment area of 10 km^2 and a water area of 0.461 km^2. The lagoon contains a small area of seagrass representing *Zosteraceae* species. No mangroves are associated with the lagoon; however, a small area of saltmarsh (0.115 km^2) has been recorded.

The Nangudga Lake catchment consists of disturbed and undisturbed freehold land, with approximately 50-75% of the catchment cleared (Bell and Edwards 1980).

A total of 256 fish were caught during February and July 1999 at the entrance of Nangudga Lake. Sixteen species were found and seven of those species are of significance to commercial and recreational fisheries (Table 4.12). The highest numbers of fish caught were the small mouth hardyhead (*Atherinasoma microstoma*) and sand mullet (*Myxus elongatus*).

Table 4.12: Total number of fish caught by each species, at the entrance of Nangudga Lake during February and July 1999.

Family *Species*	**Number Caught**
Atherinidae	
Atherinosoma microstoma	92
Syngnathidae	
Urocampus carinirostris	25
Ambassidae	
Ambassis jacksoniensis	7
Teraponidae	
Pelates quadrilineatus	17
Sparidae	
*Acanthopagrus australis**	3
Gerreidae	
*Gerres subfasciatus**	2
Girellidae	
*Girella tricuspidata**	16
Mugilidae	
*Mugil cephalus**	1
*Myxus elongatus**	52
Labridae	
*Achoerodus viridis**	2
Gobiidae	
Favonigobius lateralis	26
Afurcagobius tamarensis	5
Pseudogobius olorum	2
Monacanthidae	
*Meuschenia trachylepis**	1
Meuschenia species	1
Tetradontidae	
Tetractenos glaber	4
TOTAL (nos. species = 16)	**256**

4.1.14 Corunna Lake

Corunna Lake (36°17'S, 150° 08'E) is an intermittently open lagoon with a catchment area of 33 km^2 and a water area of 1.699 km^2. Seagrasses comprise an area of approximately 0.179 km^2 and contain species of *Zosteraceae* and *Halophila*. No mangroves are associated with Corunna Lake; however, patchy saltmarsh cover an area of around 0.033 km^2.

The dominant land-use in the Corunna Lake catchment includes both disturbed and undisturbed freehold land. Bell and Edwards (1980) calculated that 50-75% of the catchment had been cleared, with shoreline development in the same range. Ocean flushing of Corunna Lake is infrequent; therefore, the lagoon is susceptible to pollution from a nearby piggery (Bell and Edwards 1980). Corunna Lake supports a small commercial fishery producing finfish and prawns. For the period 1995/6, the commercial fisheries production was 9 503 kg/yr.

During February and July 1999, a total of 537 fish were caught at the entrance of Corunna Lake. This represented twenty-five fish species of which ten species are considered to be of importance to recreational and commercial fisheries (Table 4.13). In terms of numbers trumpeter (*Pelates quadrilineatus*) and the yellow-finned leatherjacket (*Meuschenia trachylepis*) dominated the assemblage. Apart from *Meuschenia trachylepis,* the other main economically important fish species caught were yellowfin bream (*Acanthopagrus australis*) and the flat-tail mullet (*Liza argentea*).

Table 4.13: Total number of fish caught by each species, at the entrance of Corunna Lake during February and July 1999

Family *Species*	**Number Caught**
Hemiramphidae	
*Hyporhamphus australis**	1
Syngnathidae	
Vanacampus poecilolaemus	4
Urocampus carinirostris	4
Stigmatopora nigra	4
Scorpaenidae	
Centropogon australis	8
Ambassidae	
Ambassis jacksoniensis	92
Terapontidae	
Pelates quadrilineatus	118
Pomatomidae	
*Pomatomus saltator**	1
Sparidae	
*Acanthopagrus australis**	43

Table 4.13 Continued

Gerridae	
*Gerres subfasciatus**	6
Girellidae	
*Girella tricuspidata**	47
Mugilidae	
*Mugil cephalus**	2
*Liza argentea**	23
Labridae	
*Achoerodus viridis**	7
Blennidae	
Petroscirtes lupus	4
Gobiidae	
Subfamily Eleotridae	
Philypnodon grandiceps	1
Gobiidae	
Favonigobius exquisites	3
Favonigobius lateralis	1
Afurcagobius tamarensis	3
Redigobius macrostoma	1
Siganidae	
Siganus nebulosus	1
Monacanthidae	
*Meuschenia freycineti**	6
*Meuschenia trachylepis**	155
Mueschenia species	1
Diodontidae	
Dicotylichthys puctulatus	1
TOTAL (nos. species = 25)	**537**

4.1.15 Bermagui River

Bermagui River (36°26'S, 150° 04'E) is a barrier estuary that remains permanently open to the sea. It has a catchment area of 94 km^2 and a water area of 1.390 km^2. Seagrasses cover an area of approximately 0.338 km^2 and include *Zosteraceae species*, *Halophila spp*. and *Posidonia australis*. Stands of *Avicennia marina* mangroves cover an area of approximately 0.434 km^2. The estuary contains around 1.066 km^2 of saltmarsh.

Moderate urban and industrial development is situated at the entrance of the Bermagui River with approximately 50-75% of the catchment cleared, and shoreline development in the same range (Bell and Edwards 1980). The dominant land-use in the catchment includes disturbed freehold land and State Forest (Bell and Edwards 1980). Bermagui is generally known for its ocean fishing, however, some commercial fishing activity producing finfish and oysters occurs within the estuary. The commercial fisheries production in the Bermagui River for the period 1995/6 was 4612 kg/yr. The Bermagui River was sampled during February and July 1998 and 3850 fish were caught. A total of eighteen species were found and seven of these species are of importance to commercial and recreational fisheries (Table 4.14). High numbers of glassy perchlet (*Ambasis jacksoniensis*) dominated the seagrass fish fauna, followed by the long snout pipefish (*Vanacampus poecilolaemus*). The main economically important fish species caught were silver trevally (*Pseudocaranx dentex*) and luderick (*Girella tricuspidata*).

Table 4.14: Total number of fish caught by each species, at the entrance of Bermagui River during February and July 1998.

Family *Species*	**Number caught**
Syngnathidae	
Stigmatophora nigra	16
Syngnathoides biaculeatus	1
Urocampus carinirostiis	2
Vanacampus phillipi	3
Vanacampus poecilolaemus	95
Scorpaenidae	
Centropogon australis	1
Ambassidae	
Ambassis jacksoniensis	3644
Teraponidae	
Pelates quadrilineatus	23
Carangidae	
*Pseudocaranx dentex**	6
Sparidae	
*Rhabdosargus sarba**	1
Girellidae	
*Girella tricuspidata**	23
Mugilidae	
*Myxus elongatus**	6
Sphyraenidae	
Sphyraena obtusa	1
Labridae	
*Achoerodus viridis**	3
Blennidae	
Petroscirtes lupus	1
Gobiidae	
Afurcagobius tamarensis	12
Gobiopterus semivestitus	3
Pseudogobius olorum	11
Redigobius macrostoma	1
Monacanthidae	
*Meuschenia trachylepis**	1
*Monacanthus chinensis**	2
Tetraodontidae	
Tetractenos glaber	3
TOTAL (nos. of species = 22)	**3859**

4.1.16 Cuttagee Lake

Cuttagee Lake (36^{o}29'S, 150^o 03'E) is an intermittently open lagoon with a catchment area of 55 km^2 and a water area of 1.410 km^2. Seagrass beds cover an area of approximately 0.430 km^2 and represent *Zosteraceae* spp., *Halophila* spp. and *Ruppia* spp. No mangroves exist in Cuttagee Lake due to infrequent opening regimes. A small area (0.076 km^2) of saltmarsh is associated with the lagoon. Most of the Cuttagee

Lake catchment is located in the Murrah State Forest. Bell and Edwards (1980) estimated that 10-25% of the catchment had been cleared with shoreline development in the range of 50-75%. The entrance of Cuttagee Lake is periodically opened to the sea by dredging to alleviate pollution problems (Saenger and Bucher 1989). A commercial fishery producing oysters operates in lagoon. The commercial fisheries production for the period 1995/6 was 871 kg/yr.

A total of 571 fish were caught in Cuttagee Lake during February and July 1999. The eight seine hauls caught eleven species of which there were only two commercial species, luderick (*Girella tricuspidata*) and flat-tail mullet (*Liza argentea*). The seagrass fish fauna was dominated by the small mouth hardy head (*Atherinosoma microstoma* and the southern blue-eye (*Pseudomugil signifer*) (Table 4.15).

Table 4.15: Total number of fish caught by each species, at the entrance of Cuttagee Lake during February and July 1999.

Family *Species*	**Number Caught**
Pseudomugilidae	
Pseudomugil signifer	87
Atherinidae	
Atherinosoma microstoma	352
Syngnathidae	
Urocampus carinirostris	3
Ambassidae	
Ambassis jacksoniensis	34
Girellidae	
*Girella tricuspidata**	9
Mugilidae	
*Liza argentea**	1
Gobiidae	
-subfamily Eleotridae	
Philypnodon grandiceps	49
Gobiidae	
Amoya bifrenatus	3
Afurcagocius tamarensis	34
Psuedogobius olorum	15
Tetradontidae	
Tetractenos glaber	4
TOTAL (nos. species = 11)	**571**

4.1.17 Bega River

The Bega River (36°42’S, 149° 59’E) is a large barrier estuary with an intermittently open entrance to the sea. It has a catchment area of 1941 km^2 and a water area of 2.657 km^2. Seagrass beds consisting of *Zosteraceae* species are patchy in distribution and cover an area of approximately 0.304 km^2. No mangroves have been recorded in the estuary. The area of saltmarsh associated with the estuary is patchy and covers approximately 0.411 km^2. The Bega River and its catchment have been severely disturbed through clearing for urban development and dairy farming. Bell and Edwards (1980) estimated that 50-75% of the catchment had been cleared with shoreline development in the same range. A large proportion of the catchment consists of freehold land; however, a nature reserve exists at the southeastern perimeter of the catchment. The Bega River supports commercial fishing that produces finfish, prawns and crabs. The commercial fisheries production for the period 1995/6 was 11 737 kg/yr. In surveys carried out in February and July 1999, 812 fish were captured in the shallow waters of the Bega River (Table 4.16). Dominant in the catch were glassy perchlets (*Ambassis jacksoniensis*). In total 20 species were collected, six of which were commercially important.

Table 4.16: Total number of fish caught by each species, at the entrance of Bega River during February and July 1999.

Family *Species*	**Number Caught**
Syngnathidae	
Urocampus carinirostris	2
Vanacampus phillipi	1
Ambassidae	
Ambassis jacksoniensis	716
Teraponidae	
Pelates quadrilineatus	6
Pomatomidae	
*Pomatomus saltator**	4
Sparidae	
*Acanthopagrus australis**	4
*Rhabdosargus sarba**	2
Gerreidae	
*Gerres subfasciatus**	2
Lutjanidae	
Lutjanus argentimaculatus	1
Girellidae	
*Girella tricuspidata**	20
Mugilidae	
*Mugil cephalus**	2
Gobiidae	
Subfamily Eleotrididae	
Phylipnodon grandiceps	10
Gobiidae	
Favonigobius lateralis	3
Amoya bifrenatus	3
Redigobius macrostoma	26
Monacanthidae	
Acanthalutres spilomelanurus	1
*Scobinichthys granulatus**	1
*Meuschenia trachylepis**	5
*Meuschenia freycineti**	2
Nelsetta ayraudi	1
TOTAL (nos. species = 20)	**812**

4.1.18 Wallagoot Lake

Wallagoot Lake (36°47'S, 148° 57'E) is a barrier estuary with an intermittently open entrance to the sea. It has a catchment area of 31 km^2 and a water area of 3.672 km^2. Seagrass beds comprise an area of approximately 0.647 km^2 and contain species of

Zosteraceae, *Halophila* and *Ruppia*. There are no mangroves associated with estuary; however, small patches of saltmarsh (0.014 km^2) have been recorded. According to Bell and Edwards (1980), 25-50% of the Wallagoot Lake catchment has been cleared with shoreline development in the range of 50-75%. Approximately half of the catchment is located in the Bournda Nature Reserve. There is a small commercial fishery operating in Wallagoot Lake producing finfish and prawns. The commercial fisheries production for the period 1995/6 was 4 577 kg/yr.

The eight seine samples taken at the entrance of Wallagoot Lake during February and July 1999 caught 2326 fish (Table 4.17). This catch was largely comprised of the glass goby (*Gobiopterus semivestitus*). In total, only eight species were found and two of these were of value to commercial and recreational fisheries, the sea garfish (*Hyporhamphus australis*) and luderick (*Girella tricuspidata*).

Table 4.17: Total number of fish caught by each species, at the entrance of Wallagoot Lake during February and July 1999.

Family *Species*	**Number Caught**
Hemiramphidae	
*Hyporhamphus australis**	2
Atherinidae	
Atherinosoma microstoma	26
Syngnathidae	
Urocampus carinirostris	11
Girellidae	
*Girella tricuspidata**	2
Gobiidae	
Pseudogobius olorum	2
Redigobius macrostoma	1
Gobiopterus semivestitus	2282
TOTAL (nos. species = 8)	**2326**

4.1.19 Pambula Lake

Pambula Lake (36°57'S, 149° 55'E) is a barrier estuary with an entrance that remains permanently open to the sea. It has a catchment area of 299 km^2 and a water area of 12.949 km^2. The lake has a seagrass area of 0.868 km^2, composed of *Zosteraceae* spp. and *Posidonia australis*. Mangrove stands are patchy and cover an area of approximately 0.449 km^2. *Avicennia marina* is the only mangrove species recorded from the estuary. The area of saltmarsh associated with the lake is also patchy, covering an area of approximately 0.188 km^2. The lower reaches of Pambula Lake are located in the Ben Boyd National Park. The land-use surrounding the remainder of the lake includes disturbed freehold land and State Forest. Bell and Edwards (1980) classified the lake as having moderate to high disturbance, due to the close proximity of the Pambula township, oyster farms, and the sawmill and sand-washing plants. The estuary supports a substantial commercial fishery, producing mainly finfish and oysters. The commercial fisheries production for the period 1995/96 was 33 367 kg/yr. Pambula Lake was sampled during February and July 1998. A total of 1021 fish was caught representing twenty-three species of which eight species are of value to commercial and recreational fisheries (Table 4.18). The catch was dominated by the glassy perchlet (*Ambassis jacksoniensis*) and luderick (*Girella tricuspidata*). Other economically important fish species caught were silver trevally (*Pseudocaranx dentex*) and Monacanthids, namely the Chinaman leatherjacket (*Nelusetta ayraudi*) and six-spined leatherjacket (*Meuschenia freycinetti*).

Table 4.18: Total number of fish caught by each species, at the entrance of Pambula Lake during February and July 1998.

Family *Species*	**Number caught**
Engraulididae	
*Engraulis australis**	1
Syngnathidae	
Stigmatophora argus	3
Stigmatophora nigra	7
Urocampus carinirostiis	5
Vanacampus poecilolaemus	60
Ambassidae	
Ambassis jacksoniensis	295
Teraponidae	
Pelates quadrilineatus	3
Pomatomidae	
*Pomatomus saltator**	2
Carangidae	
*Pseudocaranx dentex**	65
Lethrinidae	
Lethrinidae species	2
Mullidae	
Parupeneus signatus	2
Girellidae	
*Girella tricuspidata**	376
Enoplosidae	
Enoplosus armatus	17
Labridae	
*Achoerodus viridis**	1
Clinidae	
Cristiceps australis	2
Gobiidae	
Afurcagobius tamarensis	5
Gobiopterus semivestitus	25
Siganidae	
Siganus nebulosus	52
Monacanthidae	
Brachaluteres jacksonianus	1
*Meuschenia freycineti**	46
*Meuschenia trachylepis**	2
*Nelusetta ayraudi**	48
Diodontidae	
Dicotylichthys punctulatus	1
TOTAL (nos. of species = 23)	**1021**

4.1.20 Comparison of Fished and Unfished Locations

Part of the one of the objectives of this project was to attempt to sample shallow water fish at locations that were open and closed to commercial fishing. There are very few estuaries along the south coast of NSW that were closed to all forms of commercial fishing during the survey period. Of particular interest however, are the possible negative impacts of haul and mesh netting for finfish.

It is not possible to make statements about the impact of fishing activities on the shallow water fishes in estuaries without specially designed experiments. However, during the course of the low intensity sampling program, no obvious differences were found in either the species composition, number of species or total catches of fish between commercially netted areas and unfished areas (Table 4.19).

Table 4.19: Comparison of catches in terms of overall numbers of species and total abundances of fish, between fished and unfished locations in selected NSW south coast estuaries.

Category *Estuary*	**Sampling Period**	**Number of Species**	**Total Abundance**
Fished			
Tabourie Lake	February & July 99	22	96
Clyde River	February & July 98	20	800
Corunna Lake	February & July 99	25	537
Cuttagee Lake	February & July 99	11	571
Pambula Lake	February & July 98	23	1021
Unfished*			
Minnamurra R	February & July 98	25	1130
Shoalhaven R	February & July 98	26	1317
Swan Lake	February & July 98	7	1006
Narrawallee Inlet	February & July 99	16	375
Durras Lake	February & July 99	24	3206
Tomago River	February & July 98	21	667
Moruya River	February & July 98	11	1414
Tuross Lake	February & July 98	24	1558
Wagonga Inlet#	February & July 99	26	956
Nangudga Lake	February & July 99	16	256
Bermagui River	February & July 98	22	3859
Bega River	February & July 99	20	812
Wallagoot Lake	February & July 99	8	2326

* Locations sampled were closed to all forms of fish netting.
# Estuary completely closed to commercial fish netting.

4.2 Medium Intensity Sampling

4.2.1 Introduction

Medium intensity sampling was carried out in 7 estuaries with the objective of providing information concerning the spatial and temporal variablility in the shallow water fish communities. Species diversity and abundance data were collected from three locations (hereafter called entrance, central and upper sites) within each estuary, four times each year for three years.

A general overview of the data will be presented and then detailed information for each of the 7 estuaries. This represents only a preliminary analysis of the large volume of data collected.

4.2.2 General Overview

A total of 209 366 fish, belonging to 101 species and 48 families were caught over the three-year study period for the medium intensity sampling program (Table 4.20). Thirty-seven of these species were considered to be of significance to commercial and/or recreational fisheries. The families with the most species found were the Gobiidae (12 species), Monacanthidae (9 species) and Syngnathidae (8 species). Also well represented in terms of species diversity were the Mullidae and Scorpididae families which both had four species found (Table 4.20).

In terms of individual numbers, members of the Gobiidae (73 733 individuals), Ambassidae (54 876 individuals) and Atherinidae (45 396 individuals) dominated the seagrass fauna and represented approximately 83% of the combined catch of the seven estuaries (Table 4.20). Twenty-seven species were common to all seven estuaries, whereas thirty-four species were unique to only one estuary. Fifteen species were caught on a single occasion and only one member was found. Forty-five species were caught with numbers less than ten.

Table 4.20: Total number of fish caught by each species during shallow water sampling of the 7 estuaries between September 1997 and July 2000. (* indicates species of commercial and/or recreational importance.)

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Anguillidae							
*Anguilla reinhardtii**	-	-	1	1	1	1	-
Clupeidae							
*Sardinops neopilchardus**	-	-	1	-	-	-	-
*Hyperlophus vittatus**	1	3	1	1	-	-	1
Spratelloides robusutus	-	-	-	-	-	-	9
Engraulidae							
*Engraulis australis**	-	-	-	-	-	5	-
Gonorynchidae							
Gonorynchus greyi	-	-	-	-	1	-	-
Plotosidae							
Cnidoglanis macrocephalus	-	2	-	-	-	-	-
Antennariidae							
Antennarius striatus	-	-	1	-	-	-	-
Hemiramphidae							
*Hyporhamphus regularis**	-	-	-	-	7	-	-
*Hyporhamphus australis**	28	2	12	10	352	1	10
Belonidae							
Tylosurus gavialoides	-	2	-	-	-	-	-
Strongylura leiura	-	1	-	-	-	-	-
Atherinidae							
Atherinasoma microstoma	6084	29	1728	2493	29763	797	1436
Atherinasoma elongata	154	388	340	54	1998	40	92
Poeciliidae							
Gambusia holbrooki	-	-	-	-	169	-	-
Pseudomuglidae							
Pseudomugil signifer	3505	-	3318	42	1	3427	5
Fistulariidae							
Fistularia commersonni	1	-	-	3	-	-	-

Table 4.20 Continued

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Syngnathidae							
Hippocampus breviceps	-	2	-	-	-	-	-
Hippocampus whitei	-	1	-	-	-	-	-
Syngnathoides biaculeatus	-	-	-	-	-	-	12
Vanacampus poecilolaemus	112	743	36	203	3	19	126
Urocampus carinirostris	191	73	125	173	315	771	100
Vanacampus phillipi	7	60	3	10	20	242	61
Stigmatophora nigra	46	216	56	45	-	-	41
Stigmatophora argus	-	277	-	52	-	9	163
Scorpaenidae							
Centropogon australis	102	23	118	21	4	83	31
Platycephalidae							
*Platycephalus fuscus**	-	-	-	-	1	-	-
Ambassidae							
Ambassis jacksoniensis	5746	9082	6478	14421	-	18081	1068
Terapontidae							
Pelates quadrilineatus	429	1006	96	596	-	298	52
Apogonidae							
Apogon limenus	-	-	-	-	-	-	1
Siphamia cephalotes	-	-	-	-	-	-	79
Dinolestidae							
*Dinolestes lewini**	-	-	-	-	-	1	-
Sillaginidae							
*Sillago flindersi**	-	-	-	-	8	-	-
*Sillago ciliata**	1	-	-	-	10	-	-
*Sillago maculata**	4	-	-	-	-	-	-
Pomatomidae							
*Pomatomus saltator**	157	135	369	28	-	211	10
Carangidae							
*Psuedocaranx dentex**	1	-	1	1	-	3	69

Table 4.20 Continued

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Sparidae							
*Acanthopagrus australis**	537	36	481	43	811	667	17
*Chrysophrys auratus**	-	2	11	-	-	-	18
*Rhabdosargus sarba**	27	5	9	1	-	44	10
Gerreidae							
*Gerres subfasciatus**	468	-	197	12	-	150	76
Lethrinidae							
Lethrinus genivittatus	-	1	4	-	-	-	-
Mullidae							
Upeneuss species	-	-	-	-	-	-	1
Upeneichthys species	-	-	-	-	-	-	3
*Upenus tragula**	2	1	-	-	-	-	-
*Parupeneus signatus**	3	-	-	-	-	-	4
Monodactylidae							
*Monodactylus argenteus**	31	22	16	22	-	30	-
Girellidae							
*Girella tricuspidata**	614	732	529	365	21	562	546
Scorpididae							
*Scorpis lineolatus**	5	65	1	1	-	-	5
*Scorpis species**	-	-	-	1	-	-	-
Microanthus striatus	-	6	-	-	-	-	-
Microanthus species	-	-	-	-	-	1	-
Enoplosidae							
Enoplosus armatus	19	7	2	3	-	-	2
Pomacentridae							
Abudefdus species	-	1	-	-	-	-	-
Mugilidae							
*Mugil cephalus**	157	146	246	1551	3	520	32
*Myxus elongatus**	90	260	880	126	4	136	84
*Liza argentea**	-	-	363	4	427	134	-

Table 4.20 Continued

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Sphyraenidae							
*Sphyraena flavicauda**	1	-	1	-	-	-	-
*Sphyraena species**	-	-	1	-	-	-	-
Sphyraena obtusa	-	5	-	-	-	-	-
Labridae							
*Achoerodus viridis**	115	21	58	8	35	6	78
Odacidae							
Odax acroptilus	-	2	-	-	-	-	-
Neodax balteatus	-	-	-	-	-	-	34
Haletta semifasciata	-	-	-	-	-	-	81
Scaridae							
Scarus species	-	-	-	1	-	-	-
Bovichtidae							
Pseudaphtitis urvilli	-	1	-	-	-	2	-
Blennidae							
Omobranchus anolius	-	1	-	-	-	3	-
Petroscirtes lupus	33	62	14	15	-	2	16
Clinidae							
Cristiceps argyropleura	-	-	-	-	-	2	-
Cristiceps australis	-	-	-	-	1	-	3
Heteroclinus perspicillatus	-	-	-	-	-	-	6
Callionymidae							
Repomucenus calcaratus	-	-	-	-	2	-	-
Galaxidae							
Galaxis maculatus	-	-	1	-	-	-	-
Gobiidae-subfamily Eleotridinae							
Philypnodon grandiceps	1440	38	3445	342	572	167	30
Philypnodon species	1	-	44	2	11	2	-
Hypseleotris compressa	-	-	8	1	-	-	-

Table 4.20 Continued

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Gobiidae							
Bathygobius kreffti	5	5	4	-	2	4	10
Favonigobius lateralis	47	131	398	44	19	17	369
Favonigobius exquisites	47	2	161	7	1934	65	30
Amoya bifrenatus	256	1	54	13	23	120	21
Amoya frenatus	435	1	46	15	157	325	61
Afurcagobius tamarensis	1151	72	1156	95	256	742	67
Pseudogobius olorum	1093	18	311	450	131	1507	7
Redigobius macrostoma	73	90	1057	164	35	5758	40
Gobiopterus semivestitus	3349	301	13908	358	4609	25997	6
Siganidae							
Siganus nebulosus	2	20	6	10	-	11	20
Bothidae							
*Pseudorhombus arsius**	-	-	-	-	1	-	2
*Pseudorhombus jenynsii**	-	-	-	-	3	1	-
Monacanthidae							
*Scobinichthys granulatus**	4	12	-	6	-	15	10
*Penicipelta vittiger**	1	2	-	-	-	-	2
Acanthaluteres spilomelanurus	7	132	10	6	-	22	96
Brachaluteres jacksonianus	2	1	-	-	-	-	10
*Monacanthus chinensis**	7	78	33	15	2	152	24
*Meuschenia freycineti**	155	117	211	110	5	163	106
*Meuschenia trachyylepis**	205	339	288	144	1	156	9
*Meuschenia species**	-	42	23	7	-	-	30
Nelusetta ayraudi	17	13	5	-	-	4	5

Table 4.20 Continued

FAMILY *species*	**Illawarra**	**St Georges Basin**	**Lake Conjola**	**Burrill Lake**	**Coila Lake**	**Wallaga Lake**	**Merimbula Lake**
Tetraodontidae							
Arothron firmamentum	3	-	-	3	-	-	-
Tetractenos hamiltoni	20	2	1	3	3	1	39
Tetractenos glaber	8	7	1	14	11	2	46
Diodontidae							
Dicotylichthys punctulatus	37	5	3	37	-	13	8
Numbers of fish caught	**27037**	**14850**	**36672**	**22153**	**41732**	**61492**	**5430**
Numbers of fish species caught	**56**	**60**	**56**	**53**	**41**	**52**	**61**

Total Number of Fish : 209 366

Total Number of Fish Species: 101

4.2.3 Fish Community Analyses (multivariate analysis)

Cluster analysis was performed on the seven lakes together by combining sampling events to investigate location within estuary effect (Figure 4.1A). The cluster analysis revealed separation into three major site groupings at 55% similarity. The first site group is comprised of all the Coila Lake samples, and is clearly separated from the other site groupings. Site Group 2 consists of all the Merimbula Lake samples, and the group then splits into another group consisting of all the samples from St Georges Basin, and the entrance samples from Lake Illawarra, Lake Conjola, and Burrill Lake. The third major site group consists of the central and upper samples from Burrill Lake, Lake Illawarra and Lake Conjola, and the last subgroup consists of all the Wallaga Lake samples. Thus, there is high degree of similarity between the different locations within Coila Lake, Merimbula Lake and Wallaga Lake. For the other lakes, the entrance samples are situated close together on the dendogram, while the central and upper location samples cluster together. Non-metric multidimensional scaling of the data reveal that the Coila Lake samples clearly separate from the other lakes in ordination space while the samples from the other six lakes cluster quite close together (Figure 4.1B).

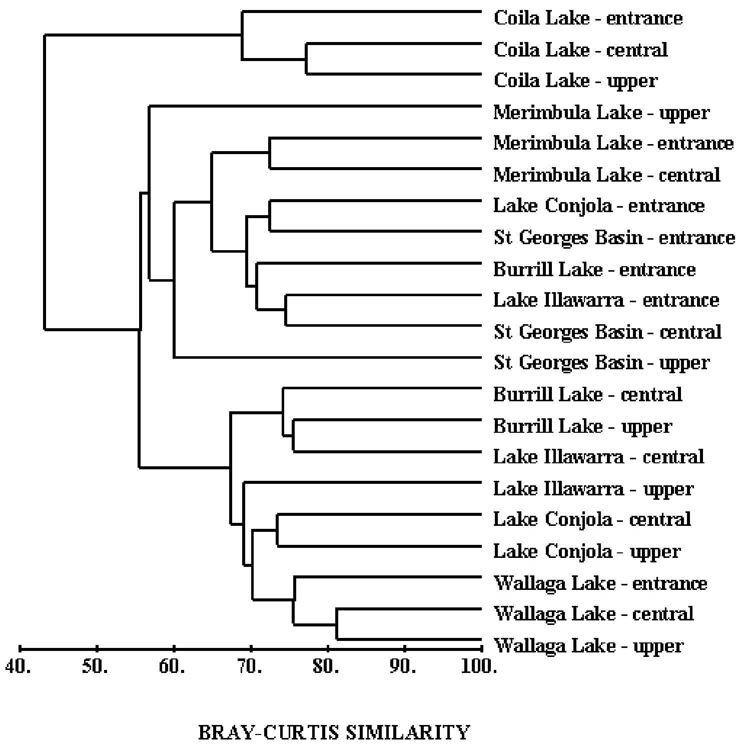
Within the major cluster the Merimbula Lake samples appear close together as do the Wallaga Lake samples. Thus, cluster analysis and MDS on the data from the seven lakes show that some of the same trends are apparent. No strong regional signal was discernable in the ordination of the data. The only pronounced division of samples was from those taken in Coila Lake.

However, this separation is unlikely to be due to regional differences in fish community structure, but may be a reflection of the morphology, entrance conditions and poor water quality causing differing biological patterns to occur. There is a high degree of similarity amongst the other lakes, with slight clustering of St Georges Basin and Burrill Lake samples, and the samples from Lake Illawarra and Lake Conjola having a higher degree of similarity between their fish assemblages. The Wallaga Lake samples always cluster very close together, and are more similar in their fish assemblages with Lake Illawarra and Lake Conjola (Figure 4.1B).

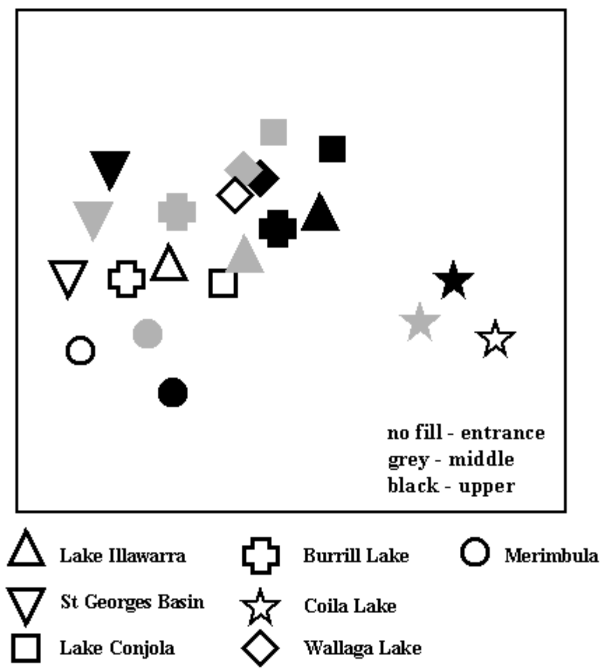
This sampling program has not tested directly for the impacts of commercial fishing an activity on shallow water fishes, however sampling was carried out at commercially fished and unfished locations. None of these data suggest that commercial fishing activities are a major influence on the shallow water fish comunities. On the contrary, Lake Merimbula, which is closed to commercial fishing and contains extensive areas of seagrass, had surprisingly low abundances of fishes (see Table 4.20).

Figure 4.1: **Multivariate analysis of the combined species abundance data for all seven "core" lakes, over the entire sampling period.**
(A) Dendogram showing results of cluster analysis.
(B) Ordination of MDS results.

A.



B.



4.2.4 Lake Illawarra

4.2.4.1 Introduction

Lake Illawarra (34^o 33'S, 150^o 52'E) has a catchment area of 150 km^2 and a water area of 36 km^2. It is classified as a barrier lagoon that is intermittently open. The lake has approximately 5.116 km^2 of seagrass area, comprising of *Zosteraceae* spp., *Ruppia* spp. and *Halophila* spp. (West et al., 1985). The annual commercial fisheries production (finfish only) for 1995/6 was 200 065 kg.yr^{-1}. The catchment of Lake Illawarra is dominated by urban and industrial land uses, disturbed freehold and leasehold (non-urban) land. The shoreline is in high use, with less than 25% in a natural condition (Bell & Edwards, 1980). A number of aboriginal sites of archaeological significance occur near the lake including a burial ground, quarry and open middens (Bell & Edwards, 1980).

During this project, sampling of shallow water fish in Lake Illawarra occurred at three locations (labelled entrance, central and upper sites) approximately quarterly for 3 years. Results have been summarised below.

4.2.4.2 Environmental Data

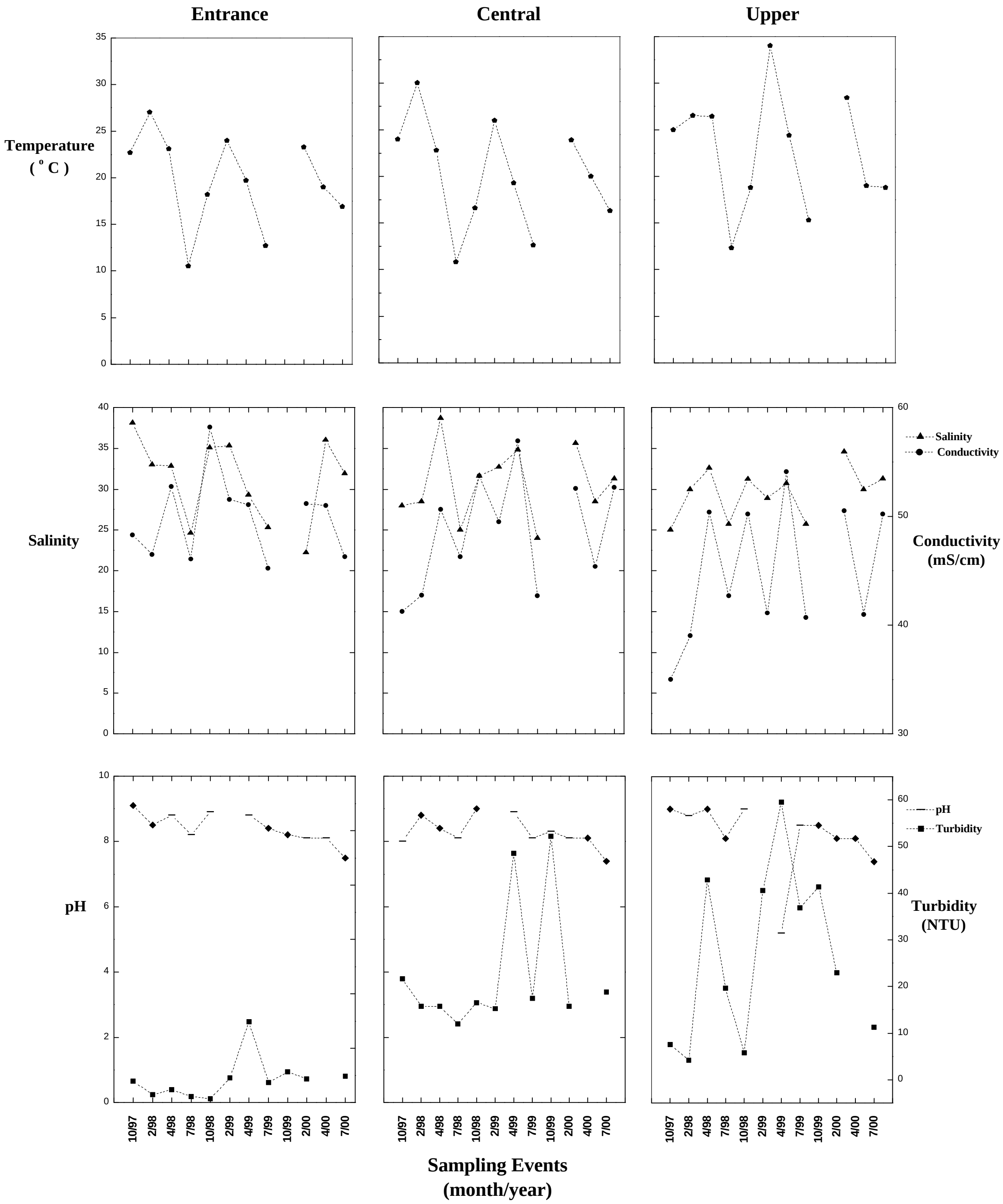
Lake Illawarra exhibited temperature ranges from a minimum of 10.5°C to a maximum of 34.0°C, and these minima and maxima values were related to seasonal effects (Figure 4.2). The very high temperature of 34.0°C recorded at the upper site is due to several reasons. The upper site of Lake Illawarra is a shallow bay, and at this sampling event the water level was low (only 0.3m) and there was a high air temperature, resulting in very warm water temperature.

Salinity and conductivity values were from a minimum salinity of 22.2‰ to a maximum of 38.7‰, and a minimum conductivity of 36.9 mS.cm^{-1} to a maximum conductivity of 57.6 mS.cm^{-1} (Figure 4.2). There were no major differences in salinity and conductivity between the three sites and the results did not follow the expected estuarine salinity gradient. Entrance salinity values ranged from 22.2‰ to 38.1‰, with the central site exhibiting salinity values from 24‰ to 38.7‰. The upper site also had values in this salinity range, from 25.7‰ to 34.6‰.

pH values were quite consistent throughout the sampling period, with the majority of samples ranging from 7.4 – 9.1. A pH value of 5.2 was recorded during February 1999 at the upper site, and this was substantially lower than any other value recorded in any of the lakes (Figure 4.2).

Turbidity values exhibited a similar pattern of change and values for the entrance and central site, but were quite erratic for the upper site. Turbidity ranges from 0.7 to 15.4 NTU at the entrance and central sites. At the upper region it ranged from 4.1 to 59.5 NTU (Figure 4.2). The highest values for turbidity of all the lakes were consistently recorded at the upper location of Lake Illawarra, which may be a reflection of the characteristics of this site. The shallowness of the bay causes the sediment, which is a thick mud silt, to be stirred up very easily when it is windy, resulting in high turbidity values.

Figure 4.2: Summary of environmental data for the entrance, central and upper locations within Lake Illawarra (1997-2000)



4.2.4.3 Shallow Water Fishes

A total of 27 037 fish were caught in Lake Illawarra over the three year sampling period (Table 4.21). Fifty-six fish species were found, of which twenty-four species are of significance to commercial and/or recreational fisheries. The seagrass fish fauna of Lake Illawarra consisted of small cryptic species that are of little commercial significance and juveniles of fish species that are considered to be of importance to commercial and recreational fisheries. The majority of fish species caught were in the length range of 5–150mm.

The most specious families collected were the Gobiidae (11 species), Monacanthidae (8 species) and the Syngnathidae (4 species). In terms of individual numbers, members of the Gobiidae (7897 individuals), Atherinidae (6238), Ambassidae (5746), and Psuedomugilidae (3505) dominated the seagrass assemblage and constituted approximately 87% of the total catch. These taxa were caught in differing abundances at locations, with some taxa showing restrictions in where they were found. Southern blue-eye (*Pseudomugil signifer*) was caught only at the upper location, while (long-finned goby (*Favonigobius lateralis*) had preference for the entrance site.

Small mouth hardyhead (*Atherina microstoma*), half-bridled goby (*Amoya frenatus*), Tamar River goby (*Afurcagobius tamarensis*), blue spotted goby (*Pseudogobius olorum*) and glass goby (*Gobiopterus semivestitus*) were consistently found in higher abundance at the upper location throughout the sampling period. Large numbers of these schooling species was the main reason that the highest number of individuals was caught at the upper site (14 548 individuals). Less than half the number of individuals were caught at the entrance and central locations combined (Table 4.21). These small, cryptic, non-commercial species are an important food source to many species of bird and fish, and thus the upper region of an estuary may be an important area to protect for this reason.

Dominant among the finfish catches from Lake Illawarra were luderick (*Girella tricuspidata*), silver biddies (*Gerres subfasciatus*), yellowfin bream (*Acanthapagrus australis*), yellow-finned leatherjacket (*Meuschenia trachylepis*) and sea mullet (*Mugil cephalus*). These commercial species were found at all of the sites, but the abundance differed between the sites. Yellwofin bream (*Acanthapagrus australis*) and silver biddies (*Gerres subfasciatus*) were caught in higher abundances at the upper site, whereas luderick (*Girella tricuspidata*) and yellow-finned leatherjacket (*Meuschenia trachylepis*) were found more frequently at the entrance and central location (Table 4.21).

Seven species were caught one only one occasion and these include sandy sprat (*Hyperlophus vittatus*), silver trevally (*Pseudocaranx dentex*) and the long-jawed sea pike (*Sphyraena flavicauda*). There were no species that were found only in Lake Illawarra.

Table 4.21: Total number of fish caught by each species, at the entrance location, central location and upper location within Lake Illawarra during pooled across sampling events from July 1997 to July 2000. (* indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Clupeidae	0	1	0	1
*Hyperlophus vittatus**				
Hemiramphidae				
*Hyporhamphus australis**	1	21	6	28
Atherinidae				
Atherinasoma microstoma	65	1842	4177	6084
Atherinasoma elongata	88	51	15	154
Fistulariidae				
Fistularia commersonni	1	0	0	1
Pseudomuglidae				
Pseudomugil signifer	0	0	3505	3505
Syngnathidae				
Vanacampus poecilolaemus	109	3	0	112
Urocampus carinirostris	15	49	127	191
Vanacampus phillipi	7	0	0	7
Stigmatophora nigra	46	0	0	46
Scorpaenidae				
Centropogon australis	28	73	1	102
Ambassidae				
Ambassis jacksoniensis	4182	1471	93	5746
Terapontidae				
Pelates quadrilineatus	133	199	97	429
Sillaginidae				
*Sillago ciliata**	1	0	0	1
*Sillago maculata**	0	0	4	4
Pomatomidae				
*Pomatomus saltator**	16	4	137	157
Carangidae				
*Pseudocaranx dentex**	1	0	0	1
Sparidae				
*Acanthopagrus australis**	36	213	288	537
*Rhabdosargus sarba**	0	26	1	27
Gerreidae				
*Gerres subfasciatus**	1	139	328	468
Mullidae				
*Upenus tragula**	2	0	0	2
*Parupeneus signatus**	3	0	0	3
Monodactylidae				
*Monodactylus argenteus**	1	8	22	31

Table 4.21 Continued

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Girellidae				
*Girella tricuspidata**	287	262	65	614
Scorpididae				
*Scorpis lineolatus**	5	0	0	5
Enoplosidae				
Enoplosus armatus	19	0	0	19
Mugilidae				
*Myxus elongatus**	6	54	30	90
*Mugil cephalus**	80	30	47	157
Sphyraenidae				
*Sphyraena flavicauda**	0	1	0	1
Labridae				
*Achoerodus viridis**	113	2	0	115
Blennidae				
Petroscirtes lupus	31	1	1	33
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	6	916	518	1440
Philypnodon species	0	0	1	1
Gobiidae				
Favonigobius lateralis	45	1	1	47
Favonigobius exsquisites	2	3	42	47
Amoya bifrenatus	0	12	244	256
Amoya frenatus	2	85	348	435
Bathygobius kreffti	4	0	1	5
Afurcagobius tamarensis	73	170	908	1151
Pseudogobius olorum	8	42	1043	1093
Redigobius macrostoma	13	48	12	73
Gobiopterus semivestitus	364	517	2468	3349
Siganidae				
Siganus nebulosus	1	1	0	2
Bothidae				
*Pseudorhombus arsius**	1	0	0	1
Monacanthidae				
Acanthaluteres spilomelanurus	6	1	0	7
*Scobinichthys granulatus**	4	0	0	4
*Penicipelta vittiger**	1	0	0	1
*Monacanthus chinensis**	5	1	1	7
Brachaluteres jacksoniensis	2	0	0	2
*Meuschenia freycineti**	77	74	4	155
*Meuschenia trachyylepis**	70	128	7	205
Nelusetta ayraudi	8	9	0	17
Tetraodontidae				
Tetractenos hamiltoni	11	5	4	20
Tetractenos glaber	6	1	1	8
Arothron firmamentum	3	0	0	3
Diodontidae				
Dicotylichthys punctulatus	4	32	1	37
Total individuals	**5993**	**6496**	**14548**	**27037**
Total species	**49**	**38**	**35**	**56**

4.2.4.4 Fish Abundances and Diversities

Preliminary statistical analyses of the catches from Lake Illawarra have been carried out and are shown in Tables 4.22 and 4.23. For mean numbers of fish captured, there are significant differences between locations within Lake Illawarra and between sampling events, and there are significant interactions between these two factors (Table 4.22). Means comparisons tests indicate a large number of significant differences between individual means, without any general patterns of note. All locations had some seasonal changes and these will be investigated in more detail in future publications (Figure 4.3A).

Table 4.22: Results of ANOVA for numbers of fish captured in Lake Illawarra over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	7.501773	3.750886	24.49	0.000000*	0.999998
B: Sampling Event	11	20.87969	1.898153	12.39	0.000000*	1.000000
AB	22	12.11403	0.5506379	3.59	0.000005*	0.999959

* Term significant at alpha=0.05

There were no signicant differences in mean numbers of species between locations within Lake Illawarra, however significant differences did exist between sampling events (Table 4.23). Highest numbers of fish species were found in spring and summer of the second year of sampling, and lowest during the winter sampling of the first and third year (Figure 4.3B).

Table 4.23: Results of ANOVA for numbers of fish species captured in Lake Illawarra over (factors are Location and Sampling Event).

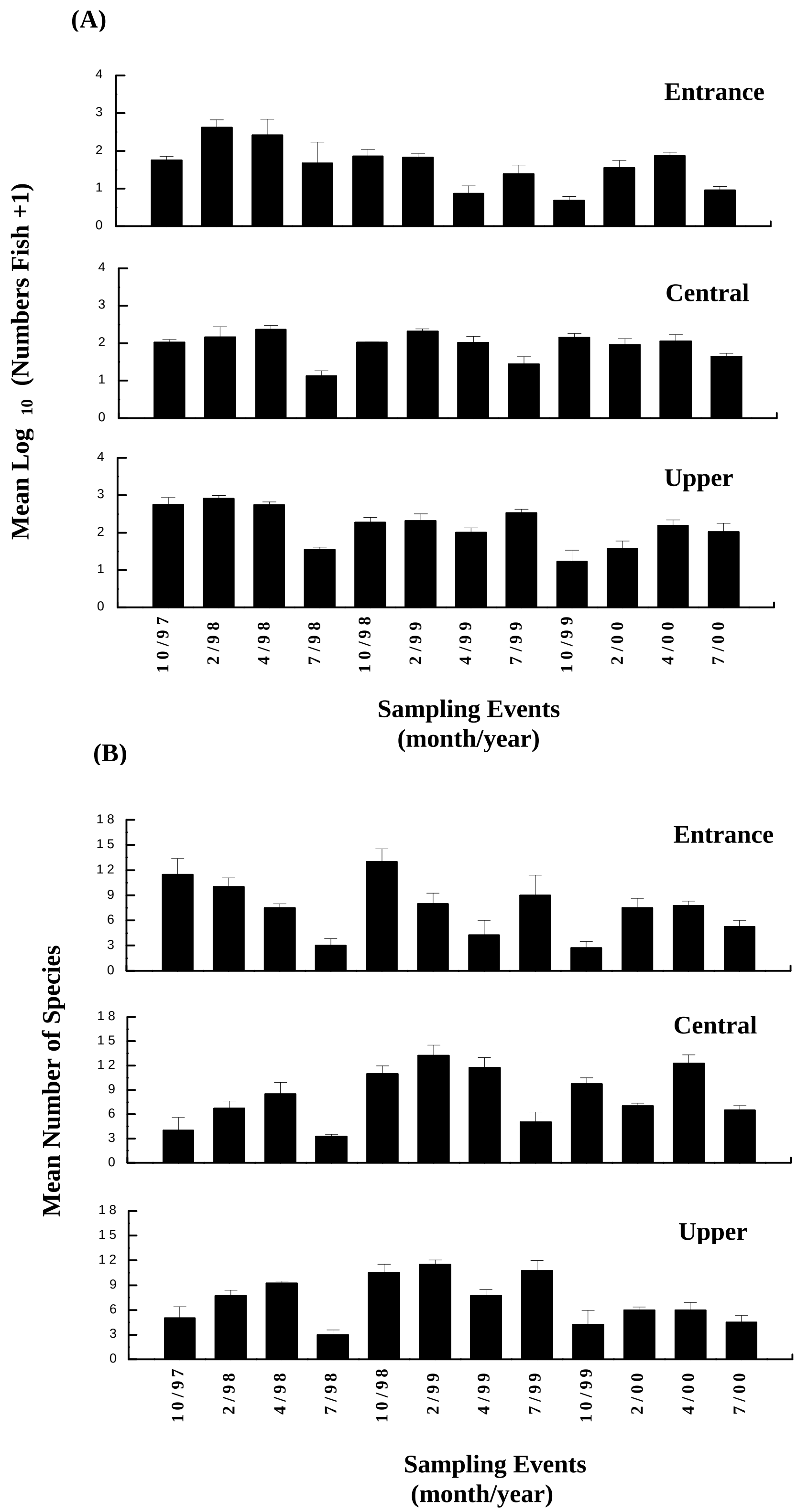
Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	27.54167	13.77083	2.23	0.112934	0.445241
B: Sampling Event	11	697.3542	63.39583	10.25	0.000000*	1.000000
AB	22	605.2917	27.51326	4.45	0.000000*	0.999999

* Term significant at alpha=0.05

4.2.4.5 Patterns in Shallow Water Fish Communities

Multivariate analysis of the fish community data for Lake Illawarra revealed that there was some degree of clustering based on locations within the estuary. There was a pattern of the majority of the entrance samples clustering in site groups together in the central of the dendogram (not included), with the other site groups representing a combination of the central and upper samples. There was also a pattern of the first year samples taken at the central and upper locations concentrating together, and the second year central and upper samples situated together. The MDS analysis revealed that the stress ordination values for the two-dimensional analysis were high, ranging from 0.15 to 0.22. Clarke (1993) suggested that, while stress values of less than 0.1 give excellent representation of community data in ordination space, less reliance should be placed on the results where the stress values are in the order of 0.2.

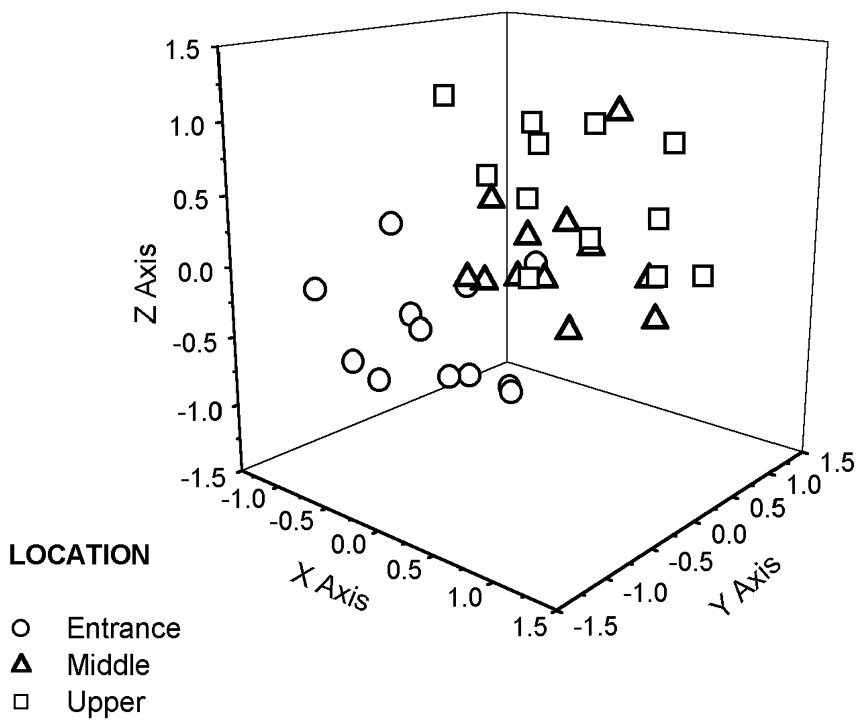
Figure 4.3: Mean numbers of fish (A) and mean number of fish species (B) caught in Lake Illawarra at the entrance, central and upper locations over the sampling period. Bars denote standard error.



It was therefore decided that two-dimensional ordination plots were not an adequate representation of data. As a result, three-dimensional ordination have been adopted in this study and provide much lower stress values, and hence greater assurance of an adequete representation of data in ordination plots.

Visual representation of the clustering through MDS revealed that there was no distinct clustering among sites from different locations within estuaries, and there was a lack of sharp differentiation associated with different sampling events, on the basis of the distribution and abundance of the seagrass fish fauna (Figure 4.4). Thus, while the clustering showed that there was a degree of separation among sites, the MDS indicates there is a high degree of similarity between the samples within the lake, with the majority of the samples clustering closely together.

Figure 4.4: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of Lake Illawarra for each of the sampling periods. (Stress = 0.12).



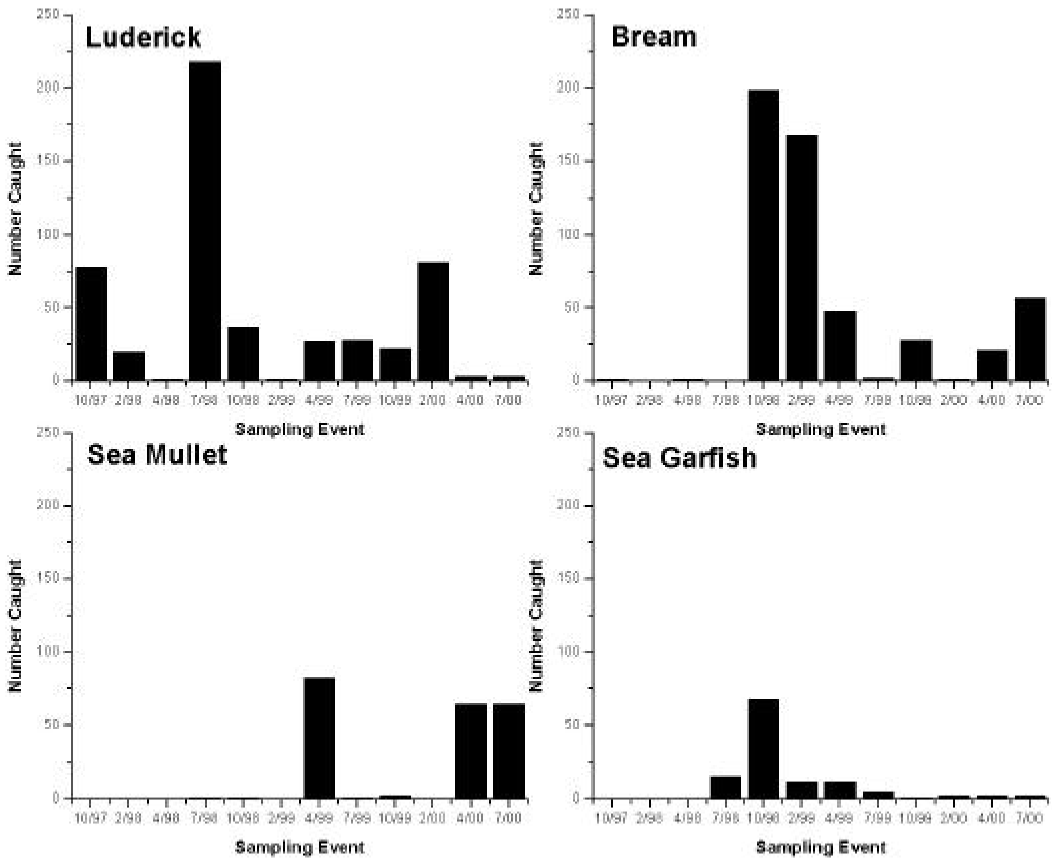
4.2.4.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in Lake Illawarra, only a limited number of species have been investigated, namely: luderick, yellowfin bream, sea mullet and sea garfish. Numbers of new recruits have been pooled for each sampling event.

For the species analysed, new recruits (fish <50 mm in fork length) were found during most sampling events (Figure 4.5). Recruitment for luderick and yellowfin bream was strongest in the spring and summer of the second year (10/98 and 2/99 in Figure 4.5).

Figure 4.5: Numbers of new recruits of luderick, yellowfin bream, sea mullet and sea garfish, captured during sampling of Lake Illawarra. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.5 St Georges Basin

4.2.5.1 Introduction

St Georges Basin (35^o 11'S, 150^o 36'E) has a catchment area of 390 km^2 and water area of 38.859 km^2. It is a barrier lagoon that remains open to the sea. It has approximately 8.538 km^2 of seagrass area that contains *Zosteraceae* spp., *Posidonia australis, Halophila* spp. and *Ruppia* spp. (West et al., 1985). Commercial fisheries production over the 1995/6 period was 106 751 kg. St Georges Basin has low to moderate catchments use and disturbance, with approximately 50-70% of continuous shoreline in natural condition (Bell and Edwards, 1980). Land uses surrounding the basin include; freehold land, Crown land, urban and industrial, and national park/nature reserve exists on one small section of the lake. Extensive clearing of freehold land is of concern and may impact on the lake's water quality in the future (Bell & Edward, 1980).

4.2.5.2 Environmental Data

Figure 4.6 presents data collected for a number of environmental varaiables. Water temperature measured in the field ranged from 9.3 °C to 28.0 °C during the study period, and each location exhibited a very similar pattern of seasonal temperature change. The salinity in St Georges Basin was very consistent throughout the estuary, with values ranging from 29‰ to 36.9‰ at the entrance, 22‰ to 35.1‰ at the central, and the upper salinity values were in the range of 24‰ to 33.8‰. Conductivity values were from a minimum of 33.8mS/cm to a maximum conductivity of 55.5mS/cm. pH values were very consistent over time and between locations, with values in the range of 7.9 to 8.9. Turbidity values were always very low for St Georges Basin, within the range of 0.46 NTU to 4.26 NTU.

4.2.5.3 Shallow Water Fishes

Over the three-year study period 14 850 fish were caught in St Georges Basin, representing 60 species of which 20 species are considered important to commercial and recreational fisheries (Table 4.24). When compared to the other estuaries, St Georges Basin had one of the most diverse fish community but a low number of fish. St Georges Basin seagrass fish fauna was dominated by non-commercial species, with a seasonal contribution from juveniles of commercially important species. The families with the most species collected were the Gobiidae (10 species), Monacanthidae (9 species) and the Syngnthidae (7 species). In terms of abundance if fish, the catch was dominated by glassy perchlet (*Ambassis jacksoniensis*, 9082 individuals), trumpeter (*Pelates quadrilineatus,* 1006 individuals) and long-snout pipefish (*Vanacampus poecililaemus,* 743 individuals). These species were caught in differing abundance throughout the lake. Glassy perchlets (*Ambassis jacksoniensis*) were caught in high abundance at all the locations, while the long-snout pipefish (*Vanacampus poecilolaemus*) were found at the entrance and upper locations in higher numbers. In the commercial finfish category, luderick (*Girella tricuspidata*), yellow-finned leatherjacket (*Meuschenia trachylepis*), sand mullet (*Myxus elongatus*), sea mullet (*Mugil cephalus*) and tailor (*Pomatomus saltator*) were the dominant species caught in St Georges Basin.

Figure 4.6: Summary of environmental data for the entrance, central and upper locations within St Georges Basin (1997-2000).

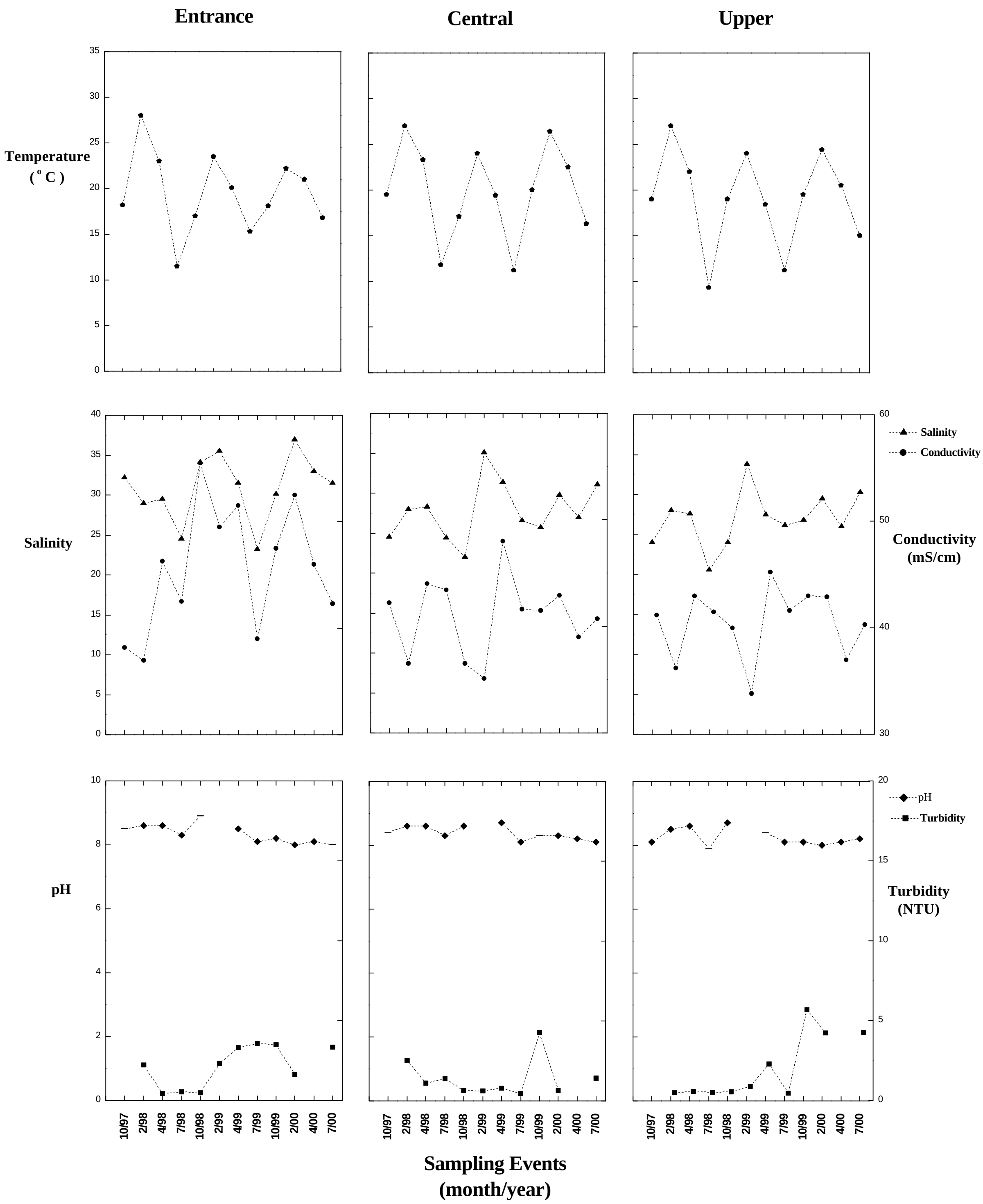


Table 4.24: Total number of fish caught by each species, at the entrance location, central location and upper location within St Georges Basin during pooled across sampling events from July 1997 to July 2000. (* indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Clupeidae				
*Hyperlophus vittatus**	3	0	0	3
Plotosidae				
Cnidoglanis macrocephalus	0	2	0	2
Hemiramphidae				
*Hyporhamphus australis**	0	2	0	2
Belonidae				
*Tylosurus gavialoides**	0	0	2	2
Strongylura leiura	0	0	1	1
Atherinidae				
Atherinasoma microstoma	3	26	0	29
Atherinasoma elongata	38	327	23	388
Syngnathidae				
Hippocampus breviceps	0	1	1	2
Hippocampus whitei	1	0	0	1
Vanacampus poecilolaemus	292	16	435	743
Urocampus carinirostris	27	15	31	73
Vanacampus phillipi	23	15	22	60
Stigmatophora nigra	173	1	42	216
Stigmatophora argus	1	1	275	277
Scorpaenidae				
Centropogon australis	7	13	3	23
Ambassidae				
Ambassis jacksoniensis	3565	3293	2224	9082
Terapontidae				
Pelates quadrilineatus	127	823	56	1006
Pomatomidae				
*Pomatomus saltator**	91	8	36	135
Sparidae				
*Acanthopagrus australis**	5	13	18	36
*Rhabdosargus sarba**	0	0	5	5
*Chrysophrys auratus**	2	0	0	2
Lethrinidae				
Lethrinus genivittatus	1	0	0	1
Mullidae				
*Upenus tragula**	1	0	0	1
Monodactylidae				
*Monodactylus argenteus**	3	13	6	22
Girellidae				
*Girella tricuspidata**	129	522	81	732
Scorpididae				
*Scorpis lineolatus**	65	0	0	65
*Microanthus strigatus**	0	6	0	6

Table 4.24 Continued

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Enoplosidae				
Enoplosus armatus	5	2	0	7
Pomacentridae				
Abudefduf species	0	0	1	1
Mugilidae				
*Myxus elongatus**	251	4	5	260
*Mugil cephalus**	28	97	21	146
Sphyraenidae				
Sphyraena obtusata	3	2	0	5
Labridae				
*Achoerodus viridis**	15	6	0	21
Odacidae				
Odax acroptilus	2	0	0	2
Bovichthyidae				
Pseudaphritis urvillii	1	0	0	1
Blennidae				
Petroscirtes lupus	43	19	0	62
Omobranchus anolius	0	0	1	1
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	35	3	0	38
Gobiidae				
Favonigobius lateralis	127	1	3	131
Favonigobius exsquisites	1	0	1	2
Amoya bifrenatus	1	0	0	1
Amoya frenatus	0	0	1	1
Bathygobius kreffti	5	0	0	5
Afurcagobius tamarensis	26	3	43	72
Pseudogobius olorum	4	3	11	18
Redigobius macrostoma	29	15	46	90
Gobiopterus semivestitus	4	54	243	301
Siganidae				
Siganus nebulosus	19	1	0	20
Monacanthidae				
Acanthaluteres spilomelanurus	129	3	0	132
*Scobinichthys granulatus**	11	1	0	12
*Penicipelta vittiger**	0	2	0	2
*Monacanthus chinensis**	19	5	54	78
Brachaluteres jacksoniensis	1	0	0	1
*Meuschenia freycineti**	44	52	21	117
*Meuschenia trachyylepis**	175	135	29	339
Nelusetta ayraudi	13	0	0	13
Meuschenia species	41	0	1	42
Tetraodontidae				
Tetractenos hamiltoni	1	1	0	2
Tetractenos glaber	4	3	0	7
Diodontidae				
Dicotylichthys punctulatus	0	2	3	5
Total individuals	**5594**	**5511**	**3745**	**14850**
Total species	**48**	**40**	**33**	**60**

Ten species were caught only on one occasion and these include a seahorse species, White's seahorse (*Hippocampus whitei*), from the Syngnathidae family and species such as bar-tailed goatfish (*Upeneus tragula*) and the oyster blenny (*Omobranchus anolius*). Nine fish species were unique to St Georges Basin, such as the estuary catfish (*Cnidoglanis macrocephalus*), two species of longtom (Belonidae) and two seahorse species (*Hippocampus breviceps* and *Hippocampus whitei*).

4.2.5.4 Fish Abundances and Diversities

Preliminary statistical analyses for the catches from St Georges Basin have been carried out are shown in Tables 4.25 and 4.26.

There were significant differences in the mean numbers of fish captured in St Georges Baisn between both locations within the estuary and between sampling events. There were also significant interactions between these two factors (Table 4.25). Means comparisons tests indicated there was no consistent pattern in the mean numbers of fishes between location and sampling event, but this will be investigated further in later publications (see also Figure 4.7A).

Table 4.25: Results of ANOVA for numbers of fish captured in St Georges Basin over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	0.8011317	0.4005659	3.28	0.041541*	0.611791
B: Sampling Event	11	10.48681	0.9533464	7.80	0.000000*	1.000000
AB	22	14.73359	0.6697088	5.48	0.000000*	1.000000

* Term significant at alpha=0.05

In similarity with Lake Illawarra, no significant differences were found between mean numbers of species between locations within St Georges Basin, but there were significant differnces between sampling events and an interaction between the two factors (Table 4.26). In general, winter sampling events tended to have lowest species diversity (Figure 4.7B).

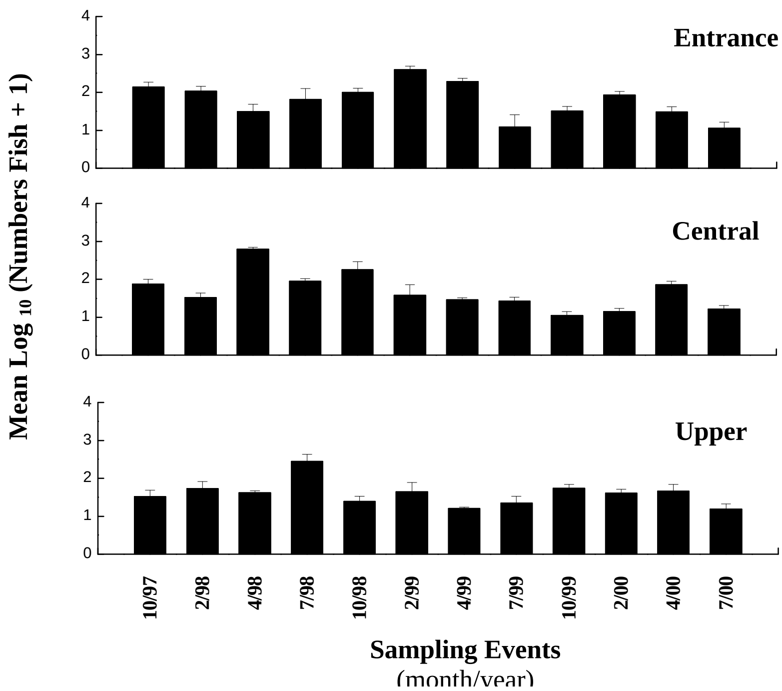
Table 4.26: Results of ANOVA for numbers of fish species captured in St Georges Basin over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	13.51389	6.756945	1.32	0.270878	0.280409
B: Sampling Event	11	323.3889	29.39899	5.75	0.000000*	0.999971
AB	22	293.6528	13.34785	2.61	0.000567*	0.997841

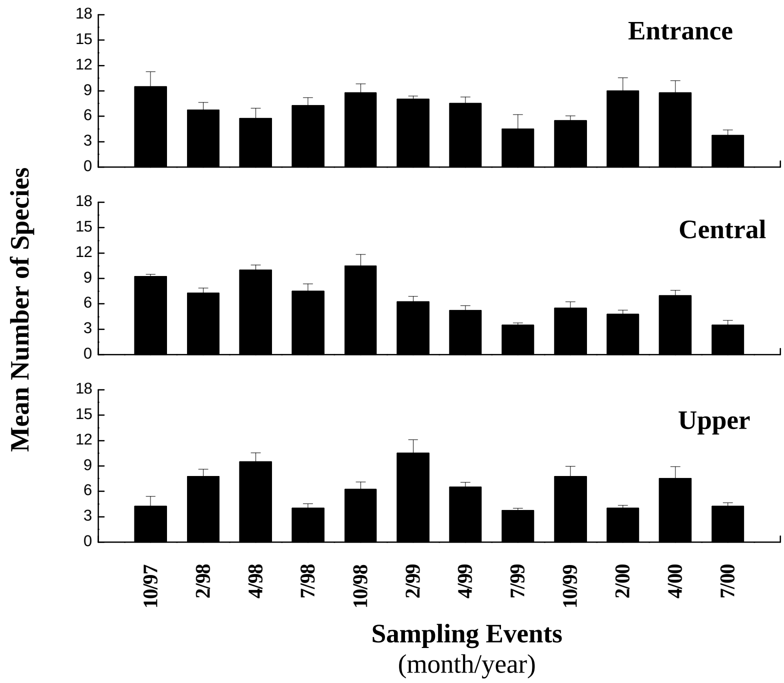
* Term significant at alpha=0.05

Figure 4.7: Mean numbers of fish (A) and mean number of fish species (B) caught in St Georges Basin at the entrance, central and upper locations over the sampling period. Bars denote standard error.

(A)



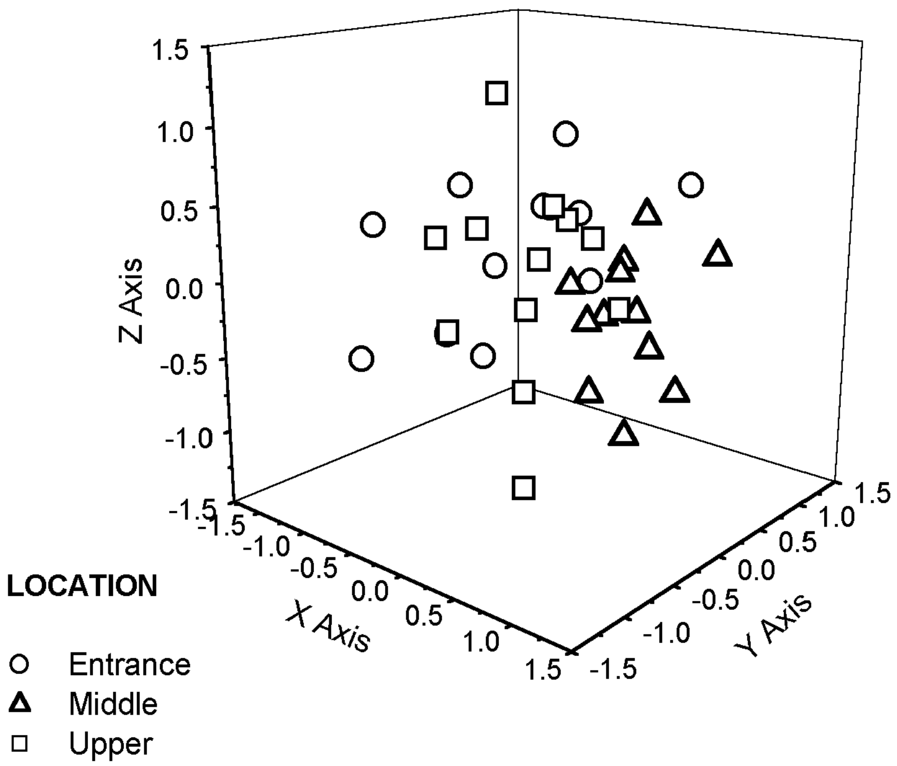
(B)



4.2.5.5 Patterns in Shallow Water Fish Communities

Cluster analysis of the fish assemblage found in St Georges Basin showed that there was no distinctive separation of the samples on the basis of fish assemblages at locations, sampling events or years (not included). The sample taken at the entrance during July 1999 constituted a site group and this appeared as an outlier. This sample contained the lowest number of fish found in St Georges Basin over the study period. The three-dimensional MDS ordination plot shows that while there is no clear separation of the localities, there is some degree of clustering. Samples from the central sites tended to cluster close together and half of the upper site samples form a separate cluster to the rest of the samples (Figure 4.8).

Figure 4.8: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of St Georges Basin for each of the sampling periods. (stress = 0.12).



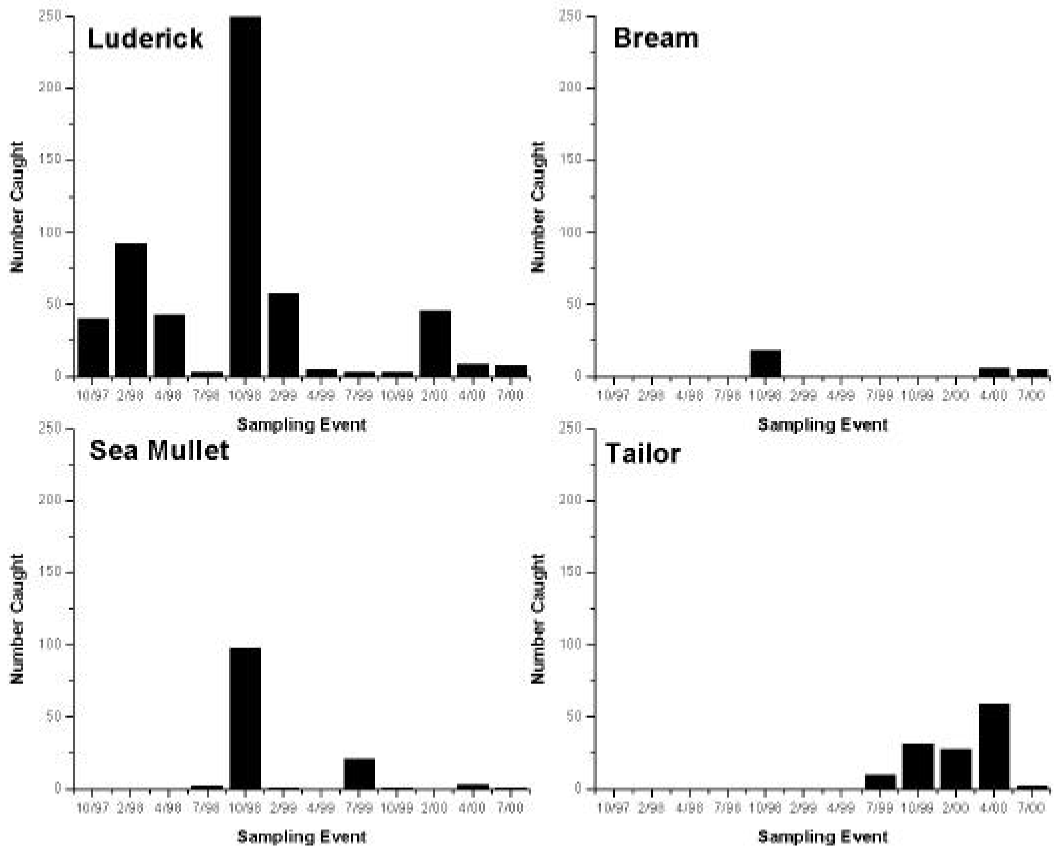
4.2.5.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in St Georges Basin, only a limited number of species have been investigated, namely: luderick, yellowfin bream, sea mullet and tailor. Numbers of new recruits have been pooled for each sampling event.

For the species analysed, new recruits (fish <50 mm in fork length) were found during most sampling events (Figure 4.5). Recruitment for luderick was strongest in the spring and summer of the second year (10/98 and 2/99 in Figure 4.9). Recruitment of tailor was strongest in the third year. These patterns require further detailed examination.

Figure 4.9: Numbers of new recruits of luderick, yellowfin bream, sea mullet and tailor, captured during sampling of St Georges Basin. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.6 Lake Conjola

4.2.6.1 Introduction

Lake Conjola (35^o 16’s, 150^o 30’E) is a barrier lagoon that has little infilling and is intermittently open/closed. Its catchment area is 145 km^2, with the area of water being 5.84 km^2. The lake has approximately 0.527 km^2 of seagrass area, which is dominated by *Zosteraceae spp*. and *Halophila spp*. (West et al., 1985). The commercial fisheries production for the period 1995/6 was 14 159 kg. Lake Conjola is a popular tourist and holiday destination, with caravan parks, urban and industrial land uses situated at the entrance and central reaches of the lagoon. These activities have resulted in deterioration of the water quality in the lake, mainly due to septic overflows. On the eastern side of the lake, there is a large tract of natural bushland situated on Crown Land (Bell & Edwards, 1980).

4.2.6.2 Environmental Data

Lake Conjola exhibited temperature ranges from a minimum temperature of 11.2°C to a maximum temperature of 29°C, and these minima and maxima values were related to seasonal effects (Figure 4.10). There was a large range in the salinity and conductivity values recorded for Lake Conjola, with a similar pattern of change occurring at each location. At entrance, salinity and conductivity values were from a minimum salinity of 19.2‰ to a maximum of 37.5‰, and a minimum conductivity of 26.7 mS/cm to a maximum conductivity of 57.5 $mS.cm^{-1}$ (Figure 4.10). The central location had similar values with salinity ranging from 15.9 ‰ to 36.3 ‰, and conductivity in the range of 26.7 to 55.9 $mS.cm^{-1}$. The upper location experienced the largest fluctuations in salinity values, ranging from 6.75‰ in October 1997 to a maximum of 34.2‰ the same time the following year, and conductivity ranged from 12.6 mS/cm to 54.6 $mS.cm^{-1}$ (Figure 4.10). The changes in salinity values recorded at the upper location are due to a freshwater input that is situated close to the sampling site. pH values were quite consistent throughout the sampling period and across localities, ranging from 7.5 – 9.0. Turbidity values were the lowest at the entrance site ranging from 0.5 to 4.84 NTU. At the central and upper region, turbidity values were similar, ranging from a minimum of 0.55 to a maximum of 14.1 NTU (Figure 4.10).

4.2.6.3 Shallow Water Fishes

A total of 36 672 fish were caught in Lake Conjola, representing 56 fish species of which 23 species are considered to be of significance to commercial and recreational fisheries (Table 4.27). High numbers of small cryptic fish species dominated the assemblage, followed by juveniles of commercial and recreationally important fish species. The most specious families collected in Lake Conjola were the Gobiidae (12 species), Monacanthidae (6 species) and the Syngnathidae (4 species). The total catch was dominated by glass goby (G*obiopterus semivestitus*, 13 908 individuals), glassy perchlets (*Ambasis jacksoniensis*, 6478), flatheaded gudgeon (*Philypnodon grandiceps* (3445) and southern blue-eye (*Psuedomugil signifer*, 3318). The finfish catches from Lake Conjola were comprised of species from the Muglidae family, with high numbers of sand mullet (*Myxus elongatus*) caught, together with flat-tail mullet (*Liza argentea*) and sea mullet (*Mugil cephalus*) and catches of yelowfin bream

(*Acanthopagrus australis*), luderick (*Girella tricuspidata*) and yellow-fin leatherjacket (*M. trachylepis*).

Figure 4.10: Summary of environmental data for the entrance, central and upper locations within Lake Conjola (1997-2000).

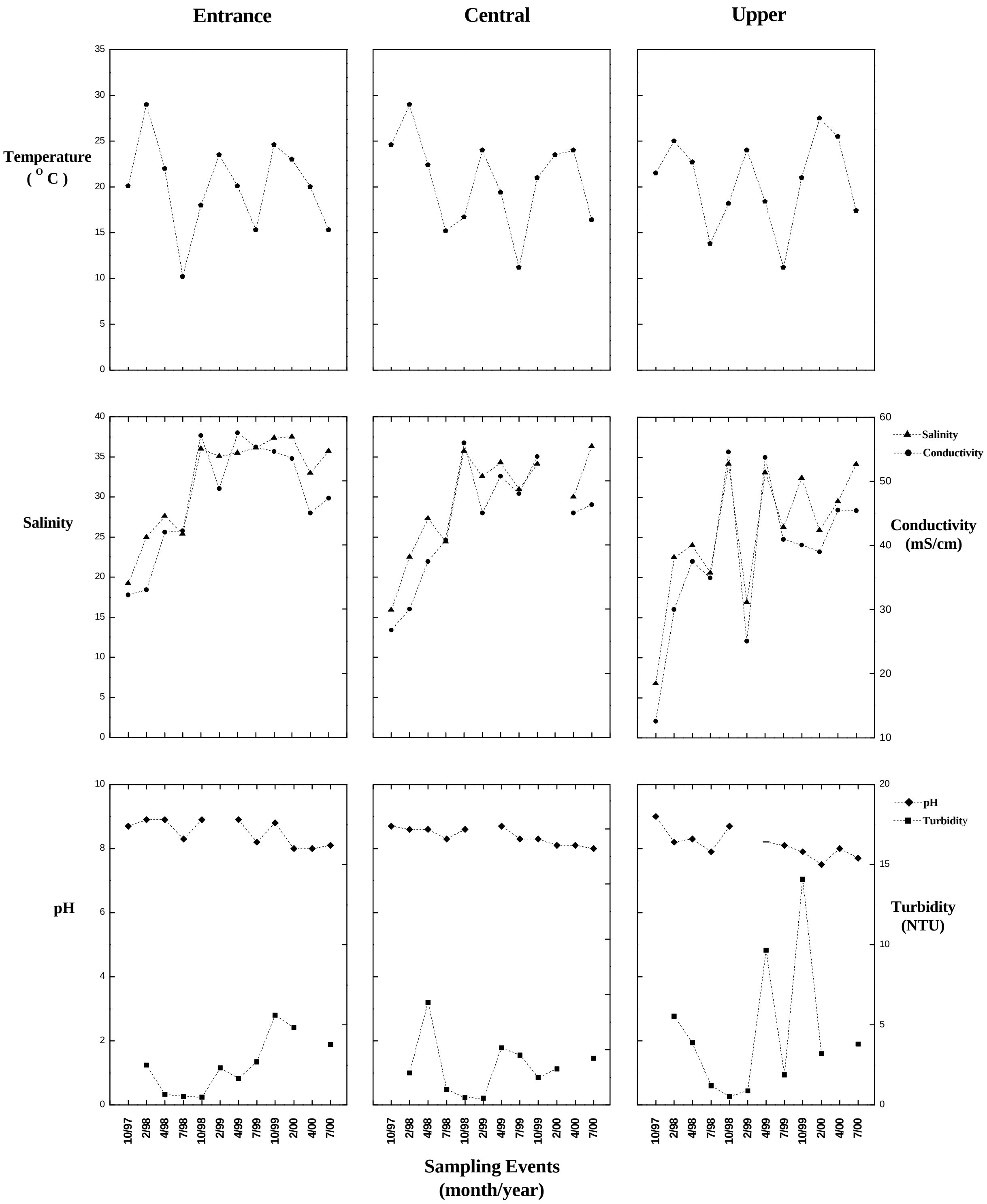


Table 4.27: Total number of fish caught by each species, at the entrance location, central location and upper location within Lake Conjola during pooled across sampling events from July 1997 to July 2000. (* indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Clupeidae				
*Sardinops neopilchards**	0	1	0	1
*Hyperlophus vittatus**	1	0	0	1
Anguillidae				
*Anguilla reinhardtii**	0	1	0	1
Antennariidae				
Antennarius striatus	1	0	0	1
Hemiramphidae				
*Hyporhamphus australis**	0	11	1	12
Atherinidae				
Atherinasoma microstoma	1723	0	5	1728
Atherinasoma elongata	338	2	0	340
Pseudomuglidae				
Pseudomugil signifer	80	1858	1380	3318
Syngnathidae				
Vanacampus poecilolaemus	33	2	1	36
Urocampus carinirostris	56	30	39	125
Vanacampus phillipi	3	0	0	3
Stigmatophora nigra	55	0	1	56
Scorpaenidae				
Centropogon australis	107	11	0	118
Ambassidae				
Ambassis jacksoniensis	745	5616	117	6478
Terapontidae				
Pelates quadrilineatus	46	48	2	96
Pomatomidae				
*Pomatomus saltator**	144	152	73	369
Carangidae				
*Pseudocaranx dentex**	0	1	0	1
Sparidae				
*Acanthopagrus australis**	80	321	80	481
*Chrysophrys auratus**	11	0	0	11
*Rhabdosargus sarba**	0	6	3	9
Gerreidae				
*Gerres subfasciatus**	8	73	116	197
Lethrinidae				
Lethrinus genivittatus	4	0	0	4
Monodactylidae				
*Monodactylus argenteus**	0	16	0	16
Girellidae				
*Girella tricuspidata**	165	315	49	529
Scorpididae				
*Scorpis lineolatus**	1	0	0	1
Enoplosidae				
Enoplosus armatus	3	0	0	3

Table 4.27 Continued

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Mugilidae				
*Myxus elongatus**	4	771	105	880
*Mugil cephalus**	29	191	26	246
*Liza argentea**	0	330	33	363
Sphyraenidae				
*Sphyraena flavicauda**	0	1	0	1
*Sphyraena species**	0	1	0	1
Labridae				
*Achoerodus viridis**	56	2	0	58
Blennidae				
Petroscirtes lupus	14	0	0	14
Galaxaiidae				
Galaxis maculatus	0	1	0	1
Gobiidae – subfamily Eleotridinae				
Philypnodon grandicep	210	2414	821	3445
Philypnodon species	0	15	29	44
Hypseleotris compressa	4	3	1	8
Gobiidae				
Favonigobius lateralis	382	9	7	398
Favonigobius exsquisites	1	105	55	161
Amoya bifrenatus	14	34	6	54
Amoya frenatus	19	25	3	46
Bathygobius kreffti	2	0	2	4
Afurcagobius tamarensis	26	704	424	1156
Pseudogobius olorum	25	226	60	311
Redigobius macrostoma	19	677	361	1057
Gobiopterus semivestitus	9	3207	10692	13908
Siganidae				
Siganus nebulosus	6	0	0	6
Monacanthidae				
Acanthaluteres spilomelanurus	2	8	0	10
*Monacanthus chinensis**	8	22	3	33
*Meuschenia freycineti**	31	175	5	211
*Meuschenia trachyylepis**	21	257	10	288
*Meuschenia species**	21	2	0	23
Nelusetta ayraudi	4	1	0	5
Tetraodontidae				
Tetractenos hamiltoni	1	0	0	1
Tetractenos glaber	1	0	0	1
Diodontidae				
Dicotylichthys punctulatus	1	0	2	3
Total individuals	**4516**	**17645**	**14511**	**36672**
Total species	**44**	**41**	**31**	**56**

Eight species were found on one occasion only, and include such commercial fish species as pilchard (*Sardinops neopilchards*), sandy sprat (*Hyperlophus vittatus*) and silver sweep (*Scorpis lineolatus*). There were four species that were unique to Lake Conjola. Examples are the striped anglerfish (*Antennarius striatus*) and the common jollytail (*Galaxis maculatus*).

4.2.6.4 Fish Abundances and Diversities

Preliminary statistical analyses for the catches from Lake Conjola that have been carried out are shown in Tables 4.28 and 4.29.

Mean numbers of fish were significantly different between locations within Lake Conjola and between sampling events. There was also a significant interaction betwen these factors (Table 4.28). Means comparison tests (SNK) indicate a large number of significant differences between means, which will be analysed in more detail in future publications. Fish numbers were very low during winter in the first year but relatively consistent during most other sampling periods (Figure 4.11A).

Table 4.28: Results of ANOVA for numbers of fish captured in Lake Conjola over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	21.89325	10.94662	64.57	0.000000*	1.000000
B: Sampling Event	11	10.09141	0.9174013	5.41	0.000001*	0.999930
AB	22	10.32154	0.469161	2.77	0.000266*	0.998801

* Term significant at alpha=0.05

Mean numbers of fish species were also significantly different between locations and between sampling events and, again these factors interacted significantly (Table 4.29). Winter sampling at the entrance location of Lake Conjola produced few species, whereas spring sampling at most locations produced highest numbers of fish species (Figure 4.11B). These data will be analysed in further detail in future publications.

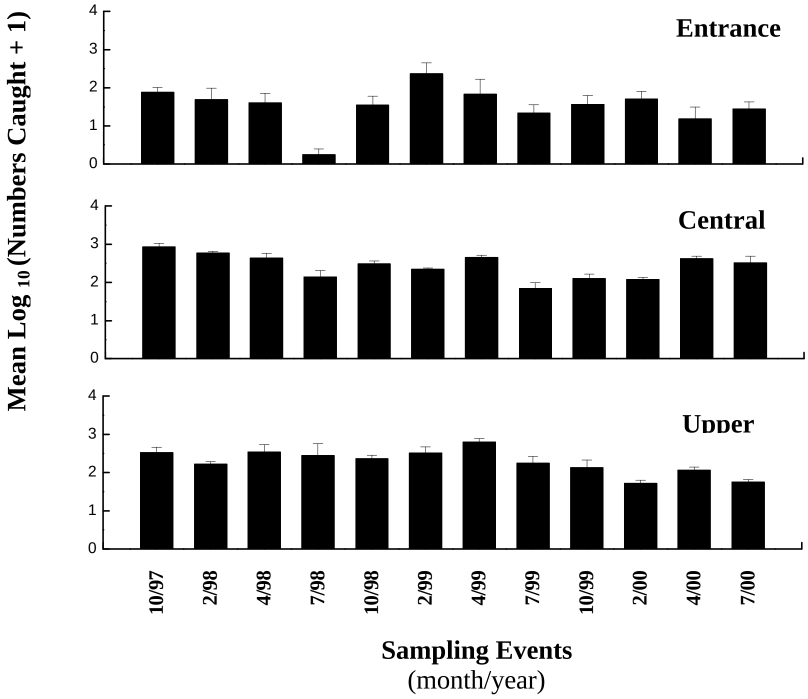
Table 4.29: Results of ANOVA for numbers of fish species captured in Lake Conjola over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	399.0417	199.5208	29.94	0.000000*	1.000000
B: Sampling Event	11	574.6875	52.24432	7.84	0.000000*	1.000000
AB	22	430.4583	19.56629	2.94	0.000117*	0.999377

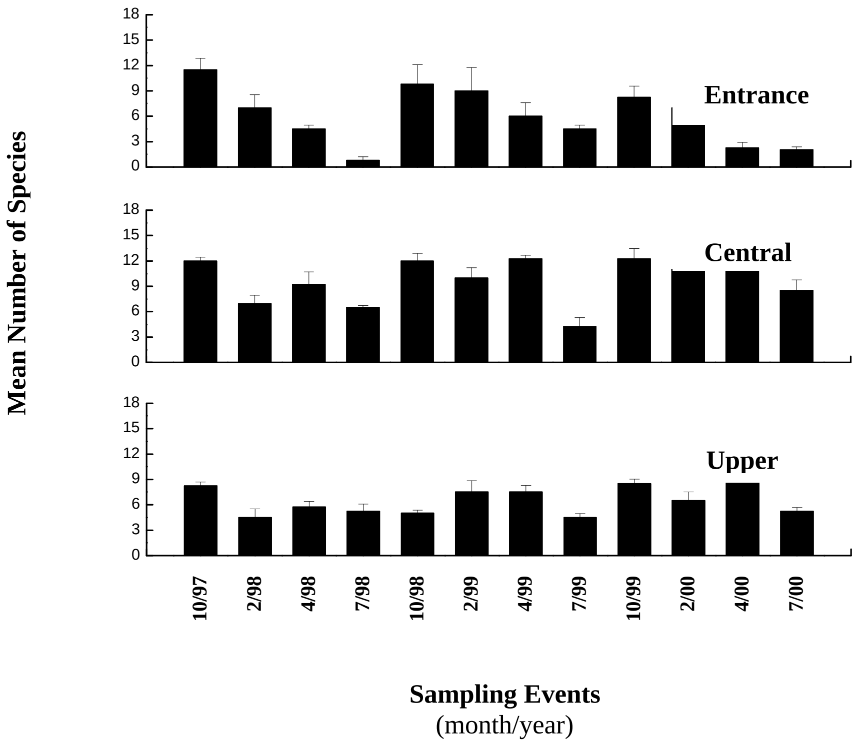
* Term significant at alpha=0.05

Figure 4.11: Mean numbers of fish (A) and mean number of fish species (B) caught in Lake Conjola at the entrance, central and upper locations over the sampling period. Bars denote standard error.

(A)



(B)

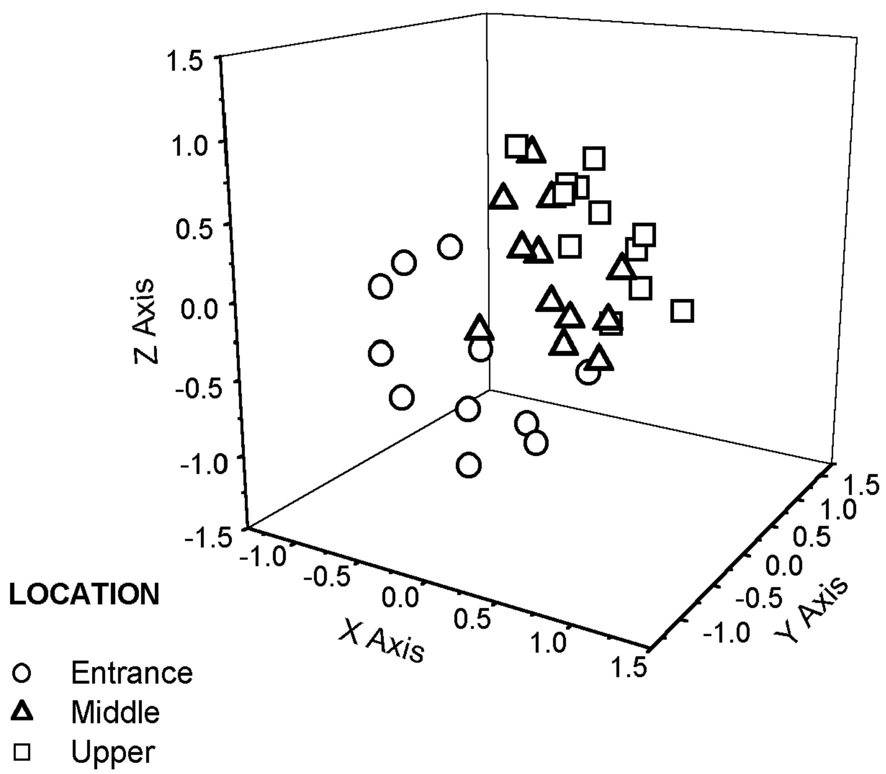


4.2.6.5 Patterns in Shallow Water Fish Communities

The cluster analysis of the Lake Conjola fish assemblage showed there was clear separation of the locations based on fish abundance and distribution (not shown). The entrance site samples comprised site groups at the top of the dendogram, followed by the central location samples comprising a site group. At the bottom of the dendogram, the upper sites split into site groups with samples from October and February, followed by April and July samples.

The three-dimensional ordination of MDS results shows that while there is some separation among the different localities, there is still a high degree of clustering indicating that the samples are very similar (Figure 4.12).

Figure 4.12: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of Lake Conjola for each of the sampling periods. (stress = 0.17).



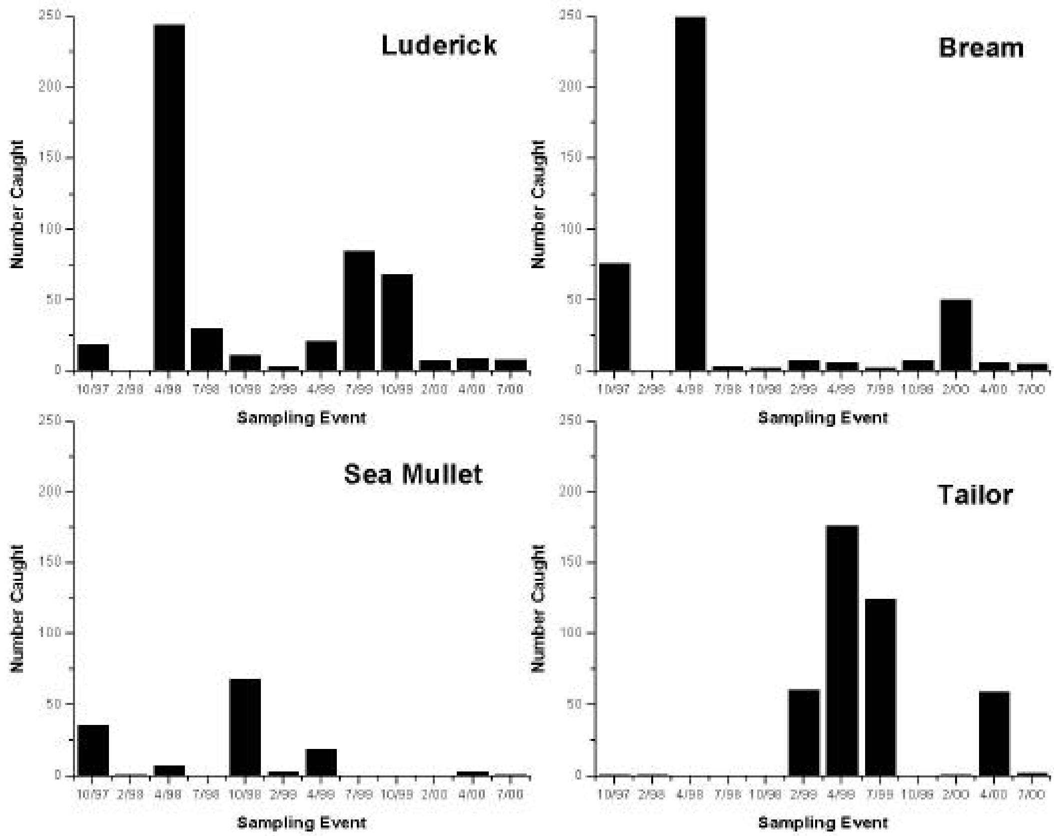
4.2.6.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in Lake Conjola, only a limited number of species have been investigated, namely: luderick, yellowfin bream, sea mullet and tailor. Numbers of new recruits have been pooled for each sampling event. Lake Conjola was one of the few lakes where snapper were found as recruits albeit in low numbers.

For the species analysed, new recruits (fish <50 mm in fork length) were found during most sampling events (Figure 4.13). Recruitment for luderick was strongest in the spring of the first year and spring and summer of year two. Recruitment of tailor was strongest in the second year. These patterns require further detailed examination.

Figure 4.13: Numbers of new recruits of luderick, yellowfin bream, sea mullet and tailor, captured during sampling of Lake Conjola. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.7 Burrill Lake

4.2.7.1 Introduction

Burrill Lake (35°24'S, 150°27'E) is a barrier estuary connected to the ocean by a narrow, shallow inlet channel of approximately two kilometres in length. The Lake is in the early stages of infilling, and the entrance is intermittently open/closed. The area of water is 4.206 km^2 and the catchment area is approximately 75 km^2. Burrill Lake has a seagrass area of approximately 0.508 km^2 and contains *Zosteraceae* spp. and *Halophila* spp. (West et al., 1985). The commercial fisheries production for the 1995/6 period was 18 772 kg. The entrance of Burrill Lake is surrounded by urban and industrial land uses, predominantly coastal holiday development on the coastal fringes (White, 1987). Land use around the lake is predominantly farming in the Milton area. Forestry operations occur in the Woodburn State Forest that surrounds the southern and western shores of the lake (White, 1987). According to Bell & Edwards (1980) 50 to 75% of the catchment has been cleared, and the shoreline has been developed in the range of 25 to 50%. Burrill Lake has many Aboriginal sites of archaeological significance, including shelter sites and middens (White, 1987).

4.2.7.2 Environmental Data

Temperature values within Burrill Lake ranged from 11.4°C to 27.0°C, and each location exhibited seasonal change in temperature (Figure 4.14). Salinity and conductivity values were consistent across locations and a similar patter of change was exhibited at each location. Salinity values ranged from a minimum of 25‰ to 37.5‰, and conductivity was in the range of 32 to 58.7 $mS.cm^{-1}$ (Figure 4.14). pH values were also similar across locations, within the range of 6.8 to 9.0, with the lowest value recorded during April 1999 at the entrance location (Figure 4.14). Turbidity values were recorded in the range of 0.09 NTU to 9.17 NTU. The lowest turbidity values were recorded at the entrance, whereas the higher turbidity values were found at the upper location (Figure 4.14).

4.2.7.3 Shallow Water Fishes

22 153 fish were caught in Burrill Lake, representing fifty-three fish species of which twenty-one of these species are considered of importance to commercial and recreational fisheries (Table 4.30). High diversity and abundance of non-commercial species along with the juveniles of several commercial species characterized the Burrill Lake seagrass fish fauna. The catch was dominated by glassy perhlet (*Ambassis jacksoniensis*, 14421 individuals), small mouth hardyhead (*Atherina microstoma*, 2493) and sea mullet (*Mugil cephalus*, 1551), which constituted nearly 84% of the total catch. Large schools of glassy perchlets (*Ambassis jacksoniensis*) and sea mullet (*Mugil cephalus*) were caught at the entrance of Burrill Lake, and this resulted in this loction accounting for more than double the fish catches at other locations. The most specious families collected were the Gobiidae (11 species) and the Monacanthidae (6 species) and Syngnathidae (5 species). The Burrill Lake finfish catch was dominated by high numbers of sea mullet (*Mugil cephalus*), luderick (*Girella tricuspidata*), yellow-fin leatherjacket (*Meuschenia trachylepis*), sand mullet (*Myxus elongatus*) and six-spined leatherjacket (*Meuschenia freycinitii*).

Figure 4.14: Summary of environmental data for the entrance, central and upper locations within Burrill Lake (1997-2000).

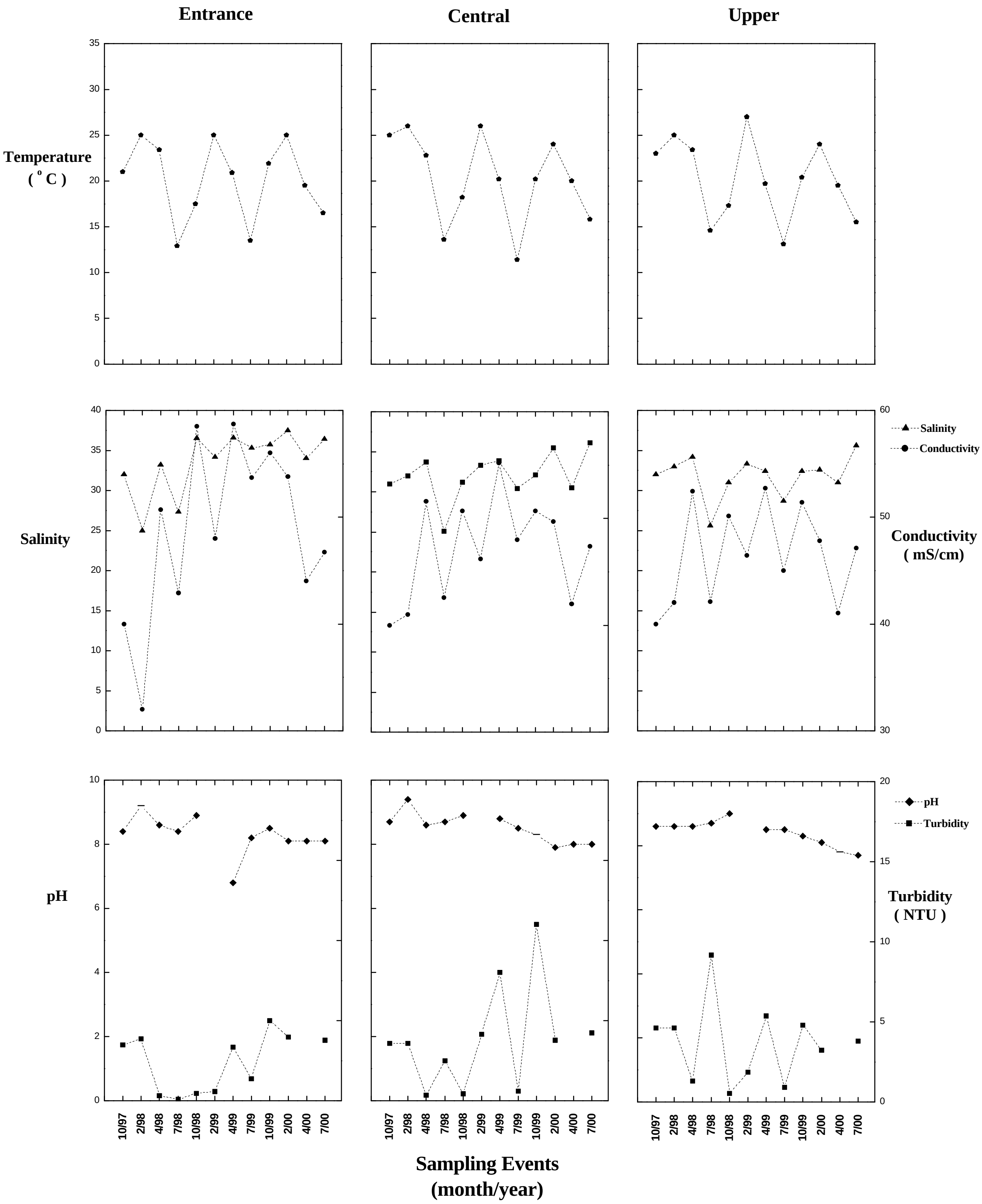


Table 4.30: Total number of fish caught by each species, at the entrance location, central location and upper location within Burrill Lake during pooled across sampling events from July 1997 to July 2000. (* indicates species of commercial and/or recreational importance.)

Family *Species*	NUMBER CAUGHT Entrance	 Central	 Upper	 Total
Clupeidae				
*Hyperlophus vittatus**	1	0	0	1
Anguillidae				
*Anguilla reinhardtii**	0	0	1	1
Hemiramphidae				
*Hyporhamphus australis**	0	3	7	10
Atherinidae				
Atherinasoma microstoma	289	55	2149	2493
Atherinasoma elongata	54	0	0	54
Fistulariidae				
Fistularia commersonni	3	0	0	3
Pseudomuglidae				
Pseudomugil signifer	0	11	31	42
Syngnathidae				
Vanacampus poecilolaemus	179	15	9	203
Urocampus carinirostris	5	56	112	173
Vanacampus phillipi	9	0	1	10
Stigmatophora argus	37	6	2	45
Stigmatophora nigra	52	0	0	52
Scorpaenidae				
Centropogon australis	3	14	4	21
Ambassidae				
Ambassis jacksoniensis	7659	4883	1879	14421
Terapontidae				
Pelates quadrilineatus	173	395	28	596
Pomatomidae				
*Pomatomus saltator**	0	28	0	28
Carangidae				
*Pseudocaranx dentex**	1	0	0	1
Sparidae				
*Acanthopagrus australis**	1	4	38	43
*Rhabdosargus sarba**	0	0	1	1
Gerreidae				
*Gerres subfasciatus**	0	2	10	12
Monodactylidae				
*Monodactylus argenteus**	2	4	16	22
Girellidae				
*Girella tricuspidata**	57	211	97	365
Scorpididae				
*Scorpis lineolatus**	1	0	0	1
*Scorpis spp**	1	0	0	1
Enoplosidae				
Enoplosus armatus	3	0	0	3
Mugilidae				
*Myxus elongatus**	88	9	29	126
*Mugil cephalus**	1493	54	4	1551
*Liza argentea**	0	3	1	4

Table 4.30 Continued

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Labridae				
*Achoerodus viridis**	2	6	0	8
Scaridae				
Scarus species	1	0	0	1
Blennidae				
Petroscirtes lupus	3	12	0	15
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	77	95	170	342
Philypnodon species	0	1	1	2
Hypseleotris compressa	0	0	1	1
Gobiidae				
Favonigobius lateralis	33	1	10	44
Favonigobius exsquisites	0	3	4	7
Amoya bifrenatus	0	5	8	13
Amoya frenatus	1	2	12	15
Afurcagobius tamarensis	16	43	36	95
Pseudogobius olorum	5	19	426	450
Redigobius macrostoma	4	65	95	164
Gobiopterus semivestitus	31	21	306	358
Siganidae				
Siganus nebulosus	8	2	0	10
Monacanthidae				
Acanthaluteres spilomelanurus	6	0	0	6
*Scobinichthys granulatus**	6	0	0	6
*Monacanthus chinensis**	13	1	1	15
*Meuschenia freycineti**	39	45	26	110
*Meuschenia trachyylepis**	44	70	30	144
*Meuschenia species**	1	5	1	7
Tetraodontidae				
Tetractenos hamiltoni	1	2	0	3
Tetractenos glaber	10	3	1	14
Arothron firmamentum	0	3	0	3
Diodontidae				
Dicotylichthys punctulatus	0	6	31	37
Total individuals	**10412**	**6163**	**5578**	**22153**
Total species	**40**	**38**	**37**	**53**

Eight species were caught only once within Burrill Lake. Such species include two species from the Scorpididae family and silver trevally (*Pseudocaranx dentex*). Two species were unique to Burrill Lake, and these were an unidentified *Scorpis* and *Scarus* species.

4.2.7.4 Fish Abundances and Diversities

Preliminary statistical analyses for the catches from Burrill Lake have been carried out and are shown in Tables 4.31 and 4.32.

There were no significant differences in mean numbers of fish between locations within Burrill Lake, but there were significant differences between sampling events. Again there were significant interactions between these two factors. More detailed analyses of these differences will need to be undertaken. There appears to be fewer numbers of fish in the third year (Figure 4.15A), after a strong recruitment of commercially important species (see later).

Table 4.31: Results of ANOVA for numbers of fish captured in Burrill Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	0.4132495	0.2066248	0.69	0.504072	0.163631
B: Sampling Event	11	21.41153	1.946502	6.49	0.000000*	0.999996
AB	22	17.53588	0.7970856	2.66	0.000449*	0.998196

* Term significant at alpha=0.05

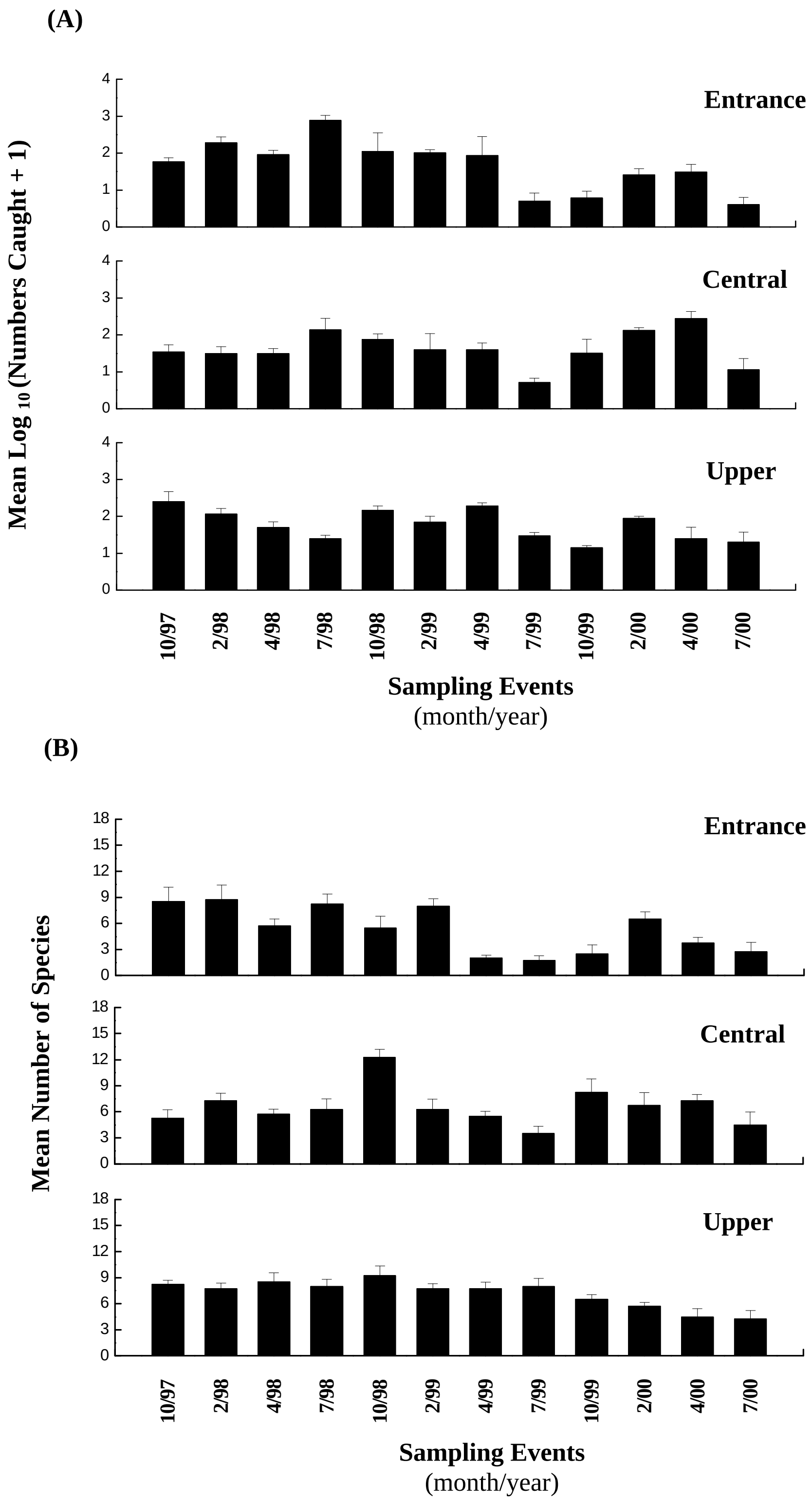
Mean numbers of fish species were also significantly different between locations and between sampling events and, again these factors interacted significantly. Again there appeared to be a reduced diversity of fishes in the third year of sampling (Figure 4.15B) and this will be investigated in more detail in later publications.

Table 4.32: Results of ANOVA for numbers of fish species captured in Burrill Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	87.48727	43.74363	7.43	0.000948*	0.935671
B: Sampling Event	11	319.6103	29.05548	4.93	0.000004*	0.999768
AB	22	322.9348	14.67886	2.49	0.001005*	0.996662

* Term significant at alpha=0.05

Figure 4.15: Mean numbers of fish (A) and mean number of fish species (B) caught in Burrill Lake at the entrance, central and upper locations over the sampling period. Bars denote standard error.



4.2.7.5 Patterns in Shallow Water Fish Communities

Cluster analysis of the fish biological data of Burrill Lake revealed that there was some degree of clustering based on locations within estuary. The majority of the entrance locations were situated at the top of the dendogram, with the remaining site groups consisting of samples from the central and upper locations (not shown). The entrance July 1999 sample constituted a site group by itself, and in the MDS analysis this was represented as an outlier in the plot (Figure 4.16). The three-dimensional plot of the community abundance data showed that the samples cluster tightly, indicating that there is a high degree of similarity between the samples.

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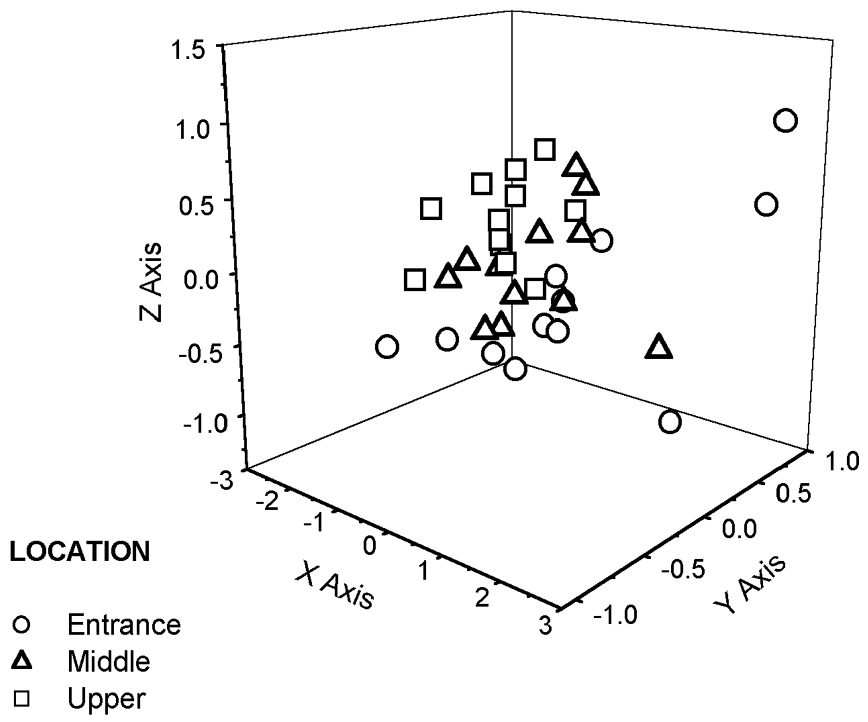
Figure 4.16: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of Burrill Lake for each of the sampling periods. (Stress = 0.13).



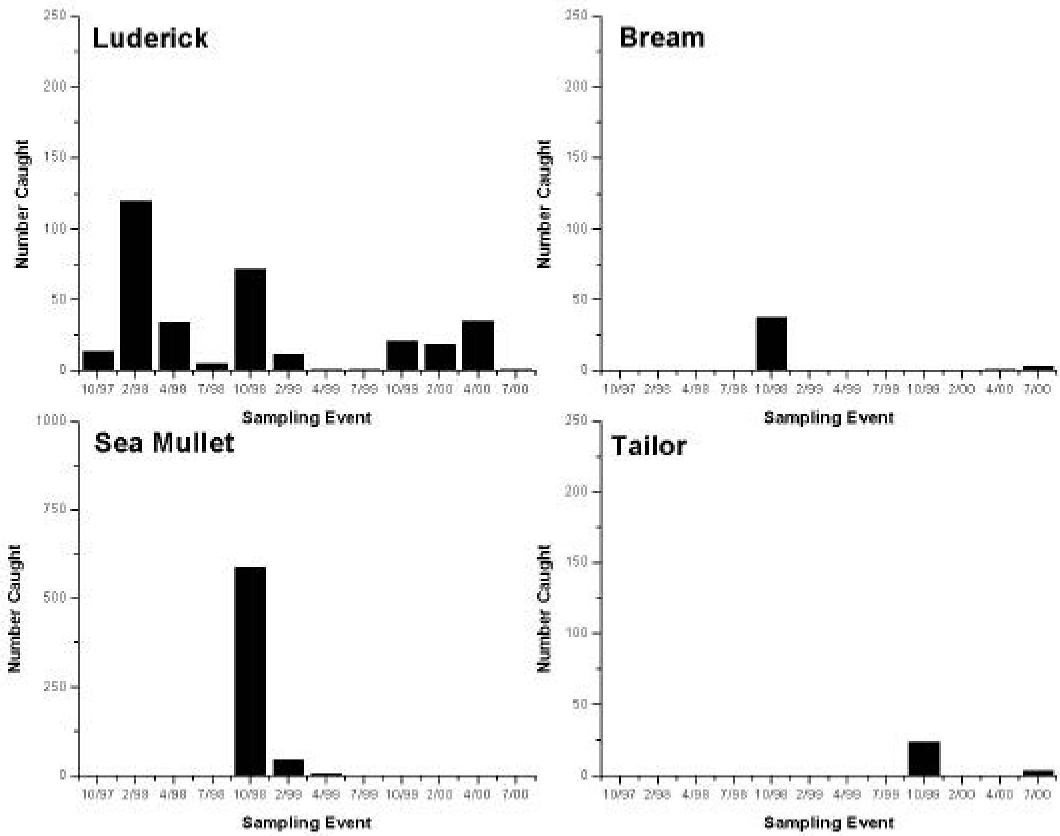
4.2.7.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in Burrill Lake, only a limited number of species have been investigated, namely: luderick, yellowfin bream, sea mullet and tailor. Numbers of new recruits have been pooled for each sampling event. Recruitment of yellowfin bream and tailor was very poor throughout the whole study, with only minor peaks in the third year (Figure 4.17).

For the species analysed, recruitment (of fish <50 mm in fork length) of luderick was by far the most consistent (Figure 4.17). A large recruitment event for seas mullet was recorded for Burrill Lake in spring of the second year. These patterns require further detailed examination.

Figure 4.17: Numbers of new recruits of luderick, yellowfin bream, sea mullet and tailor, captured during sampling of Burrill Lake. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.8 Coila Lake

4.2.8.1 Introduction

Coila Lake (36°02'S, 150°08'E) is a coastal lagoon with little infilling. With a catchment area of 48 km^2, catchment freshwater flows are unable to maintain an open entrance for any period of time. Under natural conditions the entrance would probably remain closed for lengthy periods but it is usually mechanically opened when the water level rises and floods a caravan park at its head (Briggs *et al.*, 1980). The lake has a water area of 9 km^2 and a seagrass area of 1.862 km^2 which is comprised of *Zosteraceae* spp. and *Halophila* spp. The commercial fisheries production of Coila Lake for the 1995/6 period was 28 665 kg.

The holiday resort of Tuross Heads is close to the entrance of Coila Lake, which is a popular recreational area in the summer months. The land use surrounding the rest of the lake is dominated by disturbed freehold and leasehold land (Bell & Edwards, 1980). Water quality has declined in Coila Lake over the past few years, and several fish kills have occurred (Bryant *et al.*, 1994). Bell and Edwards (1980) classified the lake as having moderate to high disturbance and use, with only 25 to 50% of the shoreline in natural condition. Sites of archeological significance include two Aboriginal middens and a typical bora ground.

4.2.8.2 Environmental Data

The temperature values exhibited in Coila Lake ranged from a minimum of 9.6°C to a maximum of 28.6°C, and this range was related to seasonal effects (Figure 4.18). Each location exhibited a similar pattern of change in salinity and conductivity values throughout the study period, with the lowest salinity values recorded during February 1999 at all locations. Salinity ranged from 6.2‰ to 35.6‰, and conductivity from 10.2 to 56.3 $mS.cm^{-1}$ (Figure 4.18). pH values were quite consistent amongst locations, from 7.4 to 9.4, with the lowest value of 7.4 occurring at the central location in July 2000 (Figure 4.18). Turbidity also showed similar patterns of change between the three locations, with values ranging from 0.17NTU to 15.89 NTU (Figure 4.18).

4.2.8.3 Shallow Water Fishes

Coila Lake was consistently different to the other six estuaries studied, as only seventeen commercial fish species were captured over the three-year period (Table 4.33). In total, forty-one fish species were found, but the total number of fish caught was very high at 41732. This was due to the shallow water fish catches being dominated by members of the Atherinidae family (31 761 individuals) and glass goby (*Gobiopterus semivestitus*, 4609 individuals), which constituted 87% of the catch. The Gobiidae with 11 species was the most specious family, followed by the Monacanthidae and Syngnathidae with three species each. The dominant commercial fish species caught were yellowfin bream (*Acanthopagrus australis*), flat-tail mullet (*Liza argentea*) and sea garfish (*Hyporhamphus australis*).

Figure 4.18: Summary of environmental data for the entrance, central and upper locations within Coila Lake (1997-2000).

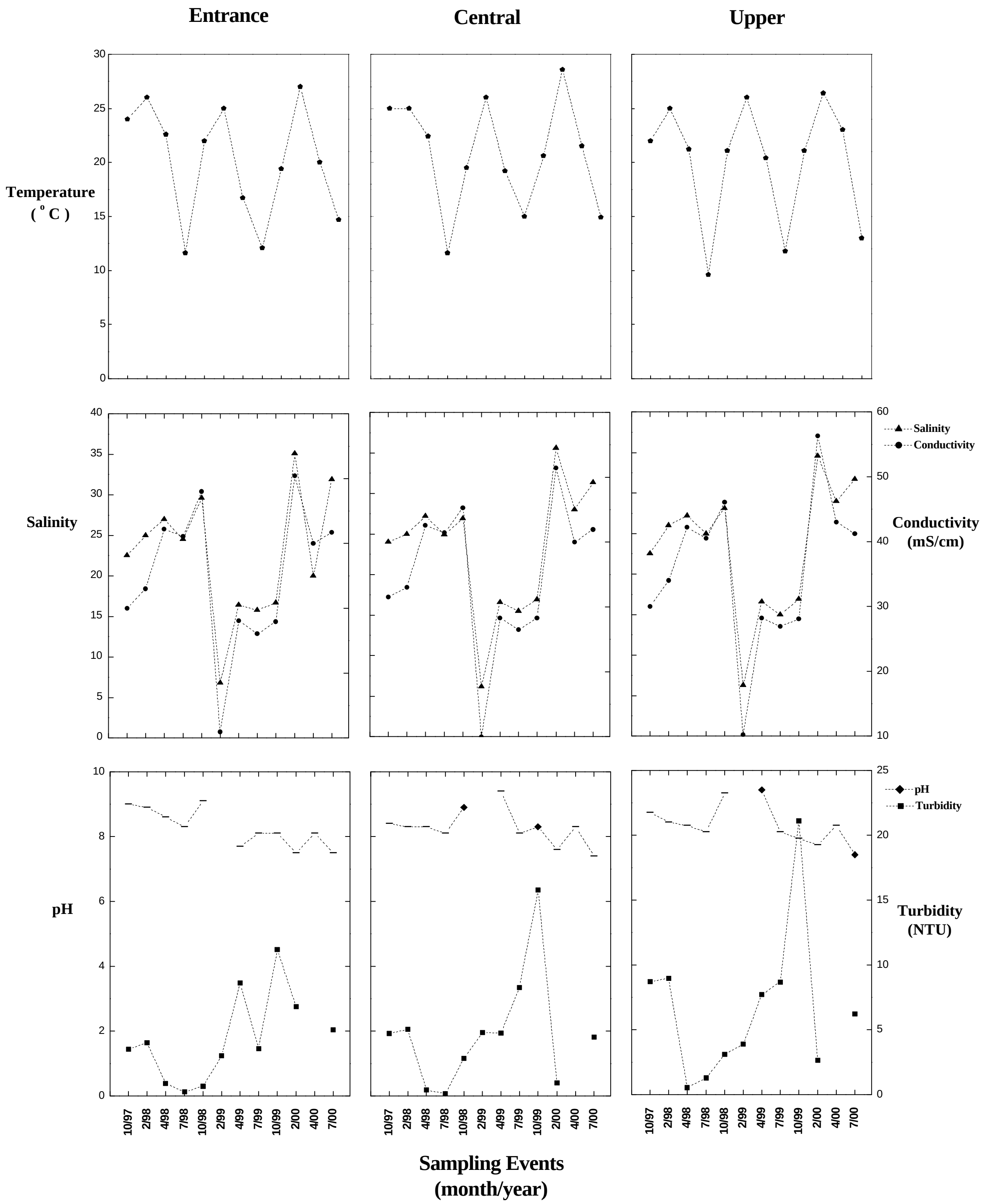


Table 4.33: Total number of fish caught by each species, at the entrance location, central location and upper location within Coila Lake during pooled across sampling events from July 1997 to July 2000. (* indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Anguillidae				
Anguilla reinhartii	0	0	1	1
Gonorynchidae				
*Gonorynchus greyi**	1	0	0	1
Hemiramphidae				
*Hyporhamphus regularis**	0	7	0	7
*Hyporhamphus australis**	61	120	171	352
Atherinidae				
Atherinasoma microstoma	15753	6913	7097	29763
Atherinasoma elongata	246	215	1537	1998
Pseudomuglidae				
Pseudomugil signifer	1	0	0	1
Poeciliidae				
Gambusia holbrooki	166	0	3	169
Syngnathidae				
Vanacampus poecilolaemus	0	0	3	3
Urocampus carinirostris	15	198	102	315
Vanacampus phillipi	2	15	3	20
Scorpaenidae				
Centropogon australis	0	4	0	4
Platycephalidae				
*Platycephalus fuscus**	1	0	0	1
Sillaginidae				
*Sillago flindersi**	0	2	6	8
*Sillago ciliata**	1	3	6	10
Sparidae				
*Acanthopagrus australis**	398	260	153	811
Girellidae				
*Girella tricuspidata**	2	17	2	21
Mugilidae				
*Myxus elongatus**	0	0	4	4
*Mugil cephalus**	0	0	3	3
*Liza argentea**	0	0	427	427
Labridae				
*Achoerodus viridis**	0	35	0	35
Clinidae				
Cristiceps australis	0	1	0	1
Callionymidae				
Repomucenus calcarartus	2	0	0	2
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	167	118	287	572
Philypnodon species	5	1	5	11

Table 4.33 Continued

Family *Species*	NUMBER CAUGHT Entrance	 Central	 Upper	 Total
Gobiidae				
Favonigobius lateralis	19	0	0	19
Favonigobius exsquisites	396	842	696	1934
Amoya bifrenatus	6	13	4	23
Amoya frenatus	0	20	137	157
Bathygobius kreffti	0	1	1	2
Afurcagobius tamarensis	30	45	181	256
Pseudogobius olorum	68	12	51	131
Redigobius macrostoma	0	2	33	35
Gobiopterus semivestitus	605	2182	182	4609
Bothidae				
*Psuedorhombus arsius**	1	0	0	1
*Psuedorhombus jenynsii**	3	0	0	3
Monacanthidae				
*Monacanthus chinensis**	0	2	0	2
*Meuschenia freycineti**	0	4	1	5
*Meuschenia trachylepis**	0	1	0	1
Tetraodontidae				
Tetractenos glaber	2	8	1	11
Tetractenos hamiltoni	3	0	0	3
Total individuals	**17951**	**11041**	**12737**	**41732**
Total species	**25**	**27**	**27**	**41**

During the first year of sampling Coila Lake was found to have an impoverished fish community (15 species) compared to the other locations (34 to 40 species), with only one species of economic importance, *Hyporhamphus australis*, being caught. Coila Lake is a coastal lagoon whose catchment freshwater flows are unable to maintain an open entrance for any period of time. Under natural conditions the entrance would probably remain closed for lengthy periods but is usually mechanically opened. For the first year of this study the entrance remained closed and had been so for the last four years. The entrance was mechanically opened in July 1998 and thus during the second year, ocean-spawning species were present in the fish catches.

Coila Lake was also the only lake in which the introduced species, *Gambusia holbrooki* was caught. Breeding populations of *G. holbrooki* occur in both natural and altered environments, and heavily polluted habitats (Lloyd *et al*. 1981). In recent years the water quality in Coila Lake has deteriorated and several fish kills have occurred (Byrant *et al*., 1994). The perimeter of the lake has been classified as having moderate to high disturbance, mainly as a result of urbanisation around its entrance and agricultural land dominating the land use around the rest of the lake (Bell & Edwards, 1980).

From the Coila Lake seagrass fish catches, seven species were caught on only one occasion, and included such species as the beaked salmon (*Gonoynchus greyi)* and the southern crested weedfish (*Cristiceps australis*). Seven fish species were unique to Coila Lake, but most of these species are common to sand habitat. These include dusky flathead (*Platycephalus fuscus*), short-toothed flounder (*Pseudorhombus jenynsii*) and eastern school whiting (*Sillago flindersi*).

4.2.8.4 Fish Abundances and Diversities

Preliminary statistical analyses for the catches from Coila Lake have been carried out are shown in Tables 4.34 and 4.35.

There were no significant differences in mean numbers of fish between locations within Coila Lake but there were significant differences between sampling events and, significant interacations between the two factors (Table 4.34). Again these data need more detailed examination before conclusions are reached. However, there appeared to be little influence on total fish numbers of the mechanical opening of the Lake in the second (Figure 4.19A), although community structure did change substantially (see below).

Table 4.34: Results of ANOVA for numbers of fish captured in Coila Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	0.8034	0.4017	2.80	0.065039	0.541092
B: Sampling Event	11	24.16642	2.196947	15.33	0.000000*	1.000000
AB	22	20.40213	0.9273695	6.47	0.000000*	1.000000

* Term significant at alpha=0.05

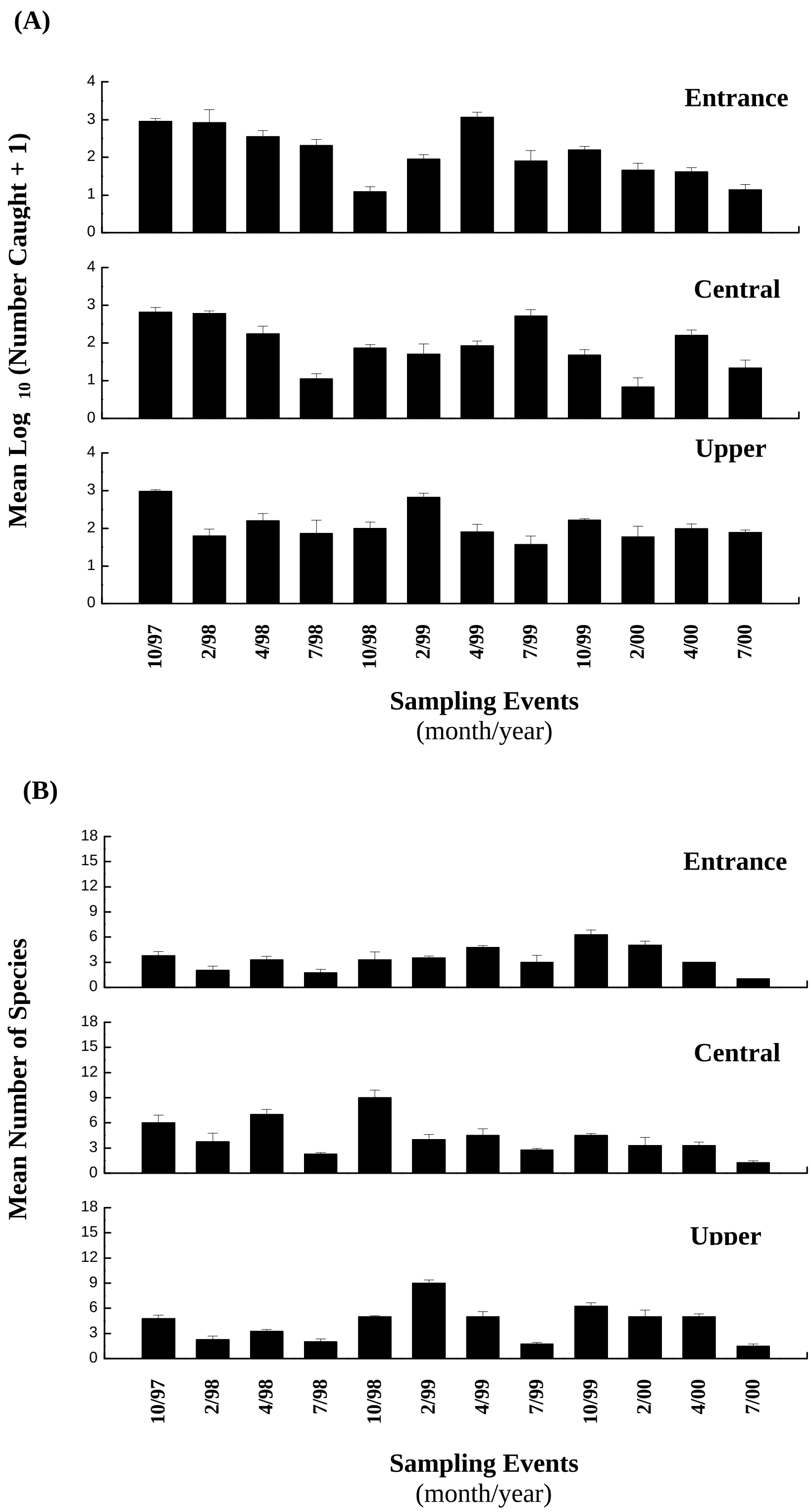
Mean numbers of fish species were significantly different between locations and between sampling events and, again these factors interacted significantly (Table 4.35). Coila Lake exhibited the lowest diversity of shallow water communities of any of the areas sampled (Figure 4.19B) and this will be investigated in more detail in later publications.

Table 4.35: Results of ANOVA for numbers of fish species captured in Coila Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	28.07443	14.03722	9.29	0.000190*	0.974896
B: Sampling Event	11	309.9622	28.17838	18.65	0.000000*	1.000000
AB	22	187.3168	8.514401	5.64	0.000000*	1.000000

* Term significant at alpha=0.05

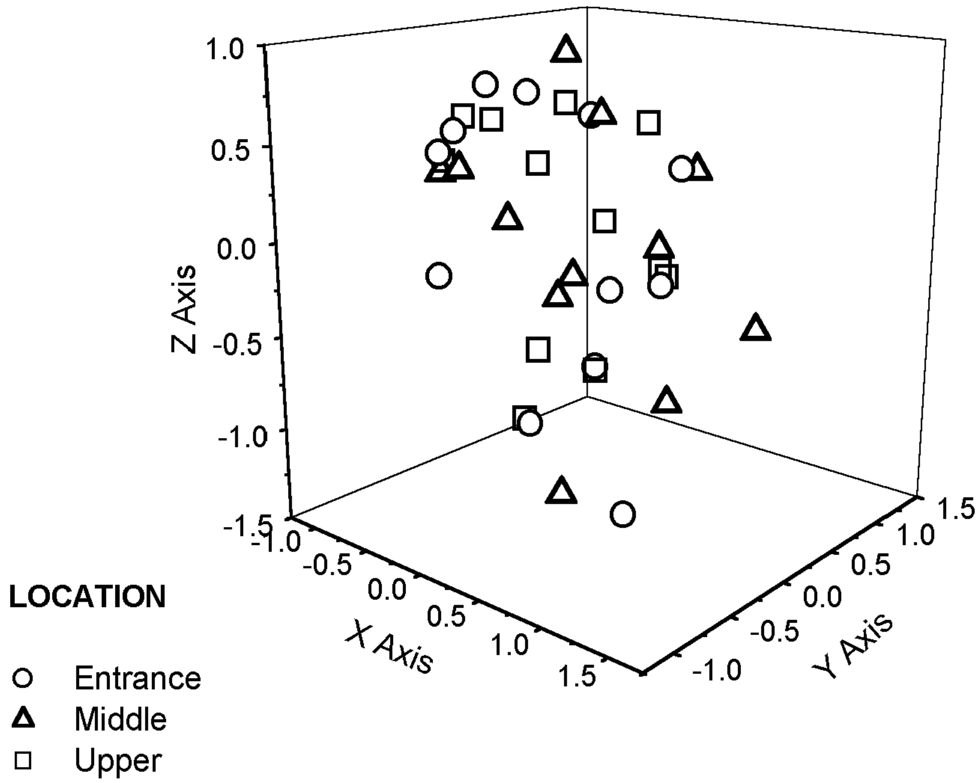
Figure 4.19: Mean numbers of fish (A) and mean number of fish species (B) caught in Coila Lake at the entrance, central and upper locations over the sampling period. Bars denote standard error.



4.2.8.5 Patterns in Shallow Water Fish Communities

Coila Lake clustered into site groups not on the basis of localities, but by the division between years and to a lesser extent between sampling events (not shown). Groups consisted of the summer months of February 1999 samples; the October1997 and 1998 samples; and, the July 1998 and July 1999 samples. The three-dimensional representation of the non-metric multidimensional scaling shows that there is no distinct pattern of clustering (Figure 5).

Figure 4.20: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of Coila Lake for each of the sampling periods (stress = 0.13).



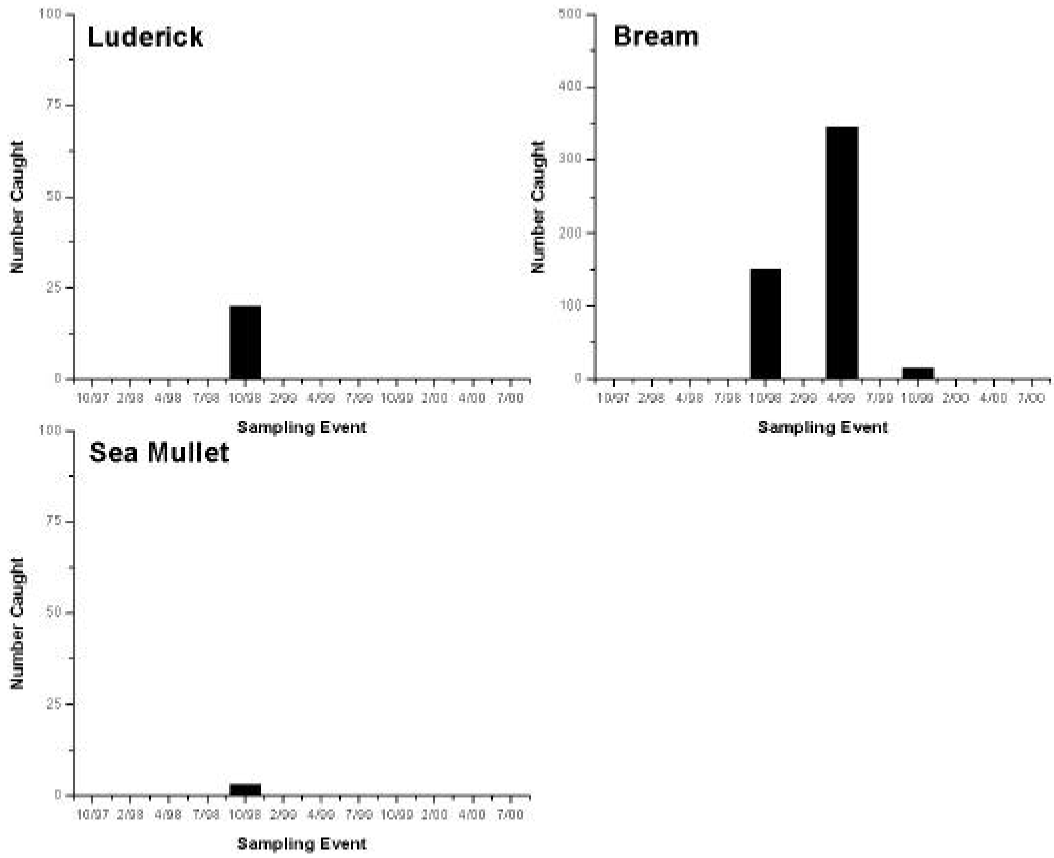
4.2.8.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in Coila Lake, only a limited number of species have been investigated, namely: luderick, yellowfin bream and sea mullet. Numbers of new recruits have been pooled for each sampling event. Recruitment of all species was very poor, except for a short periods when the Lake was mechanically opened (Figure 4.21).

These patterns will require further detailed examination.

Figure 4.21: Numbers of new recruits of luderick, yellowfin bream and sea mullet, captured during sampling of Coila Lake. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.9 Wallaga Lake

4.2.9.1 Introduction

Wallaga Lake (36°22'S, 150°05'E) is classified as a barrier lagoon with little infilling. The Lake is intermittently open/closed and is also mechanically opened at times. It has a catchment area of 28.5 km^2 and a water area of 7.805 km^2. The seagrass beds comprise an area of 1.343 km^2 and contain the species *Zosteraceae, Halophila* and *Ruppia*. For the 1995/6 period, commercial fisheries production was 48 302 kg.

Wallaga Lake has a shoreline of more than a 100 km. The western and southern shores are occupied by Wallage Lake National Park (Readers Digest, 1983). The lake's catchment has been developed for urban, rural and forestry purposes. Water quality has been perceived as good but there are concerns as a result of development, septic tank overflows, tourism and overfishing (Bryant *et al.*, 1980). A Koori community lives at the northern end of Wallaga Lake and a number of archaeologically important sites occur in the vicinity, including Wallaga Lake mission, cemetery, stone arrangements and a sacred tree.

4.2.9.2 Environmental Data

Seasonal trends in temperature were evident in Wallaga Lake across the three locations, with a temperature range of 8.2°C to 29.0°C (Figure 4.22). The characteristic estuarine gradient was not exhibited, with salinity values ranging from 22.0 to 39 ‰ at the entrance, 20.3 to 35.3 ‰ at the central, and the upper location had salinity values ranging from 21.3 to 34.9 ‰. Conductivity values ranged from a minimum of 29.7 $mS.cm^{-1}$ to a maximum of 57.4 $mS.cm^{-1}$ (Figure 4.22). pH was quite consistent among locations and sampling events, and values ranged from 8.0 to 9.1. All locations experienced peak turbidity values during October and February of the first year of sampling, and during April 1999 (Figure 4.22). Turbidity values were overall highest at the upper location, from 1.65 to 9.63 NTU. The entrance and central location had turbidity values in the range of 0.44 to 8.4 (Figure 4.22).

4.2.9.3 Shallow Water Fishes

A total of 61 492 fish were caught in Wallaga Lake over the three-year period. Fifty-two species were captured, with twenty species significant to commercial and recreational fisheries (Table 4.36). The Wallaga Lake seagrass fish fauna was characterised by the dominance of small species of little commercial value, together with juveniles of fish species considered of commercial and recreational importance. In terms of abundance, glass goby (*Gobiopterus semivestitus*, 25 997 individuals), glassy perchlet (*Ambassis jacksoniensis*, 18 081), large-mouth goby (*Redigobius macrostoma*, 5758) and southern blue eye (*Pseudogobius signifer*, 3427) were dominant. These small cryptic species were commonly caught in large numbers at the central and upper locations. The most diverse families were the Gobiidae (11 species), Monacanthidae (6 species), followed by the Syngnathidae (4 species). Among the commercial fish species found in Wallaga Lake, yellowfin bream (*Acanthopagrus australis*), luderick (*Girella tricuspidata*), sea mullet (*Mugil cephalus*), six-spined leatherjacket (*Meuschenia freycinitii*) and yellow-finned leatherjacket (*Meuschenis trachylepis*) comprised the majority of the catch (Table 4.36).

Figure 4.22: Summary of environmental data for the entrance, central and upper locations within Wallaga Lake (1997-2000).

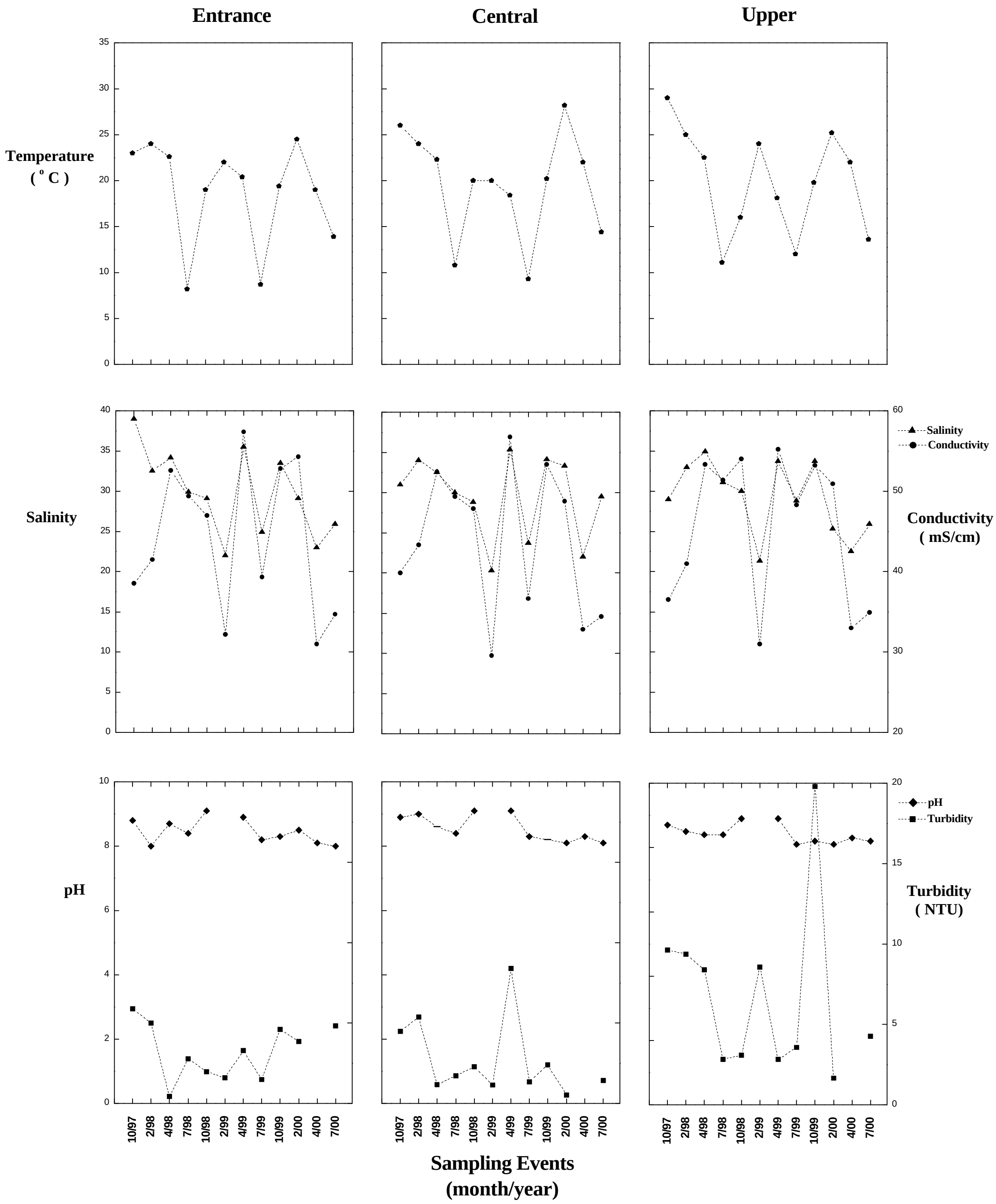


Table 4.36: Total number of fish caught by each species, at the entrance location, central location and upper location within Wallaga Lake during pooled across sampling events from July 1997 to July 2000. (*indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Anguillidae				
*Anguilla reinhardtii**	0	1	0	1
Engraulidae				
*Engraulis australis**	0	4	1	5
Hemiramphidae				
*Hyporhamphus australis**	0	0	1	1
Atherinidae				
Atherinasoma microstoma	517	124	156	797
Atherinasoma elongata	12	0	28	40
Pseudomuglidae				
Pseudomugil signifer	28	184	3215	3427
Syngnathidae				
Vanacampus poecilolaemus	3	5	11	19
Urocampus carinirostris	77	472	222	771
Vanacampus phillipi	45	160	37	242
Stigmatophora argus	1	5	3	9
Scorpaenidae				
Centropogon australis	15	56	12	83
Ambassidae				
Ambassis jacksoniensis	3214	4244	10623	18081
Terapontidae				
Pelates quadrilineatus	97	128	73	298
Dinolestidae				
*Dinolestes lewini**	0	0	1	1
Pomatomidae				
*Pomatomus saltator**	54	29	128	211
Carangidae				
*Pseudocaranx dentex**	2	0	1	3
Sparidae				
*Acanthopagrus australis**	214	88	365	667
*Rhabdosargus sarba**	7	36	1	44
Gerreidae				
*Gerres subfasciatus**	63	66	21	150
Monodactylidae				
*Monodactylus argenteus**	0	1	29	30
Girellidae				
*Girella tricuspidata**	216	128	218	562
Scorpididae				
Microcanthus species	1	0	0	1
Mugilidae				
*Myxus elongatus**	3	103	30	136
*Mugil cephalus**	269	111	140	520
*Liza argentea**	7	6	121	134
Labridae				
*Achoerodus viridis**	6	0	0	6
Bovichtidae				
Pseudaphtittis urvilli	2	0	0	2

Table 4.36 Continued

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Blennidae				
Petroscirtes lupus	1	0	1	2
Omobranchus anolius	0	0	3	3
Clinidae				
Cristiceps argyropleura	0	0	2	2
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	11	81	75	167
Philypnodon species	0	0	2	2
Gobiidae				
Favonigobius lateralis	9	6	2	17
Favonigobius exsquisites	1	58	6	65
Amoya bifrenatus	7	71	42	120
Amoya frenatus	19	252	54	325
Bathygobius kreffti	0	3	1	4
Afurcagobius tamarensis	93	255	394	742
Pseudogobius olorum	56	540	911	1507
Redigobius macrostoma	484	2316	2958	5758
Gobiopterus semivestitus	3987	12712	9298	25997
Siganidae				
Siganus nebulosus	0	11	0	11
Bothidae				
*Pseudorhomus jenysii**	0	0	1	1
Monacanthidae				
Acanthaluteres spilomelanurus	0	17	5	22
*Scobinichthys granulatus**	9	6	0	15
*Monacanthus chinensis**	1	73	78	152
*Meuschenia freycineti**	19	94	50	163
*Meuschenia trachyylepis**	4	60	92	156
Nelusetta ayraudi	0	0	4	4
Tetraodontidae				
Tetractenos hamiltoni	0	0	1	1
Tetractenos glaber	0	2	0	2
Diodontidae				
Dicotylichthys punctulatus	4	3	6	13
Total individuals	**9558**	**22511**	**29423**	**61492**
Total species	**38**	**38**	**45**	**52**

Six fish species were caught only once, and include a toadfish species (*Tetractenos hamiltoni*) and the eastern blue groper (*Achoerodus viridis*). Two species were unique to Wallaga Lake, and these were the long-finned pike (*Dinolestes lewini*) and silver-sided weedfish (*Cristiceps argypleura*).

4.2.9.4 Fish Abundances and Diversities

Preliminary statistical analyses for the catches from Wallaga Lake have been carried out and are shown in Tables 4.37 and 4.38.

Shallow water fish catches were generally high in Wallaga Lake and there were significant differences between location and between sampling events (Table 4.37). Lowest mean catches were made in the winter of the final year of sampling (Figure 4.23A).

Table 4.37: Results of ANOVA for numbers of fish captured in Wallaga Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	7.851862	3.925931	28.03	0.000000*	1.000000
B: Sampling Event	11	29.29473	2.663157	19.01	0.000000*	1.000000
AB	22	9.939537	0.4517972	3.23	0.000028*	0.999806

* Term significant at alpha=0.05

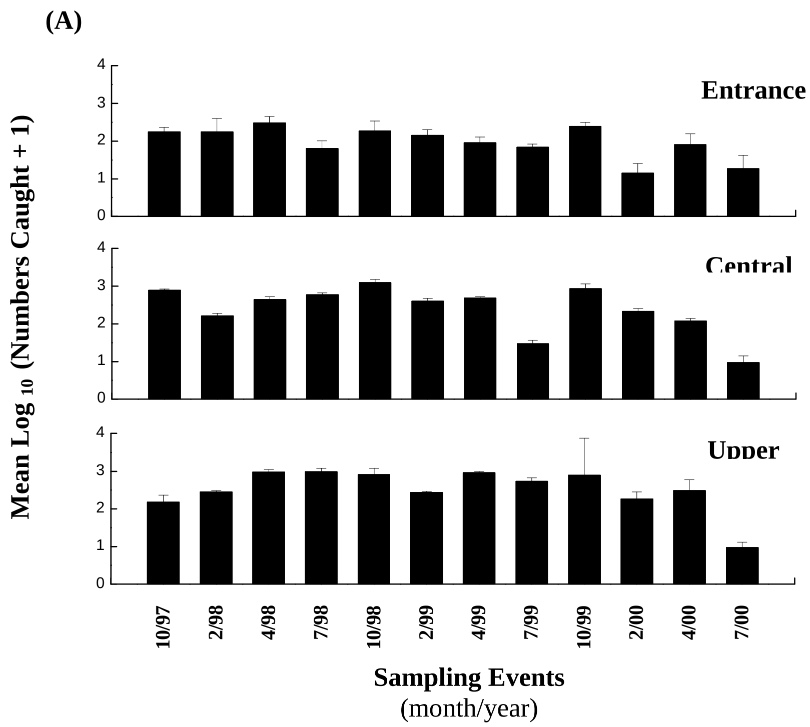
Mean numbers of fish species were significantly different between locations and between sampling events and, again these factors interacted significantly (Table 4.38). Wallaga Lake consistently exhibited the high diversity of shallow water communities with a mean number of fish species generally above ten, except in the third year of sampling (Figure 4.23B). These patterns will be investigated in more detail in later publications.

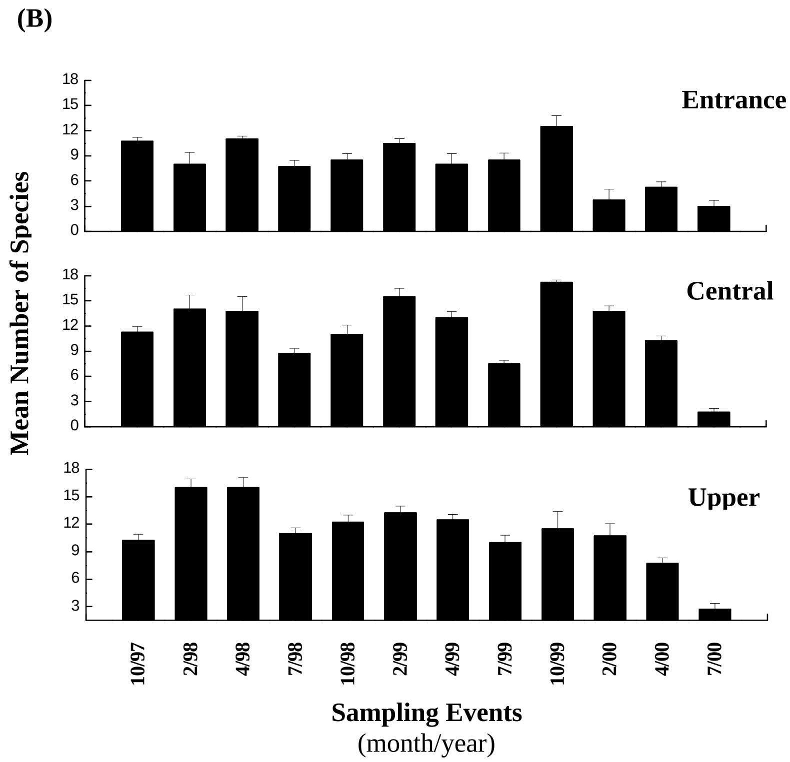
Table 4.38: Results of ANOVA for numbers of fish species captured in Wallaga Lake over (factors are Location and Sampling Event).

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Location	2	329.5972	164.7986	33.92	0.000000*	1.000000
B: Sampling Event	11	1309.41	119.0372	24.50	0.000000*	1.000000
AB	22	375.7361	17.07891	3.52	0.000007*	0.999942

* Term significant at alpha=0.05

Figure 4.23: Mean numbers of fish (A) and mean number of fish species (B) caught in Wallaga Lake at the entrance, central and upper locations over the sampling period. Bars denote standard error.

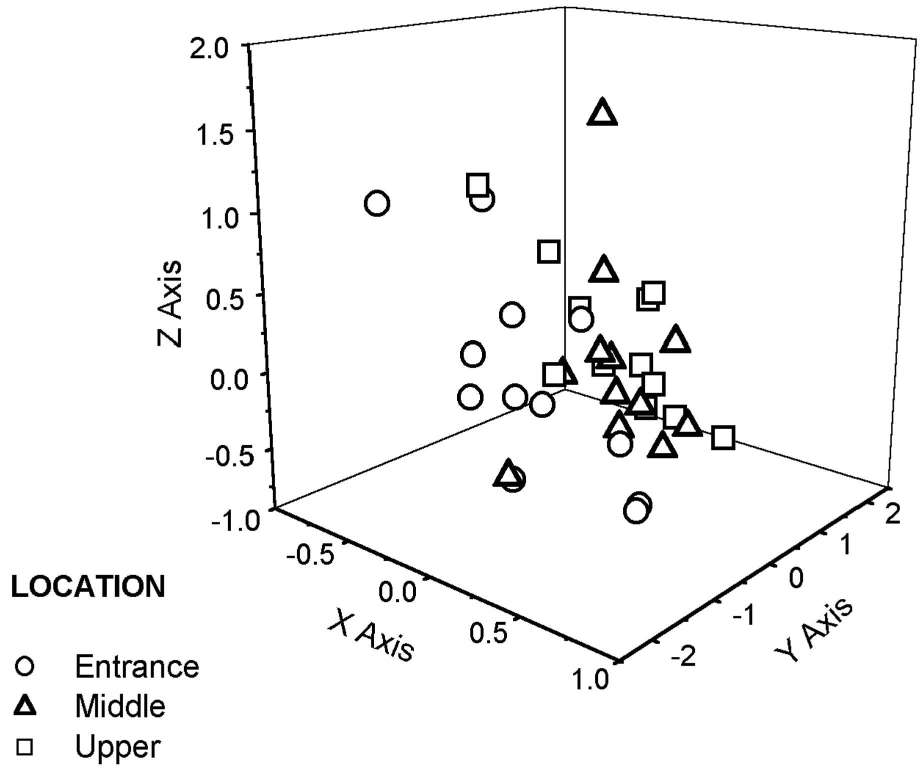




4.2.9.5 Patterns in Shallow Water Fish Communities

The dendogram for Wallaga Lake showed some degree of clustering based on locations within the estuary. There was a pattern of the majority of entrance sites clustering in site groups together, with the other site groups representing a combination of the central and upper sites (not shown). There was only one sample constituting a site group, the entrance July 1998 sample, in the dendogram and this appeared as an outlier in the MDS. Figure 4.24 shows that there are no distinct clusters but only a slight separation of the samples based on locations. The entrance samples are scattered amongst the plot, while the central and upper samples tend to cluster more closely together.

Figure 4.24: Three-dimensional plots of the non-metric multidimensional analysis using community abundance data of Wallaga Lake for each of the sampling periods (stress = 0.13).



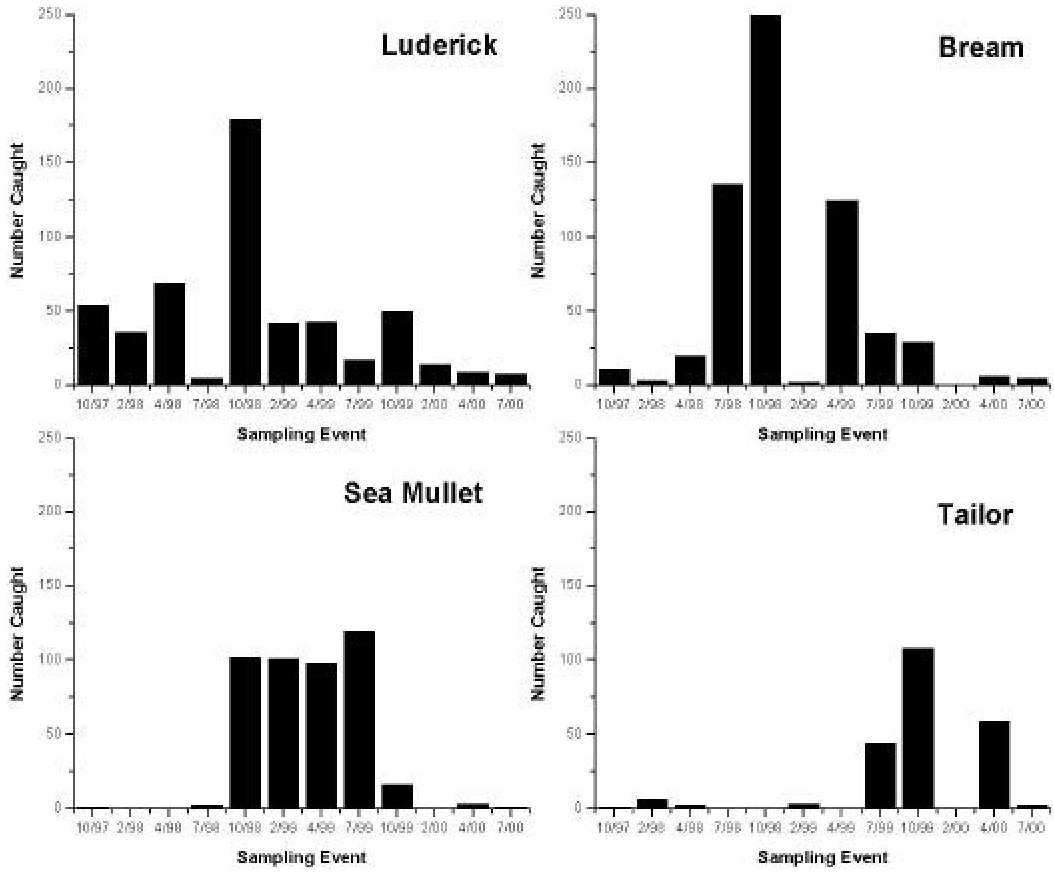
4.2.9.6 Recruitment of economically important fish species

In this preliminary analysis of the recruitment of economically important fish species in Wallaga Lake, only a limited number of species have been investigated, namely: luderick, yellowfin bream, tailor and sea mullet. Numbers of new recruits have been pooled for each sampling event. Recruitment of all species was very strong compared to many of the estuaries sampled and was particularly high during the spring and summer of the second year of sampling (Figure 4.25).

These patterns will require further detailed examination.

Figure 4.25: Numbers of new recruits of luderick, yellowfin bream and sea mullet, captured during sampling of Wallaga Lake. Data has been pooled over replicates and locations.

NB. New recruits have been defined as fish less than 50 mm in fork length.



4.2.10 Merimbula Lake

4.2.10.1 Introduction

Lake Merimbula was added to the list of "core" lakes for medium intensity sampling in the second year. A summary of this information for this lake is presented below.

4.2.10.2 Environmental Data

Merimbula Lake exhibited temperature ranges from a minimum temperature of 8.8°C to a maximum temperature of 25.4°C, and these minima and maxima values were related to seasonal effects (Figure 4.26). Salinity and conductivity values for the entrance location were always close to seawater values and were from a minimum salinity of 31.3 parts per thousand (‰) to a maximum of 36.7‰, and a minimum conductivity of 47 mS/cm to a maximum conductivity of 58 $mS.cm^{-1}$ (Figure 4.26). The central location had similar salinity values but experienced some lower values, ranging from 27.9 ‰ to 37.9 ‰, and conductivity in the range of 43.3 to 58 $mS.cm^{-1}$. The upper location also experienced high salintiy values, ranging from 32.3‰ to a maximum of 38.9‰, and conductivity ranged from 44.5 $mS.cm^{-1}$ to 58.3 $mS.cm^{-1}$ (Figure 4.26).

pH values were quite consistent throughout the sampling period and across localities, ranging from 7.9 – 9.1. Turbidity values were the lowest at the entrance site ranging from 0.09 to 5.19 NTU. At the central and upper region, turbidity values were similar, ranging from a minimum of 0.17 to a maximum of 9.28 NTU (Figure 4.26).

4.2.10.3 Shallow Water Fishes

Merimbula Lake was very different in term of its fish community to the other six estuaries mainly as a result of high fish species diversity but dramatically lower number of fish caught. A total of only 5430 fish were caught, representing sixty-one fish species of which twenty species are considered of significance to commercial and/or recreational fisheries (Table 4.39). The most specious families collected were the Gobiidae (10 species), the Monacanthidae (9 species) and the Syngnathidae (6 species). In terms of abundance, small mouth hardyhead (*Atherina microstoma*) and glassy perchlet (*Ambassis jacksoniensis*) dominated the assemblage. The highest numbers of commercial finfish were luderick (*Girella tricuspidata*), bridled leatherjacket (*Acanthaluteres spilomelanures*), yellow-finned leatherjacket (*Meuschenia trachylepis*) sand mullet (*Myxus elongatus*) and eastern blue groper (*Achoerodus viridis*).

Only three species were caught once in Merimbula Lake, and these were sandy sprat (*Hyperlophus vittatus*), cardinalfish (*Apogon limenus*) and an unidentified *Upeneuss* species. Nine fish species were unique to Merimbula Lake (Table 4.39). Examples include species from the Apogonidae family, the Sydney cardinalfish (*Apogon limenus*) and little siphonfish (*Siphamia caphalotes*), two weed whiting species and a pipefish species (*Syngnathoides biaculeatus*).

Figure 4.26: Summary of environmental data for the entrance, central and upper locations within Merimbula Lake (1998-2000).

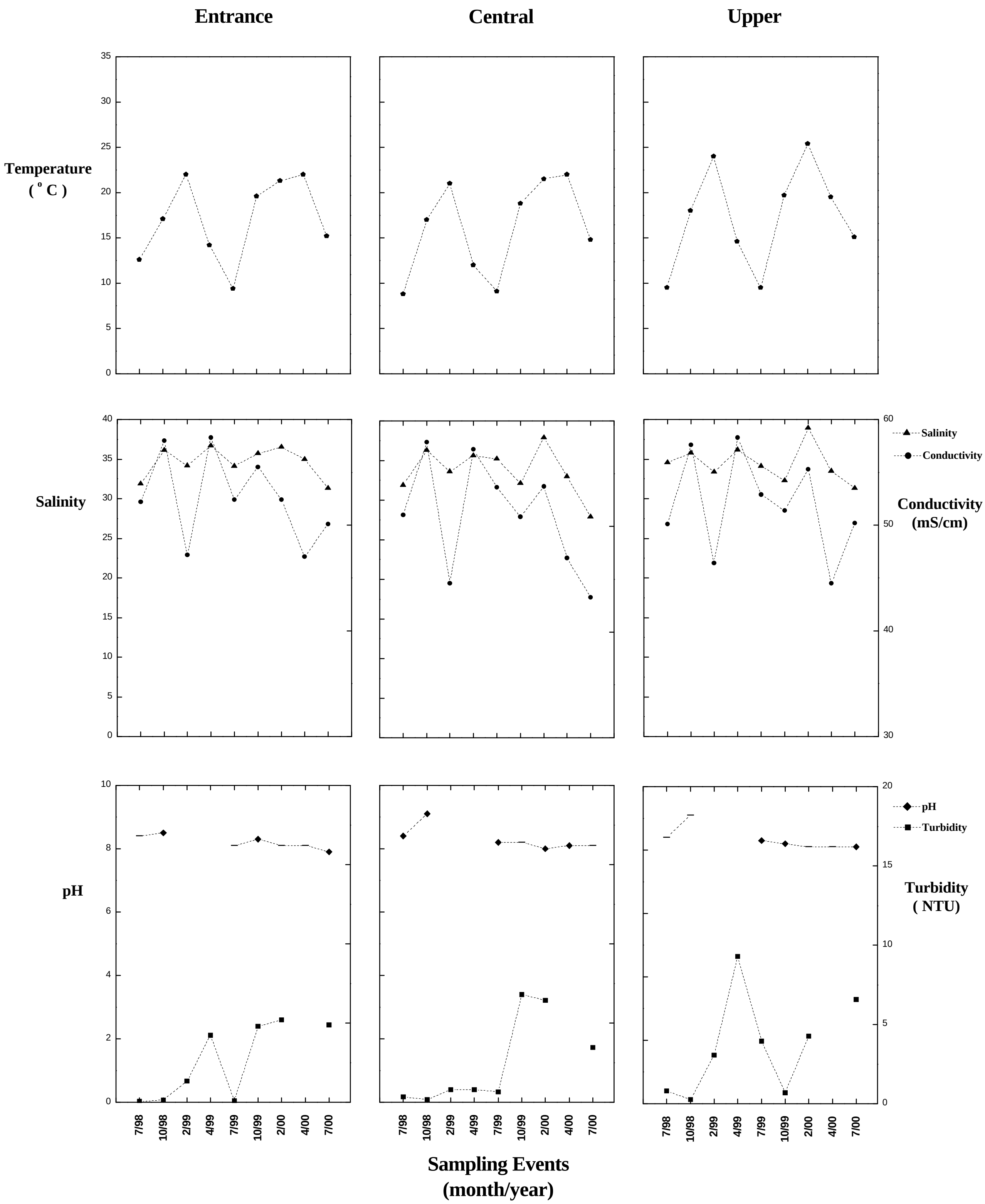


Table 4.39: Total number of fish caught by each species, at the entrance location, central location and upper location within Merimbula Lake during pooled across sampling events from July 1998 to July 2000. (* indicates species of commercial and/or recreational importance.)

	NUMBER CAUGHT			
Family *Species*	**Entrance**	**Central**	**Upper**	**Total**
Clupeidae				
*Hyperlophus vittatus**	0	0	1	1
Spratellloides robustus	9	0	0	9
Hemiramphidae				
*Hyporhamphus australis**	0	0	10	10
Atherinidae				
Atherinasoma microstoma	175	592	669	1436
Atherinasoma elongata	90	1	1	92
Pseudomuglidae				
Psuedomugil signifer	0	0	5	5
Syngnathidae				
Syngnathoides biaculeatus	0	7	5	12
Vanacampus poecilolaemus	36	61	29	126
Urocampus carinirostris	39	46	15	100
Vanacampus phillipi	16	38	7	61
Stigmatophora nigra	21	20	0	41
Stigmatophora argus	38	67	58	163
Scorpaenidae				
Centropogon australis	12	15	4	31
Ambassidae				
Ambassis jacksoniensis	237	733	98	1068
Terapontidae				
Pelates quadrilineatus	18	30	4	52
Apongonidae				
Apogon limenus	0	1	0	1
Siphamia cephalotes	38	4	37	79
Pomatomidae				
*Pomatomus saltator**	1	0	9	10
Carangidae				
*Pseudocaranx dentex**	69	0	0	69
Sparidae				
*Acanthopagrus australis**	5	12	0	17
*Chrysophrys auratus**	12	6	0	18
Rhabdosargus sarba *	4	6	0	10
Gerreidae				
*Gerres subfasciatus**	0	31	45	76
Mullidae				
Upeneuss species	1	0	0	1
Upeneichthys species	3	0	0	3
*Parupeneus signatus**	4	0	0	4
Girellidae				
*Girella tricuspidata**	481	67	28	546
Scorpididae				
*Scorpis lineolatus**	0	5	0	5
Enoplosidae				
Enoplosus armatus	1	0	1	2
Mugilidae				
*Myxus elongatus**	0	82	2	84
*Mugil cephalus**	0	11	21	32

Table 4.39 Continued

Family *Species*	NUMBER CAUGHT **Entrance**	**Central**	**Upper**	**Total**
Labridae				
*Achoerodus viridis**	26	52	0	78
Odacidae				
Haletta semifasciata	1	1	79	81
Neodax balteatus	1	13	20	34
Blennidae				
Petroscirtes lupus	5	10	1	16
Clinidae				
Heteroclinus perspicillatus	0	3	3	6
Cristiceps australis	0	3	3	6
Gobiidae – subfamily Eleotridinae				
Philypnodon grandiceps	9	2	19	30
Gobiidae				
Bathygobius kreffti	0	9	1	10
Favonigobius lateralis	123	245	1	369
Favonigobius exsquisites	0	30	0	30
Amoya bifrenatus	4	14	3	21
Amoya frenatus	30	8	23	61
Afurcagobius tamarensis	26	40	1	67
Pseudogobius olorum	7	0	0	7
Redigobius macrostoma	3	2	35	40
Gobiopterus semivestitus	4	2	0	6
Siganidae				
Siganus nebulosus	18	2	0	19
Bothidae				
*Pseudorhombus arsius**	0	2	0	2
Monacanthidae				
Acanthaluteres spilomelanurus	12	7	77	96
*Scobinichthys granulatus**	4	4	2	10
*Penicipelta vittiger**	2	0	0	2
*Monacanthus chinensis**	7	13	4	24
Brachaluteres jacksoniensis	8	2	0	10
*Meuschenia freycineti**	64	16	26	106
*Meuschenia trachyylepis**	0	4	5	9
Meuschenia species	2	20	8	30
Nelusetta ayraudi	1	3	1	4
Tetraodontidae				
Tetractenos hamiltoni	1	21	17	39
Tetractenos glaber	10	30	6	46
Diodontidae				
Dicotylichthys punctulatus	1	1	6	8
Total individuals	**1649**	**2393**	**1388**	**5430**
Total species	**46**	**49**	**42**	**61**

4.3 High Intensity Sampling

4.3.1 Introduction

An intensive sampling program was undertaken in the final year with the aim of determining the spatial and temporal variability of shallow water fish communities within individual estuaries, namely, Lake Illawarra and Durras Lake. These two estuaries were chosen, as they are the subjects of intensive water quality studies by the NSW Environment Protection Authority. A combination of these water quality studies and the intensive fish sampling will prove to be an interesting comparative data set.

At this stage, very little analysis of these data have been possible, due to time constraints between finalising the sampling program and producing this summary report. However, in the sections below, the raw data has been compiled into species abundance tables.

4.3.2 Lake Illawarra

A total of 25 963 fish were caught during the high intensity sampling period of Lake Illawarra. This catch represented forty-seven fish species of which eighteen of these species are considered of significance to commercial and recreational fisheries (Table 4.40). The most specious families collected within the sampling period were the Gobiidae (11 species) and Monacanthidae (7 species). In terms of individual numbers the seagrass fish fauna was dominated by large catches of glass goby (*Gobiopterus semivestitus*), small mouth hardyhead (*Atherinasoma microstoma*), Tamar River goby (*Afurcagobius tamarensis*) and glassy perchlet (*Ambassis jacksoniensi*), and these species represented approximately 80% of the total catch. The main economically important species caught were yellowfin bream (*A. australis)*, luderick (*Girella tricuspidata)*, silver biddy (*Gerres subfasciatus)* and tarwhine *(Rhabdasargus sarba)* (Table 4.40).

4.3.3 Durras Lake

The intensive sampling program of Durras Lake yielded 31 923 fish representing forty-eight fish species (Table 4.41). Twenty species are considered to be of importance to commercial and recreational fisheries. Nearly 85% of the total catch was comprised of glass goby (*Gobiopterus semivestitus*), flatheaded gudgeon (*Philypnodon grandiceps*), Tamar River goby (*Afurcagobius tamarensis*) and glassy perclet (*Ambassis jacksoniensis*). In terms of species diversity, the Gobiidae and Monacanthidae were the most specious with twelve and eight species, respectively. The commercial species with the highest catches in Durras Lake were silver biddy (*G. subfasciatus)*, luderick (*G. tricuspidata)* yellowfin bream (*A. australis)*, sea mullet *(Mugil cephalus)* and tarwhine *(Rhabdasargus sarba)* (Table 4.41).

Table 4.40: Total number of fish caught by each species, during high intensity sampling of Lake Illawarra between May 1999 and May 2000. Locations within lake are labelled A to H. (* indicates species of commercial and/or recreational importance.)

Family *Species*	LOCATION								
	A	B	C	D	E	F	G	H	Total
Anguillidae									
*Anguilla reinhardtii**	0	0	1	0	0	0	0	0	1
Hemiramphidae									
*Hyporhamphus australis**	19	15	38	12	2	0	0	1	87
Belonidae									
Tylosurus gavialoides	0	1	0	0	0	0	0	0	1
Atherinidae									
Atherinasoma microstoma	322	5020	614	15	414	136	73	72	6666
Atherinasoma elongata	35	0	0	0	0	0	1	0	36
Pseudomuglidae									
Pseudomugil signifer	0	0	0	2	0	0	21	7	30
Syngnathidae									
Vanacampus poecilolaemus	1	0	3	22	3	0	0	3	32
Urocampus carinirostris	12	14	6	14	6	15	8	17	92
Stigmatophora nigra	0	0	1	7	1	0	10	1	20
Scorpaenidae									
Centropogon australis	3	2	22	18	19	6	5	0	75
Ambassidae									
Ambassis jacksoniensis	48	85	225	377	138	44	189	30	1136
Terapontidae									
Pelates quadrilineatus	34	38	85	162	208	108	99	27	761
Sillaginidae									
*Sillago ciliata**	0	0	3	0	0	0	0	0	3
*Sillago maculata**	1	0	0	2	0	0	0	0	3
Pomatomidae									
*Pomatomus saltator**	7	3	4	3	0	4	2	42	65
Sparidae									
*Acanthopagrus australis**	100	11	111	83	113	11	68	41	538
*Rhabdosargus sarba**	21	16	27	6	115	3	3	0	198
Gerreidae									
*Gerres subfasciatus**	8	38	15	30	21	17	56	42	227
Monodactylidae									
*Monodactylus argenteus**	0	0	1	3	4	5	7	2	22
Girellidae									
*Girella tricuspidata**	68	12	47	44	103	65	34	17	390
Enoplosidae									
Enoplosus armatus	0	0	0	1	0	0	0	0	1
Mugilidae									
*Myxus elongatus**	7	0	13	2	2	2	4	3	33
*Mugil cephalus**	19	1	3	14	7	2	15	2	63

Table 4.40 Continued

Family *Species*	**LOCATION**								
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Total**
Labridae									
*Achoerodus viridis**	4	1	20	0	2	0	2	1	30
Blennidae									
Petroscirtes lupus	1	0	0	0	0	0	0	0	1
Gobiidae – subfamily Eleotridinae									
Philypnodon grandiceps	111	94	125	35	90	61	33	208	757
Philypnodon species	0	0	1	0	0	0	0	10	11
Gobiidae									
Favonigobius lateralis	25	0	0	19	1	0	38	107	190
Favonigobius exsquisites	26	5	40	148	172	52	68	90	601
Amoya bifrenatus	4	5	42	205	173	18	13	94	554
Amoya frenatus	1	0	0	0	0	0	1	0	2
Bathygobius kreffti	2	0	4	8	1	0	0	8	23
Afurcagobius tamarensis	213	72	216	349	829	170	157	976	2982
Pseudogobius olorum	48	6	0	0	0	1	0	5	60
Redigobius macrostoma	21	12	3	31	1	2	5	12	87
Gobiopterus semivestitus	983	28	1009	2721	956	1241	1867	1070	9875
Siganidae									
Siganus nebulosus	1	0	0	1	0	0	0	0	2
Monacanthidae									
Acanthaluteres spilomelanurus	0	0	0	1	0	0	0	0	1
*Scobinichthys granulatus**	2	0	0	1	1	0	3	0	7
*Penicipelta vittiger**	0	0	0	0	0	0	1	0	1
*Meuschenia freycineti**	2	4	6	6	2	2	2	6	30
*Meuschenia trachyylepis**	11	0	29	59	5	27	14	6	151
Meuschenia species	0	0	0	1	0	0	0	0	1
Nelusetta ayraudi	0	0	0	0	0	0	5	0	5
Tetraodontidae									
Tetractenos hamiltoni	9	0	20	0	2	2	15	4	52
Tetractenos glaber	1	0	2	6	6	1	5	1	22
Diodontidae									
Dicotylichthys punctulatus	2	1	9	3	7	2	5	9	38
Total number caught	**2172**	**5484**	**2745**	**4411**	**3404**	**1997**	**2836**	**2914**	**25963**

Table 4.41: Total number of fish caught by each species, during high intensity sampling of Durras Lake between May 1999 and May 2000. Locations within lake are labelled A to H. (* indicates species of commercial and/or recreational importance.)

Family *Species*	LOCATION								
	A	B	C	D	E	F	G	H	Total
Plotosidae									
Cnidoglanis macrocephalus	1	0	0	0	0	0	0	0	1
Hemiramphidae									
*Hyporhamphus australis**	0	0	0	0	0	3	0	0	3
*Hyporhamphus regularis**	0	2	1	0	0	5	4	1	13
Atherinidae									
Atherinasoma microstoma	0	1	53	2	2	7	24	25	114
Atherinasoma elongata	27	2	28	14	0	1	9	41	122
Pseudomuglidae									
Pseudomugil signifer	4	98	30	16	48	27	213	210	646
Syngnathidae									
Vanacampus poecilolaemus	2	0	0	0	0	0	0	0	0
Urocampus carinirostris	7	27	12	17	45	32	26	20	186
Stigmatophora nigra	3	0	0	0	0	0	0	0	0
Scorpaenidae									
Centropogon australis	26	20	5	38	34	11	3	3	140
Platycephalidae									
*Platycephalus fuscus**	0	0	0	0	0	0	1	0	1
*Thysanophrys cirronasus**	0	0	0	0	0	1	0	0	1
Ambassidae									
Ambassis jacksoniensis	398	1182	804	333	28	384	197	54	3380
Terapontidae									
Pelates quadrilineatus	18	27	28	10	12	19	6	0	120
Sillaginidae									
*Sillago flindersi**	6	3	1	0	0	0	0	0	10
Pomatomidae									
*Pomatomus saltator**	0	20	31	12	1	42	3	3	112
Sparidae									
*Acanthopagrus australis**	0	14	14	13	52	99	103	24	334
*Rhabdosargus sarba**	1	4	2	6	2	49	36	17	117
Gerreidae									
*Gerres subfasciatus**	52	138	13	101	179	112	41	13	649
Monodactylidae									
*Monodactylus argenteus**	0	2	10	23	2	31	0	2	70
Girellidae									
*Girella tricuspidata**	36	53	90	40	75	49	42	4	389
Mugilidae									
*Myxus elongatus**	1	11	10	21	14	9	13	0	79
*Mugil cephalus**	43	48	0	3	26	3	0	0	123
Labridae									
*Achoerodus viridis**	0	0	1	0	0	3	5	0	9

Table 4.41 Continued

Family Species	A	B	C	D	E	F	G	H	Total
					LOCATION				
Blennidae									
Petroscirtes lupus	0	1	0	0	0	0	0	0	1
Omobranchus anolius	0	0	0	1	0	1	0	0	2
Gobiidae – subfamily Eleotridinae									
Philypnodon grandiceps	237	1506	356	1007	705	1029	1048	710	6598
Philypnodon species	3	47	2	5	5	14	34	59	169
Gobiidae									
Favonigobius lateralis	10	0	11	0	20	9	6	1	57
Favonigobius exsquisites	13	7	13	51	7	15	16	6	128
Amoya bifrenatus	25	60	5	57	72	24	97	69	409
Amoya frenatus	0	0	0	0	1	0	0	0	1
Bathygobius kreffti	11	0	0	0	0	0	1	0	12
Afurcagobius tamarensis	92	320	98	578	940	557	969	639	4193
Pseudogobius olorum	0	0	0	0	0	2	0	1	3
Redigobius macrostoma	16	37	66	25	55	161	24	97	481
Gobiopterus semivestitus	82	2317	394	2028	2707	1205	2346	2056	13135
Cryptocentroides cristatus	0	0	0	1	0	0	0	0	1
Siganidae									
Siganus nebulosus	0	2	2	1	0	3	0	0	8
Bothidae									
*Pseudorhombus jenynsii**	2	0	0	0	0	0	0	0	2
Monacanthidae									
Acanthaluteres spilomelanurus	0	1	0	0	3	5	0	0	9
*Scobinichthys granulatus**	0	0	0	0	0	1	0	0	1
*Monacanthus chinensis**	1	0	1	0	0	0	0	0	2
*Meuschenia freycineti**	0	2	11	11	6	9	0	0	39
*Meuschenia trachyylepis**	2	6	1	8	10	18	2	1	48
Meushenia species	0	0	1	0	0	1	0	0	2
Nelusetta ayraudi	0	0	0	0	4	0	0	0	4
Diodontidae									
Dicotylichthys punctulatus	0	0	0	0	0	1	1	0	2
Total number caught	**1134**	**5958**	**2094**	**4422**	**5055**	**3939**	**5265**	**4056**	**31923**

5 DISCUSSION

5.1 Introduction

Over the past decade, Ecologically Sustainable Development (ESD) and conservation of biodiversity have become central issues in environmental management throughout the world, especially for those nations that are signatories to the United Nations "Convention on Biological Conservation" (the Rio Agreement). In Australia, these issues have provided a new framework for managing natural resource-based industries, such as mining, agriculture, fisheries and forestry, and have encouraged an ecosystem-based approach to management (DEST 1996a).

For the Australian fishing industries, this ecosystem-based approach has led to a broadening of the management goals, and a shift away from the historical single species-based management (DEST 1996b). As a result, not only has the scope of the information required for management widened to include fish biodiversity and ESD, but in some cases the fish and fisheries have themselves been adopted as indicators of health of their habitats and surrounding ecosystems (DEST 1996c).

In considering the new information requirements for estuarine fisheries management, it is apparent that there now exist some major information gaps. For example, to meet the principles of ESD and biological conservation, improved information is required on the diversity and abundances of fishes in estuaries, not just for the few species that make up the "fish harvest", but also for the bulk of the other fish species.

While less than about ten species are regularly harvested from NSW estuaries, there are in fact hundreds of species present, and very little data has been collected on the diversity and abundance of these additional species.

To date, there have been very few studies that have collected this type of detailed fish community data over large areas of the Australian coast. For example, prior to this research, the fish communities in the majority of small to medium-sized NSW estuaries south of Sydney had never been sampled.

The primary objective of this project has been to assist in dealing with these significant information gaps. During the course of this FRDC project, a large information base has been established concerning the present state of the shallow water fish communities and fish habitats in a large number of estuaries over a wide spatial scale.

As well as answering questions about the variability in diversity and abundance of these fish communities, these data will be of great benefit in the future, in preparing fisheries and estuary management plans in the south coast region of NSW.

This report represents a summary of the available data collected as part of FRDC Project 97/204. Some of these data have been partially analysed. Over the next six to twelve months, these data will be analysed further and prepared for publication in a variety of formats.

5.2 Water and habitat quality in south coast estuaries

A large volume of information has been collected on water and habitat quality at all the sites sampled between Wollongong and Eden (NSW). Some of these data are presented in this report, primarily for the medium intensity sampling program. Further data is available on request from the authors, for both the low intensity and high intensity sample sites.

The medium intensity sampling program collected information on six large coastal lakes along the NSW south coast. Interestingly, salinity, conductivity, temperature and pH did not vary as greatly as expected at locations within these lakes. The major difference between locations within these estuaries was in the level of turbidity, which was generally higher and more erratic at sites away from the estuary entrances (see Figs. 4.2, 4.6, 4.10, 4.14, 4.18, 4.22, 4.26).

The consistency in environmental factors between locations within lakes, particularly for salinity and temperature, is an important difference between these coastal lakes and river estuaries, and has a great influence on the fish communities. Unlike these coastal lakes, river estuaries (that is, coastal rivers) have a pronounced salinity and temperature gradient which is the main factor influencing the composition of fish assemblages (e.g., see West and Walford, 2000).

5.3 Diversity and abundance of shallow water fishes

During the course of this study, 289 160 fish comprising over 100 fin-fish species were collected from the shallow waters of NSW south coast estuaries. While the vast majority of these species were released, voucher specimens have been collected and will be lodged with the Australian Museum (Sydney), for future reference. This will provide a long-term fish database and reference collection for this large region of southeastern Australia.

Species lists have been presented in this report, along with some preliminary analyses of these data, to demonstrate some of the patterns in distribution and abundance of fishes. At this stage, the shallow water fish communities in the NSW south coast appear to display a remarkable degree of similarity between sites within and between estuaries. This is surprising considering the large spatial scale of the sampling program. Major differences appear to relate more to the individual morphology of particular estuaries, than to regional differences. As expected, the entrance condition (i.e., open or closed) is an important factor. However, further detailed analyses are required before trends within the data can be fully explored.

The fish surveys carried out were not designed to specifically look at the impacts of commercial or recreational fishing, as this would require a specially designed sampling program with controlled experiments (e.g., a BACI design). However, areas have been sampled that are open and closed to commercial fin-fish netiing, that is, mesh and haul nets. There were no obvious differences in sites open and closed to this form of fishing, and fish community differences appeared to relate more to the physical and environmental conditions of particular sites than to the nature of fishing activities at the location. The relationship between environmental data and fish communities will be investigated in more detail in future publications.

5.4 Recruitment of economically important species

As a consequence of sampling shallow water seagrass beds, information has been gathered on the recruitment of quite a large number of economically important species of fish. The extensive spatial coverage of sampling has meant that this information on recruitment intensity is available for a large part of the NSW south coast.

Some of this information has been presented throughout this report (see Figs. 4.5, 4.9, 4.13, 4.17, 4.21, 4.25). In addition, an overview of recruitment intensity for some of the major economically important species in the estuaries sampled along the NSW south coast has been prepared (Appendix 4).

One of the surprising findings of the study was that, for many estuaries, small new recruits of some species were found in the seagrass throughout the entire year. For example, in the case of yellowfin bream, new recruits were found in high numbers through all sampling periods of the second year (Figure 5.1, Appendix 4). This corresponded to a period after many of the lakes had opened to the sea after heavy rain. This finding needs to be analysed in more detail, as it suggests that recruitment of some species is much less seasonal than previously thought.

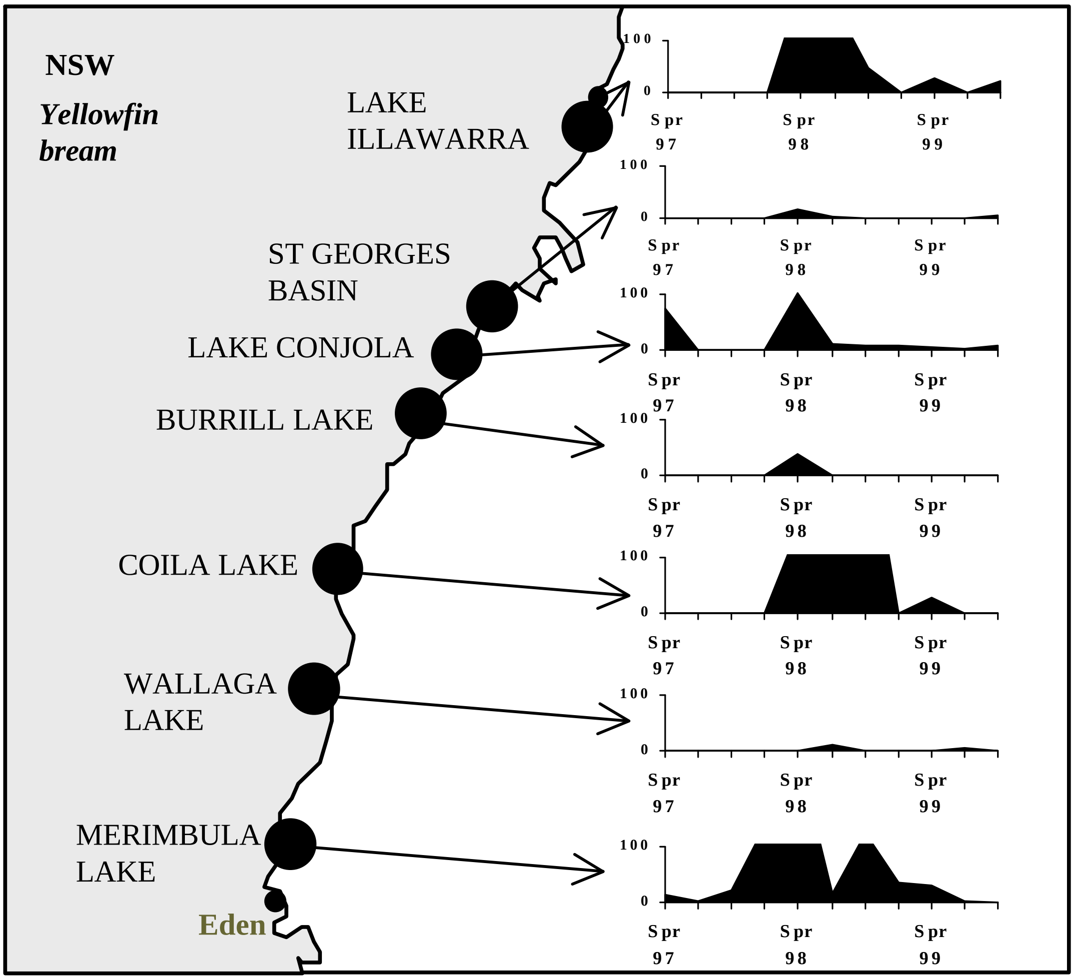
5.5 Shallow water fish as indicators of biodiversity and sustainability

One of the major activities arising from the adoption of ESD principles and biodiversity conservation has been the investiagtions of suitable environmental "indicators". Indicators are needed which would allow targets and standards to be established and progress in management to be monitored (DEST 1996c).

The use of fish as environmental indicators has several advantages over many other possible indicators. For example, they are relatively large and easy to identify and generally respond to environmental change (Stephens Jr et al. 1988, Harris 1995, Scott and Hall Jr 1997). In addition, fish have an obvious economic value and high public profile, factors that increase acceptance by the wider community. Harris and Silveira (1997) recently argued that environmental indicators based on fish are better able to integrate environmental quality and reflect river health on an ecosystem scale when compared to measures of physical parameters, such as water quality.

However, apart from commercial fish catch statistics, information about fish communities in Australian waters is generally poor. Scientific sampling programs of fish in Australian coastal waterways have generally been restricted to a few localities and short time frames, even in areas where the harvesting pressure is high. For example in southeastern Australia, very few estuaries have been sampled in a structured scientific program and none for more than one to two years. Yet most estuaries in the region are harvested commercially (Scribner and Kathuria 1996) and/or recreationally (West and Gordon 1994).

Figure 5.1: Recruitment intensity for yellowfin bream (*Acanthopagrus australis*) between 1997 and 2000, for the six estuaries sampled (see Method and Materials).



This lack of information about fish biodiversity in estuaries was highlighted in the recent Australian State of the Environment (SoE) Report where the need to develop indicators for estuary health was also emphasised (DEST 1996c; see also Zann, 1995). While the use of commercial fish catch data has been suggested as one indicator of ecosystem health (DEST 1996c), such statistics have obvious shortcomings. While useful, commercial fishing statistics are often too general in terms of species identification, sometimes poorly collected (e.g. with no data checking) and/or lack the complementary information concerning fishing effort. In any case, fish catch statistics generally provide no data for the non-commercial fish species within an area, which are usually the majority of the fish assemblage and constitute an important component of the ecosystem.

In considering possible indicators for estuary fisheries and for estuary health, there are obvious advantages in sampling shallow waters environments. Shallow waters, particularly areas such as seagrass beds, are important habitats for new recruits of many economically important fish species found in estuaries and, as a result, have been the subject of a number of previous sampling programs (e.g., Pollard 1984).

The present study has clearly demonstrated that sampling in shallow waters of estuaries can provide extremely useful information that is very relevant to a range of inshore and estuarine fisheries, and, more generally, are relevant to estuary health. The major benefits of shallow water sampling, in seagrass beds, as an environmental "indicator" are that:

- ***Economically important fish species are captured as juveniles***.
    - Many economically important species recruit to the shallow waters of east coast estuaries, including finfish such as sea mullet (*Mugil cephalus*), fantail mullet (*Liza argentea*), sand mullet (*Myxus elongatus*), yellowfin bream (*Acanthopagrus australis*), luderick (*Girella tricuspidata*), snapper (*Pagrus auratus*), sand whiting (*Sillago ciliata*), longfin eels (*Anguilla reinhardtii*), silver biddies (*Gerres ovatus*) and dusky flathead (*Platycephalus fuscus*). This means that this type of sampling provides very early information on the condition of the future fish stocks.
- ***Seagrass beds are highly diverse in terms of fish communities.***
    - As well as new recruits of economically important species, seagrass beds in east coast estuaries contain large numbers of fish and invertebrate species, often in high abundance. Some of these species are of particular significance, such as the seahorses and pipefishes. In the present study, depending on sampling frequency, most areas sampled had up to thirty species if fish.
- ***Relatively small-scale resources are required***.
    - Sampling shallow waters tends to make use of relatively simple fishing gear, such as a small seine net, and short soak times. In the present study, each replicate took a maximum of 30 minutes. This means that experiments and sampling designs could be well replicated and were statistically robust. These simple procedures also mean that the vast majority of fish can be released.
- ***The method is accessible and easily demonstrated to the public and community groups.***
    - Sampling seagrass beds provides an excellent public demonstration of the value of these habitats and of the complexity in the life history of many fish species. During the course of the present project, several public demonstrations were carried out, some in association with open days organised by Oceanwatch.

The major disadvantage in using shallow water fish samling as an environmental indicator is that there exists no long-term data on which to provide the basis for comparison. For example, it would probably be necessary to collect at least a ten years of recruitment data before a link between fish recruitment and fish catches could be attempted. Of course, once established, such a link would provide invaluable information concerning the state of the various estuarine fisheries and the relative condition of estuarine habitats.

5.6 Benefits

The results of this project have already been used by a number of Local and State Government agencies and will be an important resource for fisheries and estuary managers in the future. The benefits of the projects are non-market benefits and likely to be split between commercial and recreational industry sectors. Although difficult to estimate the nature of these benefits, it is likely that the results of this project will be used in commercial fisheries managment plans, particularly those plans and impact assessments relating to estuary fisheries. There will also be some small benefit to eastern Australian states other than NSW, in that many of the fish species caught in this study are also found in Queensland and Victorian waters.

These benefits and beneficiaries are the same as those identified in the original FRDC proposal.

5.7 Further Development

5.7.1 Dissemination of Results

The information and data collected during the course of this research program will be an important resource for future fisheries and estuarine managers. It presents a snapshot of the present state of the fish communities, populations, recruitment intensities and environmental conditions in a large number of estuaries over a wide spatial range of southeastern Australia.

It is recommended that these raw data, and appropriate summaries and interpretations, be made available, as soon as practicable, in an internet accessible form, so that it may be used by coastal, estuarine and fisheries managers.

5.7.2 Establishment of an on-going monitoring program

Sampling of shallow water fish communities, such as seagrass fishes, in estuaries represents an excellent method for monitoring the health of fish populations and, more generally, of estuaries. This is particularly true in southeastern Australia, where these fish habitats are rich in terms of species, and act as nursery areas for large numbers of economically important species.

For this reason, there should be an ongoing monitoring program established, using shallow water sampling, aimed specifically at sampling key estuaries at critical times, in order to provide an indicator for the purposes of ESD and biodiversity conservation.

5.7.3 Future comparative studies

At this stage, due to constraints on resources, it is not possible to extensively sample large numbers of estuaries on a regular basis over extended time periods. However, repeating this survey at some future date would provide the the opportunity of comparing the state of the fish communities and the environmental condition of the estuaries. Even if carried out after a relatively long term period, such data would be invaluable in determining long term changes in these shallow water habitats.

It is therefore recommended that consideration be given to repeating this extensive survey of shallow water fish communities in NSW south coast estuaries, at a future date, perhaps in 5 or 10 years time, to provide a comparative data set.

5.8 Conclusion

The primary goal of this study was to provide information concerning the shallow water fish communities inhabiting a large number of estuaries in south-eastern Australia, most of which had not been sampled in a consistent manner previously. The specific objectives were:

1. To examine variability in the diversity and abundance of fishes within and between selected estuaries, coastal lakes and lagoons in southern NSW, including fished and non-fished areas.
2. To provide the first set of comparative data for the south coast region of NSW on the recruitment intensity for a large selection of economically important fish species.
3. To investigate the usefulness of these data as indicators of biodiversity and sustainability, and for possible inclusion as performance indicators in management of estuaries.
4. To provide a comprehensive set of environmental data relating to each sampling location, including water quality and habitat quality parameters.

Each of these objectives has been reported upon and discussed throughout this report.

Overall, this report represents a summary and overview of what has probably been the most extensive scientific investigation of fish fauna undertaken in NSW waters. Over the three-year period, sampling was carried out at twenty-five estuaries, at a range of spatial and temporal scales. Voucher specimens of all species have been collected and are to be lodged with the Australian Museum.

In the previous sections, a large amount of information and data have been presented which fulfils the initial objectives of the project, as outlined above. Because of the large volume of information collected, it will mean that it may take many years to completely the data. In this report, some basic analyses have been completed and as much of the data as possible has been summarised and presented.

While the research has concentrated only on shallow water fish habitats, particularly seagrass beds, these sites are critical habitats for many species of fish, including a large range of economically important species. Many cryptic and schooling fish dominated the catches, such as Gudgeons, Gobies and Perchlets, however a large number of commercial species, such as mullets (>5000), luderick (>4000), bream (>2500), tailor (>1000) and silver biddies (>900), were also amongst the catch.

The information collected in this FRDC funded study will be invaluable as a baseline for future work and will use in a wide range of management forums, including incorporation into fisheries management plans. Already, the preliminary data from the study has been incorporated into estuary management plans, marine park plans and state of the environment reports.

Further analyses of the data are now underway and it is expected that a large number of publications will result in future years.

ACKNOWLEDGEMENTS

We would like to thank the large number of students at the University of Wollongong who assisted in this sampling program (see Appendix 2 for listing). The project was funded by the Fisheries Research and Development Corporation (Project Nos. 97/204).

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7 APPENDIX 1: INTELLECTUAL PROPERTY

There is no intellectual property associated with this research project.

8 APPENDIX 2: STAFF

List of staff engaged in this project in either a part-time or full-time capacity;

Martine Jones
Shane Griffiths
Douglas Rotherham
Carla Ganassin
Terry O'Dwyer
Vincent Huurdman
Cameron Lowndes
Louise Puslednik

9 APPENDIX 3: LIST OF FIN-FISH SPECIES CAPTURED

Table A3: List of fin-fish species captured from the shallow waters of south coast estuaries between July 1997 and July 2000 (see Method and Materials for further details).

Family	Scientific Name	Common Name
Anguillidae	*Auguilla reinhardtii*	long-finned eel
Clupeidae	*Hyperlophus vittatus*	sandy sprat
	Sardinops neopilchardus	pilchard
	Spratelloides robustas	blue sprat
Engraulididae	*Engraulis australis*	Australian anchovy
Gonorynchidae	*Gonorynchus greyi*	beaked salmon
Plotosidae	*Cnidoglanis macrocephalus*	estuary catfish
Antennariidae	*Antennarius striatus*	striped anglerfish
Hemiramphidae	*Hyporhamphus australis*	sea garfish
	Hyporhamphus regularis	river garfish
Belonidae	*Strongylura leiura*	slender longtom
	Tylosurus gavialoides	stout longtom
Atherinidae	*Atherinasoma elongata*	elongate hardyhead
	Atherinosoma microstoma	small mouth hardyhead
Poeciliidae	*Gambusia holbrooki*	mosquito fish
Pseudomugilidae	*Pseudomugil signifer*	southern blue eye
Fistulariidae	*Fistularia commersonii*	smooth flutemouth
Syngnathidae	*Hippocampus breviceps*	short-snouted seahorse
	Hippocampus whitei	white's seahorse
	Stigmatophora argus	spotted pipefish
	Stigmatophora nigra	wide body pipefish
	Syngnathoides biaculeatus	double-ended pipefish
	Urocampus carinirostiis	hairy pipefish
	Vanacampus phillipi	Port Phillip pipefish
	Vanacampus poecilolaemus	long-snout pipefish
Scorpaenidae	*Centropogon australis*	eastern fortescue
Platycephalidae	*Platycephalus fuscus*	dusky flathead
Ambassidae	*Ambassis jacksoniensis*	glassy perchlet
Teraponidae	*Pelates quadrilineatus*	trumpeter
Apogonidae	*Apogon limenus*	sydney cardinalfish
	Siphamia cephalotes	little siphonfish
Dinolestidae	*Dinolestes lewini*	longfin pike
Sillaginidae	*Sillago ciliata*	sand whiting
	Sillago flindersi	eastern school whiting
	Sillago maculata	trumpeter whiting
Pomatomidae	*Pomatomus saltator*	tailor
Carangidae	*Pseudocaranx dentex*	silver trevally
Sparidae	*Acanthopagrus australis*	yellowfin bream
	Chrysophrys auratus	snapper
	Rhabdosargus sarba	tarwhine
Gerreidae	*Gerres subfasciata*	silver biddy

Table A3 Continued

Family	Scientific Name	Common Name
Lutjanidae	*Lutjanus argentimaculatus*	mangrove jack
Lethrinidae	*Lethrinidae spp1*	emperor
	Lethrinus genivittatus	lancer
Mullidae	*Parupeneus signatus*	blackspot goatfish
	Upeneichthys spp1	goatfish
	Upeneus spp1	goatfish
	Upeneus tragula	bar-tailed goatfish
Monodactylidae	*Monadactylus argentus*	diamond fish
Girellidae	*Girella tricuspidata*	luderick
Scorpididae	*Microcanthidae spp1*	stripey
	Microcanthus strigatus	stripey
	Scorpis lineolatus	silver sweep
	Scorpis spp1	sweep
Enoplosidae	*Enoplosus armatus*	old wife
Pomacentridae	*Abudefduf spp1*	sergeant
Mugilidae	*Liza argentea*	flattail mullet
	Mugil cephalus	sea mullet
	Myxus elongatus	sand mullet
Sphyraenidae	*Sphyraena flavicauda*	long-jawed sea pike
	Sphyraena obtusa	striped sea pike
	Sphyraena spp1	sea pike species
Labridae	*Achoerodus viridis*	eastern blue groper
Odacidae	*Haletta semifasciata*	blue weed whiting
	Neodax balteatus	little weed whiting
	Odax acroptilus	rainbow cale
Scaridae	*Scarus spp1*	parrotfish
Bovichtidae	*Pseudaphritis urvillii*	congolli
Blennidae	*Omobranchus anolius*	oyster blenny
	Petroscirtes lupus	brown sabretooth blenny
Clinidae	*Cristiceps argyropleura*	silver-sided weedfish
	Cristiceps australis	crested weedfish
	Heteroclinus perspicillatus	common weedfish
Callionymidae	*Repomucenus calcaratus*	spotted sand-dragonet
Galaxiidae	*Galaxias maculatus*	common jollytail
Gobiidae	*Afurcagobius tamarensis*	Tamar River goby
	Amoya bifrenatus	bridled goby
	Amoya frenatus	half-bridled goby
	Bathygobius kreffti	frayed-fin goby
	Favonigobius exquisites	exquisite sand-goby
	Favonigobius lateralis	long-finned goby
	Gobiopterus semivestitus	glass goby
	Hypseleotris compressa	carp gudgeon
	Philypnodon grandiceps	flatheaded gudgeon
	Philypnodon spp1	dwarf flathead gudgeon
	Pseudogobius olorum	blue-spotted goby
	Redigobius macrostoma	large mouth goby
	Tridentiger trigonocephalus	trident goby
Siganidae	*Siganus nebulosus*	black spinefoot
Pleuronectidae	*Ammotretis rostratus*	long snouted flounder

Table A3 Continued

Family	Scientific Name	Common Name
Bothidae	*Pseudorhombus arsius*	long toothed flounder
	Pseudorhombus jenynsii	short toothed flounder
Monacanthidae	*Acanthaluteres spilomelanurus*	bridled leatherjacket
	Brachaluteres jacksonianus	pygmy leatherjacket
	Meuschenia freycineti	six-spined leatherjacket
	Meuschenia spp1	leatherjacket
	Meuschenia spp2	leatherjacket
	Meuschenia spp3	leatherjacket
	Meuschenia trachylepis	yellow-finned leatherjacket
	Monacanthus chinensis	fan-bellied leatherjacket
	Nelusetta ayraudi	chinaman leatherjacket
	Penicipelta vittiger	toothbrush leatherjacket
	Scobinichthys granulatus	rough leatherjacket
Tetraodontidae	*Arothron firmamentum*	starry toadfish
	Tetractenos glaber	smooth toadfish
	Tetractenos hamiltoni	common toad
Diodontidae	*Dicotylichthys punctulatus*	three-barred porcupinefish

10 APPENDIX 4: RECRUITMENT OF SOME ECONOMICALLY IMPORTANT FISH SPECIES

Figure A4.1: Recruitment intensity for yellowfin bream (*Acanthopagrus australis*) between 1997 and 2000, for the six estuaries sampled (see Method and Materials).

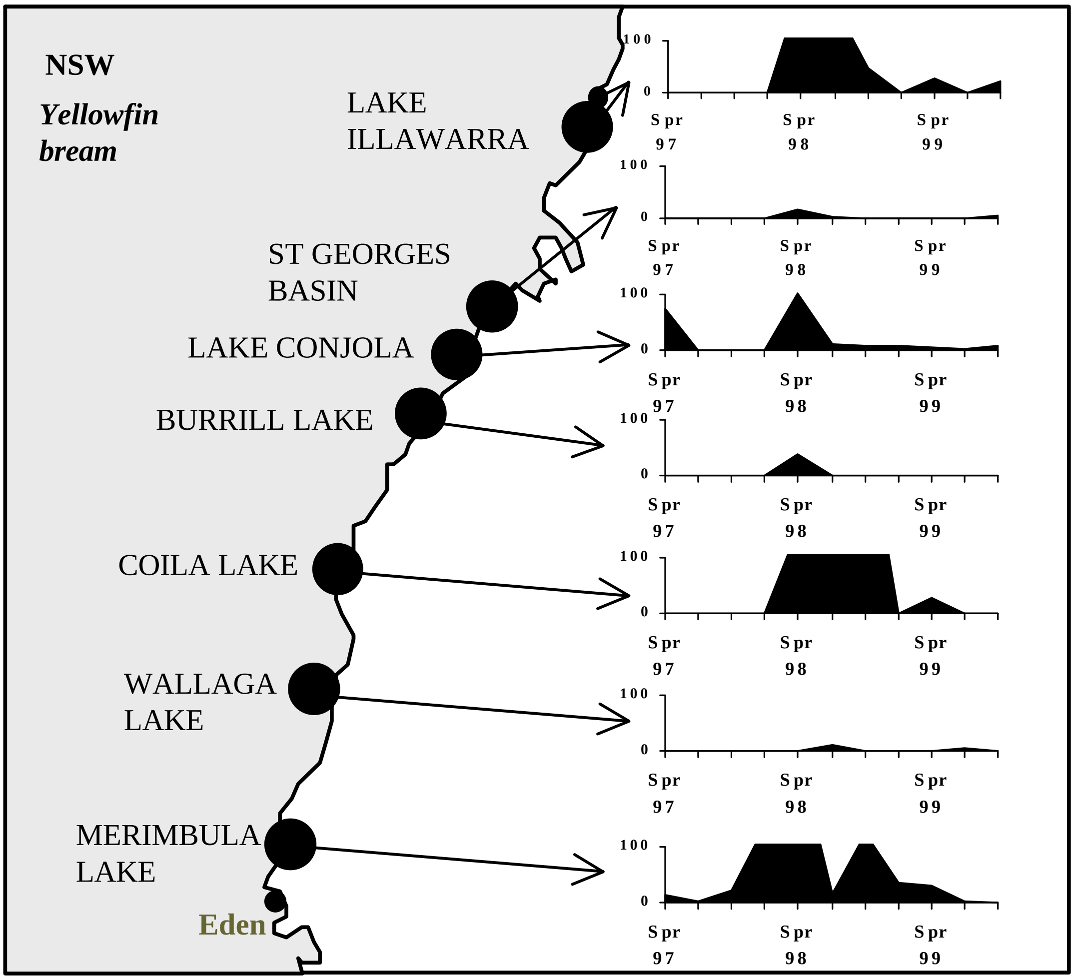

Figure A4.2: Recruitment intensity for luderick (*Girella tricuspidata*) between 1997 and 2000, for the six estuaries sampled (see Method and Materials).

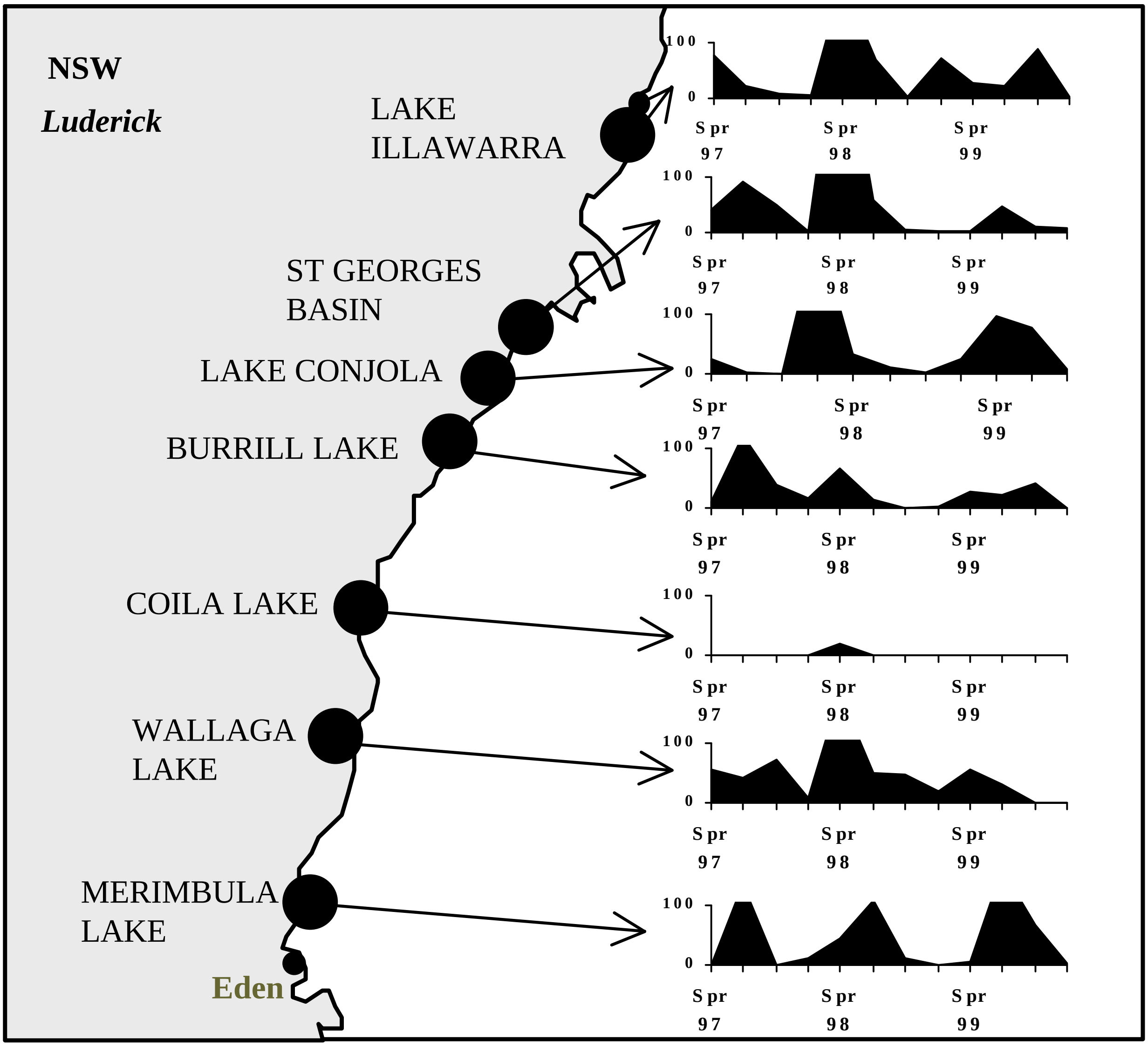

Figure A4.3: Recruitment intensity for sea mullet (*Mugil cephalus*) between 1997 and 2000, for the six estuaries sampled (see Method and Materials).

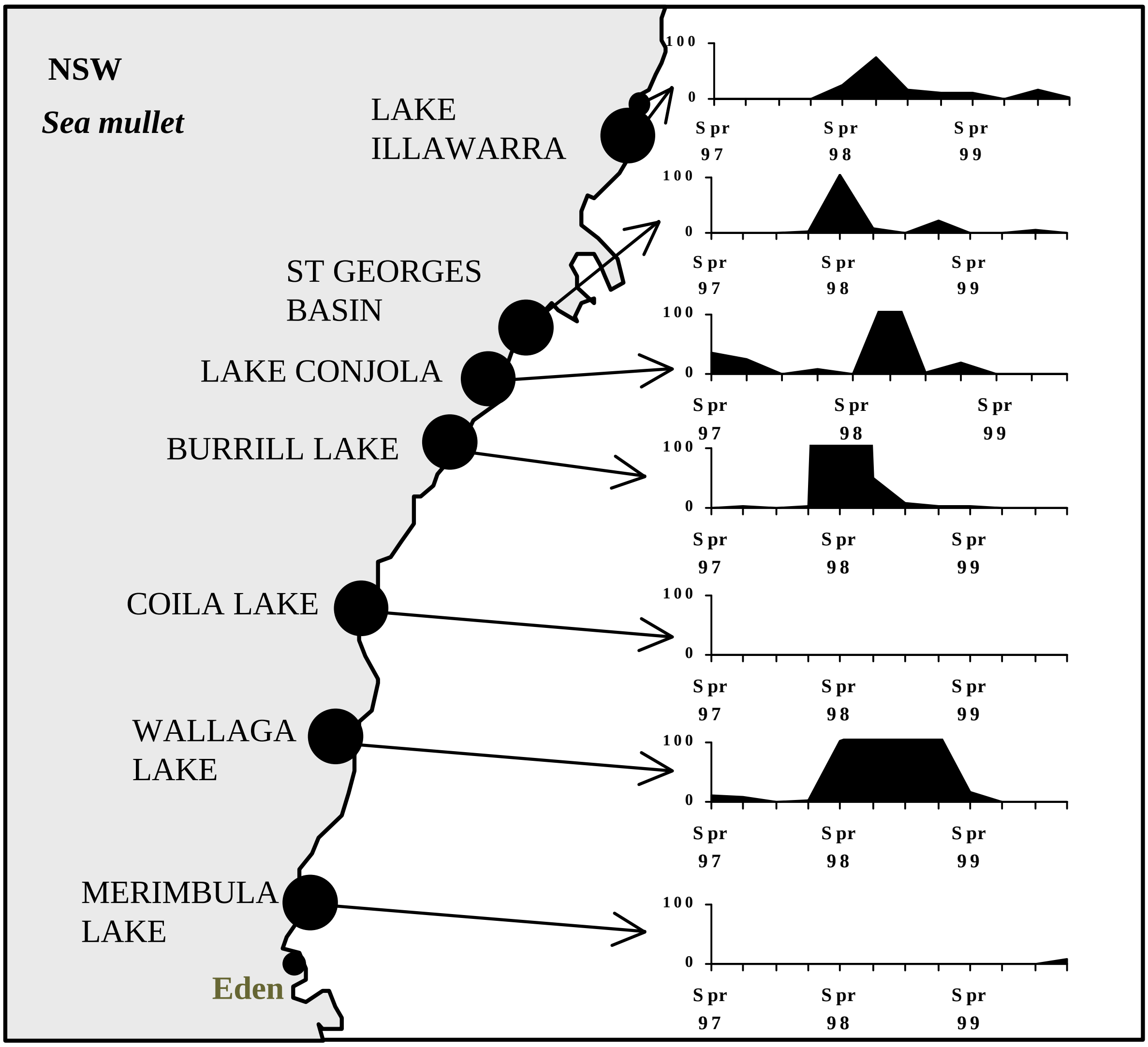

Figure A4.4: Recruitment intensity for tailor (*Pomatomus saltator*) between 1997 and 2000, for the six estuaries sampled (see Method and Materials).