NATURAL RESOURCES OF THE BARRON RIVER CATCHMENT 1

Stream Habitat, Fisheries Resources & Biological Indicators

DJ Russell
AJ McDougall
TJ Ryan
SE Kistle
G Aland
AL Cogle
PA Langford

Natural Heritage Trust
NATURAL RESOURCES
QI 00032
Queensland Government
Department of Primary Industries

Information Series QI00032

Natural Resources of the Barron River Catchment 1.

Stream habitat, fisheries resources and biological indicators

DJ Russell[1], AJ McDougall[1], TJ Ryan[2], SE Kistle[1], G Aland[3], AL Cogle[3] and PA Langford[3]

[1]Northern Fisheries Centre, Cairns, Queensland 4870
[2]Freshwater Fisheries and Aquaculture Centre, Walkamin, Queensland 4883
[3]Centre for Tropical Agriculture, Mareeba, Queensland 4880

June 2000

Natural Heritage Trust
Helping Communities Helping Australia

QI00032
ISSN 0727-6273
Agdex 470/041
First published 2000

Other publications in the same series:

Russell, DJ and Hales, PW (1993). 'Stream Habitat and Fisheries Resources in the Johnstone River Catchment.' QI93056. (Queensland Department of Primary Industries: Brisbane). 60pp

Russell, DJ; Hales, PW and Helmke, SA (1996). 'Stream Habitat and Fish Resources in the Russell and Mulgrave Rivers Catchment.' QI96008. (Queensland Department of Primary Industries: Brisbane). 58pp.

Russell, DJ; Hales, PW and Helmke, SA (1996). 'Fish Resources and Stream Habitat in the Moresby River Catchment.' QI96061. (Queensland Department of Primary Industries: Brisbane). 50pp.

Russell, DJ and Hales, PW (1997). 'Fish Resources and Stream Habitat of the Liverpool, Maria and Hull Catchments' QI97039. (Queensland Department of Primary Industries: Brisbane). 68pp.

Russell, D.J., Mc Dougall, A.J. and Kistle, S. E. (1998). 'Fish Resources and Stream Habitat of the Daintree, Saltwater, Mossman and Mowbray Catchments'. QI98062. (Queensland Department of Primary Industries: Brisbane). 72 pp.

Cogle, A..L., Langford, P.A.., Kistle, S.E., Ryan, T.J., McDougall, A.E., Russell,D.J., Best, E. (2000). 'Natural resources of the Barron River Catchment: 2.. Water Quality, Land Use and Land Management Interactions". QI00033, Queensland Department of Primary Industries:Brisbane).

The Manager
Publishing Services
GPO Box 46
Brisbane Qld 4001

Inquiries should be directed to:
John Russell
Coastal Resources Assessment Group
Northern Fisheries Centre
PO Box 5396
Cairns Qld 4870

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS AND PLATES

LIST OF ACRONYMS

ANSA	Australian National Sportfishing Association
BPA	Beach Protection Authority
CPOM	Course Particulate Organic Matter
DCDB	Digital Cadastral Database
DNR	Department of Natural Resources
FHA	Fish Habitat Area
FPOM	Fine Particulate Organic matter
GIS	Geographical Information Systems
ICM	Integrated Catchment Management
MDIA	Mareeba Dimbulah Irrigation Area
NLP	National Landcare Program
NP	National Park
NTU	Nephelometric Turbidity Units
QDPI	Queensland Department of Primary Industries
QFMA	Queensland Fisheries Management Authority
SF	State Forest
SIGNAL	Stream Invertebrate Grade Number
TFSS	Tableland Fish Stocking Society
WHA	World Heritage Area
WWF	World Wild Funds

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance given by Ms S. Helmke, Mr P. Hales and Mr S. Peverell in providing technical assistance during this project. Mr Jeff Johnson from the Queensland Museum assisted in the identification of fish. Nutrient analyses were conducted by Messrs E. Best, D. Wiffen and staff at the Department of Natural Resources, Agricultural Chemistry Unit, Mareeba. The Wet Tropics Management Authority supplied digital data on the Wet Tropics World Heritage Area. We also acknowledge assistance and data given by the Department of Natural Resources GIS and Cartography Unit (Mareeba), Auslig, the Queensland Fish Management Authority and the Bureau of Meteorology (Cairns Airport). We thank Mike Short (Department of Environment, Cairns) and staff from DNR, Cairns for the loan of aerial photographs. Mr Bill Sawynok of Australian National Sportfishing Association for supply of recreational tagging information. We wish to thank colleagues involved in the collection, identification, compilation and interpretation of the macroinvertebrate data including Jeff Watson and Paul Close (sorting and identification), Brad Pusey (assistance with analyses), Peter Cranston (reviewing Chironomid reference collection), Brett Herbert (providing information on previous macroinvertebrate studies in the Barron River), Ross Storey (Coleoptera identifications) and the staff at the Monitoring River Health Laboratory (DNR) at Rocklea for making their invertebrate reference collection available. Fish photographs on cover were supplied courtesy of Glynn Aland. This study was partially funded by a grant from the National Heritage Trust.

EXECUTIVE SUMMARY

The Barron River drains into the Coral Sea near the city of Cairns in far north Queensland. In comparison to other Queensland wet tropics streams, it has a relatively large catchment area of about 219 000 hectares. It was the most regulated of all wet tropics streams and has five major dams and/or weirs and an extensive irrigation network including drainage canals, siphons and a series of balancing storages.

There were about 1 100 hectares of primarily tidal wetlands in the delta. Between 1952 and 1996 there was a total net loss of about 16% of wetlands in the Barron River catchment. The major cause of wetland loss over this period was reclamation of tidal areas through such activities as the expansion of the Cairns International Airport. The area of freshwater wetlands including *Melaleuca* and sedge communities, was comparatively minor making up only 16% of total wetland area.

The Barron River catchment has high fish diversity with at least 209 estuarine and freshwater species representing 66 families. The Barron River estuary was a spawning and nursery ground for a variety of fish and prawn species. The estuary also supported a wide range of commercial and recreational fish species including barramundi (*Lates calcarifer*), mangrove jack (*Lutjanus argentimaculatus*), grunter (*Pomadasys sp.)*, trevally (*Caranx* spp.), queenfish (*Scombermorus* spp.) flathead (*Platycephalus fuscus*), silver jewfish (*Nibea soldada*), bream (*Acanthopagrus* spp.) and whiting (*Sillago* spp.). Mangrove jack and barramundi were also found in freshwater habitats downstream of the Barron Falls. Other recreational freshwater fish species sampled included jungle perch (*Kuhlia rupestris*), sooty grunter (*Hephaestus fuliginosus*), khaki bream (*Hephaestus* sp.) and freshwater jewfish (*Tandanus tandanus* and *Neosilurus ater*). Many of the freshwater species present in the river and impoundments above the Barron Falls were introduced from other catchments. A *put and take* recreational fishery for stocked barramundi has been established in Lake Tinaroo but there was no evidence that barramundi had become established in adjacent feeder streams. Red claw, (*Cherax quadricarinatus*) were successfully introduced into Lake Tinaroo to create a recreational fishery and are now widely established in rivers and streams across the entire catchment. A number of exotic fish species including guppies (*Poecilia reticulata*), swordtails (*Xiphophorus helleri*), mosquitofish *(Gambusia affinis*) and tilapia (*Tilapia mariae* and *Oreochromis mossambicus*) were established in the catchment. A population of *Tilapia mariae* had colonised the coastal part of the catchment below the Barron Falls while *Oreochromis mossambicus* was established in the Tinaroo catchment. There was considerable concern that tilapia could potentially colonise the western draining Mitchell River catchment by moving through either the Mareeba-Dimbulah Irrigation Area or through extraordinary flood events which periodically link the two catchments.

The variance and abundance of benthic macroinvertebrates can provide valuable information on the ecological condition of a river system. Overall, the macroinvertebrate populations at most sites sampled in the Barron River indicated a relatively healthy system although nutrient enrichment may be causing degradation at least one site. Taxa identified from the Barron system that maybe indicative of healthy environments included mayflies (Ephemeroptera) (particularly from the Caenidae and Leptophlebiidae families), and stoneflies (Plecoptera) from the Notonemouridae family. The dominance of taxa such as Diptera (an order of true flies) in macroinvertebrate samples may be indicative of some form of degradation. Physical influences such as water flow, water quality and particularly sediment composition appeared to have had an influence on the composition of macroinvertebrates samples.

On a catchment basis, riparian forest and instream habitat appeared to be in reasonable condition however localised problem areas existed particularly in the Tinaroo sub-catchment. More than 52% of sites in the Tinaroo sub-catchment had a sparse riparian vegetation cover and 37% of the total length of its major and minor streams were sparsely vegetated. In areas where the riparian vegetation was depleted, problem exotic grasses including para grass (*Bracharia mutica*) were likely to be established. Agricultural practices appeared to be implicated in much of the damage to the riparian vegetation in the Tinaroo sub-catchment. Erosion and sedimentation were of concern in a number of parts of the Barron River catchment, particularly coastal areas. In the Freshwater Creek valley, problems related to urban development, particularly sedimentation from land clearing and earth works had the potential to severely impact on instream habitat. Spot samples of water quality, including pH, dissolved oxygen, turbidity and conductivity, at habitat sampling sites identified a few concerns. At a small number of sites, mainly ephemeral streams, the dissolved oxygen saturation was as low as 14%. Exposure of acid sulphate soils from sandmining operations in the delta has the potential to spill acid leachate into the estuary. A number of ornamental plants including *Salvinia molesta*, *Eichornia crassipes*, and *Pistia statiotes* potentially pose significant problems to the hydrology (and possibly the fishes) of streams throughout the catchment, particularly in the upper reaches.

Reserves such as existing Fish Habitat Areas and a proposed Marine Park will provide ongoing protection for coastal wetlands. A series of potential management issues for the catchment and future monitoring strategies are discussed.

INTRODUCTION

Project Summary

The Barron River system was probably the most heavily utilised and regulated of all Queensland wet tropics streams. The catchment contains a broad range of land uses from intensive agriculture and dairy farming to densely populated urban areas. The Barron River catchment includes forested areas listed under the Wet Tropics World Heritage estate, Fish Habitat Areas and the river discharges into the Cairns Section of the Great Barrier Reef Marine Park (refer to *Map 1*).

The significance of the catchment was acknowledged in National Landcare Program (NLP) strategies and in the Far North Queensland 2010 regional planning process (Far North Queensland Regional Planning Advisory Committee, 1995). The community has been pro-active in the development of management strategies for the Barron River catchment. The coordinating committee of the Barron River Integrated Catchment Management Association (Barron River ICM) has representatives from a wide cross-section of the community. To ensure representation from all parts of the catchment, the association has been structured to include a number of zone fora (eg. coastal, upper and middle zones). The association was just one of a number of ICM groups which were active in the Queensland wet tropics and throughout Australia. Quality baseline information was required to assist all stakeholders and managers in development of catchment management strategies to address environmental issues in the Barron River. Issues of concern include impacts of land use practices, urban water requirements, urban runoff and recreational needs including the fishing and tourist industries.

The work reported in this document was undertaken as part of a National Heritage Truse project entitled *Techniques for optimal environmental management of tropical catchments.* It was conducted and funded through a multidisciplinary partnership between the Queensland Department of Primary Industries (QDPI) and the Queensland Department of Natural Resources (DNR). Other collaborating organisations included the community based Waterwatch program, the Queensland Environmental Protection Agency and the Trinity Inlet Management Program.

The project aims were to:

- undertake an environmental audit of the Barron River encompassing stream ecology and water quality;
- monitor the impacts of various land uses and management practices on stream environment and water quality;
- facilitate community access to these data; and
- provide information and guidelines through community consultation for optimal management of the Barron River catchment.

There have been a number of other similar studies of the stream habitat and fish resources of north Queensland wet tropics catchments. These include the Johnstone River (Russell and Hales, 1993); the Daintree, Saltwater, Mossman and Mowbray catchments (Russell *et al*., 1998); the Russell and Mulgrave Rivers (Russell *et al.,* 1996a); the Moresby (*Russell et al*., 1996b) and the Liverpool, Maria and Hull catchments (Russell and Hales, 1997). This document describes the stream habitat, instream biota and fisheries resources of the Barron River and the small, adjacent coastal catchment of Half Moon Creek. In addition to this report a second volume documents the catchment land uses and the results of an intensive water quality study (Cogle *et al*., 2000).

Catchments Description

The Barron River is a relatively large (219 000 ha), coastal catchment on the Queensland wet tropical coast. Population centres in the area include the city of Cairns and rural towns of Kuranda, Mareeba, Walkamin, Atherton, Yungaburra and Tolga (refer to *Map 1*). Approximate populations in the local government areas contained within the catchment were as follows: Cairns (4 700 for Barron River catchment suburbs), Eacham (6 300), Mareeba (18 200) and Mulgrave (8 100) and Atherton (10 100) Shires (Carr, 1994, Cook, *et al.,* 1998). Half Moon Creek is a small (3 446 ha), coastal catchment located to the north of the Barron River catchment, which is bounded by the Macalister Range to the west. The Half Moon Creek catchment includes the Cairns northern beach suburb of Yorkeys Knob which has an estimated population of 2 400 (Cook, *et al.,* 1998) (refer to *Map 1*).

Barron River: The headwaters of the Barron River are located in the southern part of the catchment in the Mount Hyipamee National Park. The Barron River drains much of the undulating dairying country of upper Atherton Tablelands before emptying into Lake Tinaroo. Lake Tinaroo has a storage capacity of 436.5 GL, a surface area of 33.7 km^2 and a shoreline length of about 209 km. Townships in the upper catchment include Atherton, Kairi and Yungaburra. The river continues in a northerly direction through the population centre of Mareeba before turning east towards the coast. At the Barron Falls, near the small township of Kuranda, the river drops about 300 metres onto the coastal plain. After then flowing through the steep and rugged Barron Falls National Park, the river meanders through forest, sugar cane farms, urban areas and mangroves before discharging into the Coral Sea. Another major impoundment, Copperlode Dam (which impounds Lake Morris), is situated on the upper reaches of Freshwater Creek. It has a storage capacity of 44.5 GL, and area of 3.1 km^2 and shoreline length of about 39 km.

To assist in data analyses the catchment was divided into five sub-catchments (see Figure 1). In their report on water quality, land use and management in the Barron catchment, Cogle *et al*. (2000) used a larger number (22) of sub-catchments to facilitate their modelling processes.

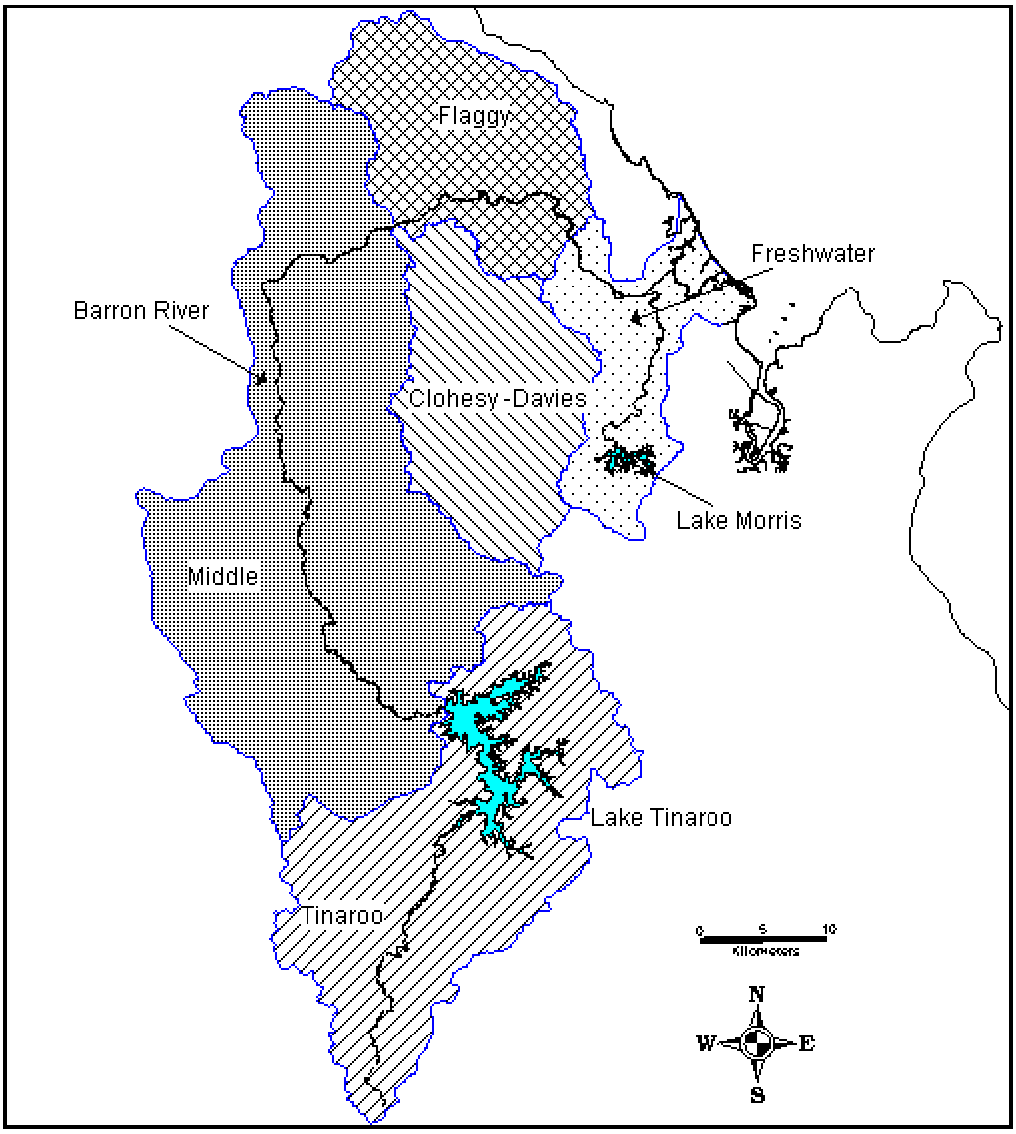


Figure 1. Barron River sub-catchments

Half Moon Creek: This catchment, which is approximately 954 ha in area, is situated at the northern end of the Barron River delta. A tidal creek for most of its length, it drains into the Coral Sea at Yorkeys Knob. The creek drains extensive tidal wetlands with sugar cane farming the predominant catchment land use.

Water infrastructure

The Barron River catchment was the most heavily regulated of all wet tropics streams. The catchment has five impoundments including two major storages; Tinaroo Falls Dam (which impounds Lake Tinaroo) on the upper Barron River and Copperlode Dam (which impounds Lake Morris) on Freshwater Creek. Tinaroo Falls Dam feeds the Mareeba-Dimbulah Irrigation Area (MDIA) through a network of irrigation channels, siphons and balancing storages. In some areas, a channel system has been constructed to provide regulated flows of irrigation water in natural watercourses. A unique feature of the MDIA was that some of the waters were diverted by gravity fed open channels across the Great Dividing Range into the western flowing Walsh and Mitchell River catchments. As well as for irrigation, water from Tinaroo Falls Dam was used for hydroelectric power generation at the Barron Falls, domestic purposes, and for livestock. Lake Tinaroo had major recreational uses including boating, fishing and swimming. Lake Morris (Copperlode Dam) was used to supply domestic water to the City of Cairns and assists with flood mitigation. Public access to Lake Morris was restricted because of its use as a source of domestic water. Investigations have been carried out to assess the potential of a number of sites for future water storage within the catchment, including one in the Flaggy Creek sub-catchment and another at Bilwon (Middle sub-catchment).

Climate

The wet tropical coast of Queensland is characterised by a very high seasonal rainfall during the hot summer months (December to February) and a relatively dry, mild winter (June to August). Table 1 shows altitude and average annual rainfall, evaporation, maximum and minimum temperatures at centres throughout the catchment. Temperatures on the Atherton Tableland, west of coastal ranges, tended to be lower and had a higher variation than in the coastal region. The City of Cairns had a mean annual rainfall of 2 129 mm (Clewett *et al.,* 1999), and mean maximum and mean minimum monthly totals of 435.9 mm and 28.2 mm respectively (Bureau of Meteorology, 1999). This section of the Queensland coast is also subject to periodic cyclonic influences during the summer wet season months (November to March).

Table 1. Altitude, average annual rainfall, evaporation, maximum and minimum temperatures for four catchment centres.

Data from Clewett et al (1999). na indicates data were not available.

Site	Altitude (m)	Average Annual Rainfall (mm)	Average Annual Evaporation (mm)	Average Annual Temperature Maximum(^{o}C)	Average Annual Temperature Minimum(^{o}C)
Upper Barron	800	2103	na	na	na
Atherton	770	1395	na	26.0	14.5
Kairi Research Station	715	1233	1132	25.1	15.7
Mareeba	406	910	1643	28.8	16.7
Cairns	3	2129	1570	28.8	20.7

Reserves

Barron River: Approximately 39% or 85 200 ha of the Barron River catchment was managed as protected areas. These included a variety of types including National Park (NP), State Forest (SF), World Heritage Area (WHA), a Fish Closure and Fish Habitat Areas (FHA) (see *Map 1* and Map 2). Approximately 59% of forested areas (including wetlands) in the catchment had some form of protection.

Half Moon Creek: About 27% or 954 ha of the Half Moon Creek catchment was protected as either WHA, SF or FHA (see *Map 1* and Map 2). About 44% of the forested areas in the catchment had protected area status of some form. A number of wetland rehabilitation strategies were being considered for the catchment. For example, there was a plan construct a vegetation corridor to link the Cattana wetlands, an isolated pocket of freshwater wetlands in the southern part of the catchment, to the existing tidal wetlands and the forests of the Macalister Ranges.

Fish Closures

A Fish Closure was declared over 30 ha of the lower freshwater reaches of the Barron River from Lake Placid upstream to Camp Oven Creek (see *Map 1*). This closure prohibits all fishing activities. In addition, recreational fishing was prohibited in the Barron Falls National Park.

Wet Tropics World Heritage

Barron River: About 45 836 ha or about 21% of the catchment was included in the Wet Tropics World Heritage Estate (see *Map 1*). Approximately one-third (32%) of the remaining forested areas in the catchment were managed as World Heritage Area. Of this total World Heritage Area, 85% (38 714 ha) was State Forest and 8% (3 749 ha) was National Park. The World Heritage Area also included large sections of the Macalister and Lambs Ranges.

Half Moon Creek: About 733 ha or 21% of this catchment was covered by World Heritage Area forest. This accounted for about 34% of the remaining forested area of the catchment (see *Map 1*).

State Forests

Barron River: About 35% (77 069 ha) of the Barron River catchment was State Forest (see *Map 1*). State Forest covered about half of the existing forested areas in the catchment and about half (53%) the State Forest was also part of the World Heritage Area. Large portions of State Forest were found adjacent to much of the northern and eastern catchment boundaries (between the Barron Falls and Tinaroo Falls Dam) and also parts of the western boundary.

Half Moon Creek: The entire State Forest area in the catchment was contained within the boundaries of the World Heritage Area (refer to *Map 1*).

National Parks

Barron River: The current area of National Park in the catchment was 4 326 ha (2% of the total catchment) and, of this, 87 % was also found within the boundaries of the Wet Tropics World Heritage Area. National Parks in the catchment included the Barron Falls, Lake Eacham, Mount Hyipamee, Davies Creek, Yungaburra and Hasties Swamp National Parks. Some of the Lake Barrine National Park was also found in the catchment (see *Map 1*). No Marine Parks presently exist within the Barron River or Half Moon Creek catchments but the proposed Marlin Coast Marine Park will include a substantial area of tidal wetlands and coastal foreshore. It was proposed that Half Moon, Yorkeys, Richter's and Barr Creeks and much of the tidal section of the Barron River will be declared as Estuarine Conservation Zones within the Marlin Coast Marine Park.

Half Moon Creek: There were no National Park areas found within the Half Moon Creek catchment.

Fish Habitat Areas

Fish Habitat Areas have been declared throughout coastal Queensland to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend (Beumer *et al.,* 1997). The QDPI has the responsibility to ensure developments involving disturbance of a declared Fish Habitat Area are restricted to reduce impact on the productivity and sustainability of fisheries. All works within a Fish Habitat Area require a permit under the *Fisheries Act 1994*.

Legal forms of taking fish and invertebrates for food or as bait are not restricted in declared Fish Habitat Areas (except for worm digging and mollusc collection). Fish Habitat Areas have been partitioned into two levels -Management Area A (critical habitat) and B (important habitat) - to assist managers in licensing of appropriate activities and works.

Barron River: There were three declared Fish Habitat Areas (both Management Area A and B) under the Queensland Fisheries Act (1994) in the catchment (see Map 2). These included 68 ha of tidal land adjacent to Barr Creek and 39 ha of tidal land in the Yorkeys Creek catchment (Management Area B). An area of approximately 256 ha around the mouth of the Barron River estuary was contained within a Fish Habitat Management Area A.

Half Moon Creek: In this catchment, a total of 221 ha of wetlands were protected under Fish Habitat Management Area B.

Fishing Activities

Fishery management

In Queensland, the Queensland Fisheries Management Authority (QFMA) was the agency responsible for controlling commercial and recreational fishing activities. In the *Fisheries Act* (1994), there were a number of key management measures pertaining to inshore fisheries. These include:

- a closed season on barramundi from 1 November until 31 January inclusive;
- prohibition on the use of river set gill nets during the closed season;
- a recreational bag limit allowing fishers to have only five barramundi in their possession at any one time;
- minimum and maximum mesh sizes and limitations on the total number of nets in the commercial fishery;
- a weekend closure to commercial fishing from 6pm Friday to 6pm Sunday; and
- size restrictions on key species.

In recognition of their importance to fisheries, all marine plants, including mangroves, sea grasses, salt couch and samphire species were protected under Section 51 of the Fisheries Act (1994). To remove, destroy or damage any marine plant required a permit from the Department of Primary Industries and strict criteria apply to the issuing of such permits.

Commercial fisheries

The Queensland Fisheries Management Authority has been collecting broad scale commercial fisheries logbook data since 1990. The minimum geographical resolutions for these data are 30' x 30' grids. Commercial fishing data from the Barron River and Half Moon Creek were pooled with other records from a larger region from Cape Grafton in the south (including the Trinity Inlet), to below the Mowbray River in the north and out into the Coral Sea.

Normal commercial fishing activities including gill netting and crabbing are presently permitted in the estuaries and along coastal foreshores within the Barron River and

Half Moon Creek catchments. There were about seven professional fishing tour guides operating in the Cairns area in 1999. In 1998, there were 13 commercial net fishers operating within the estuaries targeting species such as barramundi (*Lates calcarifer*), threadfin salmon (*Eleutheronema tetradactylum* and *Polydactylus sheridani*), mullet (Mugilidae spp.), and garfish (*Hemiramphidae* spp.). There were also 11 commercial crabbers targeting mud crabs (*Scylla serrata*) (Helmke, *et al.,* in press). There is currently a *sunset* provision applying to gill netting in the Barron River estuary and foreshores. No new licences will be endorsed for use in this area and existing licences will be extinguished upon surrender or transfer to other operators.

Between 1990 and 1998, the estimated gill net catches (total landed weight) for major fish species within the above described grid area were: mullet 66 583 kg; barramundi 45 621 kg; king salmon 29 070 kg; garfish 28 161 kg; shark 19 631 kg; and blue salmon 12 976 kg (total whole weight) (Helmke, *et al.*, in press). The total landed weight for mud crab for the same period and area was 63 kg (Helmke, *et al.*, in press).

Offshore, in the Great Barrier Reef lagoon, otter trawlers fish for a range of prawn species. The major species by catch (kg) were tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus endeavouri* and *M. ensis*) and banana prawns (*P. merguiensis*). Other species captured included king prawns (*P. latisulcatus*), leader prawns (*P. monodon*) and bay prawns (*Metapenaeus benaette*). These species, although generally in small numbers, were all listed in APPENDIX A, (Table 17). Table 17 shows prawn catch and effort data offshore between Cape Grafton and below the Mowbray River in the grid 16°50´S to 17°0´S and 145°5'E to 146°0'E (Source: QFMA QFISH Database, 1999). APPENDIX A, (Table 18) shows the difference in catch (kg) between trawled species for the same area and time period. An estimated annual catch value of the prawn fishery in this area for 1998 was about one and a half million dollars.

Recreational fisheries

Recreational line fishing was allowed within all estuarine sections of the Barron River and Half Moon Creek catchments, as well as most freshwater reaches. Fishing was permitted within the Davies Creek National Park although recent Draft Management Guidelines propose to prohibit fishing activities in this park (Queensland Parks and Wildlife Service, 1999). Recreational line fishing was also prohibited within the fishing closure area at Lake Placid and within the Barron Falls National Park. With the exception of worm digging and mollusc collection, all other fishing activities were allowed in FHAs (see Map 2).

Anglers used lures and live and dead baits to target a wide range of estuarine species including: barramundi (*Lates calcarifer*); mangrove jack (*Lutjanus argentimaculatus*); threadfin salmon (*Polydactylus sheridani* and *Eleutheronema tetradactylum*); grunter (*Pomadasys* spp.); pikey bream (*Acanthopagrus berda*); silver bream (*A. australis*); flathead (*Platycephalus spp.*); whiting (*Sillago* spp.); trevally (*Caranx* spp.); silver jewfish (*Nibea soldada*); mullet (Mugilidae spp.); and queenfish (*Scombormorus* spp.). Targeted crab species included the blue swimmer crab (*Portunus pelagicus*) and mud crab (*Scylla serrata*).

Freshwater recreational fishing species included barramundi (*Lates calcarifer),* mangrove jack (*Lutjanus argentimaculatus*), sooty grunter (*Hephaestus fuliginosus*), jungle perch (*Kuhlia rupestris*) and freshwater jewfish (*Tandanus tandanus* and *Neosilurus ater*). Redclaw (*Cherax quadricarinatus*), a freshwater crayfish native to tropical Queensland, was also a popular target for recreational anglers. A *put and take* recreational fishery, primarily for barramundi, has been created in Lake Tinaroo.

Fish stocking

The Queensland Fisheries Management Authority controls all fish stocking activities in Queensland under permit. Community based stocking dates back to 1949 with the establishment of Tableland Anglers' and Acclimatisation Society on the Atherton Tablelands. Originally, relocation of native species from Tableland waterways into Lake Tinaroo was conducted by the society to primarily improve the angling for the club members and locals. Species that survived relocation and subsequently adapted to Lake Tinaroo conditions included archerfish (*Toxotes chatareus*), sleepy cod (*Oxyeleotris lineolatus*), barred grunter (*Amniataba percoides*) and bony bream (*Nematalosa erebi*).

More recently, barramundi were first introduced into Lake Tinaroo by the QDPI in 1987 and since then a viable, *put and take* recreational fishery has become established. To enhance existing stocks of barramundi in the Barron River estuary, the Mulgrave Shire Stocking Group and the QDPI have undertaken a series of releases of hatchery reared fish. Sooty grunter, (*Hephaestus fuliginosus*) were also regularly stocked into Lake Tinaroo. A self-sustaining population of red claw (*Cherax quadricarinatus*) has also become established in Lake Tinaroo.

There have been numerous unsuccessful attempts to establish stocks of other recreational fish species including silver perch (*Bidyanus bidyanus*) in the early 1980s and more recently, pikey bream (*Acanthopagrus berda*). Trials were underway to assess the viability of snub-nosed gar (*Arrhamphus sclerolepis sclerolepis*) as a recreational fishing species.

Aquaculture

In 1999, there were 19 licensed aquaculture facilities in the Barron River catchment. These facilities cultured a range of species including red claw (*Cherax quadricarinatus*), barramundi (*Lates calcarifer*), short-finned eel (*Anguilla obscura)*, long-finned eel (*Anguilla reinhardtii),* and leader prawns (*Penaeus monodon)* (Chris Barlow, QDPI Fisheries Group, pers. comm.).

Previous Biological Studies

The earliest known fisheries studies in the catchment were undertaken about 50 years ago and published as a series of articles in the *North Queensland Naturalist* (eg. Shipway, 1947a, 1947b, 1947c & 1948). More recently, Pusey and Kennard (1994, 1996) undertook a study of freshwater fish fauna in a range of wet tropics streams including the Barron River while Russell (1988) surveyed estuarine fishes of Thomatis Creek in the delta. Pusey *et al.* (1997) also found the Lake Eacham Rainbow fish, which was previously thought to be extinct in some streams in the Barron catchment. Werren (1997) reported on the rehabilitation needs of the Barron River catchment while the Department of Natural Resources (1999) recently developed a water allocation and management plan for the Barron Basin. Cogle *et al.* (1998) used the Tinaroo catchment to develop a nutrient control strategy while Russell (1987) and MacKinnon and Herbert (1996) reported on the limnology and fishes of Tinaroo Dam. There have been a number of consultants' reports on the catchment including a management plan for Freshwater Creek (Cairns City Council, pers. comm.) and a Barron River Catchment Overview Study (Hollingsworth, Dames and Moore, 1993).

Two major studies have investigated macroinvertebrate populations in the Barron River. Herbert *et al*. (1996) identified a series of population trends including a dominance of Hydracarina, Corixid (Micronecta) and Odonata (Synthemistinae) and a distinct lack of mayfly and caddisfly larvae at relatively degraded sites. As part of a larger study assessing nutrients and biological health Cogle *et al*.. (1998) investigated macroinvertebrates in the upper Barron River catchment above Lake Tinaroo in 1994 and 1995. As part of the Monitoring River Health Initiative (MRHI), Choy *et al.* (1998) reported on macroinvertebrate information collected biannually from the Barron River catchment using rapid assessment techniques. This report provided information on the total number of taxa and the total number of families within the orders Ephemeroptera, Plectoptera and Tricoptera (EPT or PET). The EPT was widely used as an index of sensitivity to provide comparisons between sites. Choy *et al.* (1998) found, that in comparison to other north Queensland rivers, the EPT in the Barron was relatively high.

METHODOLOGY

General

An assessment of fish resources, stream habitat and biota of the catchment was conducted using similar methodology to that used for the Johnstone River (Russell and Hales, 1993), the Russell and Mulgrave Rivers (Russell *et al.,* 1996a), the Moresby River (Russell *et al.,* 1996b), Liverpool and Maria Creeks, the Hull River (Russell and Hales, 1997); and the Daintree, Mossman and Mowbray Rivers, and Saltwater Creek (Russell *et al.,* 1998) studies. All fieldwork for this report was conducted between November 1996 and concluded by May 1999. Ground truthing to validate land use and wetland mapping was primarily conducted during August 1998.

In addition to the main Barron River catchment, some analyses were conducted for the Half Moon Creek catchment to the north of the Barron River delta. These analyses included land use and wetland mapping.

Instream Habitat Assessment

The condition of instream habitat was assessed according to a set pro forma (APPENDIX B) at representative sites throughout the catchment (Map 3). The condition of the riparian habitat, which has an important influence on instream health and fisheries resources, was assessed simultaneously. To establish a standard sampling protocol, all habitat assessments were done during low flow conditions (May to November 1998).

Site Selection

Locations of the habitat assessment sites were selected using 1:50,000 topographic maps. Access to streams and rivers by vehicle and/or boat, as well as stream order, adjacent land use, stream flow and tidal influence were used to determine site selection. Stream order was determined by branching. Small, unbranched tributaries that were classified as first order streams, and where two first order streams joined, a second order stream was formed and so forth (Neilsen and Johnson, 1983). In general, the larger the stream, the higher the stream order. The length of stream assessed varied greatly and depended on stream width and access to upstream and downstream reaches. A sigmoidal section or a minimum of 2.5 times the width of stream was considered an ideal length for assessment (Mitchell, 1990). This aimed to include flow types (pool and/or riffle) typical of the reach. In this study, pools were defined as areas of laminar flowing water with an average depth greater than one metre. Shallower stream reaches with higher velocities including runs, glides and riffles were collectively classified as riffles for ease of analysis.

The ten sites selected for macroinvertebrate sampling were all in the main Barron River channel and distributed throughout the upper, middle and lower catchment. Several criteria were used for site selection including adjacent land use, access and, to ensure a sufficient diversity of habitat, the presence of a riffle section with an average substrate size of 3 mm or greater. Further, to identify any temporal trends, sites used in previous macroinvertebrate studies (eg. Goonarra, Hemmings and Picnic Crossing in Cogle *et al.,* 1998 and Goonarra, Picnic Crossing, Bilwon and Myola in Choy *et al.,* 1998) were selected.

Habitat Assessment Techniques

Stream habitat parameters including riparian vegetation structure, sedimentation, stream structure, instream cover, invasive grasses, disturbance rating and *in-situ* water quality (conductivity, dissolved oxygen, pH, salinity and turbidity) were assessed at each site including all invertebrate sampling sites. Instream habitat, apart from water quality parameters, was assessed using qualitative visual techniques similar to those used by Russell and Hales (1993, 1997) and Russell *et al.* (1996a, 1996b, 1998). These techniques focused on aspects important to fish ecology. To maintain consistency, the same personnel conducted assessments at the sites.

Stream biota (living organisms occurring in freshwater) are important indicators of riverine health as biological communities generally reflect overall ecological integrity. The main benefit of using biosurveys is that biological communities integrate the effects of different pollutant stressors and provide a holistic measure of their aggregate impact (Plafkin *et al.,* 1989).

The two main taxonomic groups sampled for this study were fish and benthic macroinvertebrates. These two groups were selected for the following reasons:

Fish are useful as long-term and broad-scale indicators of environmental and habitat conditions for a number of reasons:

- they are relatively long-lived and mobile;
- they consist a range of members from different trophic groups (herbivores, insectivores, planktivores, piscivores, omnivores);
- they are consumed by humans and as such are valuable tools for assessing potential contamination;
- they are relatively easy to collect and identify making rapid assessment possible; and
- there was abundant information available on life history and tolerance ranges that provide the necessary background information (Plafkin *et al.,* 1989).

Macroinvertebrates are regarded as good integrators of stream water quality over time. For this reason they can, under some circumstances, be used to provide an assessment of water quality that was superior to discrete sampling of water chemistry. Benthic macroinvertebrates are useful as indicators of localised (site specific) environmental and habitat conditions for a number of reasons:

- they have a relatively sessile mode of life with limited migration patterns;
- they have relatively short life-cycles (just over 1 year or less) and have particular sensitive life stages;
- they are easy and inexpensive to sample and therefore are applicable to rapid assessment techniques, however identification was more difficult;

- they represent the primary food source for many higher order vertebrates;
- they are in high abundance and diversity, enabling comparisons between sites; and
- there was a substantial information database on life history and tolerances for many groups, particularly south-eastern Australia (much less was known of many taxa found in north Queensland) (Plafkin *et al.,* 1989).

There were a number of biological assessment techniques commonly used to assess waterway health. Of these, the Stream Invertebrate Grade Number – Average Level (SIGNAL) rapid assessment technique was adapted by Chessman (1995) for use with common families of Australian macroinvertebrates. The technique was developed to reduce bias associated with variations in stream size and sampling methodologies and permit greater ability of comparison between sites and sets of data.

Another simpler means of interpreting macroinvertebrate data was to combine the sampled biota into five functional feeding (or trophic) groups (after Merritt and Cummins, 1984). The five functional groups are filterers, collectors, grazers, shredders and predators (Townsend *et al.,* 1987). Characteristics of these groups are as follows:

- Filterers collect suspended material from the water column and, as such, are advantaged by moderate increases in fine particulate organic material (FPOM). Bivalves are an example of filterers;
- Collectors, such as Oligocheata, can also benefit from moderate FPOM levels, and like filterers, can often be found in stream surrounded by pastoral land use;
- Grazers and shredders can be adversely affected by high FPOM sedimentation and are reliant on coarse particulate organic matter (CPOM), and are therefore greatly influenced by the extent of riparian vegetation; and
- Predators such as many of the Hemiptera group, are more generalists and can exist under a variety of environmental and habitat conditions.

The interpretation of the functional feeding groups can therefore provide some indication of the impacts of land use throughout a catchment. However, caution must be used when interpreting such data, as many other factors (eg. flow regulation (Choy *et al.,* 1998)) may also influence invertebrate distribution patterns.

Riparian vegetation

To get as true a representation as possible of the condition of riparian vegetation within the catchment, a combination of sampling techniques were used. Aerial photography was used to provide a holistic overview of treed riparian corridor widths and continuity, while more detailed information was obtained from individual site sampling. At each site, riparian vegetation was evaluated in terms of its average width, composition and continuity on both sides of the stream. An overall stream bank disturbance rating was determined visually following criteria outlined in APPENDIX B

The most recent colour aerial photographs (1:25 000) were used to identify and classify the riparian vegetation. The most recent batch of aerial photographs (September 1997) was used for the Atherton and Bartle Frere map sections of the catchment. For the remainder of the catchment (Rumula and Cairns map sections), DNR aerial photographs from mid-1994 were used. Beach Protection Authority aerial photographs (1:12 000, July 1996) were used to map coastal wetlands. From these aerial photographs, riparian vegetation was classified into one of the following categories:

- Sparse vegetation - corridors dominated by grasses with only a few scattered trees.
- Narrow vegetation - corridors less than 30 m wide, riparian zone continuous with few or no breaks; and
- Wide vegetation - corridors generally continuous and more than 30 m wide on each side;

On smaller tributary streams, a combined assessment of both banks (eg. narrow/wide, sparse/narrow) was made. On the major streams, separate evaluations of riparian vegetation were made for each bank (eg. wide). In order to standardise the results in terms of overall stream length, the lengths of all categories where banks were assessed separately were halved prior to analyses. This information was entered into the Geographical Information System (GIS), MapInfo® and the relevant data thematically mapped.

Sedimentation

Sedimentation diminishes instream habitat diversity which, inturn, adversely impacts on riverine biota diversity. The amount and location of unstabilised substrate in the stream was visually assessed and classified into one of seven categories (APPENDIX C) (Anon, 1992).

Stream structure

The stream structure, including flow types and substrate has an important bearing on the composition of instream biota. At each site, the length of riffles and pools were estimated visually. Substrate composition of both the pool and riffle sections was estimated by the percentage of each of the four particle size categories: fine silt, sand, cobble/gravel and boulder/cobble (APPENDIX D) (Anon, 1992).

Fish habitat types

Instream cover is habitat that may be used as shelter for fish and crustaceans. It includes undercut banks, overhanging vegetation, aquatic macrophytes, leaf litter, rocks, grass and woody debris (snags). To obtain a measure of their relative importance at each site, each habitat type was assigned an abundance/coverage index and given a rating from 1 (few) to 4 (many). These instream cover types were assessed separately for riffles and pools.

Invasive grasses

Invasive grasses such as para grass (*Brachiaria mutica*), panicum grass (*Panicum.* spp.) and northern cane grass (*Mnesithea rottboellioides*) often impede waterways and/or prevent the establishment of tree seedlings in the riparian zone. The total length and average width of stream bank (both sides) impacted by invasive grass species was estimated at each site.

Wetlands

Aerial photography was used to determine the coastal wetland resources for both the Barron River and Half Moon Creek catchments in 1996 (1:12 000 colour aerial photographs) and 1952 (1:~23 600 black and white aerial photography). These years were the most recent and oldest aerial photography available for these catchments. These aerial photographs were scanned into a GIS (MapInfo®) and then rectified using the DNR Digital Cadastral Database (DCDB). Wetland boundaries were digitised from these aerial photos and stereoscopic techniques were used to classify the different wetland types (Le Cussan, 1991). Historical changes in the area and community structure of these wetlands were determined by comparing the 1952 wetland maps to the equivalent 1996 maps. Ground truthing was conducted in 1999 to verify wetland classifications taken from 1996 aerial photographs. Some wetland areas found in the 1996 aerial photographs had changed and these were updated to the wetland type or land use existing in 1999. To simplify interpretation, similar wetland types were aggregated into the following categories:

Freshwater communities

- Melaleuca; and
- Melaleuca communities - (Melaleuca mixed with other species such as Acacia and rainforest species.).

Tidal communities

- Transitional - active transition from non-tidal to mangrove and contains a mixture of species;
- Mangroves;
- Ponded water; and
- Salt pans.

Land Use

Major land uses were initially identified from the most recent colour aerial photographs (see previous section) using stereoscopic techniques. Land use boundaries were then digitised into a GIS (MapInfo®) using the scanned aerial photographs. Selected land use categories were compared and/or verified with the DNR DCDB land use codes. Verification and ground truthing also allowed for recording at some sites of specific land use types within a given category (eg. other crops - corn and aquaculture - redclaw). The major land use categories were as follows:

- Aquaculture
- Cleared Land
- Dairy Cattle
- Forest
- Grazing
- Industrial
- Other Crops (eg. corn)
- Other (eg. airport)

- Quarry
- Sugar Cane
- Tourist (eg. camping grounds)
- Water
- Rural residential
- Tree Crop (eg. mangoes)
- Urban

Cogle *et al.* (2000) gives a complete description of land use throughout the catchment.

Macroinvertebrate Sampling

Macroinvertebrate samples were taken during September 1997 (dry season), December 1997 (pre-wet season), March 1998 (post-wet season) and August 1998 (dry season).

Following the recommendation in Cogle *et al*. (1998) that riffle sites should be targeted to eliminate some inter-site variation, permanent 10 m riffle sections were selected at each site. At these riffle sections, four random invertebrate samples were collected using a surber sampler, which had a contact surface area on the substrate of 0.1 m^2. The sampler was placed on the substrate facing the direction of flow and the material within the sampler was agitated. All material dislodged during this process was subsequently washed by the current into the 350 mm wide, 250 μm mesh net set immediately downstream. A number of authors (eg. (Bunn *et al*., 1986, Marchant *et al.,* 1985, Townsend *et al.,* 1983) have shown that surber samplers can be successfully used to provide quantitative data.

Once collected in the net, the sample was emptied into a white sorting tray with a 1-2 cm depth of water. The net was then thoroughly rinsed to dislodge any remaining invertebrates. Live invertebrates were then individually selected from the sorting tray and preserved in a mixture of 70 % ethanol and 1% glycerine. This process of selecting invertebrates continued for either 30 minutes or until no more insects were found.

In the laboratory the preserved samples were identified, where possible, to genus level. In some instances identification to species level was attempted, but generally the paucity of taxonomic literature on northern Australian invertebrates made classification beyond the family level difficult. Chironomid larvae were identified to sub-family level, while Oligochaeta and Hydracarina were identified to class only. References from the Murray-Darling Freshwater Research Centre Series, CSIRO series and additional texts were used as taxonomic keys. Taxonomic validation was achieved by comparing samples with the DNR Monitoring River Health Library specimens and the previous Barron River reference collection collated by Herbert *et al.* (1996). Where data analyses required total species numbers, biota which could not be positively identified to species level were separated using gross morphological characteristics.

Riffle sediment samples were taken at each site to calculate the relative composition of fine to coarse sand, fine to coarse gravel, and cobbles based on the Wentworth classification scheme (after Gordon *et al.,* 1992). Three replicate sediment samples were collected from the 0.1 m^2 area within the surber sampler to a depth of 10 cm. Each replicate was sieved then through the appropriate sized screens. Standard 500 ml sub-samples were weighed to the nearest 0.1 g and wet sieved. The residue of each sieve was individually dried and weighed.

Water Quality

To give a more holistic description of the conditions at the habitat assessment sites, water quality parameters including conductivity, dissolved oxygen, pH, salinity, temperature and turbidity were measured *in situ.* Many of the habitat assessment sites were different to sites sampled as part of the monthly water quality monitoring program (Cogle *et al.,* 2000). Parameters were measured using a portable Horiba® water quality meter (model U-10 water quality checker). Data collected for dissolved oxygen, pH and turbidity were tested for normality using the D'Agustino test procedure. Water quality parameters (conductivity temperature, dissolved oxygen and pH) were recorded from all macroinvertebrate sites on every sampling occasion using a TPS FL90 Water Quality Logger.

Fish Resources

An inventory of fish resources in the Barron River catchment was conducted between October 1996 and February 1999 in both freshwater and estuarine areas.

Freshwater

Freshwater sites in smaller streams were fished using a Smith-Root® Model 12 backpack electrofisher both by wading and from a 2.4 m dinghy. Where practical, larger streams were assessed using a generator powered Smith-Root® Model 7.5 GPP electrofisher fitted to a 4.3 m vessel. A pulsed direct current was applied to the water in areas of likely fish habitat. Fish species and their estimated lengths and numbers and associated instream habitat were recorded. Specimens that were difficult to identify *in-situ* were retained and later frozen/preserved for more detailed inspection. Some specimens were sent to the Queensland Museum for positive identification. All sites were fished twice per year, once immediately after the wet season and again just prior to the wet season (between May 1997 and December 1998). Electrofishing time varied from site to site, but was generally between 30 to 60 minutes, depending on local conditions.

Estuarine

The high conductivities in tidal areas precluded electrofishing operations, so several alternative methods, including seine netting, beam trawling and gill netting were used.

Seine netting

Between January 1997 and March 1999, a 20 mm stretch-mesh seine net was used at monthly intervals in shallow areas of the mouth of the Barron River to catch both adult and juvenile fish. Sampling was generally conducted at three sites at low tide at the river mouth. At each of these sites, the seine net was dragged for approximately 30 m, unless fouling of the net occurred and the shot needed to be repeated. Fish were dragged onto the bank in the net, and all fish except for commercial species were returned to the laboratory for further processing.

Beam trawling

Juvenile fish and prawns were sampled in the Barron River estuary using a small mesh beam trawl (2 mm mesh and 1.5 m beam) that was towed at a constant speed over sandy and muddy substrates. This sampling was conducted after dusk, generally at high tide. Beam trawl sampling was conducted approximately every six weeks between November 1996 and November 1998. Three 100m transects were trawled at each of the two sites. A larger mesh beam trawl (19 mm mesh and 1.5 m opening) was used additionally in December 1997 and May 1998 to sample adult prawns.

Two sites were chosen for their bottom composition, relatively constant flat contour and likelihood of prawn and fish presence (Map 2). One site was located at the mouth of the estuary and consisted of sandy substrate. The second site was located approximately 3.5 kilometres upstream of the mouth adjacent to the airport, and had a bottom composition of fine mud and mangrove detritus.

Gill netting

Gill nets between 50 mm and 150 mm stretched-mesh and ranging from 15 to 100 metres in length were used to sample fish in the Barron River estuary. Between four and six nets were set at each of the sites. Nets were set on consecutive days at one of three sites. These sites were located at the mouth of the Barron River, Thomatis Creek and the upper tidal area of the Barron River (near the junction with Thomatis Creek) (see Map 2).

These sites were sampled initially every 3 months from November 1996 until June 1997. From then until November 1998, the interval between sampling was decreased to 6 weeks to coincide with either the new or full moon. Gill nets were set in the hour before dusk on a low or flood tide and were usually retrieved shortly after the change to the outgoing tide.

Nets were checked at a frequency of 30-50 minutes to ensure the survival of fish in the net. Target species such as barramundi, king salmon, mangrove jack and flathead were tagged with dart tags and measured before release. All other fish species were measured and released. Very few specimens were kept for further identification. Fish suspected of being in reproductive condition were partly stripped for confirmation.

Data Analysis

Data were entered into an Access® database for collation and preliminary analyses and further analyses were done using Excel®, Genstat®, Statistix® and Patn® (Belbin 1992) software. Maps and spatial analyses were produced using MapInfo® GIS software.

SIGNAL indices were calculated using a tolerance table of invertebrate families (from 1 as the most tolerant to 10 as the most sensitive) provided in Chessman (1995). The SIGNAL index was commonly employed to assess the impacts of salinisation and organic pollution (Mitchell, 1999). Additionally, a weighted index (SIGNAL-W) was calculated by multiplying an abundance value (1 for one to two individuals; 2 for three to eight individuals; 3 for nine to twelve individuals; 4 for greater than twelve individuals) with the SIGNAL value provided in Chessman (1995) for each family. Functional group classification was based on an examination of mouthparts and from information supplied in references such as Hawking and Smith (1997), Williams (1980), Chessman (1995) and Merritt and Cummins (1978).

A hierarchical, agglomerative classification analysis was performed with unweighted pair-groups (UPGMA) and a Bray-Curtis association measure (Faith *et al.,* 1987) was used to group sample sites using PATN (Belbin, 1992). Rare species (less than 0.5% total abundance) were eliminated from the comparative analyses and not used as indicator species (after Norris *et al*., 1982 and Marchant *et al.,* 1984), but were included in the total abundance and diversity calculations.

RESULTS AND DISCUSSION

Wetlands

Coastal wetlands comprised only a small portion (approximately 0.43%) of the Barron River catchment (218 786 ha) due to the relatively narrow coastal floodplain. By comparison, Half Moon Creek was a relatively small adjacent catchment (3 446 ha) which was entirely restricted to the coastal floodplain. Its wetlands occupied nearly 9 % of its total catchment area. Other studies in the wet tropics have shown that the percentage of catchment area occupied by wetlands was variable. For example, over 27% of the Moresby catchment (14 700 ha) were wetlands (Russell *et al.,* 1996), while in the nearby Daintree River catchment (134 200 ha) wetlands covered about 2% of the area (Russell *et al*., 1998).

Barron River

Map 4 and Map 5 show the wetland communities in 1952 and 1996 respectively. A comparison of the net loss or gain of freshwater and tidal coastal wetlands within the Barron River catchment between 1952 and 1996 is shown in Table 2 and Map 5.

Table 2. Areas of tidal and freshwater wetlands within the Barron River catchment in 1952 and 1996.

Percentage of total wetlands is shown in parenthesis.

Year	Tidal (ha)	Freshwater (ha)	Total (ha)
1952	1007 (90%)	110 (10%)	1117
1996	841 (90%)	96 (10%)	937
Total	**-166 (16%)**	**-14 (13%)**	**-180 (16 %)**

Changes in specific wetland types over the same time period are given in Table 3 and Map 5.

Table 3. Areas of the different types of tidal and freshwater wetlands within the Barron River catchment in 1952 and 1996.

Percentage of wetland loss or gain by type is shown in parenthesis in final column.

Wetland Type	1952 (ha)	1996 (ha)	Difference (ha)
Mangroves	933 (84%)	803 (86%)	-130 (14%)
Melaleuca	0	33 (4%)	+33
Melaleuca communities	110 (10%)	62 (7%)	-48 (43%)
Ponded water (tidal)	<1 (<1%)	22 (2%)	+22
Saltpan	74 (7%)	16 (2%)	-58 (78%)
Total	**1117**	**937**	**-180 (16%)**

In 1996, tidal wetlands accounted for about 90% of all wetlands, of which 86% were mangrove communities. Freshwater communities comprised only 10% of the total wetland areas. The ratio of tidal to freshwater wetlands was comparable to the adjacent Half Moon Creek catchment (see below) and the nearby Daintree River catchment (Russell *et al.* 1998). All of these catchments had substantial areas of agriculture (mainly sugar cane and grazing) and urban development, with some of these areas abutting directly onto existing wetlands area.

Coastal Wetland Changes

In 1952, coastal wetlands comprised 1 117 ha (approximately 0.51%) of the Barron River catchment. There was a total net loss of about 180 ha (16%) of wetlands in the Barron River catchment over the 47 years between 1952 and 1996. In this period, the major type of wetland loss has been tidal communities (net loss of about 166 ha). In some locations, for example to the east of the Cairns International Airport, changing patterns of sediment deposition has enabled an expansion of the mangrove area. Since 1952, changes around the Barron River mouth have increased mangrove area by approximately 60 ha.

The ratio of tidal to freshwater wetlands remained relatively stable between 1952 and 1996. Since 1952, the largest losses (166 ha or 16%) were of tidal wetlands (Table 2).

Freshwater communities, which even in 1952 were relatively small in area, have experienced a slight net decrease in area of about 14 ha (13%). Small areas of remnant freshwater wetland were found adjacent to mangrove habitat with their distribution and size limited by agricultural and urban development.

Between 1952 and 1996, salt pan communities have undergone a net decrease of about 58 ha (78% loss). For example, a large area of saltpan (23 ha) found at the upper limits of Yorkeys Creek (see Map 4) in 1952 had been lost to sugar cane expansion. In other areas including the western end of Barr Creek, mangroves, rainforest or Acacia/Melaleuca communities have replaced saltpan communities. In other areas sugar cane farming, urbanisation and the expansion of the Cairns International Airport have all contributed to loss of saltpan in other areas.

Over half the total area of mangroves was found in the southern section of the catchment, adjacent to the current Cairns International Airport (see Map 5). This mangrove community was approximately 420 ha in area and contained some stands of terrestrial vegetation, mainly *Acacia* and dune swales. In 1998, in recognition of its importance to fisheries production, a large proportion of this area was declared a FHA (Management Area A (see Map 2)) (Beumer *et al.,* 1997). The Cairns Port Authority manages some of the remaining mangroves directly adjacent to the Cairns International Airport complex, with some trees being routinely trimmed to maintain visibility of runway. Other FHAs included 39 ha adjacent to Yorkeys Creek and 68 ha in the vicinity of Barr Creek (see Map 2) (Beumer *et al.,* 1997).

The area of ponded water has increased substantially in the last 44 years due mostly to the inclusion of aquaculture ponds adjacent to the wetlands. Aquaculture ponds were constructed adjacent to Thomatis Creek on land previously being used for sugar cane production.

Half Moon Creek

A break-down of the type, location, approximate areas and net changes of coastal wetlands within the Half Moon Creek catchment between 1952 and 1996 is shown in Table 4, Table 5 and Map 5.

Table 4. Areas of tidal, freshwater and terrestrial wetlands within the Half Moon Creek catchment in 1952 and 1996.

The percentage of total wetland area is shown in parenthesis.

Year	Tidal (ha)	Freshwater (ha)	Transitional (ha)	Total (ha)
1952	280 (79%)	75 (21%)	0	355
1996	230 (77%)	67 (23%)	1 (<1%)	298
Total Difference	**-50 (18%)**	**-8 (11%)**	**1**	**-57 (16%)**

In 1996, the total area of wetlands in the Half Moon Creek catchment was about 298 ha or 8.6% of its total area of 3 446 ha (Table 4). This compares to a total wetland area of 355 ha or 10.3% of the catchment area in 1952. In comparison to wetland areas of other small neighbouring coastal catchments of the Mowbray (2%) and Mossman (<1%) Rivers (Russell *et al., 19*98), the proportion of wetlands in Half Moon Creek catchment was relatively high.

Table 5. Areas of the different types of tidal, freshwater and terrestrial wetlands within the Half Moon Creek catchment in 1952 and 1996.

Percentage of wetland loss or gain by type is shown in parenthesis.

Wetland Type	1952 (ha)	1996 (ha)	Difference (ha)
Mangroves	243 (68%)	197 (66%)	-45 (19%)
Melaleuca	1 (<1%)	37 (12%)	+36 (3722%)
Melaleuca communities	74 (21%)	31 (10%)	-44 (59%)
Ponded water (tidal)	2 (<1%)	11 (4%)	+9 (394%)
Salt Pan	35 (10%)	20 (7%)	-15 (42%)
Transition	0	2 (<1%)	+2 (%)
Total Difference	**355**	**298**	**-57 (16%)**

In 1996, tidal wetlands accounted for about 77% of all wetlands. Mangrove communities (66%) were the major component with most of the remainder being freshwater wetlands (22% by area. The Half Moon Creek catchment had very little transitional wetlands or regrowth areas (2 ha).

A total of 221 ha or nearly 74% of all wetlands in the catchment were protected as FHA (see Map 2). Mangrove was the dominant community type in the FHA, with only small areas of predominantly *Melaleuca* wetlands and saltpans. Sugar cane farms and urban areas were found to abut landward margins of these wetland areas.

It was proposed to create an artificial wetland (known as Cattana wetlands) in the headwaters of Half Moon Creek adjacent to the FHA (see Map 2). This will be done by rehabilitation of degraded sugar cane land and a quarry and will include existing rainforest. Included in the proposal was a plan to create a wildlife corridor from the existing wetlands to the forested hill-slopes of the Macalister Range by linking existing remnant vegetation.

Wetland Changes between 1952 and 1996

In 1952, wetlands composed 355 ha (10.3%) of the total catchment area. Between 1952 and 1996, there was a total net loss of wetlands in the Half Moon Creek catchment of 57 ha or 16% (see Table 5). There was an 18% reduction of tidal wetlands (50 ha) and an 11% reduction in freshwater wetlands (8 ha) during this period. Changes in drainage patterns have resulted in small areas of freshwater wetlands being inundated by tidal waters. In these areas, mangroves were gradually replacing the freshwater communities. A similar process has been previously documented in a number of areas including the Moresby catchment (Hopkins *et al*., 1979 and Russell *et al.,* 1996b).

Other freshwater wetlands

As well as the coastal wetlands discussed above there were a number of other small areas of freshwater wetlands, both artificial and natural, elsewhere in the catchment. These included Hastie Swamp and Mount Quinkan crater which were both in the headwaters of the catchment. Some artificial wetlands, such as the Nardello's Lagoon balancing storage at Walkamin were considered valuable wildlife areas.

Land Use on Reclaimed Wetlands

Table 6 shows the 1996 land uses on wetlands reclaimed since 1952 in the Barron River and the Half Moon Creek catchments.

Table 6. Total area of wetland lost by specific land use tenure within the Barron River and Half Moon Creek catchment from 1952 to 1996.

*Associated terrestrial vegetation including rainforest areas have been included. *Includes airport expansion.*

Land use	Barron (ha)	Half Moon (ha)	Total (ha)
Other*	300.3	46.9	347.2
Sugar	94.9	36.8	131.7
Urban	17.3	8.1	25.4
Industry	8.4	0	8.4
Cleared	4.6	12.8	17.4
Tree Crop	2.3	0	2.3
Aquaculture	2	0	2
Quarry	0.7	1.7	2.4
Rural Residential	0.2	0.01	0.21
Grazing	0.1	0	0.1
Water	0.1	0	0.1
Total	**430.9**	**106.3**	**537.21**

Barron River catchment

During this period (1952 to 1996), about 130 ha of wetlands was reclaimed to allow the expansion of the Cairns International Airport. The airport expansion has been responsible for 56% of the wetland area lost in the Barron River catchment. While most of this loss has been the result of reclamation of tidal wetlands (100 ha), about 30 ha of *Melaleuca* communities have also been removed. In other parts of the catchment, agricultural, urban and industrial expansion was also responsible for wetland losses (see Map 5).

Half Moon Creek catchment

In 1996, approximately 37 ha of reclaimed wetlands were under sugarcane production, with a further 25 ha being used for other purposes including landfills and golf courses. About 13 ha of mainly tidal wetland was cleared for future canal development. This development has resulted in some problems with acid sulphate soils and remediation is now underway.

There was a small net decrease of about 8 ha of freshwater wetlands in the Half Moon Creek catchment. These wetlands were reclaimed primarily for sugarcane production or for use in land fill operations.

Stream Habitat

Riparian zone assessment

Riparian disturbance

The riparian disturbance index (see APPENDIX C) was designed to enable a rapid assessment to be made of impacts, primarily those due to human activities, on the riparian vegetation at sites throughout the catchment. Similar assessments have also been made within other wet tropics catchments (eg. Russell and Hales, 1993, 1997 and Russell *et al.,* 1996a, 1996b, 1998). Aerial photos were used as a supplementary assessment tool, to identify if any major disturbances existed in areas of the catchment that could not be easily accessed.

Of the 191 sites surveyed in the catchment, 35 (18.3%) were classified as having either extreme or high disturbance. In contrast, there were 115 (60.2%) sites that were classified as being undisturbed or as having low disturbance. Compared to other wet tropics catchments, the Barron River catchment had a relatively low percentage of disturbed sites and a high percentage of undisturbed sites (Table 7).

Table 7. Percentage (number of sites) of disturbed and undisturbed sites sampled in five Wet Tropics streams

Disturbed sites include sites classified as either extreme or high disturbance while undisturbed includes sites categorised as undisturbed or low disturbance. (Source: Russell and Hales, 1993 and 1997 and Russell et al., 1996a, 1996 b and 1998).

Catchment	Percentage of disturbed sites	Percentage of undisturbed sites
Daintree	21 (12)	44 (25)
Johnstone	60 (116)	20 (38)
Russell-Mulgrave	41 (39)	40 (38)
Moresby	37 (14)	55 (21)
Barron	**18.3 (35)**	**60.2 (115)**

Easy accessibility to many parts of the WHA in the Barron River catchment enabled the assessment of a large number of sites. This helped to address any bias in the sampling strategy towards sites in more accessible areas. If the WHA sites were removed from the assessment, the percentages of extreme or high disturbance sites and the undisturbed or low disturbance sites become approximately 21.7% and 52.8% respectively.

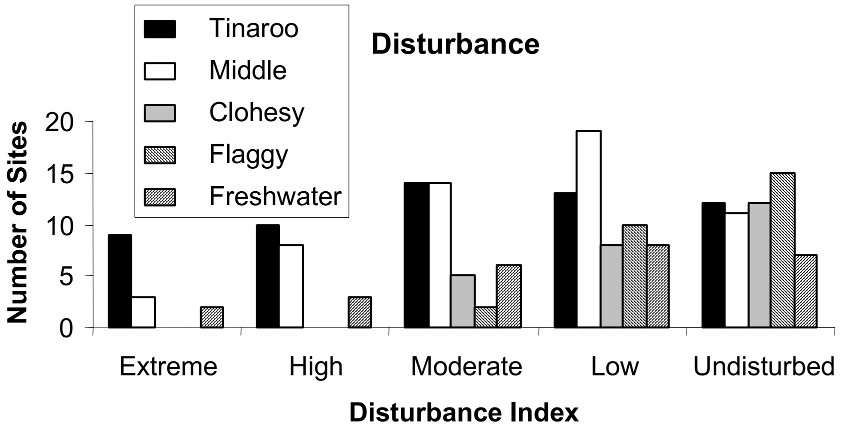


Figure 2. Number of sites in each riparian disturbance category.

Freshwater: Nearly 58% of the 26 sites surveyed in the Freshwater Creek sub-catchment were classified as either undisturbed or of low disturbance (Figure 2). By contrast, only about 19% of the sites assessed were classified as highly or extremely disturbed. Typically, these areas of high disturbance occurred adjacent to urban and agricultural (mainly sugar) areas where the riparian vegetation was severely reduced. Reduced access to the WHAs limited the number of sites assessed in this sub-catchment.

Flaggy: This sub-catchment was in relatively good condition with most (93%) sites classified as being of low disturbance or undisturbed (Figure 2). A high proportion of these sites was located in the relatively pristine WHA or in SFs. No sites were found with a high or extreme disturbance rating.

Clohesy-Davies: Of the 25 sites surveyed in this sub-catchment, 20 (80%) were classified as either undisturbed or low disturbance (Figure 2). No sites were assessed as having extreme or high disturbance. This sub-catchment included relatively large areas of World Heritage estate and SF.

Middle: Thirty (54.5%) of the sites in this large sub-catchment were classified as undisturbed or low disturbance (Figure 2). Only 11 (20%) sites had disturbances of an extreme or high nature. These sites were typically located adjacent to residential or agricultural areas. Only a small fraction of the sub-catchment (6.4%) was in the Wet Tropics WHA.

Tinaroo: In this sub-catchment only 15 (43.1%) sites were given an undisturbed or low disturbance rating, while 19 (32.8%) sites were classed as having an extreme or high disturbance rating (Figure 2). This sub-catchment has only limited areas remaining of natural forest, some of which was included in the Wet Tropics WHA. Many streams in dairy farming areas were given a high disturbance rating. These streams had been impacted through the partial or total clearing of the riparian forest resulting in watercourses with a high coverage of exotic grasses such as para grass.

Riparian vegetation components

The effect of the riparian vegetation clearing has been to restrict water flow and increase the sedimentation in the lower order streams (Bunn *et al.,* 1998). Much of the main river and its tributary streams have been left unfenced to allow cattle easy access to the water. This caused excessive erosion and reduced the possibility of natural regeneration of the riparian forest (Kaufman and Krueger, 1984).

Figure 3 shows the composition of the major vegetation components (see APPENDIX C for definitions) at sites within the five sub-catchments. The high proportion of trees/shrubs would suggest that, at many of the sites assessed, the riparian zone was in a relatively healthy condition. The presence of a relatively high percentage of invasive grasses would suggest either an open canopy or a degraded riparian zone.

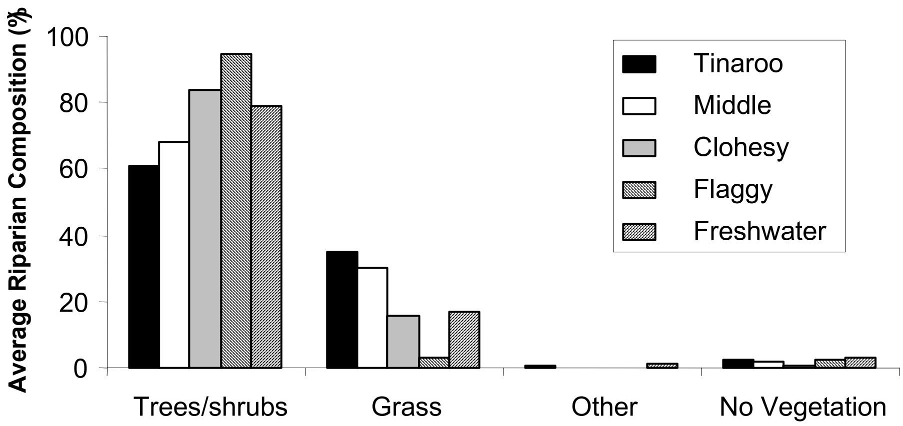


Figure 3. Major vegetation components at sites in the five sub-catchments

Freshwater: Trees and shrubs were the major component (79%) of the vegetation at sites within the Freshwater Creek sub-catchment, with grasses (17%) the only other significant vegetation type (Figure 3). The growth of grasses in the riparian corridor was primarily linked to a reduced canopy cover following clearing of the native forest in the urban and agricultural (mainly sugar) areas.

Flaggy: As discussed in the previous section, the sites within this catchment were not heavily impacted by human activities. The high proportion of trees and shrubs (95%) and low proportion of grasses (3%) in the riparian zone highlighted the relatively undisturbed nature of this sub-catchment (Figure 3). Many parts of the sub-catchment were in excellent condition including upper areas that were encompassed by WHA and SF.

Clohesy-Davies: Although the percentage of trees and shrubs was still high (84%) there were some sites where agricultural activities had impacted on the riparian forest. Many parts of the sub-catchment were in excellent condition including upper areas that were encompassed by WHA, SF and NPs.

Middle: The major vegetation component in this sub-catchment was trees and shrubs (68%), with grassed areas forming 30% of the vegetation composition. The relatively low trees and shrubs component in this sub-catchment was most likely due to degradation of the riparian zone as a result of agricultural and urban expansion. This sub-catchment contained only a small area of the WHA estate.

Tinaroo: The Tinaroo sub-catchment had the lowest percentage of trees (61%) and highest percentage of exotic grasses (35%) of all the sub-catchments. The riparian vegetation in this sub-catchment has been extensively cleared to increase the area of grassland available for grazing and dairy cattle. This sub-catchment contained limited remnant forest and only a small area included in the Wet Topics World Heritage estate.

Riparian forest width

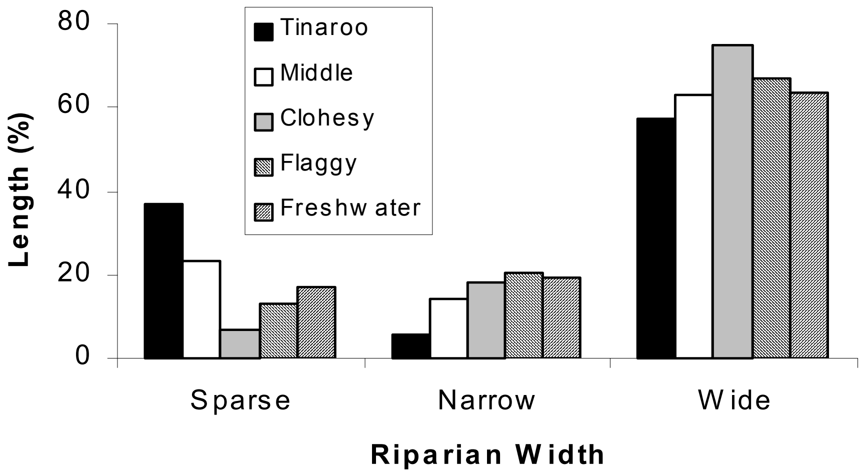


Figure 4. Percentage of the total bank length of the main river for respective riparian width classifications.

Only reaches where both left and right banks could be assessed separately were included.

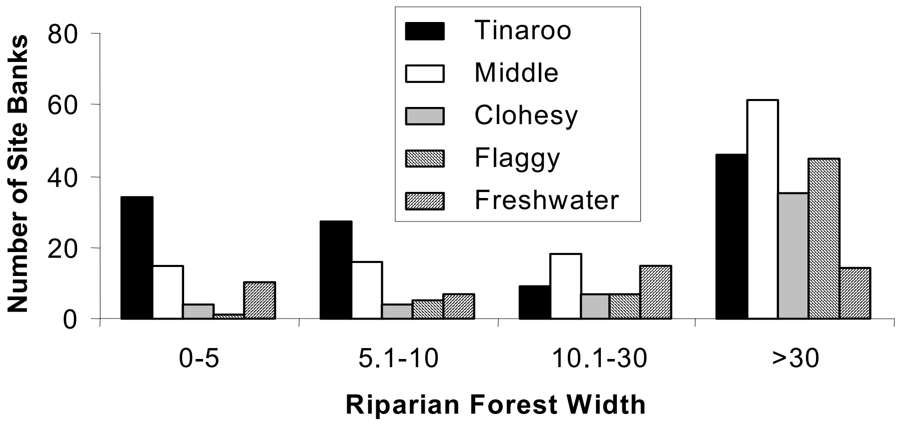


Figure 5. Average riparian forest width at all sites in each sub-catchment.

The graphic in Figure 5 shows the average riparian forest width found at sites in all sub-catchments. Figure 6 and Map 6 show riparian width as a proportion of the total bank width of the main river and tributary streams as assessed from aerial photographs. These widths were classified as sparse, narrow or wide (see APPENDIX C). For each sub-catchment, the riparian corridor width for streams were described with respect to condition at individual sites as well as the width along the main watercourse and tributary streams as assessed from aerial photographs (Map 6).

Freshwater Creek:

<u>Habitat Sampling Sites</u> - At sites in the Freshwater Creek sub-catchment, the number of banks with riparian forest of less than 5 m width accounted for about 22% of all assessments (Figure 5). Riparian corridors greater than 30 m wide made up about 30% of the total number of assessments. This reflected some significant clearing of riparian vegetation for agricultural and urban expansion.

<u>Main Channel</u> - About 24 km (64%) of the banks of the main stream of the Barron River in this sub-catchment were classified as having wide riparian vegetation, with the remaining 7 km either narrow or sparse (Figure 4). Much of the stream bank that was classified as wide was either in the mangrove areas of the lower estuary or in the Barron Falls National Park (see Map 6). If these areas were excluded from the analyses, then the proportion of banks categorised as narrow or sparse increased to 46% of the total length. The main land use along this remaining section of the river was sugar cane farming and grazing.

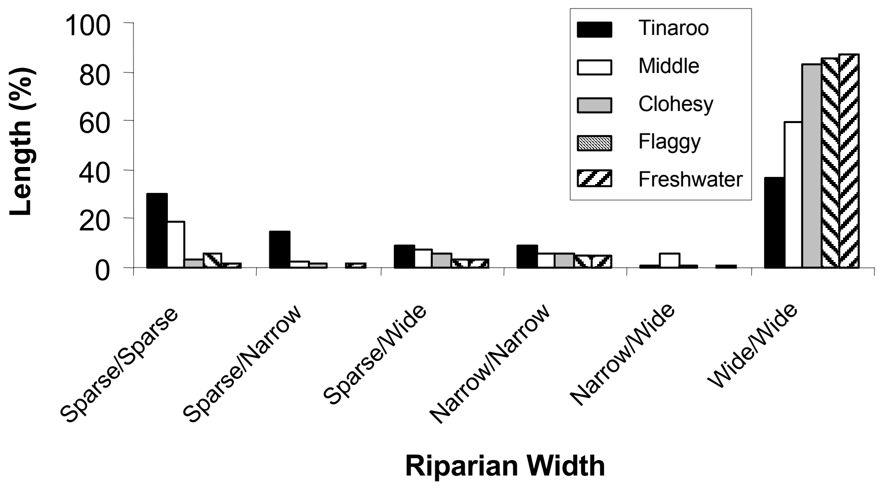


Figure 6. Percentage of the total length of the minor streams for respective riparian width classifications

<u>Minor streams</u> - Freshwater Creek was the major perennial stream in this sub-catchment. Overall, the majority of the length of minor streams contained wide vegetation (87%) (Figure 6). If the WHAs were removed from the analysis, only 65% of the total bank length had at least one side of wide vegetation, and 49% of the bank length had wide vegetation on both sides of the stream. Sugarcane farming and urban expansion were the main causes for the depletion of the riparian corridor on the minor streams in this sub-catchment.

Flaggy Creek:

<u>Habitat Sampling Sites</u> - More than 77% of all sites in the Flaggy Creek sub-catchment were considered to have a vegetation width greater than 30 metres (Figure 5). Two sites (10%) in a grazing area were considered to have sparse or narrow vegetation.

Main Channel - Much of the length of the main Barron River in this sub-catchment had a wide vegetation zone (66%) (Figure 4). In contrast, the proportion of sparse vegetation was only 13% of the total bank length. Only a small section of the river was included in reserves (eg WHAs), so it was not unexpected that these percentages would significantly change by excluding such areas from the analyses.

Minor streams - The large areas of native forests in this sub-catchment were responsible for the major percentage of stream banks with wide vegetation (85%) (Figure 6). This figure was only reduced to 79% with the exclusion of the WHAs. Grazing areas surrounded most of the banks covered with sparse vegetation.

Clohesy-Davies Creek:

Habitat Sampling Sites - Thirty-five (70%) of the sampling sites surveyed in this sub-catchment displayed wide riparian vegetation corridors (Figure 5). Only 8% of the total sites possessed riparian vegetation corridors less than 5 metres wide.

Main Channel - There was only 5 km of the main Barron River in this sub-catchment and 75% of that length contained wide vegetation (Figure 4).

Minor streams - A large portion, 232 km (83%), of streams in this sub-catchment were classified as having a wide riparian zone (Figure 6). Even when the WHA reserves were removed from the analyses, the percentage of wide riparian forests still remained high (77%). Only small lengths of streams, mostly in residential and grazing areas, contained sparse riparian vegetation on at least one side (14%).

Middle:

Habitat Sampling Sites - Of the 55 sites assessed in this sub-catchment, 55% were considered to have a wide riparian corridor (Figure 5). More than 28% of the sites displayed riparian widths less than 10 metres. The clearance of the riparian vegetation in this sub-catchment was mainly associated with the irrigated agriculture of the Mareeba Dimbulah Irrigation Area.

Main Channel - Although the Barron River section in this sub-catchment had wide vegetation on at least one bank for 63% of its length, there was a significant portion (23%) that was assessed as sparse (Figure 4). Most clearing had occurred in either agricultural or rural residential areas.

Minor streams - Over 71% of the total length of these streams were given a wide classification on at least one bank, compared to 29% of the total length which was classified as sparse (Figure 6). The relatively higher percentage of sparse vegetation in this sub-catchment may be attributable to increased clearing due to urban, rural and agricultural expansion.

Over 48% of the length of streams assessed in the Granite Creek area had sparse vegetation on at least one bank. This was not suprising since approximately 47% of the catchment area was related to agricultural practices and forests covered only about 41% of the area.

Tinaroo:

Habitat Sampling Sites - Sites in the Tinaroo sub-catchment appeared to have been the most impacted by riparian clearing. Less than 40% of the 58 sites assessed in this sub-catchment had a wide riparian corridor of 30 metres or more on at least one bank (Figure 5). In contrast, more than 52% of stream banks assessed had riparian vegetation less than 10 metres wide. The sites with poor riparian vegetation width were mostly found in the dairying areas.

<u>Main Channel</u> - Only 57% of the length of the Barron River in this sub-catchment was assessed as having a wide riparian corridor (Figure 4). In comparison with other sub-catchments, the Tinaroo sub-catchment had the smallest proportion of wide riparian vegetation along the main channel. The land uses most commonly associated with the sparse vegetation category (37% of length) were agricultural cropping and dairy farming.

<u>Minor streams</u> - Less than half the length of the minor streams were classified as having a wide riparian forest on at least one bank (Figure 6). Less than 37% of the total stream length in this sub-catchment had wide vegetation on both sides. The percentage of the length of stream with sparse vegetation on both banks was in excess of 35%, with more than 62% of the total stream length having sparse vegetation on at least one bank.

If the WHAs were excluded from the analyses, then the percentage length of stream with wide vegetation on both sides decreased to only 25%. The majority of this vegetation clearance had occurred in the dairying areas.

Riparian continuity

The corridor of forested vegetation along stream banks may not necessarily be continuous and can contain breaks of varying length. Further, the continuity of riparian forest on one bank may be different to that on the other bank. These breaks in the riparian forest may be the direct or indirect result of human activity. Petersen (1992) contends that continuity was correlated to the width of the riparian corridor, with a wide corridor more likely to have a thick, unbroken line of vegetation.

A summary of the assessments of the continuity of riparian vegetation at the sampling sites in the catchments is as follows.

Figure 7 shows the continuity of riparian vegetation at all sites and at sites in each of the sub-catchments. At over 40% of the sites, the riparian corridor was found to be continuous and uninterrupted. Other wet tropics catchments with high continuities include the Daintree (Russell *et al*., 1998), Hull and Maria (Russell and Hales, 1997) and the Moresby (Russell *et al*., 1996b).

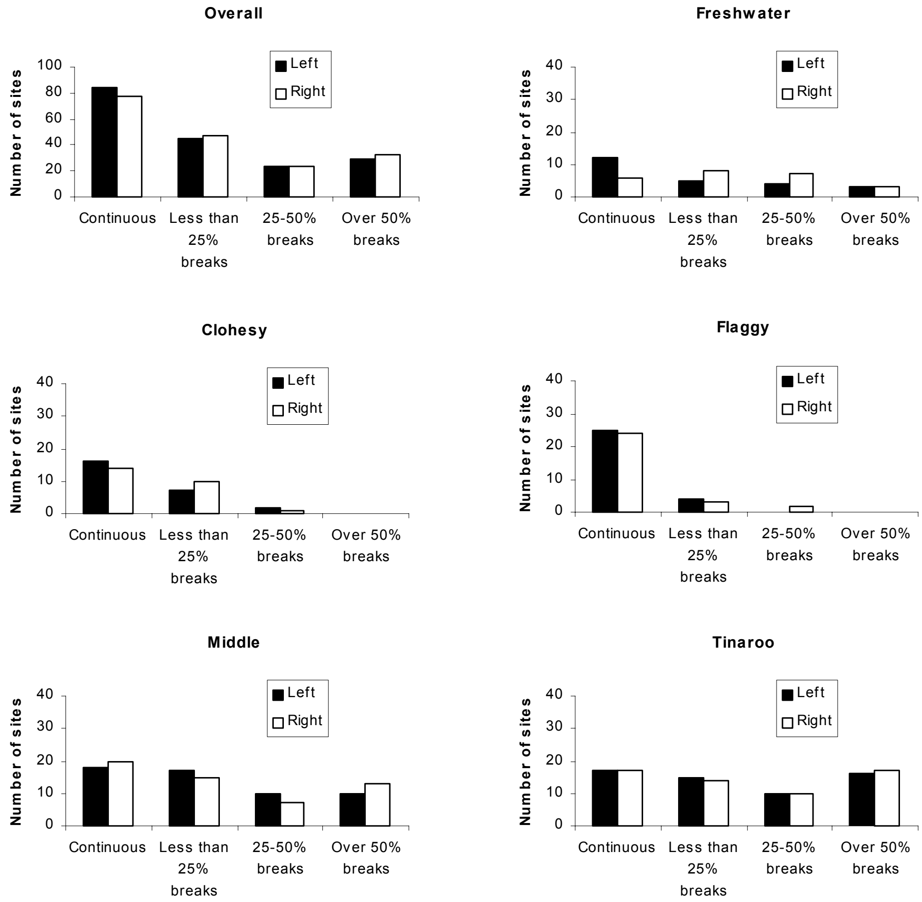


Figure 7. Continuity of riparian forest vegetation at all sites and at sites in the five sub-catchments

Freshwater: More than half of sites assessed in this sub-catchment had continuous or near continuous (less than 25% breaks) riparian forest on at least one bank. There were significant breaks (>50%) in the riparian vegetation at three sites (12.5% of sites) (Figure 7). Two of these sites, which had been impacted by clearing for urban development, were along the main channel of Freshwater Creek. The other site was situated on a constructed drain that flowed into Saltwater Creek (site 66, Map 3).

Flaggy: The vast majority of sites, around 86%, had continuous riparian vegetation. Only 14% of sites were found to have minor breaks, and no sites were found that had more than 50% breaks (Figure 7). Human impacts on the riparian corridor of sites within this sub-catchment were minimal.

Clohesy-Davies: Approximately 60% of all sites were assessed as having continuous riparian vegetation. The remaining sites consisted of minor breaks (approximately 35%) with only two sites with less than 50% breaks (Figure 7). There were no sites in this sub-catchment which had more than 50% breaks in the riparian vegetation.

Middle: More than 62% of sites in this sub-catchment had continuous or near continuous (less than 25% breaks) riparian forest. However, 13 sites (20%) contained more than 50% breaks in the riparian vegetation (Figure 7).

Tinaroo: Of the sites surveyed in this sub-catchment, 53% contained continuous or near continuous vegetation. More than 28% of sites, however, showed more than

50% breaks in the vegetation (Figure 7). Most of these sites were in the upper section of the catchment in either cropping or grazing areas. Many of these streams also had large stands of invasive grasses and high sedimentation and disturbance ratings.

Land use impacts on riparian vegetation

Approximately 25% of the total length of all streams assessed in the Barron River catchment contained sparse vegetation on at least one bank, with 15.5% having sparse vegetation on both banks. Most of the vegetation clearing, particularly in the upper catchment, was associated with dairying and grazing land use activities.

More than 73% of the total length of all streams assessed contained wide vegetation on at least one bank, with 65.7% containing wide vegetation on both sides of the streams. Many of the streams with wide vegetation were either in the WHA or another type of reserve.

The predominant land use adjacent to riparian zones was matched to the riparian condition in that area. The data were pooled for each sub-catchment and for the entire Barron River catchment, to determine the effect of adjacent land use on stream riparian cover.

Freshwater: Approximately 75% of the total length of stream banks assessed in this sub-catchment (204 km) were encompassed by forest. Of the major land use activities within the sub-catchment, sugar accounted for 11% of the catchment area. Approximately 10 kilometres of stream bank were adjacent to sugar farming activities and in these areas, more than 57% of the total length of riparian forest was classified as being sparse or narrow on both banks (Figure 8).

Other major land uses in this catchment which impact on riparian vegetation were urban and grazing activities. Most of the minor streams in the urban areas were classified as either wide (51%) or narrow (37%). In cattle grazing areas, the majority of the length of river and minor stream banks were assessed as either sparse (56%) or wide (26%). The lower portions of Freshwater Creek and lower Barron River were the main areas where these land uses were impacting on riparian forest.

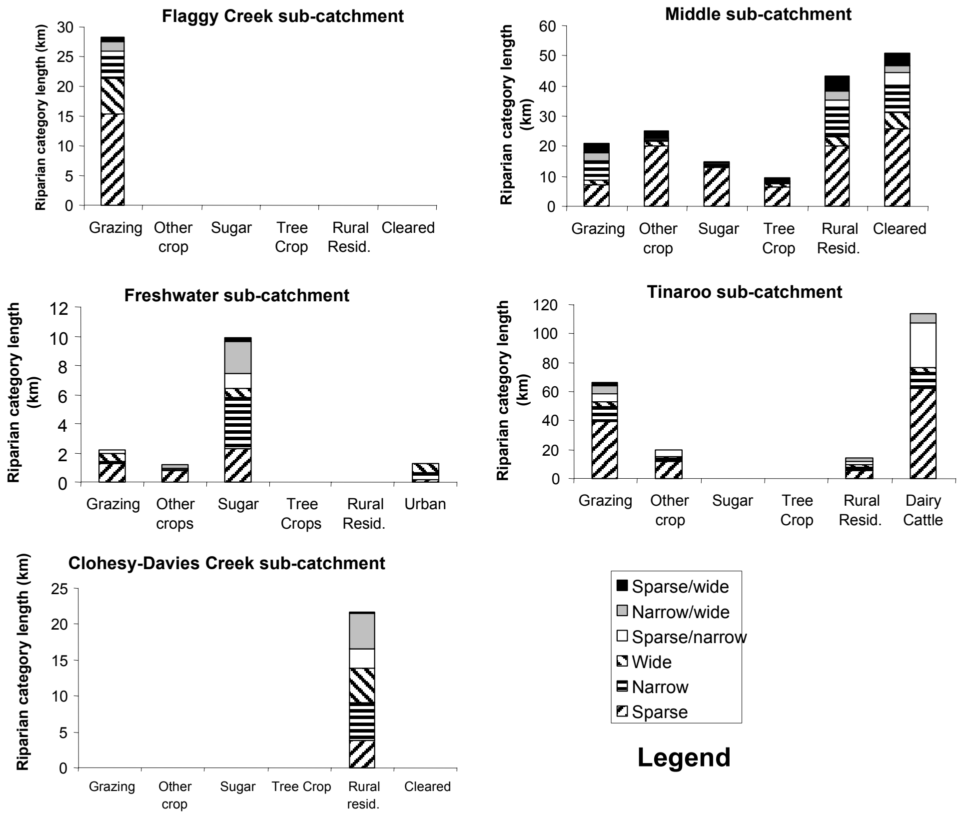


Figure 8. Length of riparian width classes associated with the major land-use categories.

Flaggy: Forested areas constituted nearly 91% of this sub-catchment and encompass nearly 88% of the total stream length. Grazing was the next largest land use (only 5% of the catchment area) and it impacted on 28 kilometres of stream banks. Most of the streams associated with grazing were minor watercourses, and more than 53% of their total length was classified as sparse. A further 16% of the total stream length in grazing areas were classified as narrow vegetation width (Figure 8).

Clohesy-Davies: The majority (90%) of the catchment was forested with the next predominant land use, rural residential, covering only 4.1% (1 186 ha) of the total area. The riparian vegetation on minor watercourses impacted by this land use was relatively evenly distributed amongst all categories (Figure 8).

Middle: This sub-catchment contained a number of diverse land uses with no one land use dominant (see Figure 8). Regardless of land use type, a large proportion of the stream bank in this sub-catchment was classified as sparse (Figure 8).

Other crops, including tobacco, peanuts and maize occupied 5.8% of the total sub-catchment area. Of the 20 kilometres of mostly minor watercourses in this area, about 78% of the total length contained sparse riparian vegetation.

There was about 43 km of watercourses in the rural residential areas (5 069 ha) of the sub-catchment. About 44% of the total length of the riparian corridors of these streams was classified as sparse and only approximately 16% as wide (Figure 8).

Watercourses associated with the other land uses also showed considerable disturbance to the riparian forest. These include:

- cleared land – over 50% of total length assessed as sparse vegetation;
- grazing – 35% of total length assessed as sparse vegetation;
- sugar – over 89% of total length assessed as sparse vegetation; and
- tree crops – more than 67% of total length assessed as sparse vegetation.

The level of agricultural and urban development in this sub-catchment has resulted in significant disturbances to the riparian vegetation, particularly along the minor streams.

Tinaroo: About 38% of the total length of streams in this sub-catchment were in forested areas. Dairying (9 330 ha) and grazing (7 278 ha) were the major land use types in this sub-catchment (Figure 8).

In the heavily agricultural areas adjacent to Mazlin, Patterson and Severin Creeks, more than 59% of the total stream length had a sparse riparian cover.

In the southern sector of this sub-catchment, dairying was the predominant land use. In this sector, more than 54% of the total stream length had sparse riparian vegetation cover on both banks. Only 5% of the whole stream length assessed in this sub-catchment had a wide vegetation cover.

In areas where "other crops" were cultivated, almost 100% of the 25 kilometres of streams assessed were classified as either sparse or narrow on at least one bank. In rural residential areas, about 68% of the 19 kilometres of stream were assessed as having either sparse or narrow riparian forest on at least one bank

Agricultural development in this sub-catchment was associated with widespread clearing of riparian vegetation and colonisation of streams by exotic grasses.

Substrate

Particle size (boulder/cobble, cobble/gravel, sand and fine material) was used as a means of substrate classification (see APPENDIX C). The major substrate type was identified at each site for both pool and riffle habitats.

When all the sites were considered in the Barron River catchment, the major components in the pool sections were the smaller particle sizes (sand and fine material). Sand was the most dominant particle component overall. This was predictable, as finer material tend to settle out in low velocity waters (eg. pools) (Carter, 1994).

In the riffles, where water velocities tend to be higher, the substrates were predominantly larger particle sizes. The dominant particle sizes in the riffle section were boulder/cobble and cobble/gravel (68%).

In the following sections use of the term 'smaller particle sizes' refer to sand and fine material and 'larger particle sizes' refer to boulder/cobble and cobble/gravel categories.

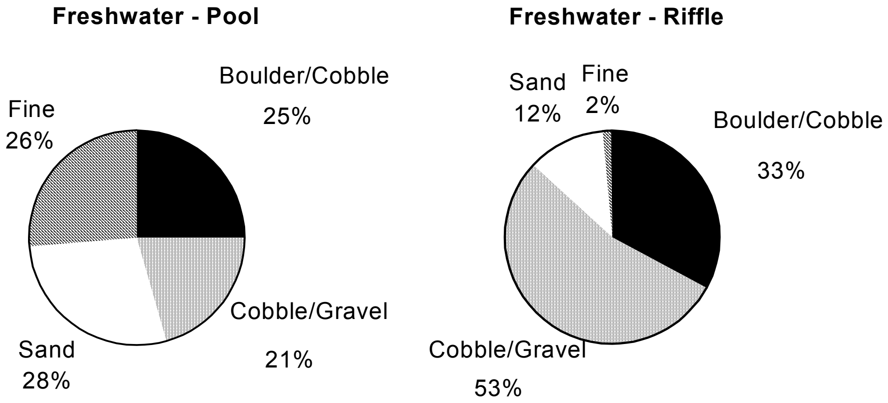


Figure 9. Particle size of pools and riffles in Freshwater sub-catchment.

Freshwater:

Figure 9 shows the major substrate components at sites in the Freshwater Creek sub-catchment. In the riffles, larger particles were the principal components (86%). By contrast the finer particle sizes were dominant (54%) in the pool sections, with sand the major component.

Flaggy: In the pools, the smaller sized particles, primarily sand, were the major components (62%) (Figure 10). In the riffles, larger particles were the dominant (70%) substrate component. At one site on Flaggy Creek, the bottom was continuous solid rock. At this site the boulder/cobble particle size was the dominant component.

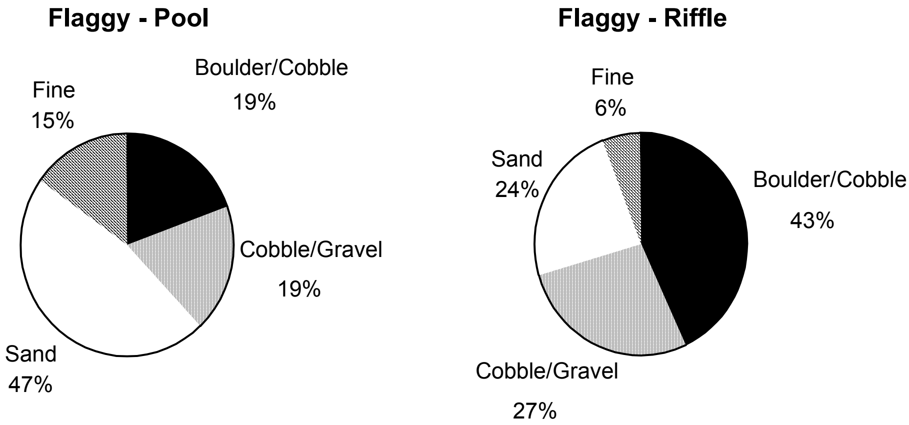


Figure 10. Particle size of pools and riffles in Flaggy sub-catchment

Clohesy-Davies: Most of the pool sites in this sub-catchment had smaller particles (sand (40%) and fine material (17%)) as the dominant components (Figure 11).

The larger particle categories comprised the major components (58%) in the riffle sections. Cobble/gravel was the dominant component (38%).

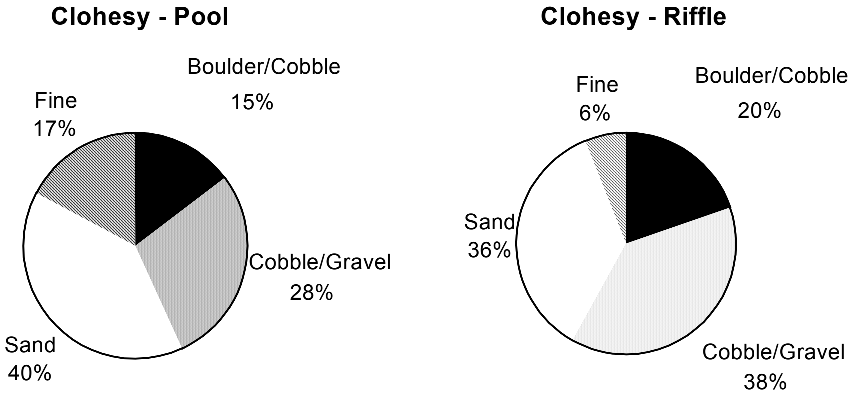


Figure 11. Particle size of pools and riffles in Clohesy-Davies sub-catchment

Middle: Particle size composition in the pool sites of this sub-catchment was slightly different to the previous sub-catchments. The proportional composition of particle size classes was relatively evenly distributed between all categories in pool sections (Figure 12). In the riffles, the larger particle sizes were the major components (80%).

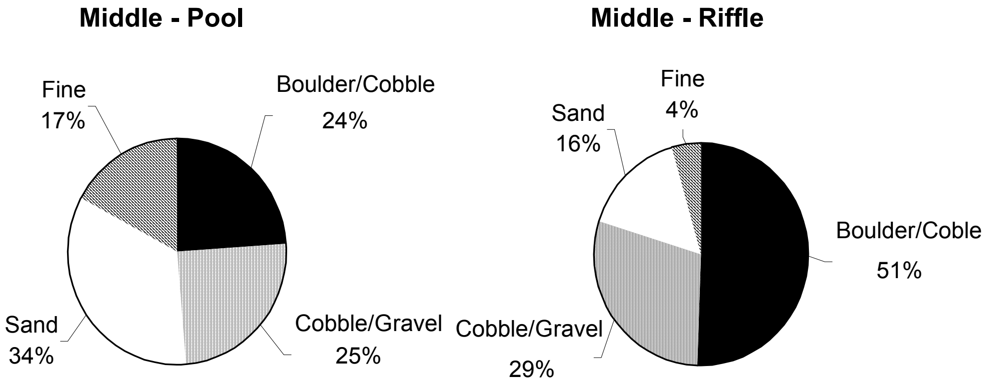


Figure 12. Particle size of pools and riffles in Middle sub-catchment.

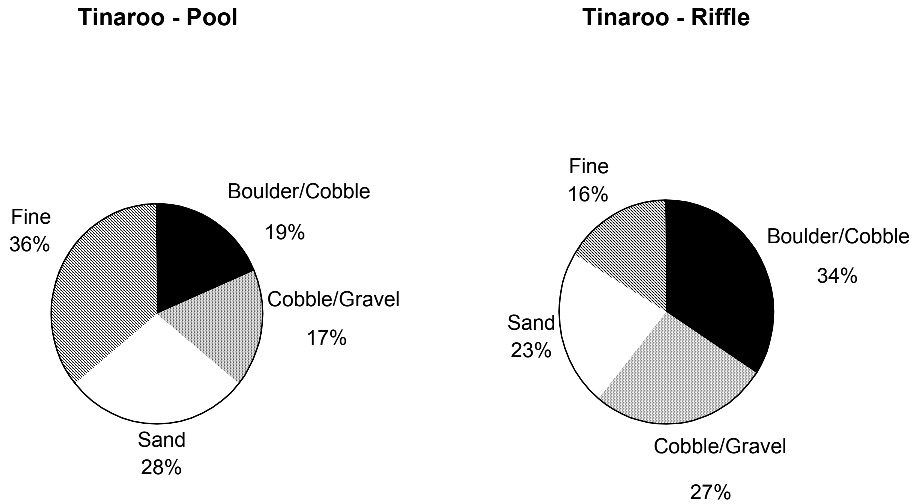


Figure 13. Particle size of pools and riffles in Tinaroo sub-catchment.

Tinaroo: Fine particles and sand were the dominant components in the pool sections within the Tinaroo sub-catchment (Figure 13). Fine materials were a major substrate component at pool sites in this sub-catchment (36%). While this may be primarily related to local soil types, other anthropomorphic factors including local land uses may also have been contributory factors.

Larger size classes were the major components (61%) in the riffles of this sub-catchment. The proportion of fine materials found in riffles in the Tinaroo sub-catchment was higher than in the other four sub-catchments.

Pool to riffle ratio

The pool to riffle ratio is widely used in stream and habitat assessments as a measure of stream gradient. As the stream gradient increases, there is a corresponding decrease in the pool to riffle ratio. By grouping the pool length and riffle length data from all sites and assuming that these sites were representative, the pool to riffle length ratio can be used to give an overall indication of the stream gradient in the parts of the catchment surveyed. Table 8 shows the total length of pools and riffles from all sites assessed in the five sub-catchments and the calculated pool to riffle ratio.

Table 8. Total pool and riffle lengths and overall pool to riffle length ratio at sites in the five sub-catchments.

Sub-catchment	Pools (m)	Riffles (m)	Total (m)	Ratio
Freshwater Creek	2 860	540	3 400	5.30
Flaggy Creek	3 160	950	4 110	3.33
Clohesy-Davies Creek	715	1 465	2 180	0.49
Middle	2 555	2 120	4 675	1.21
Tinaroo	2 305	2 325	4 630	0.99
Total (m)	**11 595**	**7 400**	**18 995**	**1.57**

Pools are generally considered to be a preferred fish habitat type, while riffles are an important source of their food, particularly invertebrate prey (Beschta and Platts, 1986).

The high ratio calculated for the Freshwater Creek sub-catchment can be mainly attributed to the number of sites on the flat coastal flood-plain. Many of the very steep sections of the Freshwater Creek sub-catchment adjacent to the mountainous Lamb Range could not be accessed. Also, numerous tributaries of the main Freshwater Creek were ephemeral and were not included in this sampling.

In comparison, the Clohesy-Davies Creek sub-catchment was dominated by an extensive system of perennial creeks that have their origin in the Lamb Range. Streams in this sub-catchment typically had a low pool to riffle ratio. Tinaroo sub-catchment, which was characterised by an undulating landscape, also had a low pool to riffle ratio.

Overhanging vegetation

Mahoney and Erman (1981) noted that overhanging riparian vegetation not only acts as cover for fish but also assisted in a number of other functions including:

- a source of food (eg. leaf litter, fruit) for aquatic biota;
- reducing water temperatures fluctuations through shading;
- increasing bank stability; and
- reducing aquatic plant coverage.

The percentage of bank length with overhanging vegetation at sites in the various sub-catchments is shown in Figure 14.

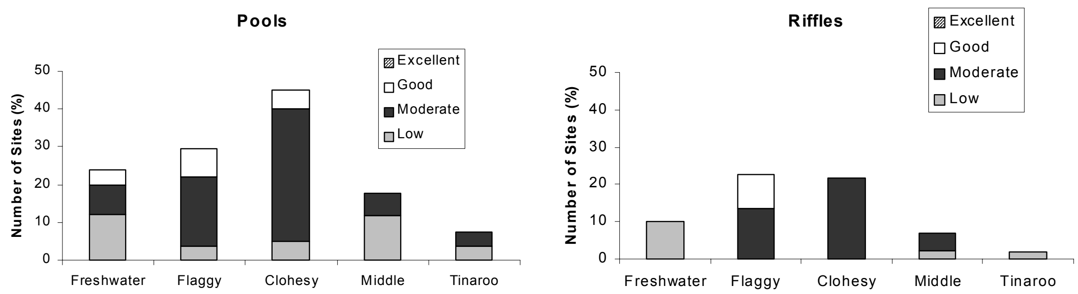


Figure 14. Percentage of sites in the various sub-catchments with overhanging vegetation.

Freshwater: Overhanging vegetation was observed in the pool sections at only about 24% of the sites assessed, with the majority of these sites displaying only a low coverage (Figure 14). There were a small number of sites with overhanging vegetation in riffle sections (10%), all with a very low coverage. Clearing due to agricultural or urban expansion had resulted in the relatively low number of sites with little overhanging vegetation.

Flaggy: More than 29% of sites with pools (27 sites) in this sub-catchment contained overhanging vegetation, and more than 23% of the 22 sites with riffles had a good or moderate coverage of overhanging vegetation (Figure 14).

Clohesy-Davies: Nearly half (45%) of the 20 sites with pools contained overhanging vegetation of low, moderate or good coverage. Of the 23 riffles sites assessed, all had a moderate coverage of overhanging vegetation (Figure 14).

Middle: Of the 51 sites with pools, 18% had low to moderate overhanging vegetation coverage (Figure 14). Similarly, of the 44 sites assessed with riffles, most banks had low or moderate coverage of overhanging vegetation. These apparently low figures may be indicative of the deleterious effect that inappropriate urban and agricultural land use practices can have on riparian buffers.

Tinaroo: Of the 53 sites with pools, 7.5% had low or moderate coverage of the overhanging vegetation (Figure 14). Approximately 2% of the 51 sites with riffles had a low coverage of overhanging vegetation.

Aquatic plants

Figure 15 shows the densities of aquatic plants at sites in Barron sub-catchments.

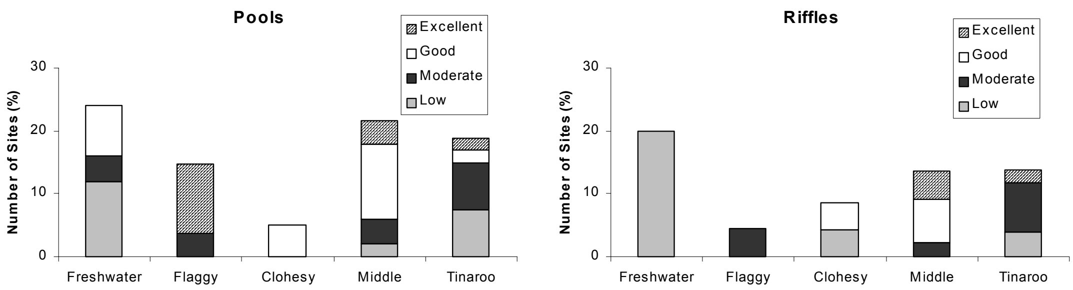


Figure 15. Percentage of sites in the various sub-catchments with aquatic plant habitat.

Freshwater: Aquatic plants were present at mostly low to moderate densities at 24% of the pools in this sub-catchment. Approximately 20% of the riffle sites also contained low densities of aquatic plants (Figure 15). The main species of aquatic vegetation was *Vallisneria gigantea* (ribbonweed) and *Blyxa* spp., although other species including *Hydrilla verticillata* (hydrilla) and *Potamogeton javanicus* were observed. There was some anecdotal evidence to suggest that sedimentation, particularly as a result of urban development, may be having an adverse impact on macrophyte beds in Freshwater Creek.

Flaggy: Aquatic plants were only found at about 14.5% of the pool sites in this sub-catchment (Figure 15). Beds of *V. gigantea* and *H. verticillata* were found at sites on the Barron River and lilies (*Nymphaea violacea)* occurred in an off-stream lagoon at site 178 (Map 3). In some places these riverine macrophyte beds were both dense and extensive. Moderate densities of aquatic vegetation were observed at less than 5% of the riffle sites.

Clohesy-Davies: Aquatic plants were found at only 5% and 9% of sites with pools and riffles respectively (Figure 15). The main species, the emergent *Persicaria decipiens* (slender knotweed) was restricted mainly to the littoral zone of minor streams.

Middle: Aquatic plants were found at over 21% of the sites with pools. Approximately 14% of riffle sites contained aquatic vegetation in moderate to excellent densities (Figure 15). The main species present were *V. gigantea* and *P. javanicus*, both being mostly restricted to the major streams. Floating species such as *Azolla* sp. (pacific azolla) and *Lemna* sp. (duckweed) and submergent/emergent species such as *H. verticillata* and *Marsilea mutica* (nardoo) were observed growing in the minor streams.

Tinaroo: In this sub-catchment aquatic plants were found at less than 19% of pool sites and generally in low to moderate densities. Similarly, only about 14% of sites with riffle sections were found to have mostly low to moderate densities of aquatic plants (Figure 15). Isolated beds of *V. gigantea*, *P. javanicus*, and *Blyxa* sp. were found in major streams in this sub-catchment. Floating species including *Lemna* sp., *Azolla* sp. and *Salvinia molesta* (salvinia) and *Eichhornia crassipes* (water hyacinth) were observed in some minor streams, including some highly impacted sites (eg. Scrubby Creek, site 4).

Snags

Woody debris or snags provide important fish habitat as well as influencing the physical form of the stream, movement of sediment and the retention of organic matter (Bilby and Ward, 1989). Figure 16 shows snag densities at sites in the various sub-catchments.

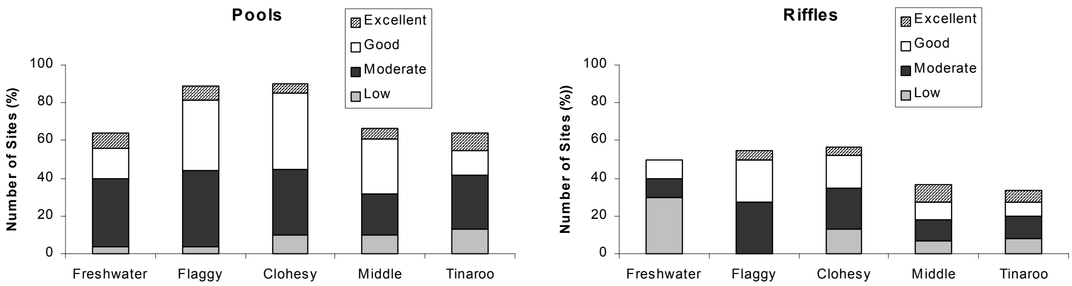


Figure 16. Percentage of sites in the various sub-catchments with snags.

Freshwater: Snags were present at 64% of the pool sites and 50% of the riffle sites (Figure 16). Compared to the Flaggy Creek and Clohesy-Davies Creek sub-catchments (see below) the percentage of sites with snags was relatively low. This was possibly one consequence of disturbance and clearing of the riparian forest. Also, construction of Copperlode Dam in the upstream catchment would likely have restricted downstream movement of woody debris.

Flaggy: More than 88% of the pool sites and 55% of the riffle sites contained snags (Figure 16). In the both the pool and riffle sites there was mostly moderate to good snag densities.

Clohesy-Davies: The majority of pool sites (90%) contained mostly moderate to good densities of snags. In the riffle sites, approximately 57% contained largely moderate to good snag densities (Figure 16).

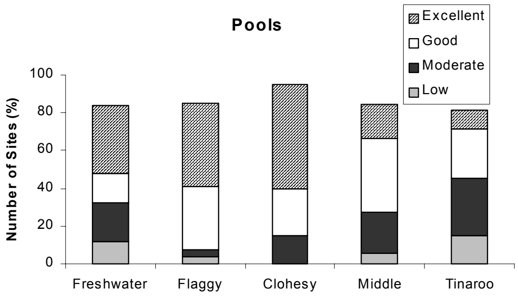
Middle: In this sub-catchment about 67% of the pool sites and 36% of riffle sites contained varying densities of snags (Figure 16).

Tinaroo: About 64% of the pooled sites and 33% of the riffle sites with were assessed as containing woody debris at varying densities (Figure 16).

There were relatively fewer disturbances to the riparian forests of the Flaggy and Clohesy-Davies sub-catchments than to the forests in either the Middle or Tinaroo sub-catchments. This may largely explain the differences in the snag densities between these catchments.

Undercut banks/roots

Figure 17 shows the percentage of sites with undercut banks in the Barron sub-catchments.



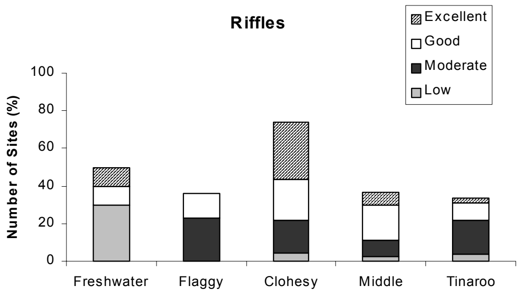


Figure 17. Percentage of sites in the sub-catchments with undercut banks.

Freshwater: In this sub-catchment, undercut banks and root systems were observed in around 84% of pool sites and about 50% of riffle sites. A high proportion of pool sites had good or excellent coverage while most riffle sites had low coverages (Figure 17).

Flaggy: Over 85% of the pool sites and 37% of the riffle sites in this sub-catchment contained undercut banks or root system habitat (Figure 17). Most of the pool sites had good or excellent coverage while riffle sites had moderate or good coverages (Figure 17).

Clohesy-Davies: Most of the sites assessed with pools (95% of all sites) and riffles (74% of all sites) had good or excellent coverages (Figure 17).

Middle: A high percentage (84%) of the sites with pools contained undercut banks and/or sub-surface root systems. This habitat type was only found at 36% of the sites with riffles (Figure 17). Both the pool and riffle sites had mostly good or excellent coverage.

Tinaroo: Of the 53 sites with pools, 81% (n=43) were assessed as having undercut banks and/or root systems (Figure 17). The coverage in pools was predominantly moderate or good. Only 17 (33%) of the 51 sites with riffles contained this type of habitat mostly at a low to moderate coverage.

Invasive grasses

The presence of invasive, exotic species such as para grass (*Brachiara mutica*) and guinea grass (*Panicum* sp.) was of considerable concern in this catchment. Para grass was introduced in Queensland in 1884 as a pasture plant and to control bank erosion (Middleton, 1991). This is a prolific species that has become widespread in watercourses throughout the catchment, particularly in disturbed areas. Para grass does contribute substantially to the food web of streams and rivers and was often the only stream habitat in very disturbed sites. The effect of the overabundance of this one type of habitat has been to skew the balance of organisms suited to this unnatural environment (Bunn *et al.,* 1997). Restoration of streamside riparian vegetation appears to be an effective long-term means of controlling invasive plants such as para grass (Bunn *et al.,* 1998).

Figure 18 shows the impact that invasive grasses have had on sites in the Barron sub-catchments. Sites in the middle and Tinaroo sub-catchments appeared to more affected than the sub-catchments in the lower part of the catchment.

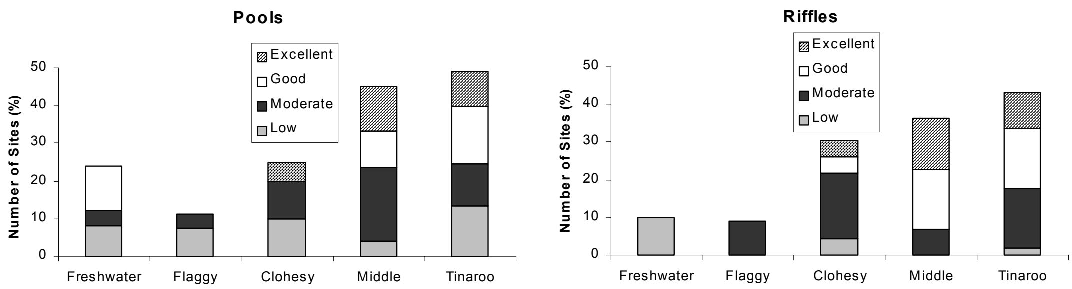


Figure 18. Percentage of sites in the various sub-catchments with invasive grasses.

Freshwater: About 24% of the pool sites and 10% of the riffle sites surveyed had varying densities of grasses present on the stream banks (Figure 18). Invasive grasses appeared to impact more on pools (low-good coverages) than the riffles (low coverages) in this sub-catchment.

Flaggy: Invasive grasses were present in this sub-catchment at only a few sites (11% of pools and 9% of riffles) and generally in low/moderate densities (Figure 18).

Clohesy-Davies: About 25% of the pool sites and 30% of riffle sites assessed in this sub-catchment contained generally low to moderate densities of littoral grasses (Figure 18). There were a few sites heavily impacted by invasive grasses.

Middle: Grasses affected a relatively high number of sites in this sub-catchment. More than 45% of the sites with pools and 36 % of sites with riffles were impacted (Figure 18).

Tinaroo: In this sub-catchment, invasive grasses were found to be impacting on over 49% of pool sites and 43% of riffle sites (Figure 18). At some sites, in both in pool and riffle sections, there was a dense coverage of these grasses.

Rocks

Figure 19 shows the occurrence of rock habitat at sites within the Barron sub-catchments. Generally, rock habitat was more commonly found in riffles sections.

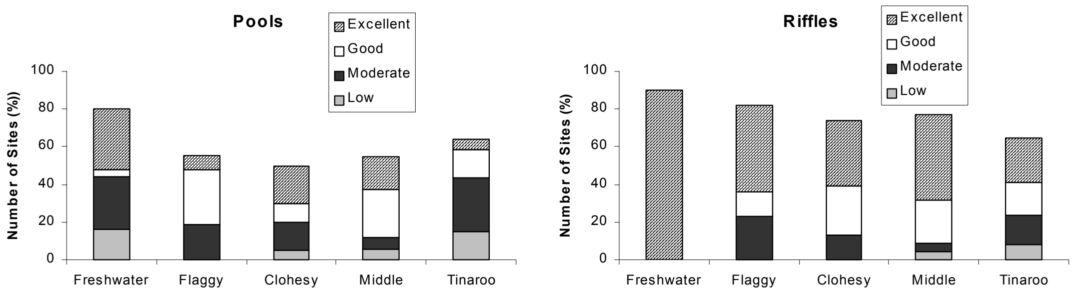


Figure 19. Percentage of sites in the various sub-catchments with rock habitat

Freshwater: About 80% of the sites with pools and 90% of riffle sites had some form of rock habitat (Figure 19). The gradient of the watercourses in this sub-catchment was generally steep, particularly in the upper catchment and most sites had a low pool to riffle ratio. It was not surprising that rock structures were dominant under these conditions.

Flaggy: Over 55% and 81% of the sites assessed with pools and riffles respectively contained some form of rock habitat (Figure 19). Coverage with rock habitat was mostly low to moderate in pool areas, and predominantly excellent in riffle sections.

Clohesy-Davies: Approximately half of the sites assessed with pools and more than 73% of sites with riffles had generally moderate to excellent coverage with rock habitat (Figure 19).

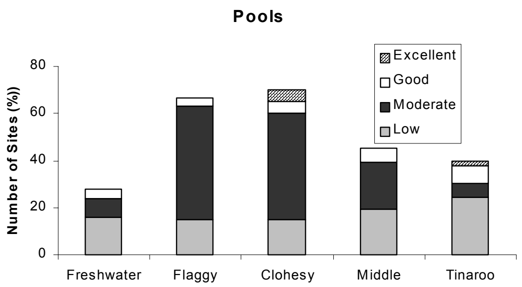
Middle: Of the 51 sites with pool sections, more than 54% contained areas of mostly moderate coverage rock habitat. In excess 77% of the riffle sites had largely good or excellent rock coverage (Figure 19).

Tinaroo: Rocky habitat was observed at approximately 64% of sites containing pool and riffle sections (Figure 19). Pool sections were found to have a predominantly moderate coverage, whereas many sites had riffles with an excellent rocky substrate.

Leaf litter

Plant leaf litter and other detrital material accumulates at the leading edge of obstructions in the current and settles out in pools, alcoves, and other depositional zones. It was less likely to be found in riffles. Leaf litter is an extremely important component of the food chain in watercourses. Fisher and Likens (1972) noted that some whole ecosystems, particularly small streams and estuaries, were dependent on solar energy fixed elsewhere by photosynthesis and transported across the ecosystem boundary in the form of reduced carbon compounds (organic material). This energy is moved into the food chain primarily by shredders, a type of stream invertebrate, which depends heavily upon leaf litter material as a source of nutrients (Cummins *et al.,* 1989). Some fish species use leaf litter for both cover and food sources.

Figure 20 shows the abundance of leaf litter habitat at sites in the Barron sub-catchments. The small quantities of in-stream leaf litter found within the Freshwater, Middle and Tinaroo sub-catchments was likely to be a reflection of the reduced forested areas and relative high riparian disturbance that was recorded within these sub-catchments.



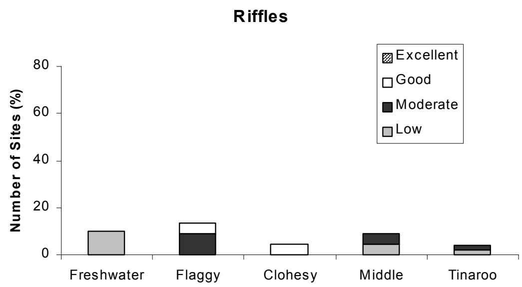


Figure 20. Percentage of sites in the various sub-catchments with leaf litter habitat

Freshwater: Only a small percentage (28%) of sites with pools in this sub-catchment contained areas of mostly low coverage leaf litter. Leaf litter was only found at 10% of the riffle sites at mainly of low coverage (Figure 20). The low proportion of sites with leaf litter deposits was probably the result of steep stream gradients and relatively swift flowing watercourses in this sub-catchment.

Flaggy: Leaf litter was present at 67% of sites with pools but at only 14% of riffle sites (Figure 20). The high percentage of pool sites with leaf litter probably reflects low human impacts on riparian vegetation in this sub-catchment.

Clohesy-Davies: This sub-catchment also had a high percentage (70%) of pool sites with deposits of leaf litter material. However, only about 4% of the riffle sites had leaf litter material present (Figure 20). The high percentage of pool sites with leaf litter probably reflects both the high contribution of organic material from the forested areas of the catchment and the relatively healthy condition of the riparian forests.

Middle: Nearly half (45%) of the sites with pool sections and 9% of sites with riffles contained generally low to moderate deposits of leaf litter (Figure 20).

Tinaroo: More than 39% of the pool sites and only 10% riffle sites contained leaf litter material (Figure 20). Generally, where leaf litter was present, it was only found in small amounts.

Habitat Disturbances

Freshwater: Feral pig damage was evident at only two of the sites surveyed in this sub-catchment. These two sites were near Lake Placid, adjacent to the rainforest covered foothills of the Lamb Range. The distribution of feral pigs appeared to be restricted mainly to the heavily forested areas.

Invasive grass species, predominantly para grass (*Brachiaria mutica*), were present at 11 (42%) of the sites. Para grass was found mainly at sites in the lower sections of Freshwater Creek and its tributaries, which were impacted by urban and agricultural development. Other invasive grasses and weeds found impacting on the riparian corridor included northern cow cane (*Mnesithea rottboellioides*) and guinea grass (*Panicum* sp.). Para grass is an aggressive, introduced forage species (Middleton, 1991) which may impact on native fishes (Arthington *et al.,* 1983).

At one site (site 55, Map 3), the stream has been channelled and its riparian vegetation cleared to facilitate urban run-off. This has resulted in the entire stream becoming choked with para grass and the deposition of excessive quantities of sediment. The net effect was to increase the likelihood of localised flooding during heavy run-off events. Sediment deposition was also a problem in other parts of the sub-catchment. For example, prior to and during the 1998-99 wet season, soil erosion from road-works and newly developed urban estates caused severe sediment deposition and increased stream turbidity in the nearby Freshwater Creek (see Plate 1) of dirty water). Local council by-laws have since addressed this issue by placing restrictions on earth works at urban sites during the periods when heavy rainfall is likely.

Armouring of stream banks to prevent or minimise erosion was commonplace, particularly along the lower Barron River (see Land use impacts on riparian vegetation section). Scrap materials, cement blocks and rocks and other debris have all been used in an attempt to stop erosion of the riverbank. The areas where armouring was necessary were generally agricultural or industrial (airport) locations where the stream banks were largely devoid of riparian vegetation. There was also at least one sugar farming area along Thomatis Creek where bank slumping and erosion had caused the loss of agricultural land.

Green cane trash blanketing has recently been implemented by a number of sugar cane farmers in the Barron River delta with mixed success. This is usually an environmentally friendly agricultural practice involving leaving unwanted parts of the sugar cane plant in the field to mulch. Previously, this waste was burned prior to harvesting. While this techniques has environmental advantages, there appeared to be some problems using this technique in low, poorly drained areas adjacent to creeks. During the 1998-99 wet season, floodwaters washed excessive amounts of cane trash into Freshwater Creek. This resulted in deposition of large amounts of organic material both in the creek and on the creek banks. At one location, cane trash up to one metre thick was observed deposited on a creek bank and this would have undoubtedly had an adverse impact on the growth of tree seedlings. In addition, excessive amounts of organic material deposited in backwaters have the potential to increase the biological oxygen demand of creek waters.

The upper reaches of Freshwater Creek have been impounded to form Lake Morris. The dam wall does not have a fishway and effectively blocks all upstream fish movements. Another smaller weir further downstream is easily submerged during heavy runoff-events and probably has minimal impact on fish movements. There were a number of off-stream sand mining operations in the Barron River delta, at least two of which have disturbed acid sulphate soils. The pits were left by these mining operations were inundated and contained waters with a low pH. Overflow after heavy rainfall resulted in the release of acid leachate into adjacent watercourses.

Secondary-treated sewerage was being discharged into the Barron River adjacent to the airport, during the study. Impacts of these discharges are discussed more fully in Cogle *et al*. (2000).

Flaggy: The disturbances observed in this sub-catchment were minimal. Invasive grasses were found at only four sites (14%) with only about 6% of the overall length of stream bank impacted. These disturbances were associated with land clearing in grazing or rural residential areas. Other minor disturbances included erosion due to cattle trampling (eg. site 176, Map 3) and some domestic sand gravel extraction (eg. site 56, Map 3). Treated sewerage was also being discharged into Jum Rum Creek in the lower area of the sub-catchment.

Clohesy-Davies: The disturbances in this sub-catchment were also minimal. There was some evidence of feral pig damage at two sites in the rainforest areas of the upper catchment while para grass was present at only three sites. At one of these sites (Site 72, Map 3) located in a rural residential area, more than 50% of the length of the stream bank was impacted by para grass.

Middle: Twenty-five sites (48%) in this sub-catchment contained varying infestations of the invasive para grass. Of these, the most impacted included Site 1, (Maude Creek), Sites 52 (Atherton Creek), 138 (Maude Creek) and 17 (Barron River) (Map 3).

Damage to the stream bank from feral pigs was observed at one site (site 24), with cattle trampling observed at six sites.

Fish passage was interrupted by a weir located on Granite Creek and a large road culvert on Rocky Creek.

Tinaroo: More than 69% (n=36) of the sites assessed in this sub-catchment showed some evidence of colonisation by invasive grasses. Of these, most (34 sites) were infested with para grass. Most of the heavily impacted sites (where more than 50% of the stream length at the site was colonised with invasive grass) were adjacent to grazing (dairy and beef) activities. At some sites (eg. Site 7, Gywnne Creek) invasive grasses covered the entire bank and most of the water.

Stream bank damage caused by feral pigs was observed at two sites, both of which were adjacent to heavily forested areas. Similarly, cattle damage to stream banks was observed at a further 17 sites (30%). In this sub-catchment there were few off-stream-watering points and most watercourses were not fenced to prevent cattle access.

Treated sewerage from the township of Atherton was discharged into Mazlin Creek and then ultimately into Lake Tinaroo. There was also evidence of high nutrient concentrations in the Barron River above Lake Tinaroo (see Cogle *et al.* 2000 and Physical Influences on page 46).

Macroinvertebrates

All 10 macoinvertebrate sampling sites were in the main channel of the Barron River (Map 3). Of these, three sites (Hemmings, Goonarra, and Picnic Crossing) were in the Tinaroo sub-catchment, five sites (Henry Hannan, Kenneally , Bilwon, Emerald and Koah) were in the middle sub-catchment and one each were located in the Flaggy (Myola) and Freshwater (Kamerunga) sub-catchments. These sites were adjacent to a wide variety of land uses (see Cogle *et al.,* 2000).

Physical Influences

In many circumstances, moderate river discharge can favour some macroinvertebrate groups more than others, however, large flows events (eg. over 1 000 ML/day) would be expected to disadvantage most macroinvertebrates. Therefore, it would be expected that samples taken in March 1998 after the elevated flows resulting from the 1997/98 wet season, (see Cogle *et al.,* 2000), would show low macroinvertebrate abundances and diversities. However, this was not the case, and there was no detectable seasonal pattern in either macroinvertebrate abundance or diversity. More frequent sampling every month may be needed to uncover seasonal patterns.

Comparisons of the water quality at sites sampled for macroinvertebrates were made using the monthly water samples collected as part of the overall investigation (see Cogle *et al*., 2000). For the majority of the year, the upper three sites (Hemmings, Goonarra, Picnic Crossing) had generally higher suspended solids, nitrogenous (NO_3^--N and TKN) compounds and turbidity levels than the other sites. There was some variability in the water quality at the middle catchment sites, particularly during wet season periods. Phosphate-P (PO_4-P) concentrations were highest at Picnic Crossing, Kenneally and Henry Hannan, possibly as a result of local land use practices, while the total phosphorus was substantially higher at Picnic Crossing compared to all other sites.

Analysis of sediment composition at each macroinvertebrate site demonstrated marked inter-site differences. A two factor ANOVA of the sediment at eight sites showed that there was a significant difference in the composition of sediment at each site ($F = 5.29$, $df = 70$, $p = <0.001$). Picnic Crossing and Kamerunga were excluded from these analyses due to the high proportion of large stones and low proportion of sand particles. Sediment diversity (Shannon-weaver) was highest for Hemmings (2.11 ± 0.05), Goonarra (2.10 ±- 0.04), Kenneally (1.83 ± 0.10) and Henry Hannan (1.81 ± 0.25) and lowest at Bilwon (1.51 ± 0.04) and Emerald (1.36 ± 0.05).0.03). Median sediment size classes (based on 50% total weight) was 8-16 mm for Goonarra and Henry Hannan, 2-4 mm for Hemmings, Emerald, Bilwon and Kenneally and 1-2 mm for Koah and Myola.

Macroinvertebrate composition and abundance

Sample Identification and Abundance

A total of 68 families and 271 species were collected from the ten sites. Four replicate samples were collected on each of the four separate sampling occasions. The summarised data-set for the information collected is provided in APPENDIX E, including the site name, replicate number and abundance of each family. The total abundance of species collected over the four sampling periods shows differences between the 10 Barron River sites (Figure 21). Total abundance of taxa collected at Kamerunga and Picnic Crossing was substantially lower than other sites. Total abundance at Bilwon was considerably lower than at other sites in the vicinity (eg. Emerald upstream and Koah downstream). The highest total abundances were observed at Kenneally , Hemmings, Emerald and Koah.

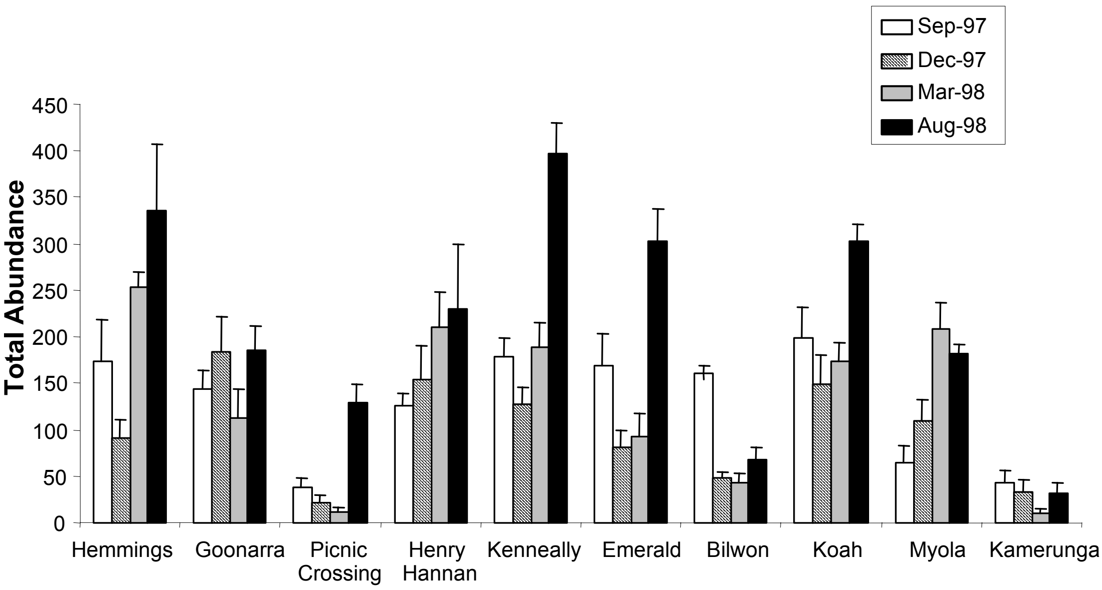


Figure 21. Total abundance (mean and standard error bars) of macroinvertebrates at each site on each of the four sampling occasions

A two factor ANOVA (general linear model, using Type III sums of squares) was performed on the transformed (log x+1) (Day and Quinn, 1989) total abundance data for each site (n=10) and each sampling occasion (n=4). There was a significant difference in the transformed total abundance of macroinvertebrates collected at each site (F =10.41, p = 0.001; Table 9). The total abundances of macroinvertebrates were significantly higher at Kenneally (220±27.5), Hemmings (211±30.0) and Koah (205±19.12) compared with the lower values at Kamerunga (32±6.2), Picnic Crossing (49±12.5) and Bilwon (80±13.0). There was also a significant difference in the transformed total abundances between four sampling periods (F=4.89, 0.01<p>0.005, Table 9). Abundances observed in August 1989 (Figure 21) were especially high.

The interaction of site and sampling occasion was highly significant (F=3.97, p=0.001, Table 9) indicating an influence of seasonal factors such as flow events. While all factors were significant, it is important to note that the majority of the variance was explained by the interaction of site and sampling occasion (53%), and by site alone (42%), while seasonal variance represented only a small proportion (5%) (method from Neter and Wasserman, 1974).

Table 9. A two factor ANOVA on the transformed (log (x+1)) total abundance of macroinvertebrates comparing sites and sampling occasion.

Note: because of significant interaction between site and sampling occasion, the interaction MS was used to calculate the F values).

Source	df	MS	F	p
Site	9	2.061	10.41	0.001
Sampling Occasion	3	0.969	4.89	0.01 – 0.005
Site * Occasion	27	0.198	3.97	0.001
Residual	128	0.050		

Although a direct comparison of the total number of taxa found in this current study to the numbers found in previous studies (eg. Cogle *et al.,* 1998, Choy *et al*., 1998) was not appropriate because of different methodologies, it was possible to compare the trends between sites (Table 10). At the upper Barron River sites, on a species level, the number of taxa recorded was lower at Goonarra than upstream at Hemmings. At the family level, while similar patterns were observed, the number of taxa identified at the AusRivAS sites (Choy *et al*., 1998) were generally higher than numbers obtained in this study. This was probably due to a greater diversity in the types of habitats sampled in the AusRivAS program. Highest values were recorded at Myola and Goonarra, while lower values and a general decline in macroinvertebrate diversity (particularly in caddis fly larvae) were recorded at Picnic Crossing and Bilwon. (Table 10).

Table 10. Comparison of number of macroinvertebrate families , species and EPT species found by different studies at a sites throughout the catchment.

Current refers to data collected in this present study, Cogle to Cogle et al. (1998) and Choy to Choy et al. (1998).

Site	Number of Species		EPT Species		Number of Families		EPT Families	
	Cogle	Current	Cogle	Current	Choy	Current	Choy	Current
Hemmings	100	122	31	22				
Goonarra	64	101	23	24	45	33	10	11
Picnic Crossing	64	82	23	12	40	31	11	9
Bilwon					37	27	10	7
Myola					47	32	11	9

A comparison of the collective total number of families within each Order (only families with representatives greater than >0.05% of the total numbers were used) also demonstrated the differences between sites (Figure 22). Most sites were dominated by the orders Tricoptera, Ephemeroptera, Coleoptera and Diptera. The number of Tricopterans was found to be highest at the upper and middle sites while Emphemeropterans were dominant at the lower Barron sites excluding Kamerunga. The proportion of Coleopterans was relatively high at a range of sites including the (in order) Koah, Kenneally, Hemmings, Bilwon, Picnic Crossing, Goonarra and

Henry Hannan sites. The highest proportions of Dipterans were observed at Picnic Crossing, Hemmings, Goonarra and Kamerunga sites. The highest proportion of Acarina, Lepidoptera, Ostracoda, Odonata and Hemiptera were sampled from the Picnic Crossing, Kenneally, Myola, Henry Hannan and Emerald sites respectively.

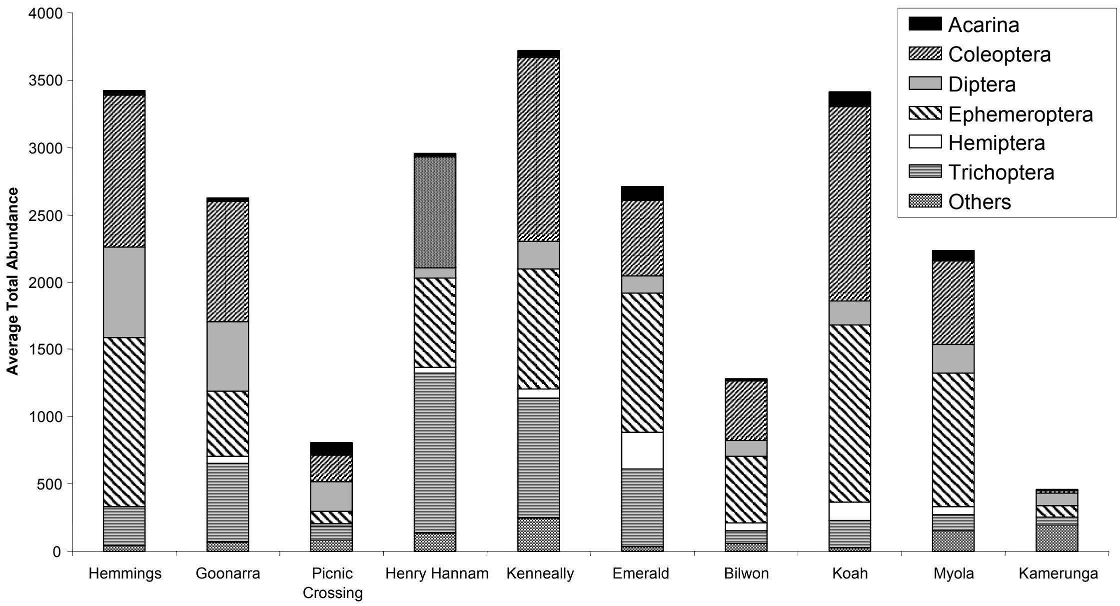


Figure 22. Families composition at each site for all sampling periods.

There were some similarities and notable differences between geographically close sites. For example, the Goonarra and Hemmings sites in the upper catchment had similar proportions of Dipterans and Colepterans but Hemmings had a higher proportion of Ephemeroptera and a lower proportion of Tricoptera. At another upper catchment site, Picnic Crossing, the ratios were different, with higher proportions of invertebrates from the orders Diptera, Coleoptera and Acarina. In earlier studies however, Choy *et al.* (1998) and Cogle *et al.* (1998) found that Picnic Crossing was comparatively devoid of Emphemeroptera and Tricoptera.

Compared to the adjacent sites at Emerald and Koah, the Bilwon site had a higher proportion of Diptera and a lower proportion Acarina. Choy *et al*. (1998) showed (Table 10) that the number of macroinvertebrate families identified at Bilwon was distinctly less than the number sampled at other sites, particularly the relatively degraded site at Picnic Crossing. While Choy *et al.* (1998) found little difference in the proportions of EPT taxa (at a family level of identification) between sites (Table 10), this study found a lower proportion of EPT taxa at Bilwon than at other sites. (Table 10). In contrast to other sites, the dominant taxa at the Kamerunga site were Isopoda, Diptera and Tricoptera. The reasons for these differences were unclear, but were likely to be related to tidal influences.

Feeding Groups

The classification of macroinvertebrate families into functional feeding groups (see page 14) has provided baseline information on the ecological status of each site (Figure 23).

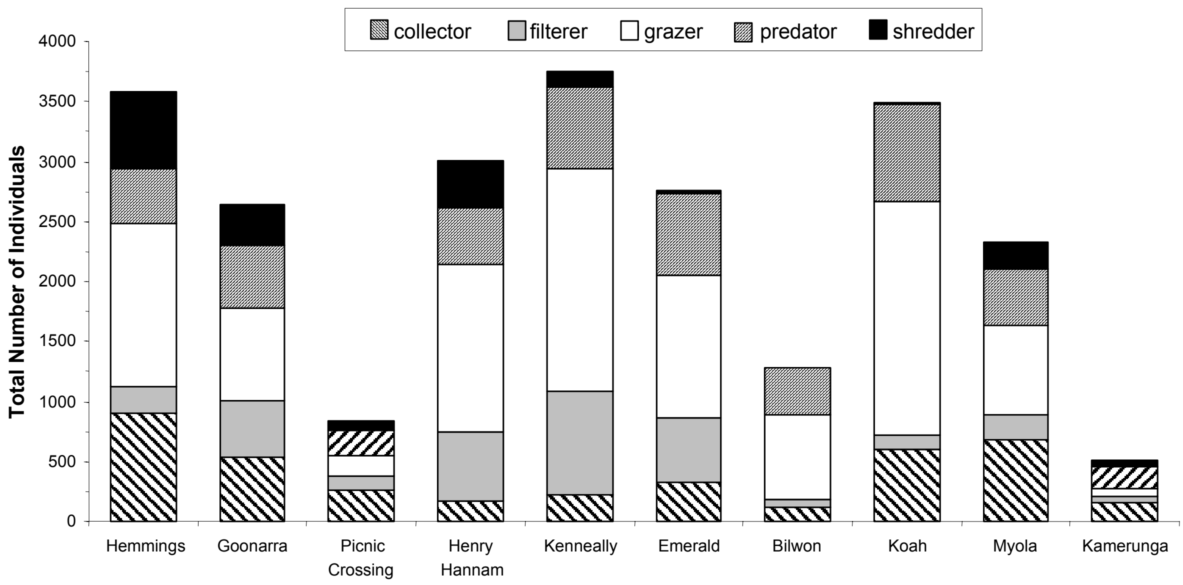


Figure 23. Functional feeding groups at each site for all sampling periods.

At the upper Barron sites (Picnic Crossing, Hemmings and Goonarra) between 20 to 30% of macroinvertebrates were collectors groups (see page 14 for definition). Below Tinaroo Dam at the Henry Hannan site, this percentage dropped to less than 10% and progressively increased at downstream sites to over 30% at Kamerunga. This was probably the result of increasing deposits of Fine Particle Organic Matter (FPOM) (Townsend *et al.*, 1987). Filterers composed about 20% of the total sample at the Kenneally, Henry Hannan and Emerald sites but were found in lower proportions at downstream sites. Grazers were well represented in the middle to lower Barron at the Koah, Bilwon, Kenneally , Henry Hannan and Emerald sites. At the Bilwon and Koah sites, over 50% of the samples were grazers. Predator composition was comparatively high at Kamerunga and Bilwon sites but was comparatively low at the Hemmings and Henry Hannan sites. Shredders were more abundant at the upper sites at Hemmings and Goonarra and less abundant at Myola and Kamerunga. All of the mid-catchment sites (Kenneally , Emerald, Bilwon and Koah) had relatively low abundances of shredders. The proportion of shedders may be related to the amount of riparian vegetation adjacent to and upstream of the sites.

SIGNAL Indices

The SIGNAL index and weighted SIGNAL index (SIGNAL-w) were calculated to simplify the patterns of macroinvertebrate family occurrence. Figure 24 shows these indices for each site and all sample dates combined. In the literature, clean water sites generally score SIGNAL index values of 6 and higher (Chessman, 1995). Using this criterion, the Henry Hannan, Kenneally , Emerald and Goonarra sites rated highly and most other sites scored between 5 and 6. The presence of more sensitive species such as Lepidoptera and Plecoptera (Chessman, 1995) at sites including Emerald and Kenneally resulted in higher SIGNAL values, while lower scores were recorded at Bilwon where more tolerant taxa (eg. Diptera) made up a higher proportion of the invertebrate population. In the upper catchment, the SIGNAL scores for the Hemmings site were slightly lower than those calculated for the Goonarra site, a trend also noted by Cogle *et al.*, 1998. At another upper catchment site, Picnic Crossing, the relatively high SIGNAL indices obtained during this study were considerably more than those calculated during an earlier investigation (Cogle *et al.,* 1998).

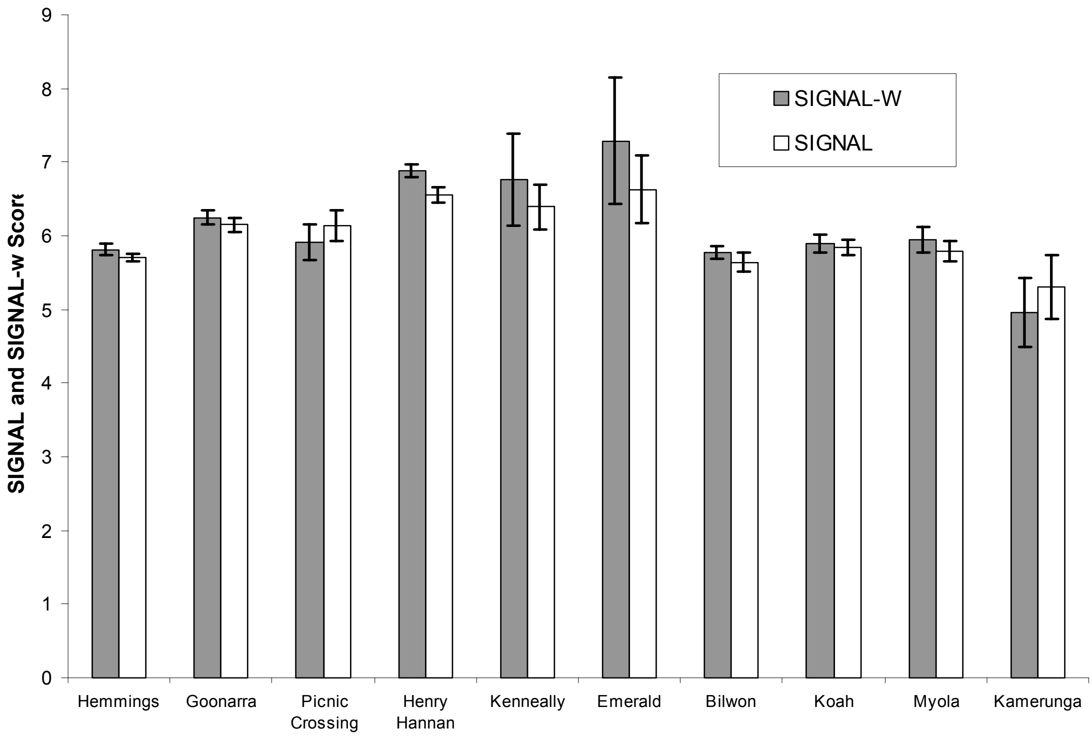


Figure 24. SIGNAL and weighted SIGNAL indices for each site (mean values with standard error bars).

A hierarchical cluster analysis was applied to the averaged taxon abundance data (families > 0.05% of the total abundance) to group sites using a Bray-Curtis association matrix (Figure 25).

```
                 0.1890     0.2464     0.3038     0.3612     0.4186     0.4760
                   |          |          |          |          |          |
Bilwon           (1)______________
Emerald          (2)_            |
Kenneally        (7)_|___________|_______
Koah             (8)_                   |
Myola            (9)|___________________|_____________
Goonarra         (3)_________                        |
Hemmings         (4)________|_______                 |
Henry Hannan     (5)_______________|_________________|____________________
Kamerunga        (6)_____________________________________________        |
Picnic  Cross.  (10)____________________________________________|________|
                   |          |          |          |          |          |
                 0.1890     0.2464     0.3038     0.3612     0.4186     0.4760
```

Dissimilarity

Figure 25. Dendrogram plot of sites based on Bray-Curtis association matrix.

This diagram should be interpreted as a sideways 'Family Tree', with the most related sites linked closer towards the left side (ie. dissimilarity increases to the right).

The Kamerunga and Picnic Crossing sites were dissimilar to each other and also to the other eight sites (Figure 25). The Emerald site was similar to the Kenneally site and the Koah and Myola sites were also alike. The Bilwon site, which was geographically located between these groupings was more closely related to the Emerald - Kenneally cluster. Of the upper catchment sites, Goonarra and Hemmings were relatively similar but both of these were dissociated from the Picnic Crossing site.

Water quality

Habitat sites

A summary of the water quality parameters including pH, dissolved oxygen, turbidity and conductivity at all sites where habitat assessments were conducted is given below. A more detailed discussion of water quality issues in the Barron River catchment was available in a separate report (Cogle *et al.,* 2000).

pH

Figure 26 shows the range of pH values found in each sub-catchment. The box and whisker plot shown in Figure 27 shows the distribution of pH values at habitat sites for the entire Barron River catchment and its five sub-catchments. For all sites the pH ranged between 5.44 and 8.88 with a median value of 7.07. The median values for the sub-catchments were between 6.5 and 7.7 with the Freshwater sub-catchment showing the most variation.

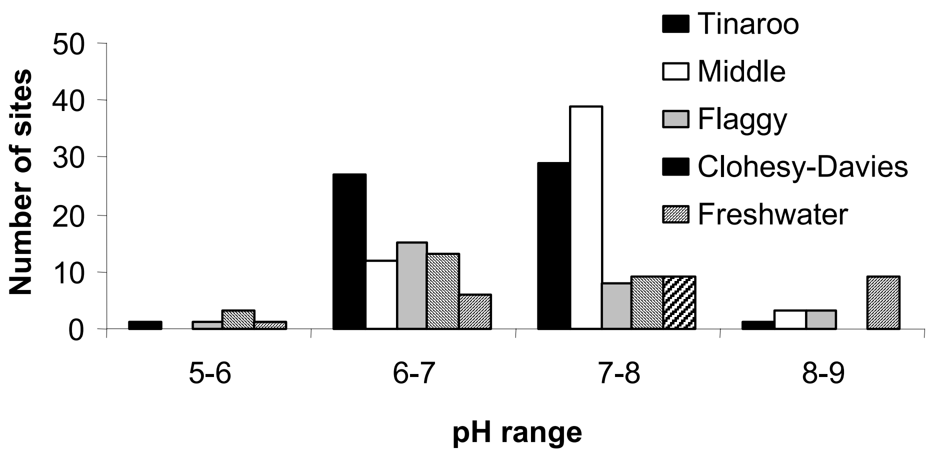


Figure 26. Distribution of pH values at habitat sites in each sub-catchment.

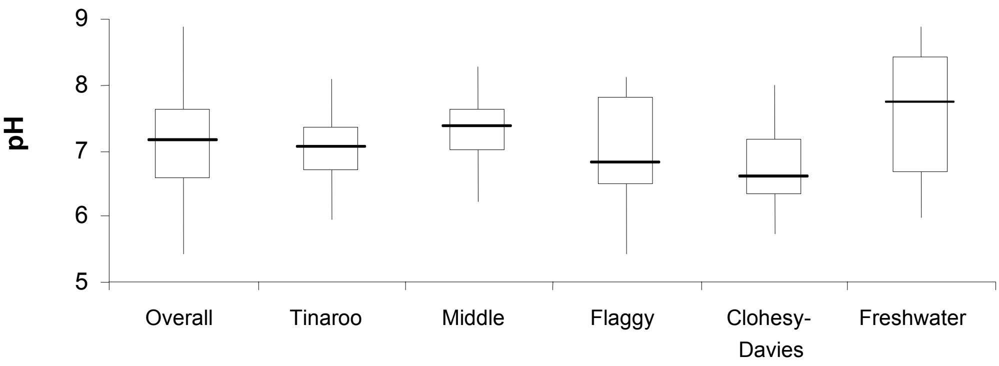


Figure 27. Box and whisker plot of pH values at habitat assessment sites

Data is shown for the entire catchment and broken down by sub-catchment.

Freshwater: The average (± SE) pH of the 25 samples taken in the Freshwater Creek sub-catchment was 7.56 ± 0.18 (median=7.65), with a minimum of 5.97 and a maximum of 8.88 (Figure 26 and Figure 27). The average pH values of 8.49 and 7.04 at tidal and non-tidal sites respectively, were found to be significantly different ($t=6.60$, d.f.=23, $p<0.001$). Only one site, Yorkeys Creek (site 64), had a pH value less than 6.0. This site was located in close proximity to a recently cleared wetlands area and was stagnant at the time of sampling. The higher pH values obtained in this sub-catchment were found in the estuarine sections of the Barron River and Thomatis Creek.

Flaggy: The 27 samples analysed from the Flaggy Creek sub-catchment had an average pH (±SE) of 6.98 ± 0.13 (median=6.73), with a minimum of 5.44 and a maximum of 8.10 (Figure 26 and Figure 27). The site that recorded the lowest pH was at Jum Rum Creek, near Kuranda. This site was impacted by both by urban run-off and sewerage discharges. All the sites with pH values above 8 were found on the main Barron River.

Clohesy-Davies: In the Clohesy-Davies Creeks` sub-catchment, the 25 samples taken had a mean pH (±SE) of 6.72 ± 0.12 (median=6.54) with a maximum of 7.98 and a minimum of 5.74 (Figure 26 and Figure 27).

Middle: pH values of the 54 samples taken in the Middle sub-catchment ranged from a minimum of 6.23 and a maximum of 8.27, with an average (±SE) of 7.32 ± 0.06 (Figure 26 and Figure 27). The median value was 7.3.

Tinaroo: The pH values of the 58 samples taken in this sub-catchment ranged from a minimum of 5.95 to a maximum of 8.09 was an average (±SE) of 6.97 ± 0. (Figure 26 and Figure 27). The median value was 7.0.

Dissolved oxygen

Figure 28 shows the distribution of dissolved oxygen values at habitat assessment sites for the entire catchment and broken down by sub-catchment. The values for most (60%) sites were between about 69% and 95% saturation. Some sites in the Middle, Flaggy and Freshwater sub-catchments had values of less than 20% saturation.

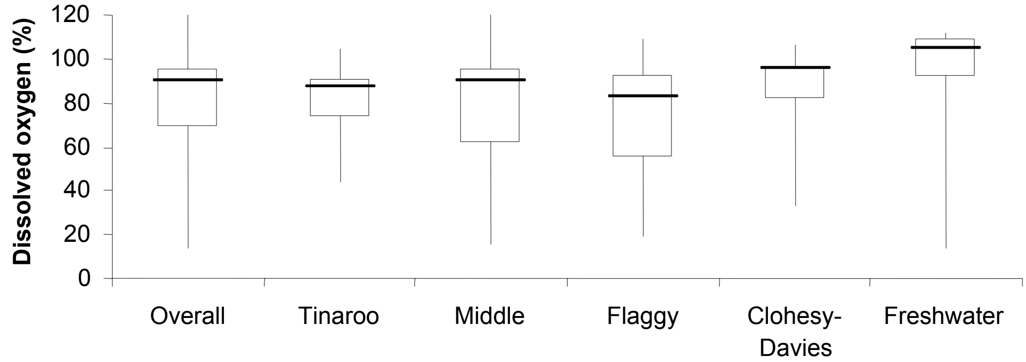


Figure 28. Box and whisker plot showing distribution of dissolved oxygen concentrations at habitat assessment sites.

Data is shown for the entire catchment and broken down by sub-catchment.

Figure 29 shows a breakdown of the percentage dissolved oxygen values at sites in the five sub-catchments. Most sites had a dissolved oxygen values in excess of 80% while a small number were super-saturated (>100%).

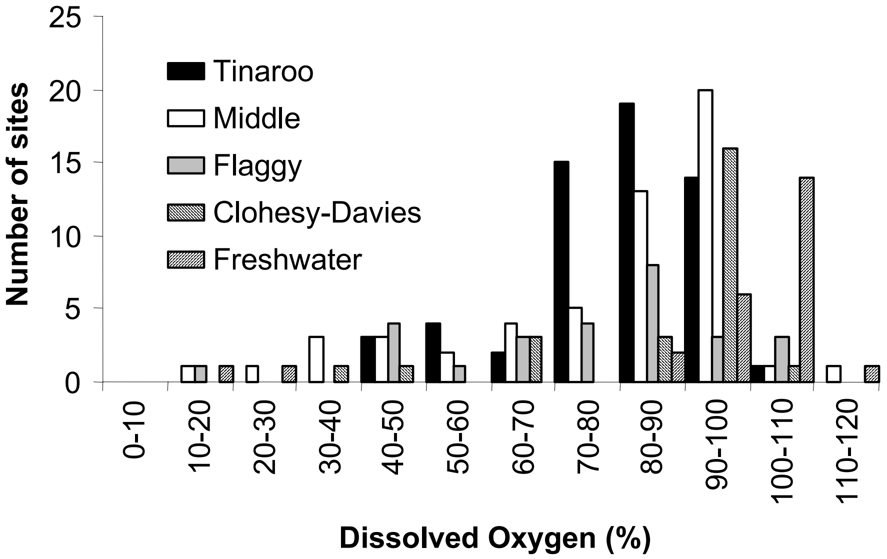


Figure 29. Distribution of dissolved oxygen values for sites in each sub-catchment.

Freshwater: The average percent oxygen saturation of the 25 sites sampled in this sub-catchment was 96.0% ± 4.7% (median=103%) with a minimum of 14% and a maximum of 112% (Figure 28 and Figure 29). The two sites with percent oxygen values of less than 50% were Yorkeys Creek (site 64) and a drain adjacent to Saltwater Creek (site 66). Both sites were stagnant at the time of sampling. Dissolved oxygen at most sites was more than 90% (see Figure 28).

Flaggy: The 27 sites sampled in this sub-catchment had a mean percent saturation (±SE) of 75.3% ± 4.2% (median=81%) and a maximum of 109 % and a minimum of 19% (Figure 28 and Figure 29). Only a few sites displayed quite low dissolved oxygen saturation values (eg. as low as 19%) and these were all small, slow-flowing creeks with little visible signs of disturbances.

Clohesy-Davies: Of the 25 sites sampled in this sub-catchment, the mean percent oxygen saturation was 86.3% ± 3.5% (median=93%), with a minimum of 33% (sampled from Groves Creek, a tributary of the Clohesy River) and a maximum of 106% (Figure 28 and Figure 29). Most sites were between 81% and 96% saturation.

Middle: The average percent saturation (±SE) of the 54 sites sampled in this sub-catchment was 78.9%±3.0% (median=88%) with a minimum of 16% and a maximum of 120% (Figure 28 and Figure 29). Most sites had dissolved oxygen concentrations of between 61% and 95%. The two sites with the lowest oxygen saturation value were found on Narcotic Creek (sites 138 and 139). These sites were highly disturbed, with high sedimentation and excessive invasive grass cover. Another site with a poor oxygen saturation value was a highly disturbed site on Maud Creek (site 130). Maud Creek received high organic and nutrient inputs from a nearby piggery (see *Cogle et al.*, 2000). In contrast, a site in another section of the same creek (site 131) had a supersaturated oxygen value. Abundant macrophyte cover at this site (site 130) would have assisted in elevating the dissolved oxygen during the day.

Tinaroo: At the 58 sites tested, a mean percent oxygen saturation (±SE) of 81.1% ± 1.8% (median=85%), and minimum of 44% (obtained from a drain in Atherton) and maximum of 104% (Figure 28 and Figure 29) was obtained. Most sites had dissolved oxygen concentrations of between 73% and 91%.

Turbidity

Figure 30 shows the turbidity values obtained at sites in the five sub-catchments. Most sites had turbidity values less than 5 NTU (Figure 30).

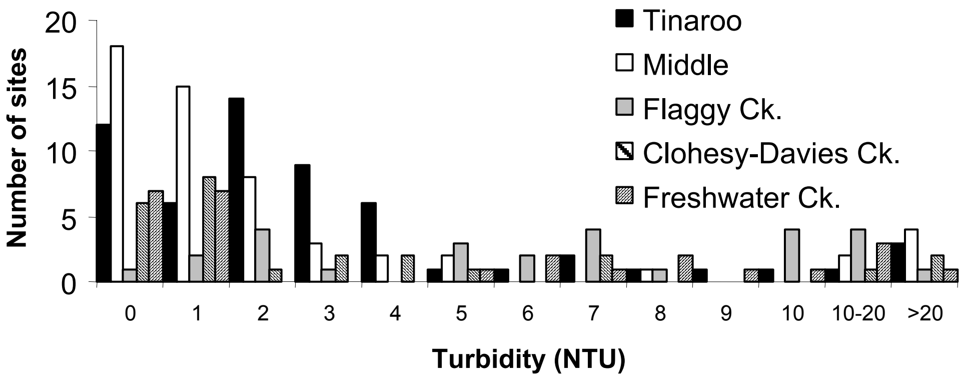


Figure 30. Distribution of turbidity values at sites in each sub-catchment.

The range of turbidities found at habitat assessment sites, both for the entire catchment and broken down by sub-catchment, is shown in Figure 31. The sampling was done during the dry, winter months so no exceedingly high values, which could be expected as a result of large runoff events, were recorded. Ranges that occur during such events are discussed fully in Cogle *et al.* (2000).

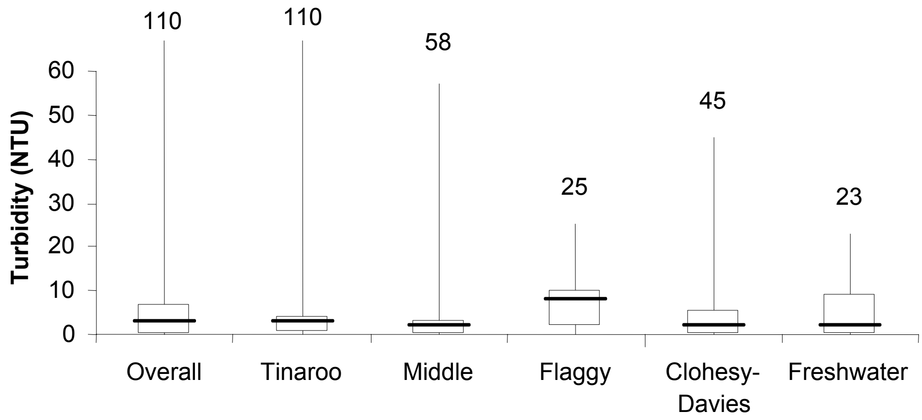


Figure 31. Box and whisker plot showing distribution of turbidity values at habitat assessment sites.

Data is shown for the entire catchment and broken down by sub-catchment. Numbers above the vertical bars indicate maximum values.

Freshwater: The 26 samples analysed from the Freshwater Creek sub-catchment had a mean turbidity (±SE) of 5.2 ± 1.2 NTU (median=1 NTU), with a minimum of 0 NTU and a maximum of 23 NTU (Figure 30 and Figure 31). Sites where turbidity values exceeded 10 NTU were mainly in the estuary.

Flaggy: Figure 30 and Figure 31 show the distribution of turbidities at 27 sites in the Flaggy Creek sub-catchment. Samples taken from these sites had a mean turbidity (±SE) of 7.3 ± 1.1 NTU (median=7 NTU) and a minimum of 0 NTU and a maximum of 25 NTU (Figure 30 and Figure 31). While most sites had a turbidity of less than 10 NTU, a sample taken from Dismal Creek (site 183) had a turbidity of 25 NTU. The water at this site appeared to contain tannins and was stagnant at the time of sampling.

Clohesy-Davies: In this sub-catchment, the 25 sites sampled had a mean turbidity (±SE) of 4.9 ± 1.9 NTU (median=1 NTU) with a maximum value of 45 NTU and a minimum of 0 NTU (Figure 30 and Figure 31).

Middle: Water samples taken from the 58 sites in this sub-catchment had a mean turbidity (±SE) of 4.5±1.2 NTU (median=1 NTU), a minimum value of 0 NTU and maximum of 58 NTU (Figure 30 and Figure 31). The two highest turbidity readings were sampled from sites in Narcotic Creek (sites 138 and 139). These sites had a high disturbance rating, extensive stands of invasive para grass and low dissolved oxygen levels.

Tinaroo: The mean turbidity (±SE) of the 58 sites sampled this sub-catchment was 5.5 ± 2.0 NTU (median=2 NTU) (Figure 30 and Figure 31). Minimum and maximum values obtained were 0 NTU and 110 NTU respectively, the latter sampled from Ahyah Creek (site 111), where there was evidence of heavy sedimentation caused by cattle grazing and sparse riparian cover.

Conductivity

The distribution of conductivities found at habitat assessment sites, both for the entire catchment and broken down by sub-catchment is shown in Figure 32. Some sites in the tidal section of the Freshwater sub-catchment had high values. Median values ranged from 0.053 µs cm^{-1} in the Tinaroo sub-catchment to 0.096 µs cm^{-1} in the Freshwater sub-catchment.

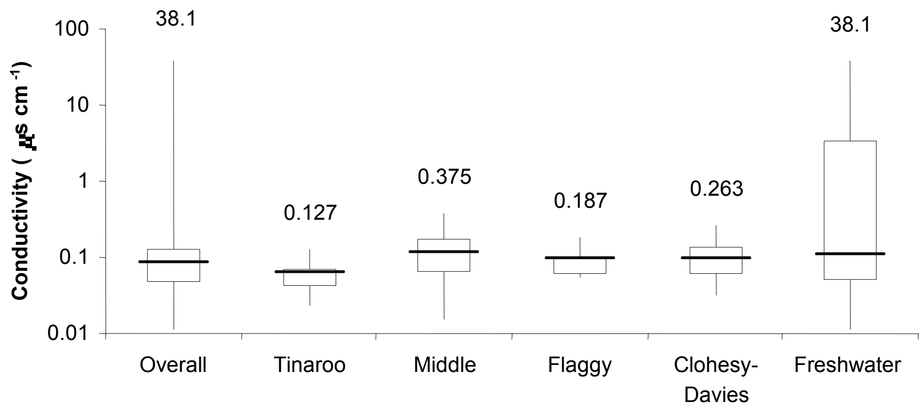


Figure 32. Conductivity at all habitat assessment sites.

The vertical axis has been plotted on a log scale.

Sedimentation

Fish use sediments directly for spawning, feeding and cover, but utilisation varies between species and also with life cycle (Anon, 1992). While sedimentation is a natural process, the degree of sedimentation can be accelerated through anthropomorphic activities ranging from inappropriate on-farm management practices to unsuitable timing of, or lack of precautions during earth-moving activities.

Riverine areas with a mosaic of sediment types are more likely to provide habitat for a diverse assemblage of fishes and the highest densities of macroinvertebrates are usually found in gravel and cobble riffles (Anon, 1992). Excessive deposition of fine particles tends to create a uniform, shallow stream, thus decreasing the diversity of available sediment types with subsequent consequences for instream fauna including fishes and their prey.

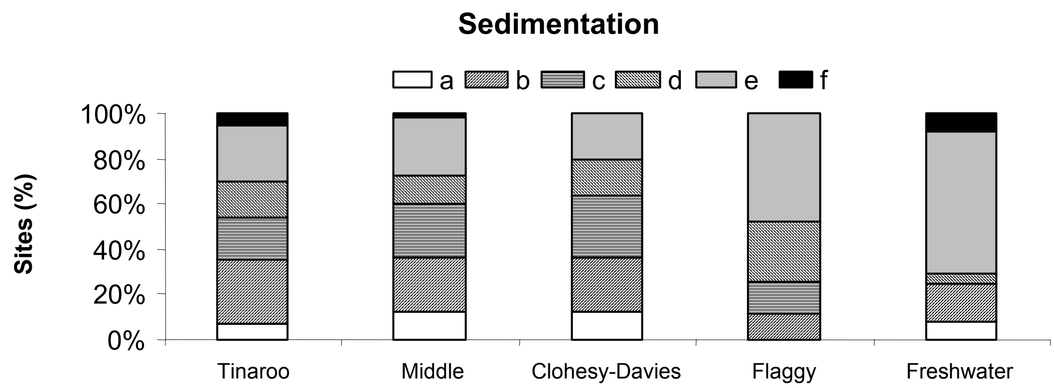


Figure 33. Sedimentation ranking of sites in all sub-catchments.

A ranking of "a" suggests little evidence of sedimentation while "f" indicates the stream channel is nearly filled with silt. A key to the types of sedimentation is given in Appendix D.

Freshwater: This sub-catchment had a high proportion (about 75%) of sites with excessive quantities transportable material. This was partially due to the inclusion of a number of estuarine sites with mud substrate, but also may reflect local agricultural and urban land practices. If the estuarine sites were excluded from the analyses, then the number of sites rated 'e' or 'f' was reduced to about 60%. Issues which could impact on sedimentation in this catchment include clearing of the riparian vegetation, quarrying and land management practices associated with sugar cane crops and grazing. Earth works associated with urban development may have also contributed to sedimentation in this catchment. (see Plate 1).

In parts of the lower Barron River delta, there were a number of areas that are particularly prone to erosion. This is discussed in detail in the Riparian disturbance Section of this report on page 24.

Flaggy: This sub-catchment also had a high component (69%), of transportable material present at the sites sampled. While this sub-catchment was relatively remote and sparsely populated, there was a large area of State Forest plantation (about 61% of the catchment area) and an associated network of unsealed roads. Activities associated with this State Forest and the geology of the area may have contributed, in part, to the high sediment loads.

Clohesy-Davies: Nine (36%) of the sites assessed in this sub-catchment were ranked between "d" and "f". Most of these sites were located adjacent to rural residential areas where there was significant clearing, particularly close to the stream bank.

Middle: Of the 55 sites examined in this sub-catchment, 40% (22 sites) exhibited signs of high sedimentation (ranks between "d" and "f"). The sites were distributed throughout the whole of the sub-catchment, with many located adjacent to urban and rural developments.

Tinaroo: The majority of the 46% of sites that were ranked between "d" and "f" in this sub-catchment were adjacent to grazing areas. Many of these sites had poor riparian cover and showed evidence of cattle trampling on the stream banks.

Fisheries Resources

At least 209 species of estuarine and freshwater fish from 66 families were sampled in the Barron River catchment (see). A number of juveniles could not be identified to species level either because of their size or because they had been damaged during sampling. This was more than in the Daintree, Saltwater, Mossman and Mowbray River catchments where 132 fish species were found (Russell *et al.* (1998). Similarly in the Liverpool, Maria and Hull catchments Russell *et al.* (1997) identified 134 species.

Fish movements

During the two years of the study, 54 mangrove jack and 192 barramundi were tagged. In addition to these records, tagging data from an additional 445 fish from 21 species were obtained from the AUSTAG recreational fishing database (W. Sawynok, AUSTAG, pers. comm.) for the Barron River catchment (APPENDIX A, Table 19). Barramundi was the only species tagged in a previous QDPI study in the Barron River by Russell (1988). More detailed results of these tagging studies are provided in subsequent the sections of this report.

Recreational and commercial fish

A wide range of recreational and commercial fish was sampled in the estuarine areas of the catchment. These included: barramundi (*Lates calcarifer)*; mangrove jack (*Lutjanus argentimaculatus*); fingermark (*Lutjanus johnii*), salmon (Polynemidae spp.); grunter (*Pomadasys* spp.); trevally (*Caranx* spp.); flathead (*Platycephalus fuscus*); pikey bream (*Acanthopagrus berda*); silver jewfish (*Nibea soldada*); whiting (*Sillago* spp.); mullet (Mugilidae spp.) and queenfish (*Scombormorus* spp.).

At the freshwater sites, recreational species sampled included: barramundi (*Lates calcarifer);* mangrove jack (*Lutjanus argentimaculatus*); sooty grunter (*Hephaestus fuliginosus*); jungle perch (*Kuhlia rupestris*) and freshwater jewfish (*Tandanus tandanus* and *Neosilurus ater*).

Uncommon freshwater species

Uncommon freshwater species are native fishes that are found in low abundances and generally have a restricted range.

Freshwater: The gobies *Sicyopterus* sp. and *Schismatogobius* sp. were sampled in Stoney Creek and Freshwater Creek respectively, and have only been documented from specimens caught in a few rivers on the wet tropics coast (J. Johnson, Queensland Museum, pers. comm.). Russell *et al*. (1998) also found these two species in the Daintree River while Pusey and Kennard (1994) noted that they were present in small numbers in the wet tropics region. Both species were found in clear water rapids or glides with cobble-gravel substrate and in the lower freshwater reaches of the creeks.

Another goby, *Stenogobius* sp. was collected from the same location as *Schismatogobius* sp. and appeared to be either a geographic varient of *S. psilosinionus* (Watson, 1991) or an undescribed species (J. Johnson, Queensland Museum, pers. comm.).

The flag-tailed glass perchlet (*Ambassis miops*) was another species that was found resident in the lower sections of Freshwater Creek and the Barron River at Kamerunga (see Map 2). The range of this was listed as restricted by Allen (1989) and was found in only four drainages in the wet tropics region by Pusey and Kennard (1994). A large number of mainly juveniles were sampled with adults at the brackish interface on the Barron River (site 38) in October 1998. It would appear that this species requires access to marine areas for part of its lifecycle (Allen, 1989).

A small number of swamp eels (*Ophisternon* cf. *bengalense*) were found at the lower Freshwater Creek site (site 43). Pusey and Kennard (1994) found a single specimen from two locations in the Cardwell area. Herbert and Peeters (1995) also recorded specimens from the east coast of the wet tropics but suggested that these specimens were dissimilar to *O. bengalense* found in western-flowing rivers on Cape York Peninsula. Further biological information is needed to determine the differences between these species.

The eleotrid, *Ophiocara porocephala*, was found in Freshwater Creek in 1974 by the Queensland Museum (Wager, 1993) but only a single specimen was found by Pusey and Kennard (1994) in the Cape Tribulation area. No specimens of this species were found during this current study.

Flaggy: Specimens of Macleay's glass perchlet (*Ambassis macleayi*) and rendahl's catfish (*Porochilus rendahli*) were found at sites in the Barron River above the falls. Both these species were previously thought to be endemic to western drainages including the Gulf of Carpentaria but not eastern drainages. Their presence in the Barron River catchment may be the result of translocation by stocking programs or through natural inter-catchment connections (Pusey and Kennard, 1996). It was thought that during heavy flow events that the Barron River and Mitchell River catchments become connected, thus providing a mechanism for inter-catchment fish movements (Alf Hogan, QDPI, pers. comm).

Flat-headed gudgeon (*Glossogobius giurus*) were also found resident above the falls in the Barron River. Allen (1989) reported it to be a common species that has a wide range in northern Australia, but during this study only a few specimens were found at locations on the main Barron River. Herbert and Peeters (1995) were not able to find specimens in Cape York Peninsula or around Cairns and a survey by Pusey and Kennard (1994) found only four specimens in the Bloomfield River. The Celebes goby (*Glossogobius celebius*) was found in high numbers below the falls in the Freshwater Creek sub-catchment, but was not found above the falls in this sub-catchment. It is thought that *G. giurus* occupies the same niche (gravel substrate) as the Celebes goby in the Barron River above the falls, and does not have a marine stage of the lifecycle as was once thought (Merrick and Schmida, 1984).

Specimens of the striped sleepy cod, *Oxyeleotris selhemi*, were found in the main Barron River in this section of the catchment. This species was found in all western-flowing rivers of the gulf systems and a small number of rivers on the east coast of Queensland (Herbert and Peters, 1995). This sleepy cod may have been deliberately stocked or may have moved naturally from the Mitchell system via the inter-catchment connection discussed previously.

Clohesy-Davies: No uncommon freshwater fish species were found in this sub-catchment.

Middle: The ambassid, Macleay's glass perchlet (*A. macleayi*), and specimens of the flat-headed gudgeon (*G. giurus*) were also present at Barron River sites in this sub-catchment.

Specimens of the toothless catfish, *Anodontiglanis dahli*, were recorded in the Tinaroo Irrigation Channel north of Mareeba but were not found in this current study. This species appears to have migrated from the Mitchell catchment via the irrigation channel system, but has not formed a self-sustaining population (Wager, 1993).

Tinaroo: Gertrude's blue eyes (*Pseudomugil gertrudae)* were found at three sites in the Leslie Creek area (sites 8, 45 and 50). This species was found in northern coastal Queensland, with isolated populations found in swamps and creeks between Innisfail and Tully (Allen, 1989; Pusey and Kennard, 1996). Isolated populations were previously found in tributaries flowing into Lake Tinaroo (Herbert and Peeters, 1995). All specimens were found closely associated with submerged or floating macrophytes or para grass and out of the main current.

Lake Eacham rainbow fish (*Melanotaenia eachamensis*) were thought extinct from their type locality, Lake Eacham (Barlow *et. al*., 1987). These authors suggested that translocated species, in particular mouth-all-mighty, were strongly implicated in the disappearance of *M. eachamensi* from Lake Eacham. It now appears that *M. eachamensis* species is still present in the Barron River, as well as the Tully, Herbert and Johnstone Rivers (Pusey *et al.,* 1997; Katrina McGuigan, University of Queensland, pers. comm.). Although many of specimens of rainbow fish were retained from many sites in this current study, and examined using the meristic characters described by Pusey *et. al*. (1997) and Allen (1989), no positive identifications of *M. eachamensis* could be made. Furthermore, extra samples were sent to the Queensland Museum and all were classified as *Melanotaenia splendida splendida*. It appears that *M. eachamensis* was present in a few tributaries of the upper Barron River (Pusey *et al*., 1997), but formed only a minor proportion of the total rainbow fish population in the entire Barron River catchment.

Exotic species

Exotic fish species are non-natives that have become established in natural waterways. They include aquarium fish such as guppies and swordtails which have become established as escapees or have been deliberately stocked or species such as mosquito fish which have been introduced to address specific problems.

Freshwater: Two populations of guppies (*Poecilia reticulata*) were identified in this sub-catchment in tributary streams off the main Freshwater (site 55 and 60). Both sites had considerable disturbance to the natural riparian vegetation and the Brinsmead site (site 55) was totally devoid of treed vegetation and had a significant infestation of para grass. There were very few other species present at this channelled site. Guppies were also found in other wet tropics streams (Pusey and Kennard, 1996; Russell and Hales, 1993a; Russell *et al*., 1996; Russell *et al*., 1998).

Swordtails (*Xiphophorus helleri*) were also found upstream in the same tributary of Freshwater Creek (above site 55). These fish were first sampled after the 1998/99 wet season and may have escaped from an urban ornamental pond. There was no evidence that these two species were established in the main Freshwater Creek, possibly because a greater number of predator species present. Populations of swordtails were also found in areas of the Johnstone, and Russell and Mulgrave River catchments (Russell and Hales, 1993a; Russell *et al*., 1996

The introduced mosquito fish (*Gambusia holbrooki*) was only sampled in an isolated, unnamed tributary of the lower Barron River near Kamerunga on one occasion after the 1998/99 wet season.

The most common exotic fish (found at seven sites) in this sub-catchment was tilapia (*Tilapia mariae*). This species made up about 3.4% of the total number of freshwater fish caught in this area. Tilapias were abundant in all sites of Freshwater Creek below the Crystal Cascades site (site 35), where the stream gradient was less and the pool to riffle ratio was reduced. *T. mariae* appeared to prefer slow laminar stream flow, and in particular, in backwater eddies. Pusey and Kennard (1996) also recorded the presence of tilapia (*Oreochromis mossambicus*) in Freshwater Creek, however this species was not found in the present study. Other populations of *T. mariae* are now well established in a number of wet tropics streams including the Johnstone River (Russell and Hales, 1993a; Pusey and Kennard, 1996).

Flaggy: No exotic fish species were sampled in this sub-catchment.

Clohesy-Davies: No exotic fish species were sampled in this sub-catchment.

Middle: Guppies (*Poecilia reticulata*) were sampled in the lower reaches of Emerald Creek at site 37. These fish were likely to have been introduced from the nearby rural residential area and appeared to prefer shallow pools adjacent to the main flowing creek. It appeared that this was only a very localised population, as thorough sampling at a site immediately adjacent in the Barron River (site 36) found no evidence of the their presence.

Tinaroo: Guppies were also sampled at a number of sites within this sub-catchment. Most of these sites were assessed as having a high or extreme disturbance rating. There was also some evidence that populations have spread from disturbed sites into adjacent areas. Most sites where guppies were found had very poor fish species diversity and a lack of higher order predators and/or were impacted by other human activities.

The mosambique mouthbrooder (*Oreochromis mossambicus*), or tilapia (as it is known locally), was sampled at four sites in this sub-catchment and represented more than 5% of the total fish caught. This species has been found previously in southeast Queensland and in the Townsville region by Arthington *et. al* (1984) and was recently been found in sections of Lake Tinaroo (Alf Hogan, QDPI, pers. comm.). Fish from sites in the upper catchment were almost certainly responsible for colonising Lake Tinaroo.

The distribution of this species appeared to be somewhat patchy. Sites adjacent to locations where tilapia were known to be established appeared to be free of this species. This species appeared to be able to adapt to a variety of different habitats and flow conditions. For example, at some sites it made use of abundant macrophyte cover, while in other areas, snags, undercut banks or para grass appeared to be the preferred habitat. Nests were only observed in areas where there were beds of macrophytes and slow-flowing water during the summer breeding months.

Common freshwater species

Figure 34 shows the nine species that occurred at 40% or more of the freshwater sites. The ten species listed in Table 11 make up almost 87% of all the fish sampled in freshwater areas. Rainbow fish (*Melanotaenia splendida splendida*) were the most numerically dominant freshwater species (over 51% of the total fish caught) and were sampled at over 94% of the sites. As well as rainbow fish, the total catch was heavily dominated by a few species, particularly the purple-spotted gudgeon (*Mogurnda adspersa*) and the fly-speckled hardyhead (*Craterocephalus stercusmuscarum*). These three species represented over 68% of the total number of fish collected. The next three most abundant species, freshwater bony bream (*Nematalosa erebi*), pacific blue-eye (*Pseudomugil signifer*) and the mouth almighty (*Glossamia aprion*), together made up just 11% of the total number of fish collected (Table 11).

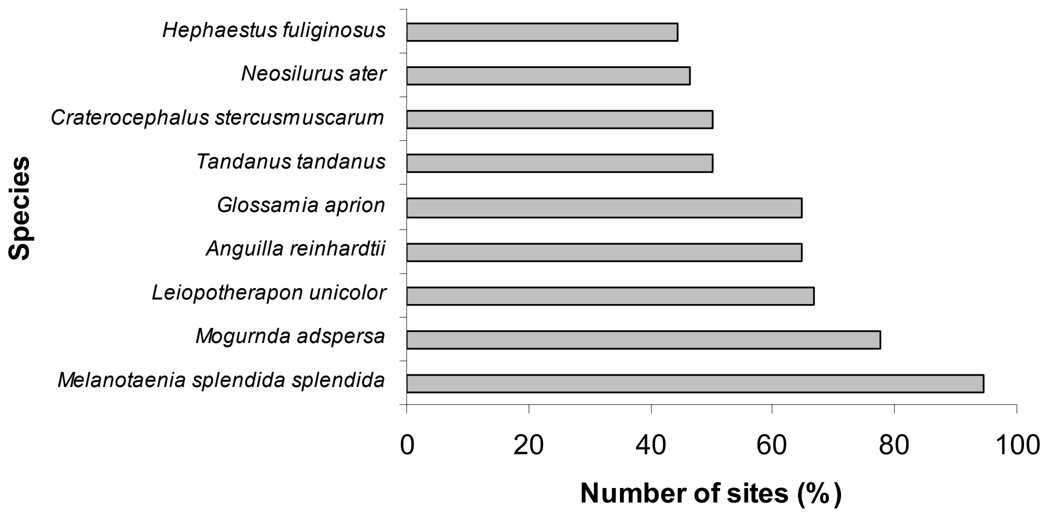


Figure 34. Species occurrence at freshwater sites.

Only species sampled at more than 40% of sites were included

Table 11. The ten most numerically common freshwater fish in the Barron River catchment.

Common name	Species name	Total number	Percent
Australian rainbow fish	*Melanotaenia splendida splendida*	27,272	51.13
Purple-spotted gudgeon	*Mogurnda adspersa*	5,499	10.31
Fly-specked hardyhead	*Craterocephalus stercusmuscarum*	3,744	7.02
Freshwater bony bream	*Nematalosa erebi*	2,540	4.76
Pacific blue-eye	*Pseudomugil signifer*	1,743	3.27
Mouth almighty	*Glossamia aprion*	1,555	2.92
Empire gudgeon	*Hypseleotris compressa*	1,199	2.25
Spangled perch	*Leiopotherapon unicolor*	1,125	2.11
Long-finned eel	*Anguilla reinhardtii*	951	1.78
Redclaw	*Cherax quadricarinatus*	700	1.31

Although there was an increase in species number as the stream order increased, the dominant freshwater species shown in Figure 35 were common to most sites.

Pusey and Kennard (1996) found that the fish sampled from a number of streams in the wet tropics region were dominated by *M. s. splendida*, *P. signifer*, *Hypseleotris compressa* and *Anguilla reinhardtii* which represented 65% of the total number of fish collected during their work.

In the Barron River, Pusey and Kennard (1994) found *M. s. splendida*, *H. compressa*, *C. stercusmuscarum* and *A. reinhardtii* respectively to be the four most numerically dominant species. Their study did not find either *N. erebi* which they blamed on the technique used (back-pack electrofishing was used in both studies) or, significantly, *M. adspersa*. In this present study, *M. adspersa* and *N. erebi* were both recorded in the top four numerically dominant species present (see Table 11), with the former also being recorded from 78% of sites in the catchment.

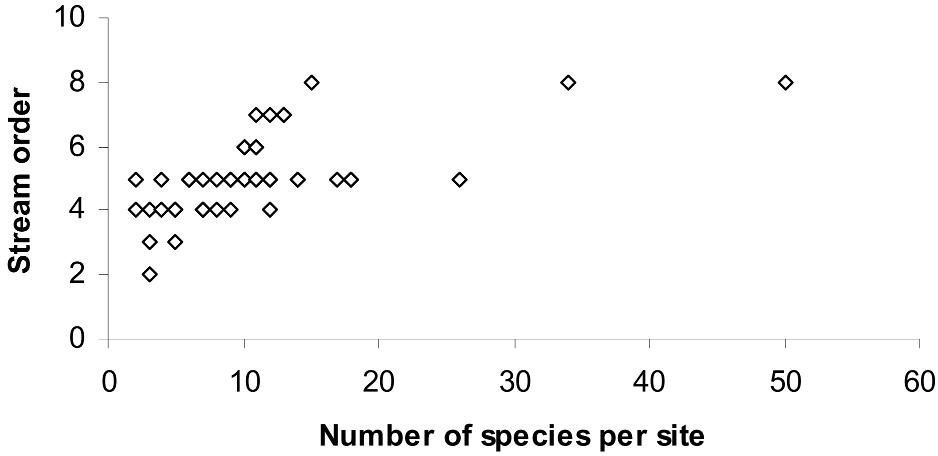


Figure 35. Number of species sampled at sites by stream order.

The estuarine site (40) was excluded.

H. compressa was listed by Pusey and Kennard (1994) as the second most numerically dominant species but in this current study this species represented only just over 2% of the total fish caught and was found at 29% of the sampling sites. On one occasion during the 1998/99 wet season, post larvae of this species were observed moving en-mass (probably millions) into the Freshwater Creek sub-catchment.

The long-finned eel (*A. reinhardtii*) contributed to less than 2% of the total fish sampled but was found at 65% of sites. By contrast, Pusey and Kennard's (1994) survey of wet tropics streams found eels to be the fourth most abundant species.

Eleotridae was found to be the most speciose family (9 species), and was represented at all sites throughout the catchment. There next most speciose family, Gobiidae, was represented by seven species and was found at 31% of sites sampled. Chandidae was also well represented, with five species at 27% of sites.

Freshwater: Of the 48 species and 27 families that were sampled in this sub-catchment, six species belonged to both the families Eleotrididae and Gobiidae, and another five species were from the family Teraponidae. Twenty-one species found in this sub-catchment were either vagrant marine species or utilised estuarine areas as part in their lifecycle.

Jungle perch (*K. rupestris*) were present at the most sites (n=11), with long-finned eels (*A. reinhardtii*), empire gudgeons (*H. compressa*) and rainbow fish (*M. s. splendida*) also widely distributed. Other species present at more than half the sites were *L. argentimaculatus*, *N. ater* and *P. signifer*. While barramundi (*L. calcarifer*) were present in moderate numbers in the main river, only one specimen was sampled in Freshwater Creek. In contrast, *T. tandanus* was found exclusively at five sites in Freshwater Creek.

Flaggy: Nineteen fish species from ten families were sampled from the Flaggy Creek sub-catchment. Of these 19 species, ten belonged to three families, Eleotrididae (three species), Plotosidae (four species) and Teraponidae (three species).

The two most numerically dominant species, *M. s. splendida* and *N. erebi*, represented 52% and 18% of the total catch respectively. Most sites had many of these 19 species present.

Clohesy-Davies: Twelve fish species from eight families were sampled from four sites in this sub-catchment. Of these, the most speciose family was Plotosidae (three species). Six species were present at all sites, with *M. s. splendida* and *M. adspersa* being the most numerically dominant at 69% and 13% of the total catch respectively. Hyrtlii's tandan (*Neosilurus hyrtlii*) was present in large numbers (n>50) in the leaf litter in backwaters of the lower Clohesy River, but was not found at sites away from the main river.

Middle: Twenty-three species of fish from 11 families were collected from 16 sites in this sub-catchment. The three families, Chandidae, Eleotridae and Plotosidae, were each represented by four species.

The three numerically dominant species, *M. s. splendida*, *M. adspersa* and *C. stermuscarum* composed 63%, 11% and 10% respectively of the total fish caught. Seven species were present at more than 50% of the sites surveyed.

The plotosids, *N. hyrtlii* and *N. ater* were found in similar numbers at eight sites in this sub-catchment, whereas *T. tandanus* was only found at one site.

Tinaroo: Of the 12 families and 20 species caught in this sub-catchment, three families, Teraponidae, Plotsidae and Eleotridae accounted for 11 species. More than 66% of the total number of fish caught in this sub-catchment were *M. s. splendida* (48%) and *M. adspersa* (18%). These two species were also the most widely distributed, being present at 17 and 16 sites respectively.

In contrast to the Middle sub-catchment, *T. tandanus* was present at the majority of sites (n>75%) and yet *N. hyrtlii* was absent and *N. ater* was found at only one site within this sub-catchment. The number of *T. tandanus* caught was less than 1% of the total number of fish sampled.

Red claw and other freshwater crustaceans

Red claw (*Cherax quadricarinatus*), which is a native of the Gulf of Carpentaria drainage and a popular aquaculture and recreational species, was found at 26 (49%) sites throughout the catchment. The establishment of this species in the Barron River catchment was probably the result of deliberate, unauthorised introductions or escapees from aquaculture farms. Red claw were been stocked into Lake Tinaroo where a self sustaining population has become the focus of a popular recreational fishery. Stocks in the rivers appeared to be much smaller and were not the basis for any significant recreational fishery. Red claw were sampled in all sub catchments although only one specimen was caught in the Clohesy-Davies sub catchment near its confluence with the Barron River. Most of the sites where they were sampled were either on the main Barron River or a major tributary stream. All sites where red claw were found were of stream order four or higher and at most sites (54%) the stream order was six or higher.

Other freshwater crayfish occurring within the catchment include *Cherax wasselli* (yabby) and *Euasticus balanensis* (spiny crayfish). The former species occured in relatively low abundances in Tableland streams while the later was restricted to watercourses in Lamb Range Area (J. Short, Queensland Museum, pers. comm.).

The freshwater prawn, *Macrobrachium australiense*, was found throughout the catchment. Other freshwater prawn species including M. *equidens, M. idae, M. lar, M. latidactylus, M. novaehollandiae* and *M. tolmerum*, had restricted coastal distributions because of a marine phase in their lifecycle (J. Short, Queensland Museum, pers. comm.). Higher abundances of these species were observed in coastal lowland sections of the catchment although the presence of *M. tolmerum* in the middle reaches of the Barron including Emerald and Jum Rum Creeks (G. Aland, QDPI, pers. obs.) suggested that some species were capable of negotiating significant barriers including the Barron Falls.

A number of species of Aytiid shrimp (riffle shrimp) were found in streams throughout the catchment. The distribution of *Caridina zebra* and *C. confusa* was restricted to cooler, upper tableland, feeder streams while *C. indistincta* were observed to be widespread in the mid-catchment section of the Barron River and the associated feeder streams. Some shrimp species, including *C. longirostris* and *C. gracilirostris*, also had a marine phase in their life cycle and were found only in the coastal freshwater sections of the Barron catchment (J. Short, Queensland Museum, pers. comm.).

The two species of freshwater crabs, *Holthuisana wasselli* (peppered crab) and *H. aggassizi* (deaths head crab), were found in small streams and gullies above the Barron Falls. A marine vagrant, *Varuna literata* (grapsid crab), occured in the lower freshwater sections of the catchment.

Although most freshwater crustacea do not contribute significantly to the commercial or recreational catch they provide important roles in the ecosystem of the Barron River including scavenging and breaking down organic matter and were vital as a food source to the predatory fish and other vertebrates within the catchment.

Estuarine fish

Of the 15 264 fish sampled in gill nets, trawl nets and seine nets at estuarine sites between October 1996 and December 1998, there were 155 species identified from 59 families. Sixteen of these species were also recorded in samples from freshwater sites. Two of these, *Kuhlia rupestris* and *Nematolosa erebi* were essentially freshwater species that were also found in the upper tidal section of the Barron River.

Of all species sampled in the estuary using these techniques, ten species made up nearly 60% of the total catch. These included *Nematolosa come*, *Liza subviridis* and *Herklotsichthys castelnaui*, which were important bait species utilised by commercial and recreational fishermen and *Sillago sihama* that was caught by recreational fishermen.

Beam trawling samples consisted primarily of larval fish and prawns. Details of the catches from the various sampling techniques used in the estuary follow.

Gill netting

Nearly 5 000 fish from 81 species were caught in estuarine set gill nets over the period of the study. Table 12 shows the ten most numerically common fish taken in estuarine gill nets during this study. Over 18% of the total number of fish caught in gill nets were catfish (*Arius graeffei* and *Arius macrocephalus*), but baitfish including bony bream, mullet, anchovies and ponyfish also made up a significant component (44%). Of the recreational and commercial food fish, only barramundi (4.1%) and silver jewfish (4.0%) were in the top ten species found. Other common recreational and commercial species including mangrove jack (n=17, 0.3%), banded grunter (*Pomadasys kaakan*, (n=32, 0.7%); *P. argenteus* (n=48, 1%)) and salmon (*Polydactylus sheridani* (n=44, 0.9%); *Eleutheronema tetradactylum* (n=32, 0.7%)) only made up a small proportion of the gill net catch.

Table 12. The ten most numerically common estuarine species caught in gill nets. Total number and percent composition are shown.

Common name	Species name	Total number	Percent
Saltwater bony bream	*Nematalosa come*	911	18.4%
Hamilton's anchovy	*Thryssa hamiltonii*	668	13.5%
Flathead catfish	*Arius macrocephalus*	508	10.3%
Common ponyfish	*Leiognathus equulus*	473	9.6%
Catfish	*Arius graeffei*	404	8.2%
Barramundi	*Lates calcarifer*	203	4.1%
Silver jewfish	*Nibea soldado*	194	3.9%
Greenback mullet	*Liza subviridis*	144	2.9%
Tarpon	*Megalops cyprinoides*	118	2.4%
Archer fish	*Toxotes chatareus*	114	2.3%

Seine netting

The ten most numerically common species sampled in seine nets, accounted for approximately 55% of the 3 580 fish caught (Table 13). Eighty-seven species of fish from 31 families were sampled using this method at the mouth of the Barron River. Carangidae (seven species), Mullidae (seven species), Clupeidae (six species) and Leiognathidae (six species) were the most speciose families sampled.

Table 13. The ten most numerically common estuarine species caught in seine nets. Total number and percent composition are shown.

Common name	Species name	Total number	Percent
Greenback mullet	*Liza subviridis*	559	11.3%
Herring	*Herklotsichthys castelnaui*	410	8.3%
Anchovy	*Thryssa hamiltonii*	353	7.1%
Common ponyfish	*Leiognathus equulus*	303	6.1%
Longfin mullet	*Valamugil cunnesius*	297	6.0%
Glass perchlet	*Ambassis nalua*	267	5.4%
Saltwater bony bream	*Nematalosa come*	179	3.6%
Northern whiting	*Sillago sihama*	168	3.4%
Ponyfish	*Leiognathus decorus*	93	1.9%
Indian Anchovy	*Stolephorus indicus*	66	1.3%

Although no one species was numerically dominant, most of the ten most common species (Table 13) were used as bait by recreational fishers. Recreational and commercial food fish were not a major component of the seine net catch.

Juvenile food fish species sampled included pikey bream (*Acanthopagrus berda*), flathead (*Platycephalus fuscus*), trevally (*Caranx* spp.), queenfish (*Scomberoides* spp.), grunter (*Pomadasys* spp.) and whiting (*Sillago* spp.).

The sand and mudflats at the mouth of the Barron River appeared to be important spawning grounds for a number of species. Adult *Ambassis nalua* were observed in ripe condition over two sequential summer seasons at the mouth of the Barron River. Robertson and Duke (1990) made similar observations in another north Queensland estuary.

Small numbers of juveniles of estuary cod (*Ephinephelus* cf. *malabaricus*), bonito (*Rastrelliger* cf. *faughni*), spanish mackerel (*Scomberomorus commerson*) and the oyster crusher (*Trachinotus blochi*) were also sampled.

Beam trawling

The estuarine goby (*Favonigobius* sp.) composed nearly 40% of the 5929 fish caught in the beam trawls (Table 14). Gobiidae was the most speciose family of the 32 families sampled, with the top four species composing nearly 59% of the total number of fish caught. The top ten species numerically dominated the overall catch and accounted for more than 96% of the fish sampled. Most of these species were juvenile or larval fish, and in some instances identification was difficult. All of the top ten fish species caught belonged to only three families: Gobiidae; Leiognathidae; and Engraulidae.

Table 14. The ten most numerically dominant fish species sampled in beam trawls.

Common name	Species name	Total number	Percent
Goby (estuarine)	*Favonigobius* sp.	1956	39.5%
Estuarine Goby	*Acentrogobius* sp.	417	8.4%
Common ponyfish	*Leiognathus equulus*	401	8.1%
Anchovy	*Stolephorus commersonii*	353	7.1%
Black-tipped ponyfish	*Leiognathus splendens*	320	6.5%
Mangrove goby	*Glossogobius biocellatus*	317	6.4%
Anchovy	*Stolephorus* sp.	314	6.4%
Anchovy	*Stolephorus* cf. *commersonii*	268	5.4%
Goby	*Illana bicirrhosa*	215	4.4%
Ponyfish	*Leiognathus decorus*	206	4.2%

Only small numbers of economically important species were caught in the trawls. These included juvenile grunter, flathead, jewfish (*Nibea soldado*) and whiting.

Economic Fishes

Barramundi (*Lates calcarifer*)

Barramundi was the most economically important fish species found in the catchment. It was naturally distributed throughout estuarine and freshwater reaches of the catchment below the Barron Falls. It has also been stocked into Lake Tinaroo and Lake Morris. In Lake Tinaroo, it is the basis of an important recreational fishery but the conditions of these stocks are not reported upon in this document. While barramundi with a size range of between 30 cm and 90 cm total length (TL), were caught in both freshwater and in the estuaries, the freshwater areas had a higher proportion of smaller fish (Figure 36). About 40% of the barramundi caught in freshwater were less than 50 cm TL compared to only 18% of the estuarine fish. More fish were caught in the estuary, however this may simply be a reflection of fishing effort and sampling technique, and may not be a true reflection of abundances.

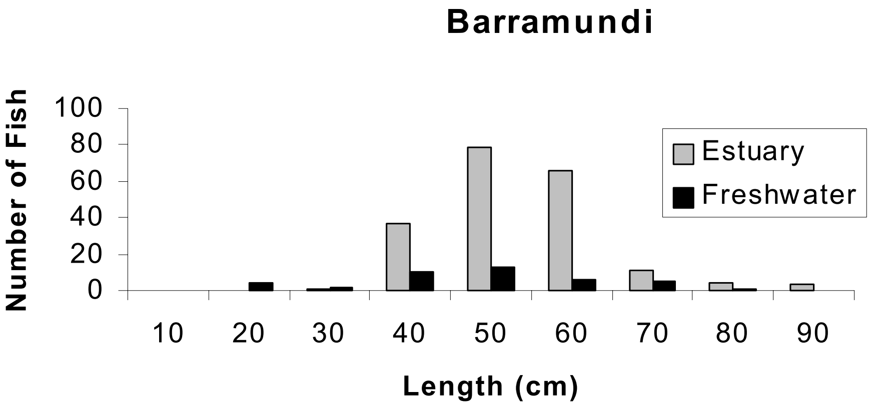


Figure 36. Size distribution of barramundi caught in freshwater and the estuary.

The average length (±SE) of 242 barramundi caught during the study was 47.8±0.7 cm with a range of 12 to 90 cm. Fish caught in the estuary and freshwater were 48.7 ± 0.7cm and 43.9 ± 2.4 cm TL respectively. The length of the estuarine barramundi sample was significantly greater than the length of the freshwater fish (t-test, df=241, p=0.005). The majority of barramundi sampled in the estuary (87%) and in freshwater (83%) were smaller than the minimum legal size of 58 cm.

Barramundi movement studies

A total of 191 barramundi were tagged during this study, and data were obtained on a further 54 fish which were tagged by recreational fishers since 1986. The majority of the recaptures from this study (~66%) were made by the project team, with the balance being caught by recreational fishers. In a similar tagging study, Russell (1988) found that his research team recaptured almost the same number of fish as the recreational and commercial fishers combined.

No recaptures were reported from commercial fishers from our study. Of the 54 fish tagged by recreational fishers, commercial fishers have only reported two recaptures. The majority of the fish tagged in this study were less than the legal size, with an average length (± SE) of 46.8 ± 0.9 cm or approximately two years old (Davis and Kirkwood, 1984). The majority of the recaptured fish (26) from this study were less than legal size at time of recapture. Most of these fish were released (average size of 48.3 ± 1.5 cm). The four fish kept by recreational fishers were an average of 63.3 ± 2.2 cm long.

The overall recapture rate for barramundi from this study was 14.7%, which was very similar to the overall recapture rate of 14.2% reported by Sawynok (1998). In contrast, Russell (1988) reported a high recapture rate for this species of 26% in the

Cairns area, which he postulated was the result of increased fishing pressure due to the proximity to a large city. It is expected that the recapture rate from this study will increase as time progresses.

More than 90% of recaptures were at liberty for less than a year. Similarly, Russell (1988) also found that most barramundi (76%) on the east coast of Queensland were recaptured within the first year. Average time of liberty (± SE) was 210.0±28.3 days for all 42 fish recaptured in this present study.

Recapture rates varied between sampling sites and with technique used. The Lake Placid and Kamerunga sites on the Barron River had low recapture rates of 5.4% and 8.0% respectively. This was due primarily to low fishing pressure resulting from area closures. Lake Placid was part of a National Park where fishing was prohibited and was partly included in a Fish Closure Area (*Fisheries Act*, 1994). The Barron River mouth and Thomatis Creek sites had much higher recapture rates (19.6% and 29.7% respectively) than the freshwater sites and these were more reflective of the results obtained by Russell (1988).

Approximately 90% of the recaptured fish from this study were caught within 5 km of the release site. It was evident from the gill netting surveys that many fish were being re-caught in the same location. The range of these fish, at least in the short term, appeared to be very limited. Long distance movements included one fish that moved from the upstream netting site in the Barron River (Map 2) and was recaptured in the upper tidal reaches of the North Johnstone River at Innisfail. A small number of fish (four) were found to have moved between the Barron River and Trinity Inlet.

A number of fish tagged in other areas were recaptured in the Barron River. For example, a fish that was tagged by a recreational fisherman in the Annan River near Cooktown was later recaptured in the Barron River.

Mangrove jack (*Lutjanus argentimaculatus*)

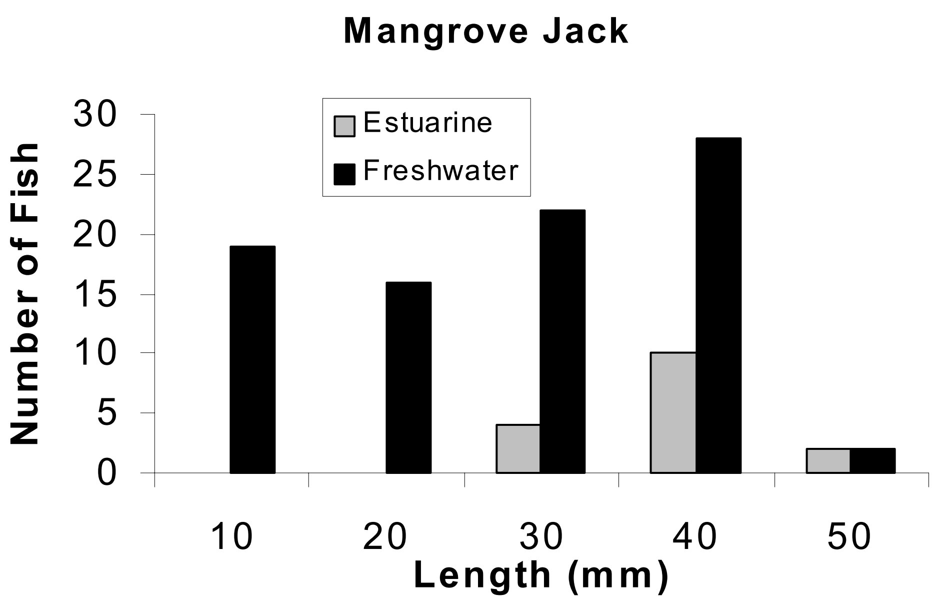


Figure 37. Size distribution of mangrove jack caught in freshwater and the estuary.

Figure 37 shows the size distribution for 102 mangrove jack caught during this study. Although commonly caught be recreational fishers in the estuary, their behaviour does not make them vulnerable to netting. As a result, few fish were caught in the estuary during this study. Recreational fishers use lures and live and dead baits to catch mangrove jack. In freshwater, most of the fish (98%) caught were juveniles up to 40 cm long and had an average length (±SE) of 23.11 ± 1.23 cm. The average length of the small sample of estuarine fish was 32.65 ± 1.62 cm, which was significantly longer than those fish caught in freshwater (t-test, $t=3.48$, $df=101$, $p=0.003$).

Fifty-four mangrove jack were tagged during this study and data was obtained on a further 43 fish tagged by recreational fishers (see AUSTAG database explanation in previous section). Of the fish tagged by the research team, three fish were recaptured by the team during this project, and recreational fishers recaptured a further two. Overall, the recapture rate for the combined data set was about 10%, or 7.3 % if the recaptures from the research team are excluded. The latter recapture rate was comparable with return rates from the AUSTAG database. Sawynok (1998) found that the recapture rate for this species from over 10 000 tagged fish tagged throughout Queensland was 6.3 % (637 recaptures).

Only one recaptured mangrove jack had moved from the tagging site. It moved downstream from Lake Placid to the upper estuarine area of the Barron River (less than 3 km movement). Recent recapture information from the AUSTAG database (Sawynok, 1998) revealed that over 90% of recaptures of this species were within 5km of the tagging site, with approximately 78% of recaptures showing no movement. Up to the period ending June 1999, there was only one multiple recaptures of a mangrove jack and this fish did not move.

Fingermark (*Lutjanus johnii*)

Fingermark were not a common species caught in the Barron River estuary during this study. Of the three fingermark sampled, only one was tagged and released. However, the AUSTAG database contained records of 33 fish that were tagged in the Barron River since 1990 by recreational fishers. Four of these fish were subsequently recaptured, one fish being recaptured twice. These four recaptures represented a recapture rate of 12.1%, which was similar to 10% recapture rate for the recreational fishery (Sawynok, 1998) (approximately 1 700 fish tagged). Of these recaptures, one was caught in Trinity Inlet to the south of the Barron River but the remainder made no net movements.

Banded grunter (*Pomadasys kaakan*)

A total of 60 fish were tagged in the Barron River by ANSA members with only four (4) recaptures to date. This represented a recapture rate of 11.5%, which was higher than the 3% reported by Sawynok (1998) for the approximately 8 000 fish tagged in the recreational fishery. The discrepancy between these two figures may be indicative of a higher fishing pressure on this species in the Cairns area.

Movements of other species

One dusky flathead (*Platycephalus fuscus*) which was originally tagged in Dickson's Inlet at Port Douglas was later recaptured at the mouth of the Barron River (B. Sawynok, AUSTAG, pers. com.).

Fishes of Lake Tinaroo

No intensive sampling of the fishes was undertaken in Lake Tinaroo because they were the subject of a number of previous surveys. In a survey conducted in the early 1970s, Russell (1987) found 14 species present in Lake Tinaroo and noted that another four had been introduced after his surveys (Table 15). Herbert (QDPI, pers. comm.) has supplied a more recent listing (1990's) from Lake Tinaroo (Table 15).

Table 15. Fishes present in Tinaroo Dam as sampled by Russell (1987) and Herbert (pers comm).

P- indicates present in dam, n- presence noted but not sampled, a- present in Tinaroo catchment, l- present below Tinaroo, r- rare or absent.

Common name	Scientific Name	Russell	Herbert
Glass perchlet	*Ambassis sp.*	p	
Barred grunter	*Amniataba percoides*	p	p
Long-finned eel	*Anguilla reinhardtii*	p	p
Silver perch	*Bidyanus bidyanus*	n	r
Fly-specked hardyhead	*Craterocephalus*	p	p
Mouth almighty	*Glossamia aprion*	p	p
Sooty Grunter	*Hephaestus fuliginosus*	p	p
Khaki bream	*Hephaestus sp.*		p
Firetailed gudgeon	*Hypseleotris galli*		p
Barramundi	*Lates calcarifer*		p
Spangled Perch	*Leiopotherapon unicolor*	p	p
Common rainbow fish	*Melanotaenia splendida*	p	p
Purple-spotted gudgeon	*Mogurnda adspersa*	p	p
Bony Bream	*Nematalosa erebi*	n	p
Eeltailed catfish/jewfish	*Neosilurus ater*	p	p
Tilapia	*Oreochromis mossambicus.*		p
Tilapia	*Tilapia mariae*		l
Sleepy cod	*Oxyeleotris lineolatus*	p	p
Guppy	*Poecilia reticulata*		a
Rendahl's Catfish	*Porochilus rendahli*	p	p
Gertrude's blue-eye	*Pseudomugil gertrudae*		u
Gulf saratoga	*Scleropages jardinii*	n	a
Eeltailed catfish	*Tandanus tandanus*	p	p
Archer fish	*Toxotes chatareus*	p	p

A number of species appeared to have become less abundant or disappeared since the first survey in the 1970's. A perchlet was sampled in Lake Tinaroo that appeared to be absent in the later study. In the present study, perchlets were found at 13 freshwater sites, all downstream of Lake Tinaroo but recent surveys (Herbert, pers. comm.) have found no record of them in the lake. Similarly, Russell (1987) recorded the presence of eels (*Anguilla reinhardtii*) in Lake Tinaroo, but they now appear to have either disappeared altogether or are extremely rare. Eels were not sampled in the watercourses of the Tinaroo sub-catchment during this study.

Of the fish species that have been stocked into Lake Tinaroo, a number have failed to become established either in the lake or its catchment. For example, Gulf saratoga, silver perch (Russell, 1987), fork tailed catfish, brown and rainbow trout (Grant, 1982) have all been unsuccessfully introduced into the lake. A recreational fishery was established for barramundi from the mid 1980s (Russell, 1987), however no evidence was found during this study that barramundi were established in the feeder streams or in the catchment below Lake Tinaroo but above the Barron Falls. They appear to be entirely restricted to the impoundment.

The fish assemblages in the lower reaches of some streams that flow directly into the dam were similar to those found in Tinaroo. However, with the exception of these areas, the fish assemblages in most watercourses that feed into the dam, including the Barron River, were not as diverse as those found in Tinaroo. Hogan (QDPI, pers. comm.) has observed numerous barramundi killed moving downstream when the spillway was overtopping. Presumably other fish meet the same fate however it was possible that some fish, particularly smaller fish, do survive the fall over the spillway. In an effort to protect existing stocks, the Tablelands Fish Stocking Society has now installed a spillway barrier net to prevent downstream movement of barramundi during the wet season. A small waterfall at Picnic Crossing hampers fish access to the Barron River approximately two km upstream of Lake Tinaroo. Sites on feeder streams immediately adjacent to the impoundment do, to some extent, reflect the assemblage in the dam, particularly when the water level in the dam is high. For example, bony bream which were normally only found in the dam or in still waters of the main river, were sampled at creek sites adjacent to the dam (eg. Petersen (site 9), Kauri (site 13) and lower Mazlin (site 11) Creeks) (Map 3). Bony bream were the most numerous and second most numerous species caught at the Petersen Creek and Kauri Creek sites respectively. Other typically lentic species which were represented at these sites included sleepy cod and Rendahl's catfish.

Interbasin fish transfers

Earlier DPI surveys indicated that *O. mossambicus* were present in the Barron River and tributary streams above Lake Tinaroo in the mid 1990's (A. Hogan, QDPI, pers. comm.). This present study confirmed their presence in Leslie and Kennie Creeks and in the Barron River immediately above Lake Tinaroo and established a new record of their upstream range in the Barron River at Pinks Bridge (site 50). Tilapia were first observed in Lake Tinaroo in December 1997 at the mouth of Severin Creek, and by December 1998 populations were well established in the southern parts of the lake (A. Hogan, QDPI, pers. comm.). With the establishment of populations of tilapia in Lake Tinaroo, it is probable that, sooner or later, they will also become established in the Barron River below Lake Tinaroo and possibly the adjacent Mitchell River. Colonisation of the lower river could occur by:

- some fish surviving being washed over the spillway, through the river outlet, or by water releases to supplement streams;
- deliberate translocations by the public; and
- birds.

There was wide spread community concern, particularly by ICM groups (Barron and Mitchell), that tilapia will find their way from the Barron River system into the Mitchell River, and therefore into the Gulf of Carpentaria drainage. There was already some evidence of inter-basin transfer of fish using the MDIA drainage system as a conduit. Guppies sampled in Walsh River immediately downstream of an MDIA drainage outlet would most probably have originated from somewhere within the channel system. (T. Ryan,DNR, unpublished data). Once established, there could be little done to stop tilapia spreading throughout the extensive waterways and lagoonal systems of the Mitchell River catchment. Potential impacts that populations could have on the environment and fisheries of that system, whilst unknown, could be very serious.

There were at least four possible mechanisms for tilapia to become established in the Mitchell system. These are:

- movement from Lake Tinaroo through the irrigation channel;
- movement first into the Barron River below Lake Tinaroo and then into the Mitchell catchment via low lying country to the north of Mareeba (see section: Uncommon freshwater species);
- movement into the Barron River and tributaries of the Barron River below Lake Tinaroo via water releases and then into the Mitchell River catchment via irrigation pumps and drains; and
- direct translocation by humans.

Of these four scenarios, it would seem likely that the most probable mechanism for interbasin transfer of fishes would be through direct human intervention.

While interbasin transfer of tilapia was of concern, there was little doubt that other species could use, or have used, the same routes to move between the Barron River and the Mitchell River and vice versa.

The Barron Falls is a natural barrier that would stop the upstream colonisation of *Tilapia mariae* from coastal locations. *T. mariae* are already established along the coast and in watercourses to the north (Arthington *et al*, 1984) and south (Helmke *et al*., (in press)) of the Barron River.

Other species that have been translocated into the Barron River catchment in the past and have not produced self-sustaining populations include southern saratoga, Murray-Darling yellowbelly and silver perch (Queensland Fisheries Management Authority, 1996) and others discussed in the previous section of this report.

Fish Diversity

Figure 38 shows the species diversity for all sites and all sampling times in the Barron River catchment. Species diversity at coastal freshwater sites was found to be greatest at locations both on the main Barron River and in larger tributary streams such as Freshwater and Stoney Creeks. Freshwater Creek sites, despite disturbances associated with urbanisation and agricultural development, had amongst the highest species diversity indices. As well as fish which spend their entire life cycles in freshwater, coastal streams were utilised by a range of freshwater species which spend at least some of their life cycle in coastal and marine waters (eg. jungle perch and mangrove jack). Primarily estuarine species (eg. mullet) also made occasional forays into freshwater. While not as high as many coastal sites, sampling locations on the main Barron River above the falls also had higher fish diversities, while smaller, tributary streams had lower diversities.

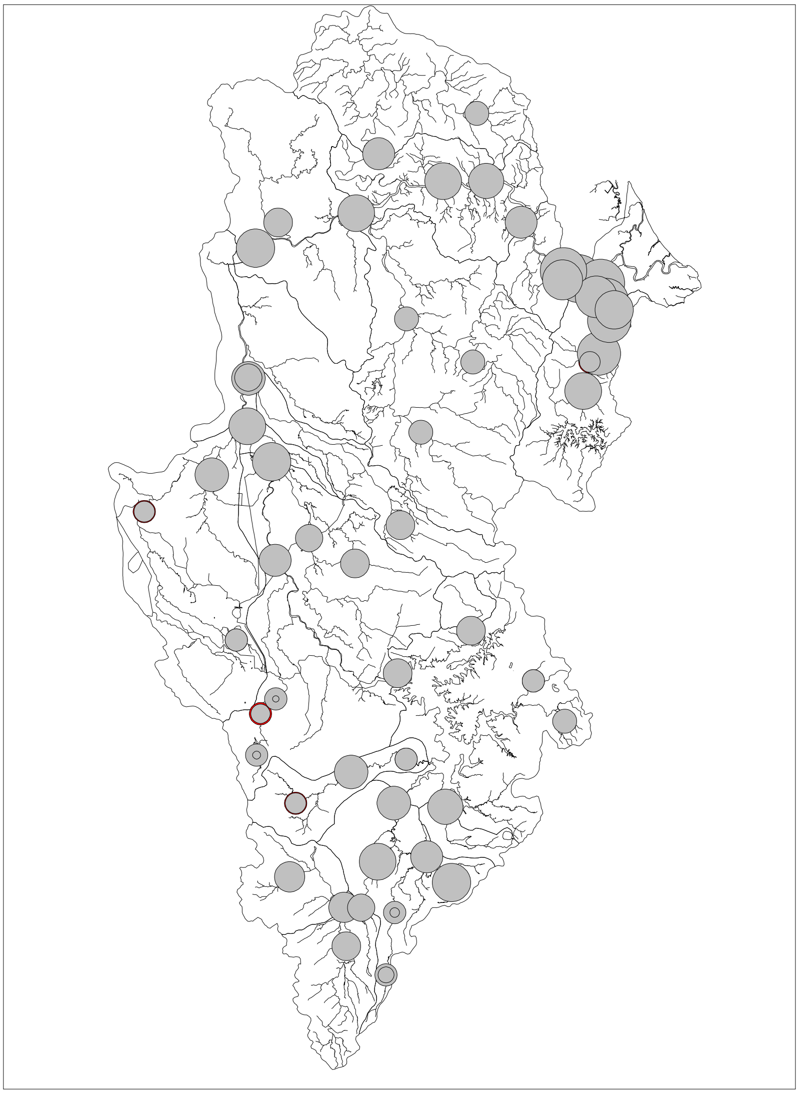


Figure 38. Fish species diversity at sites within the Barron River catchment.

The size of the circle at each location represents the magnitude of species diversity at each site.

An analysis of variance showed significant differences between the zonal diversities ($p<0.001$) and the LSD (least significant difference) suggested that the four Tableland sub-catchments (Tinaroo, Middle, Clohesy-Davies and Flaggy) were a homogenous group which was significantly different ($p<0.05$) from the coastal zone.

As discussed previously, fish assemblages in Lake Tinaroo influenced sites on feeder streams in close proximity to the lake, and some of these had elevated species diversities. Also, some sites above Lake Tinaroo, including locations on the main Barron River and Kennie and Leslie Creeks, also had relatively high species diversities. Previous studies (Pusey and Kennard, 1996; Russell *et al*., 1998) showed that the species diversity decreased with distance from the coast and it was possible that activities such as stocking and construction of impoundments could have resulted in some upper sites having higher diversities than might otherwise have been expected.

Changes in Catch Per Unit Effort

The Queensland Department of Primary Industries conducted a gill netting study in Thomatis Creek during the early 1980s (Russell, 1988). The large amount of variation in catches and confounding problems related to gill net selectivity and varying net lengths made any direct comparison between this study and the present survey difficult, there were a number of interesting trends.

Table 16 shows the catch per unit effort (CPUE) for the major species during the two periods. In the present study, a greater number of smaller mesh nets were used, so in an effort to make the results more comparable, only the catches in nets with mesh sizes from 100 mm to 150 mm were considered. In the 1980s study, blue salmon, silver jewfish, barramundi and king salmon all had CPUE's in excess of 0.1 fish caught/hour. In the present study, only silver jewfish and barramundi had CPUE's in excess of 0.1 fish caught/hour. The CPUE for blue salmon had declined considerably, with only 12 caught in nets set in Thomatis Creek during the present study. The average CPUE for silver jewfish remained constant for both periods. While the CPUE for barramundi had increased, possibly due to stocking activities or to historic changes to the management strategy for the fishery.

Table 16. CPUE (number of fish caught per net hour) for major fish species caught in Thomatis creek in the early 1980s and in this present study.

Species	CPUE –early 1980s	CPUE – 1997-98
Barramundi	0.125	0.45
Blue salmon	0.297	0.017
King salmon	0.104	0.063
Sea mullet	0.009	0.043
Banded grunter	0.003	0.009
Silver jewfish	0.135	0.138

Prawns

Beam trawling using small mesh nets was conducted at two sites in the Barron River between November 1996 and November 1998. Numerically, Sergestids and Carids were the most abundant species, however there was a range of Penaeid prawns

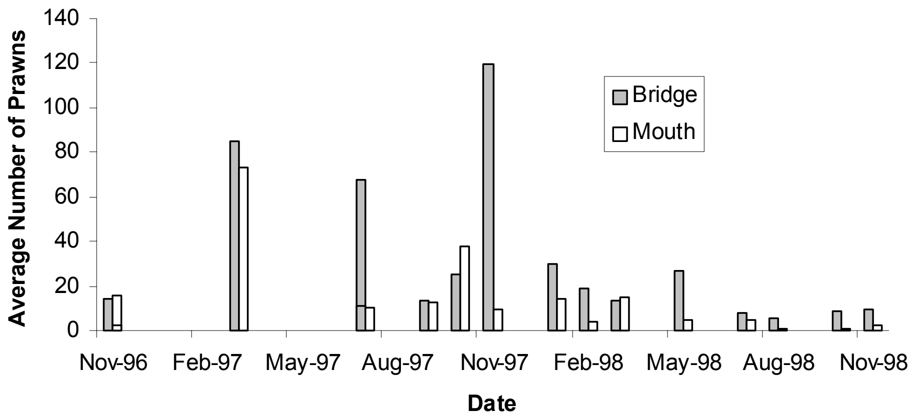


Figure 39. Average number of penaeid prawns caught per 100 m trawl.

caught including six species of Metapenaeids and seven *Penaeus* species.

Species of commercial importance (see Commercial fisheries section in the Introduction) included: red and blue endeavour prawns (*Metapenaeus ensis and M. endeavouri*); brown and grooved tiger prawns *(Penaeus esculentus and P. semisulcatus*)*;* banana prawns *(P. merguiensis, P. longistylus* and *P. indicus*)*;* leader prawns (*P monodon);* western king (*P. latisulcatus*); and *M. beneatte* (bay prawns) were caught, but generally in small numbers.

Figure 39 shows the monthly average number of penaeid prawns caught in 100 metre trawls at the two trawling sites in the Barron River. Generally, the upstream bridge site was more productive than the downstream site at the mouth. This was probably related, in part, to substrate type; the upper site was a mud substrate that was generally preferred prawn habitat while the lower site had a predominantly sandy bottom. A seasonal pattern of abundance was not readily apparent, but catches in 1997 were generally larger than in 1998.

M. eboracensis was numerically the most abundant of the Penaeid prawns caught at both sites. While *M. eboracensis* was not a commercial species, it was commonly used by recreational fishers as bait. Of the commercial prawns caught, red endeavour prawns (*Metapenaeus ensis*) were the most common species at both sites. In previous resource surveys of wet tropics streams (eg. Russell and Hales, 1993, Russell *et al.*, 1996a, 1996b), at least some sites were located in seagrass meadows and these were generally quite productive for juvenile prawns. There were no significant seagrass beds to trawl in the Barron River estuary and prawn species generally associated with seagrass, for example juvenile tiger prawns (Coles *et al.*, 1993) were found only in relatively small numbers.

Recreational fishers targeted banana prawns (*P. merguiensis*) with cast nets, particularly just prior to and during the wet season, to use as bait and human consumption. Staples (1980) noted that banana prawns use mangroves as nursery areas prior to being recruited into the offshore otter trawl fishery. While banana prawns were commonly found in north Queensland estuaries, in this study juveniles did not form a major portion of the catch. The reasons for this were unclear, but it was possible that banana prawns were simply not present at the sampling sites or they were in amongst the mangroves rather than adjacent to the mangroves where the

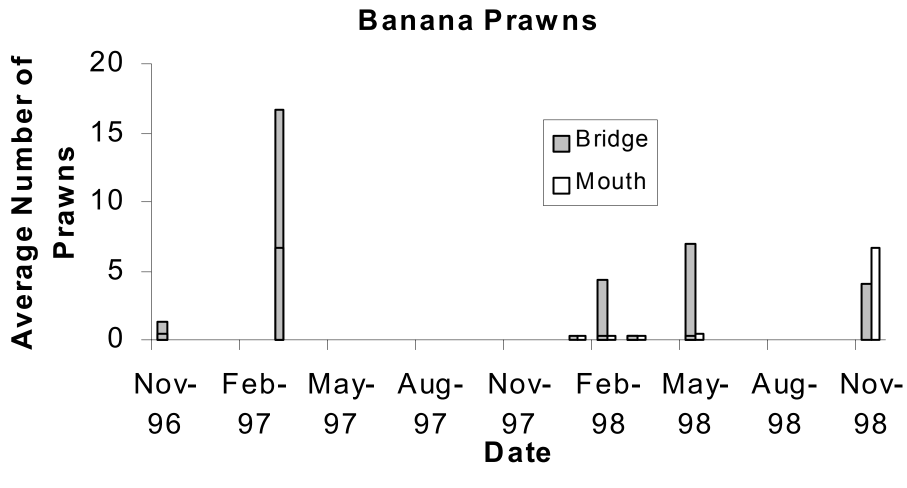


Figure 40. Seasonal variation in average banana prawn catch per 100 m trawl.

trawling took place.

Figure 40 shows the seasonal variation in the average number of banana prawns caught per 100 m trawl at both sites. Banana prawns in the Barron River were commonly caught during the period from late November through to May. The bridge site with its muddy substrate proved more productive for banana prawns than the sandy site at the mouth of the river.

Figure 41 shows seasonal variation in the red endeavour prawn (*M. ensis*) catches at the two sites in the Barron River. Red endeavour prawns were commonly targeted by recreational fishers in the estuaries as bait. Red endeavour prawns were seasonally more abundant during the warmer months from November through February although they were also caught at other times of the year (Figure 41). Relatively high densities of *M. ensis* were sampled by Russell *et al*., (1997) in Maria Creek, in March 1995, while Russell and Hales (1993) found a high abundance in February in the Johnstone River.

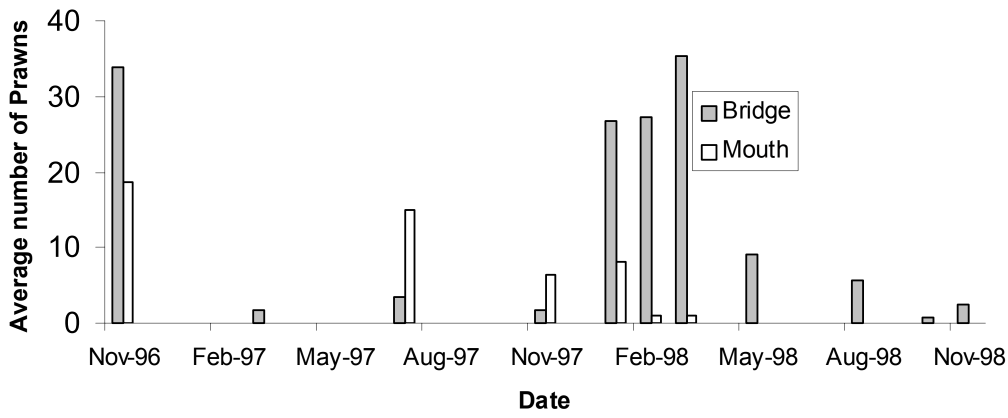


Figure 41. Seasonal variation in average catch of red endeavour prawns per 100 m trawl.

CONCLUSIONS

Wetlands and Associated Land Use

While there were some small freshwater wetlands in the upper catchment, the largest areas were on the narrow coastal floodplain. This coastal belt was the most densely populated part of the catchment and there was limited land available for urban, industrial and agricultural expansion. In such circumstances, the potential for anthropomorphic impacts on coastal wetlands was high.

Compared to other wet tropics catchments, for example the Moresby (Russell *et al.,* 1996a) the area of wetlands in the Barron River delta was relatively small. Even in 1952, the total area of wetlands was just over 1 100 ha, compared to over 5600 ha in the Moresby catchment (Russell *et al.,* 1996a). In the Barron River delta, freshwater wetlands, including *Melaleuca* swamps, were only a minor component of the total coastal wetlands and the ratio of tidal to freshwater wetlands (about 9:1) has remained relatively constant over the past 47 years. This compared to the Moresby River catchment where, in 1951, 60% of the wetlands were non-tidal (Russell *et al.,* 1996a). While the area of wetlands cleared prior to 1952 was unknown, it was possible that there were some significant losses. However, it was also likely that the topography of this part of the coastal belt made it unsuitable for the establishment of large tracts of freshwater wetlands.

In the Barron River delta, there has been a net wetland loss of about 180 ha (16%) between 1952 and 1996. Most of this loss was due to the reclamation of tidal wetlands, predominantly mangroves and salt pans. The percentage of *Melaleuca* wetlands has remained relatively stable over this period. About 63% of the total wetland loss were attributed to the reclamation of tidal wetlands during various expansion phases of the Cairns International Airport.

In the Half Moon Creek catchment there was a net wetland loss of around 57 ha (16%) between 1952 and 1996. The expansion of sugar cane farming was responsible for the major single loss of wetlands in this catchment (37 ha). Other activities which have contributed to wetland loss include the expansion of a local golf course, a land fill and construction of a canal estate and tourist complex. The loss of predominantly tidal wetlands in this area was in contrast to types of losses that were recorded over about the same period in other wet tropics catchments. For example, most of the wetland contraction in the Moresby (Russell *et al*., 1996a) and Russell-Mulgrave (Russell *et al.*, 1996b) catchments has been due to reclamation of non tidal wetlands.

With the exception of a small area in the south of the Half-Moon Creek catchment, freshwater wetlands such as *Melaleuca* and sedge communities, which were normal components of coastal wetlands in the wet tropics (Stanton, 1975; Russell and Hales, 1993a, 1997; Russell *et al.,* 1996a, 1996b), were scarce. Indeed, in many places agriculture (largely sugar cane farms) and urban areas abut directly onto tidal wetlands and were separated only by drains, roads or levees. There were also agricultural areas adjacent to tidal wetlands, which from aerial photographs and direct observation, appeared marginal and had either been reclaimed or were under the influence of a high saline water table. Some of these marginal blocks appeared to have been abandoned and contained sugar cane regrowth, weeds and grasses. There was clearly potential for rehabilitation of some of these areas.

It was apparent that there were ongoing anthropomorphic threats to the integrity of remnant coastal wetlands in the Barron River delta and consideration needs to be given to ways of best protecting the remaining communities. This can be done through public education on the value of coastal wetlands, enforcement and by identification and protection of critical wetland habitat. Some tidal wetlands in the Barron River delta and the Half Moon Creek catchment were presently protected as FHAs (see Map 2). There are two categories of FHAs: management zone A where virtually no development is allowed and management zone B where minor public or private works may be allowed under certain circumstances. Currently there is 256 ha of wetlands in zone A FHAs and 315 ha in zone B FHAs. This represents 571 ha (53%) of a total of 1 071 ha of tidal wetlands that were currently protected as reserves. More than 93% of the wetlands in the FHAs were tidal communities. The establishment of a proposed coastal marine park may afford further protection of remaining wetlands.

Erosion and Sedimentation

While it is acknowledged that erosion is a natural process, it can be exacerbated by anthropomorphic activity. Major activities in this catchment contributing to erosion and sedimentation included clearing and disturbance of the riparian vegetation, quarrying and some inappropriate land management practices. Earth works, particularly those associated with urban development, may periodically contribute to sedimentation in this catchment, although sediment control guidelines were now widely practiced.

In many parts of the Barron River catchment where the riparian forest has been cleared or depleted, bank erosion appeared to have become a significant problem. For example, on the Barron River after the heavy flood rains of 1998/99, there were a number of areas where cleared, steep banks had slumped into the river (see Plate 2) particularly on the northern bank immediately upstream of the confluence with Thomatis Creek. In this area, the natural riparian vegetation had been extensively cleared and sugar cane was grown right up to the riverbank. The extensive use of rocks and other building debris to protect stream banks was further evidence of the impact of erosion in the lower catchment. While such measures provided a quick fix for immediate problems, consideration needs also to be given to the development of strategies that provide for long term, environmentally friendly solutions to bank stabilisation issues. Such solutions could include the development of riparian regeneration strategies and fencing of stream banks to minimise cattle damage.

Major flood events can also exacerbate erosion and can result in excessive sedimentation. For example, after the 1998/99 wet season, parts of the floodplain adjacent to the coastal reaches of the Barron River were covered with considerable deposits of sand and gravel.

Fisheries Resources

Of the 209 species sampled in the estuarine and freshwater areas of the catchment, only a small number were important economic species while others were significant because of their conservation value. Sampling also identified the presence of a number of exotic and translocated species. The river was also utilised as a nursery by a number of species of prawns including at least ten species of commercial importance.

Exotic and translocated species

Sampling in estuarine and freshwater habitats identified five species of exotic fishes that were established in the Barron River catchment. One of the most common species, guppies (*Poecilia reticulata*), were found at eight sites throughout the Barron River catchment. Their distribution appeared limited and there was no evidence to suggest that they will eventually spread and become widespread throughout the catchment. Most of the sites where they were established were characterised by high levels of disturbance and/or poor water quality. Arthington and Lloyd (1989) noted that it was not uncommon to find Poeciliids dominant in highly modified urban creeks. All impacted sites were in either agricultural or urban areas and it was probable that these populations became established after releases from domestic aquariums. The impact that these populations were having on native fishes appeared to be minimal, although Arthington and Lloyd (1989) cautioned that widespread distribution of carnivorous exotic species, such as guppies, was of concern.

Swordtails (*Xiphophorus helleri*) and mosquito fish (*Gambusia holbrooki*) were also found at single sites in the coastal section of the catchment. Mosquito fish were first introduced into the Cairns area over 50 years ago during the Second World War but, fortuitously, they have not become widely established in the Barron River catchment. There was evidence of their adverse impacts on native fishes including predation on larval Melanotaenids, Pseudomugils and Eleotrids (Ivantsoff and Aarn, 1999). MacKay (1984) noted that fast flowing rivers and streams were not suited to mosquito fish and that, when present, they generally inhabit quieter backwaters away from the main current. If these observations were correct, the generally fast flowing streams of the wet tropics would not provide suitable habitat for mosquito fish. The distribution of swordtails was very limited and existing feral populations were probably the result of recent releases from domestic aquariums.

Two species of tilapia, *Tilapia mariae* and *Oreochromis mossambicus* (or mosambique mouthbrooder), were found in the catchment, however there was a possibility that a number of hybrids may also be present (J. Johnson, Queensland Museum, pers. comm.). The two species of tilapia were established in separate geographical parts of the catchment. *T. mariae* were widespread in coastal freshwater parts, including Freshwater Creek, and were also occasionally caught in estuarine areas. The Barron Falls blocks natural upstream movements of *T. mariae*. Anecdotal evidence from local residents suggests that it first became established in Freshwater Creek around the early 1990s and has been gradually been increasing in abundance. *T. mariae* was also established in other wet tropics streams including the Johnstone River (Russell and Hales, 1993) and the Russell and Mulgrave Rivers. *O. mossambicus* was found at a number of sites above Lake Tinaroo during this study, including both in the main river and minor streams. This species has been found in previous surveys in this sub-catchment and has now been located in Lake Tinaroo (Alf Hogan, DPI Fisheries Group, pers. comm.). *O. mossambicus* was also established in other Queensland waterways including the Ross River (Townsville) and in the Brisbane area (Arthington *et. al*., 1984).

While guppies, swordtails and mosquito fish were present within the catchment, they appear not to have become established in large numbers. There was considerable concern that populations of tilapia will become widely established in the Barron River catchment. Furthermore, there is a reasonable probability that the fish found in the upper catchment will eventually become established in the Gulf of Carpentaria drainage. While tilapia has not been recorded in any drainage to the west of the catchment, there was considerable speculation that the billabongs and slow flowing streams characteristic of this region could provide ideal habitat. The Queensland

Department of Primary Industries was developing a regional plan for the management of noxious fish in the Barron River catchment. An education and extension strategy that will target both school students and the adult community was being developed by the QDPI in an effort to control the spread of noxious fish in Queensland.

Translocated fish appeared to make up a high proportion of the total number of species in the Barron River catchment. Earlier studies by Shipway (1947abc,1948) suggested that the number of species originally present in the freshwater reaches of the catchment upstream of the falls was extremely limited. The activities of fish acclimatisation societies around the time of construction of Tinaroo Falls Dam, appeared to have resulted in the establishment of a large number of translocated species. For example, a number of species sampled during this study including striped sleepy cod (*Oxyeleotris selhemi*), Macleay's glass perchlet (*Ambassis macleayi*) and Rendahl's catfish (*Porochilus rendahli*) were thought to be endemic to the gulf river streams. How these species were translocated into the Barron River system is a matter for conjecture, but possible means include through the activities of now defunct acclimatisation societies (eg. Tableland Anglers' and Acclimatisation Society) or natural movements when the catchments were linked during large flood events.

Another translocated Gulf species, redclaw (*Cherax quadricarinatus*), were found at 49% of the sites sampled and the wide distribution was almost certainly a result of unauthorised introductions and/or from escapees from aquaculture farms. Self-sustaining populations now exist in streams throughout the catchment and in Lake Tinaroo, where a recreational fishery has been created. In Lake Tinaroo, management measures have been introduced to protect female redclaw in breeding condition (Freshwater Fishery Management Plan, 1999). Apart from impounded waters, redclaw were found predominantly in the main river or larger tributary streams. The impacts of redclaw on native crustacean (eg. *Macrobrachium australiense* and *Cherax* spp.) were unknown, although they appeared to co-exist at a number of locations sampled.

Previous studies (eg. Pusey and Kennard, 1994 and Russell *et. al*., 1998) have found a number of uncommon or rare freshwater fish species in wet tropics streams. This present study also found a number of fish species, mainly gobies, which were of conservation importance. For example, *Sicyopterus* sp. was sampled in Stoney Creek while *Schismatogobius* sp. and *Stenogobius* sp. were caught in Freshwater Creek. These gobies were relatively rare species with specific habitat requirements including fast flowing, clear water, a cobble-gravel substrate and access to estuarine systems to complete life cycle phases (Allen, 1991). Habitat degradation may potentially threaten the distribution of these species. Other uncommon species that also inhabit upper tidal/lower freshwater areas of the coastal zone in the Barron River catchment were the flag-tailed glass perchlet (*Ambassis miops*) and the swamp eel (*Ophisternon* cf. *bengalense*). Both of these species had uncertain or restricted distributions.

The flat-headed gudgeon (*Glossogobius giurus*) were resident above the falls in the Barron River. While Allen (1989) reported that in northern Australia, it was a common species with a large range, it appeared to be less abundant in north Queensland. Herbert and Peeters (1995) were unable to find specimens in Cape York Peninsula or Cairns, and Pusey and Kennard (1994) found only four specimens in the Bloomfield River.

Estuarine recreational and commercial species included barramundi, mangrove jack, king salmon, blue salmon, grunter and silver jewfish. Of these, barramundi was among the most common species sampled, with 242 fish up to 90 cm long being caught. Coastal streams of the Barron River delta supported stocks of mostly juvenile and sub-adult barramundi and mangrove jack. This study found no evidence of any offshore mangrove jack movements, although the absence of adults in the estuary and coastal streams suggests that they do migrate out of riverine systems.

It was difficult to draw too many definitive conclusions on the relative health of the river's fisheries despite the availability of some historical, fisheries independent catch data from the early 1980s. It appeared that the CPUE for species such as silver jewfish remained relatively constant over this time period but decreased for other species such as king salmon and blue salmon. The CPUE for barramundi appeared to have increased, possibly due, in part, to recent barramundi stocking programs that have taken place in the Barron River and nearby Trinity Inlet.

Spawning and nursery grounds

The sand and mud flats at the mouth of the Barron River acted as spawning grounds for many fish species. During this study, fish of economic importance which were found in running ripe condition included silver grunter (*Mesopristes argenteus*), silver jewfish (*Nibea soldada*), dusky flathead *(Platycephalus* sp.*)* and blue salmon (*Eleutheronema tetradactylum*).

Juveniles of many species utilised the Barron River estuary as a nursery area. . Juveniles of other species including mangrove jack (*Lutjanus argentimaculatus*) and barramundi (*Lates calcarifer*) inhabited estuaries and also moved into freshwater areas. In addition, the juveniles of a number of pelagic species including queenfish (*Scomberoides* spp.), trevally (*Caranx* spp.) and mackerel (*Scomberomorus* sp.) appear to opportunistically utilise the sand and mud flats at the mouth of the Barron River as nurseries.

Lake Placid, which was closed to all fishing, appeared to be an important refuge for many fish including estuarine species, such as barramundi and mangrove jack, which utilised freshwater areas as part of their life cycle. This body of water was part of the Barron Falls National Park and has had little disturbance to its riparian and instream habitat.

Prawn nurseries

The river appeared to be a nursery for a range of penaeid prawns, including a number of commercial species. Of these, the red endeavour prawn (*Metapenaeus ensis*) was the dominant species. Red endeavour prawns were known to be utilised as a bait source by recreational fishers and undoubtedly contributed to the offshore commercial fishery. Although not as abundant in the beam trawl catches as red endeavour prawns, banana prawns (*P. merguiensis*) were also targeted as a bait/food species by recreational fishers just prior to, and during the wet season. Both species were seasonally more abundant during the warm, wetter months between about late November and May. Banana prawns (Staples, 1980) and other species used rivers as nurseries before moving offshore, where they were targeted by the commercial fishery.

The almost complete absence of sea grasses inside the river mouth explained the relatively low abundances of species such as juvenile tiger prawns, which were usually associated with sea grass meadows (Coles *et al*., 1993). In the absence of sea grass, it would appear that upstream, mud substrate habitat was more productive for prawns than the shallow, sandy areas close to the mouth.

The Barron River does not appear to support a large number of prawns, either juveniles or adults, of commercial or recreational importance. However, the abundant seagrass beds found immediately to the south of the river mouth at Ellie Point (see Map 2) provide habitat for larger juvenile prawn stocks (Coles *et al*., 1993).

Biodiversity

Pusey and Kennard (1994) noted that the wet tropics region contains 41% of Australia's freshwater fish species and 55% of the species within families typical of northern Australia. Pusey and Kennard (1994,1996) suggested that a dependable stream flow and a diverse and reliably available array of river habitats were the major reasons behind the exceptionally high diversity of fish species in the wet tropics.

This current study found 61 species of freshwater fish from 27 families. A minority of the species found (21) also utilised estuarine areas at some time in their lifecycle. Pusey and Kennard (1994) found 31 species of freshwater fish in a previous survey of the Barron River, with some notable differences in species composition to this current study.

Even with major impacts from the agricultural and urban development in the Freshwater Creek sub-catchment, this area was found to have a significantly higher diversity of species than the other sub-catchments. The coastal zone forms an important link in the lifecycle of many fish species that rely on access to a variety of habitat types both in the estuarine and freshwater environments. The importance of Freshwater Creek and tributary streams to the maintenance of biodiversity in the catchment and the wet tropics region should not be underestimated. Future management and development strategies for Freshwater Creek and Stoney Creek should acknowledge the significance of their fish fauna and seek to maintain or enhance existing populations.

Riparian Vegetation and Riverine Habitat

On a catchment basis, the riparian vegetation was found to be in reasonable condition. Over 75% of the length of all streams assessed had wide riparian cover on at least one bank, and 65.7% of the length of streams had wide vegetation on both banks. Approximately 25% of the length of all streams had sparse vegetation on at least one bank, with 15.5% of the length of all streams had sparse vegetation on both banks.

The majority of the riparian vegetation was composed of trees and shrubs, however grass made up to 35% of the stream length of sites assessed in the Tinaroo sub-catchment. Overall, more than 40% of all sites in the catchment had a continuous riparian vegetation cover. The Tinaroo sub-catchment showed reduced riparian continuity, with greater than 28% of sites with more than 50% breaks in riparian vegetation.

The predominantly agricultural sub-catchments (Middle and Tinaroo) were more severely impacted by riparian disturbance. More than 25% and 52% of all sites in the Middle and Tinaroo sub-catchments respectively had a sparse riparian vegetation cover. More than 37% of the length of major and minor streams in the Tinaroo sub-catchment were assessed as having sparse riparian vegetation cover.

Past and present agricultural practices, particularly dairying and grazing, appeared to be implicated in causing much of the damage to the riparian vegetation in the Tinaroo sub-catchment. Repair and protection of the riparian vegetation needs to be a priority for maintenance and improvement of river health in these sub-catchments.

Depletion of riparian forest appeared to have an impact on the availability of fish habitat, particularly woody debris, overhanging vegetation and leaf litter. Excluding Lake Tinaroo, most of the major beds of aquatic plants appear restricted to the main river, particularly in the middle Barron and around Lake Placid. There was evidence of colonisation by noxious plants, including *Salvinia molesta, Eichornia crassipes* (water hyacinth*)* and *Pistia stratiotes* (water lettuce). These plant species were established in some parts of catchment, particularly above Lake Tinaroo.

Impacts on fish habitat

Overhanging vegetation offers unique fish habitat by providing shade and cover and acts in maintaining acceptable water temperatures by blocking out sunlight. Clearing of the riparian vegetation in the Freshwater and Middle sub-catchments has led to a low coverage of overhanging vegetation of 24% and 18% respectively. Only 7.5% of sites with pools in the Tinaroo sub-catchment had overhanging vegetation, possibly the result of a depleted riparian forest. In these areas, exotic grasses such as para grass have become well established. Para grass was present at over 40% of all of the sites in the Tinaroo and Middle sub-catchments. Thick mats of para grass have resulted in a restriction of stream flow and increased sedimentation. The percentage of fine material (36%) found in sediment at the sites in the Tinaroo catchment was substantially higher than in other sub-catchments.

The highest snag density was found in pools in the Clohesy-Davies Creek and Flaggy Creek sub-catchments. This was probably the result of a relatively undisturbed riparian forest associated with the Wet Tropics World Heritage estate or other types of reserves.

Water Quality and Riverine Health

Riverine health

Seven of the ten sites sampled on the Barron River appeared to be quite healthy with good macroinvertebrate abundances and diversities. Invertebrate diversities (Shannon-weiner) were highest at Hemmings (20.5 ± 0.07), Henry Hannan (1.85 ± 0.07), and Goonarra (1.84 ± 0.08) and lowest at Bilwon (1.49 ± 0.13). While the lack of variation of SIGNAL scores for the Barron Rivers sites made direct site comparisons difficult, some conclusions were possible. SIGNAL scores were greater than 6 at the Emerald, Kenneally, Henry Hannan, and Goonarra sites indicating the occurrence of relatively sensitive taxa and suggesting good water quality. The remaining sites had scores between 5 and 6 (except for Kamerunga with a value of 4.96), which also suggested no direct impacts as a result of poor water quality. It is noteworthy that the SIGNAL index for the Bilwon site was at the lower end of the scale.

Sites with poor macroinvertebrate abundances and diversities were Picnic Crossing, Kamerunga and possibly Bilwon. Physical factors including increased sediment diversity hampered sampling at the Picnic Crossing and Kamerunga and probably, at least partially, contributed to lower taxa abundances. But, water quality data and an over-representation of tolerant macroinvertebrate groups at the Picnic Crossing site supported the contention that this site had problems with nutrient enrichment. Other macroinvertebrate studies (eg Choy *et al.*, 1997 and Cogle *et al.*, 1998) also noted that degradation at Picnic Crossing was probably due to nutrient enrichment and possibly flow regulation. The Kamerunga site was subject to marine influences that may have adversely impacted on the macroinvertebrate communities. Additionally, marine predatory vagrants (eg. grapsid crabs) not present at other sites may also have adversely impacted on the macroinvertebrate fauna. At the Bilwon site, a number of indicators including macroinvertebrate abundance, total taxa, composition of families and SIGNAL scores suggest that this site had suffered some degree of degradation the cause of which was unknown.

Bioindicators

Of the thirty-nine macroinvertebrate families listed in the abundance data, three appeared to have value as indicator species. These families included Caenidae (mayfly larvae), Leptophlebiidae (mayfly larvae) and Notonemouridae (stonefly larvae). The Caenidae mayflies genera (Tasmanocoenis and Wundacaenis) were generally found in moderate flowing environments, existing cryptically in sand substrata (Hawkin and Smith, 1997) and were more common at Koah, Myola, Emerald and Hemmings (in order of highest to lowest abundance). The genera of Leptophlebiidae mayflies (Atalophlebia, Austrophlebiodes, Jappa and Nousia) were predominantly detrivores (Williams, 1980) and occurred at all sites, but were more abundant at Goonarra, Hemmings and Henry Hannan. While the mayflies (Ephemeroptera) generally increased in abundance with distance downstream these particular families may have potential for use as indicators of clean water quality in the Barron River. Notonemouridae stoneflies (Plecoptera) were observed primarily at Goonarra and Hemmings, but were also found at Emerald and Henry Hannan, all sites with permanent running water and a high proportion of detrital plant material (indicative of the greater riparian vegetation overhanging).

Water quality

The majority of the 189 habitat sites assessed within the catchment displayed relatively good *in situ* water quality values. A more comprehensive analyses of water quality in the catchment is given in Cogle (2000).

pH values between 6 and 8 were recorded at more than 88% of the sites. There was some evidence of problems with acid sulphate soils in some coastal areas. Sand mining activities in some parts of the delta have disturbed acid sulphate soils with the result that water in the burrow pits had very low pH values. During heavy rainfall the burrow pits overflow into adjacent watercourses. While this study found no evidence of fish kills or other obvious environmental damage resulting release of acid leachate, this problem needed to be addressed. Other sites which had low pH values and which maybe potentially impacted by acid leachate (eg. site 64 on Yorkeys Creek) need to be further investigated.

Percentage dissolved oxygen saturation were relatively high with the values at most (66.6%) sites exceeding 80% saturation. A small number were supersaturated (11%). Many of the sites that exhibited low dissolved oxygen concentrations were ephemeral, becoming isolated, stagnant pools during the drier months.

The average turbidity values for the sub-catchments were less than the recommended maximum level of 10 NTU given in the draft ANZECC guidelines (Australian and New Zealand Environment and Conservation Council, 1999) . Most of the higher turbidity values recorded in normal site sampling (not event sampling) were found at estuarine sites.

Future Monitoring

There would be considerable benefits in continuing, or repeating at a later date, some of the work that has been undertaken during this study. This would assist in determining if remedial actions were having the desired affect or as an early warning system to detect changes which may be having deleterious impacts on catchment health.

Many of the tasks, particularly related to fisheries and wetlands, require specialised skills and are best conducted by an appropriate agency such as QDPI. However, there are other valuable tasks such as water quality, habitat and invertebrate monitoring which community groups could perform. Indeed, WaterWatch groups are presently heavily involved in water quality monitoring in the catchment and it may be feasible to extend their skills to include habitat assessments and invertebrate sampling.

Habitat assessments would probably be best conducted at about five year intervals and include most, if not all, of the sites surveyed in this study. For maximum benefit, invertebrate sampling should be conducted at the sites surveyed in this study (except Kamerunga) at about quarterly intervals. This frequency should be sufficient to ensure seasonal variation does not impact on the results. Ideally, strategic invertebrate sampling should also be conducted over a range of flow events and habitat types to ascertain appropriate environmental flow regimes to assist with the objectives of the Water Allocation Management Plans.

MANAGEMENT ISSUES

The local community has a lot to offer in the development and implementation of catchment management strategies. Some management issues that should be considered by responsible government agencies, landholders and community groups to enhance the status of stream and fisheries habitat, wetlands and fisheries resources of the area are as follows:

Wetland Protection

The health and extent of the coastal wetlands directly relates to issues such as water quality and fisheries productivity. The integrity of the remaining coastal wetlands needs to be protected, nurtured and enhanced. This can be done, to a large extent, through the use of reserves and protected areas.

With the existing Fish Habitat Areas and the proposed Northern Beaches State Marine Park there would appear to be little scope for the declaration of further coastal wetland reserves with the possible exception of lower Stoney Creek. During this study, a number of fish species of conservation importance were sampled from the lower section of Stoney Creek and it is probably the only permanent coastal stream it the Barron catchment which is presently relatively undisturbed.

Other actions that could be considered include:

- Rehabilitation of degraded wetlands; and
- Public education on the importance of wetlands including their fisheries values.

While such actions are traditionally the responsibility of governments there is also scope for community involvement through distribution and promotion of educational material and on-ground rehabilitation works.

Water Quality

The community based WaterWatch program is an important tool in monitoring and management of water quality throughout the catchment. The program could have a valuable role to play in monitoring the performance of future rehabilitation programs.

Water quality problems related to the disturbance of acid sulphate soils in some parts of the delta need to be addressed. These issues include:

- Determining the extent of acid sulphate soils in the delta;
- Developing management strategies for existing sites including ways of minimising any potential environmental hazards; and
- Forming guidelines for future excavations in areas that have potential acid sulphate soils.

There was evidence of some high nutrient levels particularly in the upper part of the catchment and possible management strategies were outlined in Cogle *et al.* (2000). Specifically, they made recommendations on urban sediment and nutrient management practices to reduce loads flowing into watercourses.

Noxious Plant and Animal Pests

The spread of tilapia throughout the Barron catchment and the possibility of it becoming established in the Mitchell and Walsh River systems is of concern. The QDPI Community Consultative Committee on Exotic Fish was developing a regional management plan to address this issue.

The Barron River Integrated Catchment Management Association has a project that aims to control tilapia in the Tinaroo sub-catchment using habitat restoration, primarily through riparian revegetation. Government and/or the community need to monitor the success of this program to determine if riparian revegetation is an appropriate management tool for the control of this species.

The Barron River Integrated Catchment Management Association, the Kuranda Enviro-Centre and the Department of Primary Industries are working to raise public awareness of this issue through distribution of educational material and displays. The Cairns City Council has developed a management plan for Freshwater Creek that addresses many natural resource issues.

The wide spread establishment of noxious plant species in the catchment is of concern and could have serious consequences for the stream habitat, water quality and fisheries resources of the catchment. The Department of Natural Resources, the agency responsible for controlling the spread of noxious plant species in the catchment, are addressing this issue but community vigilance is needed in monitoring outbreaks.

Riparian and Instream Habitat Restoration

There is little doubt that in parts of the catchment, the riparian forest and instream habitat are degraded and are in urgent need of rehabilitation.

There is a need for more strategically targeted riparian restoration particularly in the Tinaroo and coastal sub-catchments. Some riparian revegetation was already underway with the Wet Tropics Tree Planting Scheme active in the delta while in the upper catchment, the Barron River Integrated Catchment Management Association, Kuranda EnviroCare Inc. and the Trees for the Evelyn and Atherton Tableland group were undertaking various tree planting projects.

Other activities that will enhance the quality of instream habitat and assist in riparian vegetation include:

- Fencing off waterways to restrict cattle access and establishment of off-stream watering points in grazing and dairying areas.
- Refining and better enforcing land clearing and earthworks practices for urban developments will assist in reducing erosion, sedimentation and nutrient outflow.
- Identification and remediation of areas where bank erosion or slumping was occurring on a regular basis. The lower reaches of Thomatis Creek were one example of where remedial action was needed.

Plate 1. Turbid water entering Freshwater Creek. Note para grass on creek banks.

Plate 2. Bank erosion on Thomatis Creek after the 1998/99 floods.

REFERENCES

Allen, G.R. (1989). 'Freshwater Fishes of Australia'. (T.F.H. Publications: Neptune City, New Jersey, USA). 240 pp.

Allen, G.R. (1991). 'Field guide to the Freshwater Fishes of New Guinea'. (Christensen Research Institute: Madang, Papua New Guinea). 268 pp.

Anon (1992). Sediment and aquatic habitat in river systems. *Journal of Hydraulic Engineering* **18(5)**, 669-687.

Australian and New Zealand Environment and Conservation Council (ANZECC). (1999). 'DRAFT Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality'. (ANZECC: Canberra).

Arthington, A. H., Milton, D. A. and McKay, R. J. (1983). Effects of urban development and habitat alterations on the distribution and abundance of native and exotic freshwater fish in the Brisbane region, Queensland. *Australian Journal of Ecology* **8**, 87-101.

Arthington, A.H., McKay, R.J. Russell, D.J., and Milton, D.A. (1984). Occurrence of the introduced cichlid (*Oreochromis mossambicus*) in Queensland. *Australian Journal of Marine and Freshwater Research* **35**, 267-72.

Arthington, A.H. and Lloyd, L.N. (1989). Introduced Poeciliids in Australia and New Zealand. In: 'Ecology and Evolution of Live bearing Fishes' (Eds. Meffe, G.K. and Snelson, F.F.) (Prentice Hall, N.J.) pp 333-348.

Barlow, C.G., Hogan, A.E. and Rodgers L.J. (1987). Implication of translocated fishes in the apparent extinction in the wild of Lake Eacham Rainbowfish, *Melanotaenia eachamensis*. *Australian Journal of Marine and Freshwater Research* **38**, 897-902.

Belbin L. (1992). PATN Technical Reference. Commonwealth Scientific and Industrial Research Organisation, Division of Wildlife and Ecology: Canberra, Australia.

Beschta, R.L. and Platts, W.S. (1986). Morphological features of small streams: significance and function. *Water Resources Bulletin* **22**, 369-379.

Beumer, J., Carseldine, L. and Zeller, B. (1997). 'Declared Fish Habitat Areas in Queensland'. Report No. QI 97004. (Queensland Department of Primary Industries: Brisbane).

Bilby, R.E. and Ward, J.W. (1989). Changes in Characteristics and Function of Woody Debris with Increasing Size of Streams in Western Washington. *Transactions of the. American Fisheries Society* **118**, 368-78.

Bunn, S.E., Edward, D.H. and Loneragan, N.R. (1986). Spatial and temporal variation in the macroinvertebrate fauna in streams of the northern jarrah forest, Western Australia: community structure. *Freshwater Biology* **16,** 67-91.

Bunn, S.E., Davies, P.M., and Kellaway, D.M. (1997). Contributions of sugar cane and invasive pasture grass to the aquatic food web of a tropical lowland stream. *Marine and Freshwater Research* **48**, 173-79.

Bunn, S.E., Davies, P.M., Kellaway, D.M. and Prosser, I.P. (1998). Influence of invasive macrophytes on channel morphology and hydrology in an open tropical lowland stream, and potential control by riparian shading. *Freshwater Biology* **39**, 171-78.

Bureau of Meteorology, Cairns Office. (1999). Climatological Summary for CAIRNS AERO using data from 1941 to 1999. (Commonwealth of Australia).

Carr, R. (1994). Background Report No 1: Growth Factors Analysis. In: 'FNQ 2010 Regional Planning Process. Regional Growth Management Framework – Background Reports'. (Far North Queensland Regional Planning Advisory Committee: Cairns).

Carter, R.M. (1994). Marine geoscience. In: 'Marine Biology' (Eds. Hammond, L.S. and Synnot, R.N.) (Longman Cheshire, Melbourne). pp 10-21.

Chessman B. (1995). Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* **20**, 41- 49.

Choy, S., Stowar, M. and Marshall, C. (1998). Summary Report on the Ecological Condition of Riverine Sites in the Barron River Catchment. Freshwater Biological Monitoring Report No. 8. (Department of Natural Resources).

Clewett, J.F., Smith, P.G., Partridge, I.J., George, D.A. and Peacock, A.(1999). 'Australian Rainman Version 3: An integrated software package of rainfall information for better management'. Report No. QI98071 (Department of Primary Industries Queensland).

Cogle, A.L., Gourley, J., Herbert, B. and Best. E. (1998). Nutrient control strategy for tropical catchments. Final NLP report. (Department of Natural Resources: Peters St. Mareeba).

Cogle, A.L., Langford, P.A., Kistle, S.E., Ryan, T.J., McDougall, A.E., Russell,D.J., Best, E. (2000). 'Natural Resources of the Barron River Catchment: 2. Water Quality, Land Use and Land Management Interactions'. Report No. QI00033 (Department of Primary Industries Queensland).

Coles, R.G., Lee Long, W.J., Watson, R.A. and Derbyshire, K.J. (1993). Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**, 193-210.

Cook, T., Cooper, J., and Barker, R. (1998). 'Population Projections for Queensland'. (Queensland Department of Communication and Information, Local Government and Planning: Brisbane).

Cummins, K.W., Wilzbach, M.A., Gates, D.M., Perry, J.B. and Taliaferro, W.B. (1989). Shredders and Riparian Vegetation. *Bioscience*. **39** (1), 24-30.

Davis, T.L.O. and Kirkwood, G.P. (1984). Age and Growth Studies on Barramundi, *Lates calcarifer* (Bloch), in Northern Australia. *Australian Journal of Marine and Freshwater Research* **35**, 673-89.

Day, R.W. and Quinn, G.P. (1989). Comparisons of treatments after an analysis of variance in ecology. *Ecological Monographs*. **59** (4), 433-463.

Department of Natural Resources (1999). 'Barron Basin Water Allocation and Management Plan' Draft Technical Report Number 4. Resource Management Program. (Department of Natural Resources: Brisbane).

Faith D. P., Minchin P. R. and Belbin L. (1987) Compositional dissimilarity as a robust measure of ecological distance. *Vegetation* **69**, 57-68.

Far North Queensland Regional Planning Advisory Committee (1995). 'Regional Growth Management Framework.' Technical Report for Far North Queensland Regional Planning Advisory Committee: Cairns.

Fisher, S.G. and Likens, G.E. (1972). Stream ecosystems: organic energy budget. *Bioscience* **22**, 33-35.

Gordon, N.D., McMahon, T.A. and Finlayson, B.L. (1992). Stream Hydrology: An introduction for ecologists. (John Wiley and Sons Ltd: Chichester).

Grant, E.M. (1982). 'Guide to Fishes'. (The Department of Harbours and Marine: Brisbane, Australia).

Hawking J. H. and Smith F. J. (1997). 'Colour guide to invertebrates of Australian inland water'. Identification Guide No. 8. (Co-operative Research Centre for Freshwater Ecology: Albury).

Helmke, S., Peverell, S. and Garrett, R. (in press). 'Fisheries Resources in Trinity Inlet, QLD'. (Queensland Department of Primary Industries: Cairns).

Herbert, B. and Peeters, J. (1995). 'Freshwater fishes of Far North Queensland' (Queensland Department of Primary Industries: Brisbane). 74 pp.

Herbert B., Cogle A.L., Gourley J., Wright, N. and Best, E. (1996). Water quality and land use impacts on Lake Tinaroo/Barron River III. Effect of water quality on the biota and biological indicators. In: 'Downstream effects and land use'. (Eds. Hunter, H.M., Eyles, A.G. and Rayment G.E.) Human Resources. (Department of Natural Resources: Queensland, Australia).

Hollingsworth, Dames and Moore (1993). Barron River Catchment Overview Study. 44pp. (Hollingsworth, Dames and Moore).

Hopkins, M.S., Graham, A.W. and Murtha, G.G. (1979). 'Vegetation of the Cowley Beach Area, Joint Tropical Trials Research Establishment, North Queensland'. Technical Memorandum 79/13, Division of Land Use Research, CSIRO. (CSIRO Division of Soils: Canberra). 79 pp.

Ivantsoff, W. and Aarn. (1999). Detection of predation on Australian native fishes by *Gambusia holbrooki*. *Marine and Freshwater Research* **50**, 467-8.

Kaufman, J.B. and Krueger, W.C. (1984). Livestock impacts on riparian ecosystems and streamside management implications: A review. *Journal of Rangelands Management* **37 (5)**, 430-7.

Le Cussan, J. (1991). 'A report on the intertidal vegetation of the Daintree, Endeavour and Russell/Mulgrave Rivers'. (Queensland National Parks and Wildlife Service Internal Report). 139pp.

MacKay, R.J. (1984). Introductions of exotic fishes in Australia. In: 'Distribution, Biology and Management of Exotic Fishes'. (Eds. W.J. Courtenay and J.R. Stanffer) (Johns Hopkins University Press). pp 177-199.

Mahoney, D.L. and Erman, D.C. (1981). The role of streamside bufferstrips in the ecology of aquatic biota. In: 'California Riparian Systems Ecology'. (University of California Press).

Marchant, R., Mitchell, P. and Norris, R. (1984). Distribution of benthic invertebrates along a disturbed section of the la Trobe River, Victoria: an analysis based on numerical classification. *Australian Journal Marine and Freshwater Research* **35**,355-374.

MacKinnon, M.R. and Herbert, B.W. (1996). Temperature, dissolved oxygen and stratification in a tropical reservoir, Lake Tinaroo, northern Queensland. *Australian Marine and Freshwater Research* **47**, 937-949.

Merrick, J.R. and Schmida, G.E. (1984). 'Australian Freshwater Fishes'. (Griffin Press, Adelaide.). 240pp.

Merritt R. W. and Cummins K. W. (1984). 'An introduction to aquatic insects of North America'. 2nd (Ed. Kendall/Hunt Publishing Co.:Dubuque, Iowa.).

Middleton, C.H. (1991). History of Para Grass in Queensland. In: 'Proceedings of the Probing Ponded Pastures Workshop' Rockhampton, 16-18 July 1991. (University of Central Queensland). pp. 27-30.

Mitchell, P. (1990). 'The Environmental Condition of Victorian Streams'. (Department of Water Resources: Victoria). 102 pp.

Mitchell, P. (1999). 'Mitta Mitta River Biological Monitoring Program (1987 to 1996)'. (Australian Water Technologies: Melbourne). 75pp.

Norris R. H., Lake P. S. and Swain R. (1982). Ecological effects of mine effluents on the South Esk River, north-eastern Tasmania. III. Benthic invertebrates. *Australian Journal Marine and Freshwater Research*. **33**, 789-809.

Neilson, L.A. and Johnson, D.L. (1983). 'Fisheries Techniques'. (American Fisheries Society: Bethesda, Maryland). 486 pp.

Netter, J. and Wasserman W. (1974). 'Applied linear statistical models'. (Richard D. Irwin: Homewood, Illinois, USA).

Petersen, R.C. (1992). The RCE: a riparian, channel, and environmental inventory for small streams in the agricultural landscape. *Freshwater Biology* **27**, 295-306.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K. and Hughes, R.M. (1989). 'Rapid Assessment Protocols for Use in Streams and Rivers: Benthic macroinvertebrates and fish'. (United States Environmental Protection Agency, Assessment and Watershed Protection Division, Washington, D.C.).

Pusey, B.J. and Kennard, M.J. (1994). 'The freshwater fish fauna of the Wet Tropics Region of northern Australia.' Report to the Wet Tropics Management Authority, 100pp.

Pusey, B.J., Arthington, A.H. and Read, M.G. (1995). Species richness and spatial variation in fish asemblage structure in two rivers of the wet tropics [World Heritage Area] of northern queensland, Australia. *Environmental Biology of Fishes* 42, 181-199.

Pusey, B.J. and Kennard, M.J. (1996). Species richness and geographical variation in assemblage structure of the freshwater fish fauna of the Wet Tropics region of northern Queensland. *Marine and Freshwater Research* **47**, 563-573.

Pusey, B.J., Bird, J., Kennard, M.J. and Arthington, A.H. (1997). Distribution of the Lake Eacham Rainbowfish in the Wet Tropics Region, North Queensland. *Australian Journal of Zoology* **45**, 75-84.

Queensland Fisheries Management Authority (1996). 'Queensland Freshwater Fisheries'. Discussion Paper No.4. (Queensland Fisheries Management Authority: Brisbane).

Queensland Parks and Wildlife Service. (1999). Davies Creek National Park – Draft Management Plan. Brisbane. (Queensland Parks and Wildlife Service: Cairns).

Robertson, A.I. and N.C. Duke (1990). Mangrove Fish Communities in Tropical Queensland, Australia: Spatial and temporal patterns in densities, biomass and community structure. *Marine Biology*. **104**, 369-79.

Russell, D.J. (1987). Aspects of the Limnology of Tropical Lakes in Queensland – with Notes on Their Suitability for Recreational Fisheries. *Proceedings of the Royal Society of Queensland.* **98,** 83-91.

Russell, D.J. (1988). 'An assessment of the East Queensland inshore gill net fishery'. Report No. QI88024. (Queensland Department of Primary Industries: Brisbane). 57 pp.

Russell, D.J. and Hales, P.W. (1993). 'Stream Habitat and Fisheries Resources of the Johnstone River Catchment'. Report No. QI93056. (Queensland Department of Primary Industries: Brisbane). 59 pp.

Russell, D.J., Hales, P.W. and Helmke, S.A. (1996a). 'Stream Habitat and Fish Resources in the Russell and Mulgrave Rivers Catchment'. Report No. QI96008. (Queensland Department of Primary Industries: Brisbane). 58 pp.

Russell, D.J., Hales, P.W. and Helmke, S.A. (1996b). 'Fish Resources and Stream Habitat of the Moresby River Catchment'. Report No. QI96061 (Queensland Department of Primary Industries: Brisbane). 50 pp.

Russell, D.J. and Hales, P.W. (1997). 'Fish Resources and Stream Habitat of the Liverpool, Maria and Hull Catchments' Report No. QI97039. (Queensland Department of Primary Industries: Brisbane). 67 pp.

Russell, D.J., Mc Dougall, A.J. and Kistle, S. E. (1998). 'Stream Habitat and Fish Resources of the Daintree, Saltwater, Mossman and Mowbray Catchments'. Report No.QI98062. (Queensland Department of Primary Industries: Brisbane). 72 pp.

Sawynok, B. (1998). Austag Sportfish Tagging Report 1997/98. (ANSA Ltd). 42pp.

Shipway, B. (1947a). Fresh water fishes of the Barron River. *North Queensland Naturalist*, **XIV (**83): 25-27.

Shipway, B. (1947b). Fresh water fishes of the Barron River. *North Queensland Naturalist*, **XV** (84): 5-7.

Shipway, B. (1947c). Fresh water fishes of the Barron River. *North Queensland Naturalist*, **XV** (85): 9-13**.**

Shipway, B. (1948). Fresh water fishes of the Barron River. *North Queensland Naturalist*, **XV** (86): 20-21.

Stanton, J.P. (1975). 'A preliminary assessment of wetlands in Queensland'. CSIRO Division of Land Research Technical Memorandum 75/10, 40p.

Staples, D.J. (1980). Ecology of juvenile and adolescent banana prawns, *Penaeus merguiensis* in a mangrove estuary and adjacent offshore area of the Gulf of Carpentaria 2. Emigration, population structure and growth of juveniles. *Australian Journal of Marine and Freshwater Research*, **31** (5), 653-665.

Townsend, C.R., Hildrew, A.G. and Francis, J. (1983). Community structure in some southern English streams: the influence of physicochemical factors. *Freshwater Biology,* **13,** 521-544.

Townsend C. R., Hildrew A. G. and Schofield K. (1987). Persistence of stream invertebrate communities in relation to environmental variability. *Journal of Animal Ecology,* **56**, 597-613.

Wager, R. (1993). 'The distribution and conservation status of Queensland freshwater fishes' Report No. QI93001 (Queensland Department of Primary Industries: Brisbane). 62 pp.

Watson, R.E. (1991). A provisional review of the genus, *Stenogobius,* with descriptions of a new subgenus and thirteen new species. (Pisces:Teleostei:Gobiidae*). Records of the Western Australian Museum 1991* **15**(3): 627-710.

Werren, G. (1997). Barron River Catchment Rehabilitation Plan – Technical Report on Rehabilitation Needs. NQ Joint Board, Cairns, North Queensland.

Williams W.D. (1980). 'Australian Freshwater Life: The invertebrates of Australian inland waters'. ISBN 0 333 298942. (MacMillan Press: Melbourne). 321pp.

APPENDIX A

Commercial fisheries catch and effort

Table 17. Catch and effort data for the prawn trawl fishery.

Data is for the fishery between Cape Grafton and below the Mowbray River in the grid 16°50´S to 17°0´S and 145°5'E to 146°0'E (1988 to 1999).

(Source: Queensland Fisheries Management Authority Cfish database)

Year	Fishing time (Days)	Catch (kg)
1988	3762	29575
1989	2781	74182
1990	2596	98153
1991	4570	27270
1992	1260	34859
1993	2781	33213
1994	3852	27854
1995	2875	57495
1996	4152	52617
1997	5246	29452
1998	3963	142583
Total	**38330**	**1231726**

Table 18. Catch (kg) per species data for the prawn trawl fishery.

Data is for the fishery between Cape Grafton and below the Mowbray River in the grid 16°50´S to 17°0´S and 145°5'E to 146°0'E (1988 to 1999).

(Source: Queensland Fisheries Management Authority Cfish database)

	Species by catch (kg)					
Year	*P.merguiensis*	*P. esculentus*	*M.endeavouri*	*P. latisulcatus*	*P. monodon*	*M.beneatte*
1988	15299	39091	26391	383	4028	0
1989	20292	31875	24375	220	724	0
1990	10101	42376	25297	976	2039	0
1991	35541	78183	60263	4356	2280	0
1992	2686	19689	14749	940	619	0
1993	14872	47974	30981	727	940	61
1994	18285	47662	47564	2616	1141	0
1995	8659	46499	41628	2754	1292	0
1996	12147	68194	43867	9402	622	0
1997	23777	70867	52598	10196	2337	0
1998	19763	69685	42941	7157	258	2779
Total	**183792**	**573667**	**414562**	**40585**	**16280**	**2840**

Fish tagged by recreational fishers

Table 19. Fish species tagged in the Barron River catchment

Species	Number tagged in this study	Number tagged by recreational fishers
Barramundi (*Lates calcarifer*)	192	54
Banded grunter (*Pomadasys kaakan*)		60
Bar-tailed flathead (*Platycephalus indicus*)		1
Bigeye trevally (*Caranx sexfasciatus*)		1
Black-spot estuary cod (*Ephinephelus chewa*)		1
Blue salmon (*Eleutheronema tetradactylum*)		5
Dusky flathead (*Platycephalus fuscus*)	3	9
Estuary cod (*Ephinephelus* sp.)		5
Fingermark (*Lutjanus johnii*)	1	33
Giant trevally (*Caranx ignobilus*)		29
Gold-spot estuary cod (*Ephinephelus tauvina*)		23
Golden trevally (*Gnathanodon speciosus*)		1
King salmon (*Polydactylus sheridani*)	2	4
Long-nose trevally (*Carangoides chrysophrys*)		3
Mangrove jack (*Lutjanus argentimaculatus*)	54	43
Pikey bream (*Acanthopagrus berda*)		78
Queenfish (*Scomberoides* sp.)		12
Silver jewfish (*Nibea soldado*)		21
Small-spotted grunter (*Pomadasys argenteus*)		51
Tarpon (*Megalops cyprinoides*)		10
Yellowfin bream (*Acanthopagrus australis*)		1
Total	**252**	**445**

APPENDIX B

Habitat assessment datasheet

SITE NO DATE AMG COORDS ZONE pH

STREAM NAME STREAM ORDER SITE LENGTH

AIR TEMP. WATER TEMP. % OXYGEN SAT. TURBID(NTU)

DISTURBANCE RATING

AQUATIC VEG. SPECIES

RIPARIAN VEGETATION

LEFT BANK		RIGHT BANK
	WIDTH	
	CONTINUITY	
	% TREES / SHRUBS	
	% GRASSES	
	% OTHER	
	% NO VEG	

COVER

	P	R
BANK COVER (m)		
OVERHANGING VEGETATION (m)		
AQUATIC MACROPHYTES (m^2)		
TOTAL NUMBER OF SNAGS		

SEDIMENTATION

INVASIVE GRASSES

SPECIES	
TOTAL LENGTH	
MAX. WIDTH	

STREAM STRUCTURE

POOLS/DEEP		RIFFLES / SHALLOW
	TOTAL LENGTH	
	MAX. DEPTH	
	AV. DEPTH	
	BANK FULL DEPTH	
	BANK FULL WIDTH	
	MAX. WIDTH	
	AV. WIDTH	
	BOULDER/COBBLE	
	COBBLE/GRAVEL	
	SAND	
	FINE MATERIAL	

COMMENTS

APPENDIX C

Index of disturbance ratings

1. Extreme disturbance

Valley flat: Crops or pasture on both sides, sparse or no riparian tree buffer on either side.

Banks/stream: Channellised; or weeds or grasses choking watercourse; or extensive trampling by cattle; or evidence of discharges; or stagnant water with significant decaying organics; and no canopy cover in small streams.

2. High disturbance

Valley flat: Crops or pasture on both sides but a limited riparian buffer of grasses, shrubs and some trees present on one or both sides. Trees less than 25% of total riparian vegetation.

Banks/stream: Exotic grasses or weeds extend into the channel; tree canopy shading only part of smaller creeks. Where there is adjacent pasture, cattle have unlimited access to the riparian zone.

3. Moderate disturbance

Valley flat: Agricultural land on one or both sides but limited riparian buffer of grasses, shrubs and some trees present on one side and treed riparian buffer on other side; or trees at least 25% - 50% of riparian vegetation.

Banks/stream: Banks well treed on at least one side providing adequate canopy; in smaller streams this may influence the other bank; exotic grasses and weeds may intrude into the stream; feral and domestic animals may damage stream bed and banks.

4. Low disturbance

Valley flat: Agricultural land present on one or both sides but functional treed riparian buffer of less than 30 m on both sides. Where pastures are present, they are fenced, preventing stock access to the stream.

Banks/stream: Exotic grasses limited to stream edge; banks well treed providing a substantial canopy for smaller streams; only occasional evidence of disturbances in the riparian zone by feral animals or cattle.

5. Undisturbed

Valley flat: Riparian vegetation undisturbed for at least 30 m on either side of bank; no evidence of disturbance by feral animals.

APPENDIX D

Habitat assessment explanatory notes

Riparian vegetation continuity

a. Without breaks in the native riparian vegetation

b. Breaks few, narrow, and less than 25% of total length

c. Many breaks, narrow and less than 50% of total bank length

d. Length of breaks exceed that of native riparian vegetation

Riparian composition

Tree/shrubs- All tree and shrub species

Grasses –All grasses including invasive and exotic species

Bare- Mimimum vegetation cover (<10%)

Other- Rocks, organic debris etc.

Stream structure

Sedimentation

a. No apparent unstabilised material in channel.

b. Traces of unstabilised silt, sand, or gravel in quiet areas.

c. Quiet areas covered by unstabilised materials, deep pools restricted to areas of greatest scour.

d. Pools shallow, filled with silt, sand or gravel; riffles contain noticeable silt deposits.

e. Streambed covered with varying degrees of transported material; substrates relatively uniform along stream length.

f. Stream channel nearly or completely filled with unconsolidated, transported material.

Substrate type

Boulder / cobble	> 25 mm in size
Cobble / gravel	2 - 25 mm
Sand	0.0625 - 2 mm
Fine material (Silt)	< 0.0625 mm

Flow types

Pools / deep areas	slow flowing, laminar flow, > 1 metre deep
Riffles / shallow areas	faster flow, rippled surface, < 1 metre deep

Instream cover

Bank cover	total length (left and right bank) of steep or undercut banks or root systems or rocks.
Overhanging vegetation	total length (left and right bank) of branches hanging in or just above the water surface.
Aquatic macrophytes	total area (m^2) of floating and submerged plants, filamentous algae and reeds.
Snags	total number of woody debris such as large branches and trees in the streambed.

APPENDIX E

Macroinvertebrate abundance data

Location	Date	Replicate	Aeshnidae	Amphipterygidae	Ancylidae	Annelida	Atriplectidae	Baetidae	Caenidae	Candonidae	Ceratopogonidae	Chironominae	Cirolanidae	Coenagrionidae	Colembola	Coleoptera	Copepoda	Corbiculidae	Corixidae	Corydalidae	Dapniidae	Dipseudopsidae	Dolichopodidae	Dugesiidae	Ecnomidae	Elmidae	Empididae	Gerridae	Glossosomatidae	Gomphidae	Gordiidae
Hemmings	17-Sep-97	1						7	12		2	36													1	40						
Hemmings	17-Sep-97	2						4	31		2	32												1			24						
Hemmings	17-Sep-97	3					4		32	8			18			1						2			1		1	139						
Hemmings	17-Sep-97	4						5	13			25							1							1	1	23					1
Hemmings	17-Sep-97	5					1		28	2			12													1	21						
Hemmings	05-Dec-97	1						10	1			7													10	96						
Hemmings	05-Dec-97	2						5	2		2	5						1							6	11						
Hemmings	05-Dec-97	3						4	20	1		2							2						3	23						
Hemmings	05-Dec-97	4					4		1	2			8						2								14						
Hemmings	31-Mar-98	1						25			1	5						13						2		119						
Hemmings	31-Mar-98	2						29				2						14									71				1	
Hemmings	31-Mar-98	3						75	27			6						6								9						
Hemmings	31-Mar-98	4					1		75	5			2						13					1		2	35						
Hemmings	27-Aug-98	1						32	6			11						10					1	2		38				1		
Hemmings	27-Aug-98	2					36		75	75			2						1						1		52	1		1	1	
Hemmings	27-Aug-98	3					13		34	2			11						4						3		26						
Hemmings	27-Aug-98	4						23	2		4	4						17						14		175						
Goonarra	17-Sep-97	1						15			1	17													1	63						
Goonarra	17-Sep-97	2						8	1			8														65						
Goonarra	17-Sep-97	3					1		21				10								1						1	47				1	
Goonarra	17-Sep-97	4					1		7			1	10														8						
Goonarra	17-Sep-97	5						17				9												1	2	63						
Goonarra	05-Dec-97	1	1					1	10			6													4	62						
Goonarra	05-Dec-97	2							7										1	47						2	36						
Goonarra	05-Dec-97	3						10	2	1							1							9			57						
Goonarra	05-Dec-97	4						5	1																2		49						
Goonarra	31-Mar-98	1					4		6	2														2			130						
Goonarra	31-Mar-98	2					2		19	1			6														101						
Goonarra	31-Mar-98	3						4											1								15						
Goonarra	31-Mar-98	4						9	2		1	5													1		23						
Goonarra	27-Aug-98	1						5											1						6		7				5		
Goonarra	27-Aug-98	2						9	1																2		64				2		
Goonarra	27-Aug-98	3						6																	8		9					1	
Goonarra	27-Aug-98	4						1																	7		33				16		
Picnic Crossing	17-Sep-97	1						10	1												3								41					1	
Picnic Crossing	17-Sep-97	2		1				6	4																	3	8						
Picnic Crossing	17-Sep-97	3						1	1										1									3	11						
Picnic Crossing	17-Sep-97	4						1	2											1							7	5				1		
Picnic Crossing	17-Sep-97	5						2				28							1							4	10				1		
Picnic Crossing	05-Dec-97	1																	1							4	9						
Picnic Crossing	05-Dec-97	2																										1	1						
Picnic Crossing	05-Dec-97	3						2	1	5															13	5						
Picnic Crossing	05-Dec-97	4								1			1					1	4		4				6							
Picnic Crossing	31-Mar-98	1						1																		1						
Picnic Crossing	31-Mar-98	2						4																		6						
Picnic Crossing	31-Mar-98	3																											1						
Picnic Crossing	31-Mar-98	4						8	3	1																2						
Picnic Crossing	27-Aug-98	1			1	11		4	3	17																3						
Picnic Crossing	27-Aug-98	2						3	4	1						2				1						4		46						
Picnic Crossing	27-Aug-98	3					3				9		58								1						1	10					1
Picnic Crossing	27-Aug-98	4			2					7	13		89						4	8								1	26					1
Henry Hannan	17-Sep-97	1						4			1	6														64						
Henry Hannan	17-Sep-97	2						21	2																		12					5	
Henry Hannan	17-Sep-97	3						5	4			6						1	2								82						
Henry Hannan	17-Sep-97	4						6	2									1	1						3	2	17						
Henry Hannan	17-Sep-97	5						6	1			2							4								6					1	
Henry Hannan	08-Dec-97	1		3				33	2										1								21					2	
Henry Hannan	08-Dec-97	2						29	2										1						5		21						
Henry Hannan	08-Dec-97	3		1			1	24	9	12										4								17						
Henry Hannan	08-Dec-97	4						3												1														
Henry Hannan	30-Mar-98	1		2				9	5			2												1		7						
Henry Hannan	30-Mar-98	2		1				18							1				1								10						
Henry Hannan	30-Mar-98	3		8				37	6													4						10					2	
Henry Hannan	30-Mar-98	4						14	9	1		4														123						

Location	Date	Replicate	Aeshnidae	Amphipterygidae	Ancylidae	Annelida	Atriplectidae	Baetidae	Caenidae	Candonidae	Ceratopogonidae	Chironominae	Cirolanidae	Coenagrionidae	Colembola	Coleoptera	Copepoda	Corbiculidae	Corixidae	Corydalidae	Dapniidae	Dipseudopsidae	Dolichopodidae	Dugesiidae	Ecnomidae	Elmidae	Empididae	Gerridae	Glossosomatidae	Gomphidae	Gordiidae
Emerald	18-Sep-97	1						75										1	75							21					
Emerald	18-Sep-97	2						75										1								23				2	
Emerald	18-Sep-97	3						45			2	2													1	25				1	
Emerald	18-Sep-97	4						108																	2	12					
Emerald	18-Sep-97	5						25	1		1							1								20					
Emerald	08-Dec-97	1						7	16	3								2							6	33					
Emerald	08-Dec-97	2						1	9										19							8					
Emerald	08-Dec-97	3							7										24				1			3					
Emerald	08-Dec-97	4						5				5							75							22				1	
Emerald	31-Mar-98	1						10				1						1								16					
Emerald	31-Mar-98	2						11	3		4	9						3								29					
Emerald	31-Mar-98	3						27	6		1	5													1	31					
Emerald	31-Mar-98	4						76	2			5						6								66					
Emerald	28-Aug-98	1						75	75			1						4						1	2	57				2	
Emerald	28-Aug-98	2						75	49		2	4						5								65				2	
Emerald	28-Aug-98	3						75	19		1							9						1		29			2	2	
Emerald	28-Aug-98	4						75	75		2	5						6		1						58				2	
Bilwon	18-Sep-97	1						77																1		41				1	
Bilwon	18-Sep-97	2						75		2	8													9		18				2	
Bilwon	18-Sep-97	4						75	2		12	9														42				3	
Bilwon	18-Sep-97	5						75			5	16						1								36				7	
Bilwon	04-Dec-97	1						11	11	2	1	7							1							12					
Bilwon	04-Dec-97	2						4	14	3									18			1				2				3	
Bilwon	04-Dec-97	3						5	8																	20				1	
Bilwon	04-Dec-97	4						18	1										1							7				1	
Bilwon	30-Mar-98	1										2														44					
Bilwon	30-Mar-98	2						3	1			2												1		45					
Bilwon	30-Mar-98	3																								12					
Bilwon	30-Mar-98	4						1	1		2	2														42				3	
Bilwon	28-Aug-98	1						20	6			7																		1	
Bilwon	28-Aug-98	2						9	8	8	3	3						1	1							3				2	
Bilwon	28-Aug-98	3						48	1		1	2														41				1	
Bilwon	28-Aug-98	4						23	1	1	3															22			1	1	
Koah	18-Sep-97	1						75	79																	55		1			
Koah	18-Sep-97	2						75	12									27	2						1	114					
Koah	18-Sep-97	3						75	42																	75					
Koah	18-Sep-97	4						30	35										2						2	65					
Koah	18-Sep-97	5						24	20			5						1								9				3	
Koah	08-Dec-97	1						27	75									2								45				1	
Koah	08-Dec-97	2						8	1									1								49					
Koah	08-Dec-97	3						28	8	1								17							2	63					
Koah	08-Dec-97	4						75	32	7		3						18						3		53					
Koah	01-Apr-98	1						16	25		1	19														47				5	
Koah	01-Apr-98	2						21	6		2	20														83					
Koah	01-Apr-98	3						30	11		2	11														113				1	
Koah	01-Apr-98	4						27	3		1	11													1	127					
Koah	25-Aug-98	1						75	12		4	1						6								149					
Koah	25-Aug-98	2						75	75		10	1														118				1	
Koah	25-Aug-98	3						75	26		3							4								81					
Koah	25-Aug-98	4						75	40		2															137				1	
Myola	18-Sep-97	1							2			7						2							5	1					
Myola	18-Sep-97	2																7								31					
Myola	18-Sep-97	3						2	20			7						1								6					
Myola	18-Sep-97	4						18	34		1	2						1						1	11	32					
Myola	18-Sep-97	5						4	5	1		2						7							4	16					
Myola	12-Dec-97	1						2	30	62								6	1							26					
Myola	12-Dec-97	2						1		24		1							2					1	1	9					
Myola	12-Dec-97	3							8	22								7	1						6	16					
Myola	12-Dec-97	4						2	3	16		1						1							1	5					
Myola	01-Apr-98	1						75	48		1	15													2	45					
Myola	01-Apr-98	2						75	75		1							3								103					
Myola	01-Apr-98	3						11	75			16													3	59					
Myola	01-Apr-98	4						19	75			13						1							3	32				1	
Myola	26-Aug-98	1						23	45		5	33						1						1	14	40					

APPENDIX F

Fishes of the Barron River Estuary and sub-catchments

Family	Species Name	Common Name						
Anguillidae	*Anguilla obscura*	Short-finned eel						
Anguillidae	*Anguilla reinhardtii*	Long-finned eel						
Apogonidae	*Apogon hyalosoma*	Mangrove cardinalfish						
Apogonidae	*Glossamia aprion*	Mouth almighty						
Ariidae	*Arius graeffei*	Lesser salmon catfish						
Ariidae	*Arius macrocephalus*	Flathead catfish						
Atherinidae	*Atherinomorus eendrachtensis*	Hardyhead						
Atherinidae	*Atherinomorus lacunosus*	Slender hardyhead						
Atherinidae	*Atherinomorus ogilbyi*	Hardyhead						
Atherinidae	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead						
Bathysauridae	*Saurida undosquamis*	Grinner						
Batrachoididae	*Halophyrne diemensis*	Banded frogfish						
Belonidae	*Tylosurus crocodilus*	Crocodile long tom						
Belonidae	*Tylosurus gavialoides*	Long tom						
Belonidae	*Tylosurus strongylura strongylura*	Black-spot long tom						
Bothidae	*Pseudorhombus arsius*	Large-toothed founder						
Bothidae	*Pseudorhombus sp.*	Flounder						
Callionymidae	*Callionymus cf. macdonaldi*	Grey-spotted dragonet						
Callionymidae	*Callionymus sp.*	Dragonet						
Carangidae	*Caranx sexfasciatus*	Great/Bigeye trevally						
Carangidae	*Caranx heberi*	Papuan trevally						
Carangidae	*Caranx ignobilis*	Lowly trevally						
Carangidae	*Scomberoides commersonnianus*	Queenfish/giant leatherskin						
Carangidae	*Scomberoides lysan*	Skinny queenfish						
Carangidae	*Scomberoides tala*	Deep leatherskin queenfish						
Carangidae	*Scomberoides tol*	Slender leatherskin queenfish						
Carangidae	*Trachinotus blochii*	Sub-nosed dart						
Carcharhinidae	*Carcharhinus leucus*	Bullshark						
Carcharhinidae	*Carcharhinus melanopterus*	Black tip reef shark						
Carcharhinidae	*Rhizoprionodon actus*	Milkshark						
Centropomidae	*Lates calcarifer*	Barramundi						
Chaetodontidae	*Selenotoca multifasciata*	Northern butterfish						
Chandidae	*Ambassis agassizi*	Agassiz's glass perchlet						
Chandidae	*Ambassis agrammus*	Sailfin glass perchlet						
Chandidae	*Ambassis cf. agrammus*	Glass perchlet						
Chandidae	*Ambassis gymnocephalus*	Glass perchlet						
Chandidae	*Ambassis interrupta*	Long-spined glass perchlet						
Chandidae	*Ambassis macleayi*	Macleay's glass perchlet						
Chandidae	*Ambassis miops*	Flag-tailed glass perchlet						
Chandidae	*Ambassis nalua*	Glass perchlet						
Chandidae	*Ambassis vachellii*	Vachelli's glass perchlet						
Chanidae	*Chanos chanos*	Milkfish						
Chirocentridae	*Chirocentrus dorab*	Wolf herring						
Cichlidae	*Oreochromis mossambicus*	Tilapia (mossambique)						

Family	Species Name	Common Name						
Cichlidae	*Tilapia mariae*	Tilapia						
Clupeidae	*Anodontostoma chacunda*	Bony bream (estuarine)						
Clupeidae	*Dussumieria elopsoides*	Slender rainbow sardine						
Clupeidae	*Escualosa thoracata*	White sardine						
Clupeidae	*Herklotsichthys castelnaui*	Herring						
Clupeidae	*Herklotsichthys koningsbergeri*	Herring						
Clupeidae	*Herklotsichthys quadrimaculatus*	Bluestripe herring						
Clupeidae	*Nematalosa come*	Saltwater bony bream						
Clupeidae	*Nematalosa erebi*	Freshwater bony bream						
Clupeidae	*Sardinella melanura*	Blacktip sardinella						
Congrogadidae	*Congrogadidae sp.*	Eel like blenny						
Cynoglossidae	*Cynoglossus bilineatus*	Two-lined tongue sole						
Cynoglossidae	*Cynoglossus macropthalamus*	Long-nosed tongue sole						
Cynoglossidae	*Cynoglossus maculipinnis*	Tongue sole						
Cynoglossidae	*Cynoglossus sp.*	Sole						
Cynoglossidae	*Paraplagusia bilineata*	Double lined tongue sole						
Cynoglossidae	*Paraplagusia guttata*	Spotted tongue sole						
Dasyatididae	*Himantura granulata*	Mangrove ray						
Dasyatididae	*Himantura uarnak*	Long-tailed ray						
Dasyatididae	*Pastinachus sephen*	Cow-tail ray						
Eleotrididae	*Eleotris fusca*	Brown gudgeon						
Eleotrididae	*Hypseleotris compressa*	Empire gudgeon						
Eleotrididae	*Hypseleotris galii*	Firetail gudgeon						
Eleotrididae	*Mogurnda adspersa*	Purple-spotted gudgeon						
Eleotrididae	*Mogurnda cf. mogurnda*	Gudgeon						
Eleotrididae	*Ophieleotris aporos*	Snake-headed gudgeon						
Eleotrididae	*Oxyeleotris gyrinoides*	Eastern sleepy cod/gauvina						
Eleotrididae	*Oxyeleotris lineolatus*	Sleepy cod						
Eleotrididae	*Oxyeleotris selhemi*	Striped sleepy cod						
Elopidae	*Elops australis*	Giant herring						
Engraulidae	*Stolephorus cf. commersonii*	Anchovy						
Engraulidae	*Stolephorus commersonii*	Commerson's anchovy						
Engraulidae	*Stolephorus indicus*	Indian anchovy						
Engraulidae	*Stolephorus sp.*	Anchovy						
Engraulidae	*Stolephorus waitei*	Spot faced anchovy						
Engraulidae	*Thryssa hamiltonii*	Hamilton's anchovy						
Engraulidae	*Thryssa sp.*	Anchovy						
Ephippidae	*Drepane punctata*	Sicklefish						
Gerreidae	*Gerres abbreviatus*	Short silver-belly						
Gerreidae	*Gerres filamentosus*	Spotted silver-belly						
Gerreidae	*Gerres macrosoma*	Silver-belly						
Gerreidae	*Gerres oyena*	Silver-belly						
Gobiidae	*Acentrogobius balteatus*	Estuarine goby						
Gobiidae	*Acentrogobius caninus*	Estuarine goby						
Gobiidae	*Acentrogobius sp.*	Estuarine goby						
Gobiidae	*Apocryptodon madurensis*	Goby						
Gobiidae	*Awaous crassilabrus*	Roman-nosed goby						
Gobiidae	*Bathygobius sp.*	Goby						
Gobiidae	*Drombus gobiceps*	Goby						
Gobiidae	*Drombus sp.*	Goby						
Gobiidae	*Exyrias puntang*	Goby						

Family	Species Name	Common Name						
Gobiidae	*Favonigobius sp.*	Goby						
Gobiidae	*Glossogobius biocellatus*	Mangrove goby						
Gobiidae	*Glossogobius celebius*	Celebes goby						
Gobiidae	*Glossogobius circumpectus*	Goby						
Gobiidae	*Glossogobius giurus*	Flathead goby						
Gobiidae	*Illana bicirrhosa*	Goby						
Gobiidae	*Oxyurichthys sp.*	Goby						
Gobiidae	*Prionobutis wardi*	Goby						
Gobiidae	*Redigobius bikolanus*	Speckled goby						
Gobiidae	*Schismatogobius sp.*	Redneck goby						
Gobiidae	*Sicyopterus sp.*	Goby						
Gobiidae	*Stenogobius sp.*	Goby						
Gobiidae	*Taenoides sp.*	Estuarine goby						
Gobiidae	*Yongeichthys nebulosus*	Estuarine goby						
Haemulidae	*Plectorhinchus gibbosus*	Brown morwong/Sweetlip						
Haemulidae	*Pomadasys argenteus*	Small-spotted grunter						
Haemulidae	*Pomadasys kaakan*	Large-banded / Golden grunter						
Haemulidae	*Pomadasys maculatus*	Bloched grunter						
Hemiramphidae	*Arrhamphus sclerolepis*	Snub-nosed garfish						
Hemiramphidae	*Hyporhamphus dussumeri*	Dussumier's garfish						
Hemiramphidae	*Hyporhamphus neglectissimus*	Eastern river garfish						
Hemiramphidae	*Hyporhamphus quoyi*	Short-nosed garfish						
Hemiramphidae	*Zenarchopterus buffonis*	Buffon's garfish						
Kuhliidae	*Kuhlia rupestris*	Jungle perch						
Lactariidae	*Lactarius lactarius*	False trevally						
Leiognathidae	*Gazza minuta*	Common-toothed ponyfish						
Leiognathidae	*Leiognathus decorus*	Ponyfish						
Leiognathidae	*Leiognathus equulus*	Common ponyfish						
Leiognathidae	*Leiognathus fasciatus*	Thread-finned ponyfish						
Leiognathidae	*Leiognathus smithursti*	Ponyfish						
Leiognathidae	*Leiognathus sp. (juv)*	Ponyfish						
Leiognathidae	*Leiognathus splendens*	Black-tipped ponyfish						
Leiognathidae	*Secutor ruconius*	Pig-nosed ponyfish						
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack						
Lutjanidae	*Lutjanus johnii*	Fingermark						
Lutjanidae	*Lutjanus russelli*	Moses perch						
Lutjanidae	*Plectorhynchus gibbosus*	Blubber-lip bream						
Megalopidae	*Megalops cyprinoides*	Tarpon						
Melanotaenidae	*Melanotaenia s. splendida*	Eastern rainbowfish						
Monodactylidae	*Monodactylus argenteus*	Diamond-fish / Butterfish						
Mugilidae	*Liza melinoptera*	Large scaled mullet						
Mugilidae	*Liza ramsayi*	Ramsay's mullet						
Mugilidae	*Liza subviridis*	Greenback mullet						
Mugilidae	*Liza vaigiensis*	Diamond-scaled mullet						
Mugilidae	*Mugil cephalus*	Sea mullet						
Mugilidae	*Valamugil buchanani*	Buchanan's mullet						
Mugilidae	*Valamugil cunnesius*	Long-finned mullet						
Mullidae	*Mulloidichthys auriflamma*	Gold-stripped goatfish						
Mullidae	*Upeneus sulphureus*	Yellow goatfish						
Muraenesocidae	*Muraenesox bagio*	Pike eel						
Platycephalidae	*Platycephalidae sp. (juv)*	Flathead						

Family	Species Name	Common Name
Platycephalidae	*Platycephalus fuscus*	Dusky flathead
Platycephalidae	*Platycephalus indicus*	Bartail flathead
Plotosidae	*Neosilurus ater*	Narrow-fronted catfish
Plotosidae	*Neosilurus hyrtlii*	Hyrtlii's catfish
Plotosidae	*Porochilus rendahli*	Rendahl's catfish
Plotosidae	*Tandanus tandanus*	Eel-tailed catfish
Poeciliidae	*Gambussia holbrooki*	Mosquito fish
Poeciliidae	*Poecilia reticulata*	Guppy
Poeciliidae	*Xiphophorus maculatus*	Swordtail
Polynemidae	*Eleutheronema tetradactylum*	Blue/threadfin salmon
Polynemidae	*Polydactylus multiradiatus*	Flat/threadfin salmon
Polynemidae	*Polydactylus sheridani*	King/threadfin salmon
Psettodidae	*Psettodes erumei*	Flatfish
Pseudomugilidae	*Pseudomugil gertrudae*	Gertrude's blue-eye
Pseudomugilidae	*Pseudomugil signifer*	Pacific blue-eye
Rhinobatidae	*Rhinobatos typus*	Common shovelnose ray
Rhinopteridae	*Rhinoptera neglecta*	Australian cownose
Scatophagidae	*Scatophagus argus*	Spotted scat
Sciaenidae	*Nibea soldado*	Silver jewfish
Scombridae	*Rastrelliger cf. faughni*	Mackeral
Scombridae	*Scomberomorus commerson*	Narrow-Banded spanish
Scorpaenidae	*Notesthes robusta*	Bullrout
Scorpaenidae	*Paracentropogon vespa*	Flecked waspfish
Serranidae	*Centrogenys vaigiensis*	False scorpionfish
Serranidae	*Epinephelus cf. malabaricus*	Cod
Siganidae	*Siganus lineatus*	Golden-lined spinefoot
Siganidae	*Siganus oramin*	Spinefoot
Siganidae	*Siganus sp. (juv)*	Spinefoot
Siganidae	*Siganus vermiculatus*	Scribbled spinefoot
Sillaginidae	*Sillago analis*	Golden-lined whiting
Sillaginidae	*Sillago ciliata*	Sand whiting
Sillaginidae	*Sillago maculata*	Winter whiting
Sillaginidae	*Sillago sihama*	Northern whiting
Sillaginidae	*Sillago sp.*	Whiting
Soleidae	*Dexillus muelleri*	Tufted sole
Soleidae	*Pardachirus marmoratus*	Finless sole
Soleidae	*Pardachirus sp.*	Sole
Soleidae	*Soleidae sp.*	Sole
Sparidae	*Acanthopagrus berda*	Pikey bream
Sphyraenidae	*Agrioposphyraena barracuda*	Barracuda
Sphyraenidae	*Sphyraena jello*	Slender barracuda
Sphyraenidae	*Sphyranella flavicuda*	Long-jawed sea pike
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead shark
Synbranchidae	*Ophisternon cf. bengalense*	Swamp eel
Synbranchidae	*Ophisternon gutturale*	Swamp eel
Synbranchidae	*Opisternon sp.*	Swamp eel
Syngnathidae	*Syngnathidae sp.*	Pipefish
Synodontidae	*Trachinocephalus myops*	Painted grinner
Teraponidae	*Amniataba percoides*	Banded/Barred grunter
Teraponidae	*Hephaestus fuliginosus*	Sooty grunter/black bream
Teraponidae	*Hephaestus sp.*	Grunter

Family	Species Name	Common Name						
Teraponidae	*Leiopotherapon unicolor*	Spangled perch						
Teraponidae	*Mesopristes argenteus*	Silver trumpeter / Silver grunter						
Teraponidae	*Pelates quadrilineatus*	Trumpeter (4-lined)						
Tetraodontidae	*Arothron hispidus*	Stars and stripes toadfish						
Tetraodontidae	*Arothron immaculatus*	Narrow-lined toadfish						
Tetraodontidae	*Chelonodon patoca*	Milk-spotted toadfish						
Tetraodontidae	*Marilyna pleurosticta*	Toadfish						
Tetraodontidae	*Sphaeroides hamiltoni*	Hamiltons toado						
Tetraodontidae	*Torquigener pleurostictus*	Banded toado						
Toxotidae	*Toxotes chatareus*	Acherfish						
Toxotidae	*Toxotes jaculatrix*	Archerfish						
Triacanthidae	*Tripodichthys angustifrons*	Yellow-fin tripod fish						
Trichiuridae	*Trichiurus haumela*	Hairtail						