Department of **Employment, Economic Development and Innovation**

Fisheries Resources of the Bohle River

Queensland

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Cairns

Queensland Government

Note: This document includes previously unpublished information compiled in 1999 and some information here may be outdated. Care should be exercised in extrapolating information contained within this document to the present status of fisheries resources including fish habitats. Publication of this document is intended to provide public access to a base line study of the Bohle River for potential comparative work. The Queensland Department of Primary Industries referred to in this document has been renamed and now falls under the umbrella of the Department of Employment, Economic Development and Innovation.

Other related reports include:

Helmke, *et al.* 2000. Fisheries resources of Trinity Inlet, Queensland. Queensland Department of Primary Industries Information Series, QI01093, Cairns. 94 pp.

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Table of Acronyms

ANZECC	Australian and New Zealand Environment and conservation council
CFISH	Commercial Fisheries Information System. Database of commercial fishery and charter tour fishers landings recorded from daily logbooks managed by DEEDI.
CPUE	Catch per unit effort
CW	Carapace width
DEEDI	Department of Employment, Economic Development and Innovation
DPA	Dugong Protection Area
DPI	Department of Primary Industries, Queensland (now Fisheries Queensland, a service of Department of Employment, Economic Development and Innovation)
EPA	Environmental Protection Authority (now part of Department of Environment and Resource Management)
FHA	Fish Habitat Area
FL	Fork length of a fish
GVP	Gross Value of Production
IUCN	International Union for the Conservation of Nature and Natural Resources
QBFP	Queensland Boating and Fisheries Patrol
QCFO	Queensland Commercial Fishermen Organisation (now Queensland Seafood Industry Association)
QDoT	Queensland Department of Transport and Main Roads
QFMA	Queensland Fisheries Management Authority. The QFMA was disbanded in 2000 and its functions are now incorporated within the Department of Employment, Economic Development and Innovation
RFISH	Recreational Fisheries Information System. Database of recreational fishers landings recorded from trip diaries managed by Fisheries Queensland, a service of DEEDI.
TL	Total length of a fish
TTSP	Townsville and Thuringowa Strategy Plan
ZAC	Zonal Advisory Committee

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Summary

The fisheries resources of the Bohle River and its small catchment area adjacent Townsville, north Queensland, were investigated through available literature, scientific research surveys and analysis of commercial and recreational catch and effort data.

Available literature and historic information on this catchment was limited. The Townsville and Thuringowa Strategic Plan (TTSP 1996b) provides the majority of understanding and contains several warnings regarding the current state and future use of the Bohle River catchment. Particularly with regard to noxious weeds, loss of riparian vegetation and pollution input from industrial and urban centres in the upper catchment during flood events.

Research surveys produced a total of 4383 fish from the waters of the Bohle River during 1997-1998. These were classified into 104 fish species from 49 families. Gillnetting, cast netting, fish trapping and crab potting techniques were used in the estuarine waters of the Bohle River with freshwater reaches in the upper catchment surveyed by electrofishing. This range of survey techniques was used to estimate the relative abundance of ten commercially and recreationally important species: Barramundi (*Lates calcarifer*), king threadfin (*Polydactylus macrochir*), blue threadfin (*Eleutheronema tetradactylum*), mangrove jack (*Lutjanus argentimaculatus*), banded and spotted grunter (*Pomadasys kaakan* and *Pomadasys argenteus*), pikey and yellowfin bream (*Acanthopagrus berda* and *Acanthopagrus australis*), tilapia (*Oreochromis* spp.), jungle perch (*Kuhlia rupestris*) and mud crab (*Scylla serrata*). The results of each survey method are discussed with a focus on spatial and temporal patterns in diversity and catch rate.

From the estuarine waters of the Bohle River a total of 3849 fish were caught during the survey program. These were classified into 94 fish species from 46 families. Overall species diversity (H) was high, H = 2.99, while species evenness (J) was low, J = 0.66. Low species evenness suggests a few species are well represented in the catches while many species are poorly represented. This is typical of tropical estuarine communities. Compared with other tropical estuaries, diversity in the Bohle River appears low. However, studies that have produced higher diversities have used different sampling methods targeting smaller fish and aimed at determining use of mangrove lined estuaries by juvenile fish as a nursery ground (e.g. Blaber *et al.*1985, Robertson and Duke 1990). The top ten species or species groups caught in the estuarine portion of the Bohle River included baitfish, catfish, estuary cod and three target species namely mud crabs, barramundi and bream. The average, minimum and maximum size for all species is reported. The majority of species occurred in the size range of 10–40 cm, with the exception of barramundi which ranged from 25 – 90 cm.

Six hundred and twenty-six individuals from the target fish species were captured with 485 fish tagged and released. Several recaptures were reported and are discussed. Also, 757 mud crabs were caught with 697 tagged and released resulting in 88 recaptures. All target species were caught in the Bohle River system except jungle perch, however, mangrove jack, yellowfin bream and small-spotted grunter made up only a small proportion of the catch. Barramundi were well represented in the catches with pikey bream, king threadfin and blue threadfin also caught in reasonable numbers.

Mud crabs catches displayed a sex ratio skewed toward males of 1.23:1 with very few males above the legal size being captured. Female crabs catches displayed a bimodal size class distribution and this is discussed. There were few differences in size and numbers of crabs caught each month or at each survey site with the exception of May 1998 when larger crabs were caught. The overall catch rate of mud crabs was 0.59 crabs per pot lift with the catch rate of legal crabs being lower than that recorded for Trinity Inlet (Cairns region) and Murray and St. Helens creeks (Mackay region) also surveyed by this project team. Recaptured tagged mud crabs displayed three

different movement patterns, site fidelity (< 1.5 km), mobile crabs, (1.5–7.0 km) and large migratory movements out of the estuary system altogether. Growth rates for recaptured mud crabs varied from 0.11–0.79 mm per day. The rate of movement of recaptured mud crabs varied considerably and reached a maximum of 4.429 km per day.

Five hundred and twenty seven fish from at least 15 species were captured during electrofishing surveys of the freshwater reaches of the catchment. Empire gudgeon and tilapia were the numerically dominant species with few rare species being recorded. Low diversity in the freshwater may be representative of semi-dry to dry tropical streams or may be due to water quality parametres being poorly suited to electrofishing techniques. Three exotic species were encountered, tilapia (*Oreochromis* / *Tilapia* spp.), guppy's (*Poecilia reticulata*) and mosquito fish (*Gambusia affinis*) raising concerns about the health of fish communities in the catchment. The only commercially or recreationally important species captured was barramundi . One specimen was caught although several were seen avoiding sampling gear.

Water quality parametres in estuarine waters of the Bohle River showed great variation through the year as would be expected in an estuarine environment. However, both in the upper and lower freshwater reaches of the catchment the levels of dissolved oxygen were low and conductivity was high indicating average-to-poor water quality.

Commercial fishing of estuarine species in the Bohle River area (Commercial Fisheries Information System (CFISH) Grid J21) is mainly gillnets and crab pot fishing. This fishing was assessed using the 'Mixed' and 'Net / Crab' data within the CFISH database. Data from 1990-1998 was assessed with reef fish species data, beam trawl fishery data, line fishery data and landings from gillnets longer than 600 metres excluded to allow a focus on estuarine species. Gross Value of Production in this area was $4.5 million over the 9 years including more than half a million dollars of seafood landed in 1998. Landings varied between 66 tonnes in 1992 and 142 tonnes in 1997, averaging 92 tonnes for the period 1990-1998. The most important estuarine species were barramundi, blue threadfin and mullet by dollar value and mullet, blue threadfin and barramundi by weight. Landings of the project's target species (see above) are each discussed.

Effort in the commercial fishery has been steadily decreasing and there is a general increase in CPUE since 1992. An increase in effort in the later part of 1997 was observed and is probably in response to the proposed Dugong Protection Area (DPA) closures announced in June 1997. Although blue threadfin and grunter landings declined between 1997 and 1998, overall landings (tonnes) for that year do not seemed to have been dramatically affected by the introduction of DPAs. This needs to be carefully assessed in the future with respect to the potential loss of fisheries production.

Commercial effort in the mud crab fishery has been increasing since 1993 with 1998 and 1999 recording peak landings for the 1990–1999 period. The average Gross Value of Production for the crab fishery was $16 000 with a jump to $40 000 recorded in 1998.

The little available information on recreational fishing indicates grunter, bream, barramundi, mud crabs and gold-spot cod, whiting, trevally, queenfish and mangrove jack are all important recreational fishing species. A high release rate of unwanted fish and involvement in voluntary fish tagging projects indicates a high number of enthusiastic and conscientious local recreational fishers. Movement and growth of tagged and recaptured fish are discussed.

Although not quantified high fishing pressure on the system was observed with some commercial and many recreational fishers fishing the area. The healthy catch rates of commercial fishers, research surveys and recreational fishers indicates a healthy fishery, however, upper catchment use and management may severely reduce the value of this fishery resource in the near future if rehabilitation is not undertaken.

Advice for managers:

- The upper catchment management of the Bohle River should be the primary focus with respect to improving habitat and water quality. This will provide a more natural catchment ecosystem that will reduce the impact of pest fish and plant species and support a more productive estuarine and freshwater system.
- This project can only provide a small snapshot of the fish populations in the Bohle River, however, low catch rates of blue threadfin, king threadfin and grunter may be an indication of significant problems and should be considered when planning management strategies for this region.
- More information is required on recreational catch and effort in the area and some effort should be directed to ward collecting catch and effort data on local indigenous fishing.
- Detailed geographical information on commercial landings (6 minute grids) would allow a catchment by catchment assessment of fisheries resources for more informed specific regional management.

Introduction

A thorough understanding of the dynamics of a renewable wild-stock resource, especially in relation to exploitation, is essential for managing resources in a sustainable manner. Our understanding of fish stocks in Queensland's coastal streams remained largely inadequate for sound management decision making until recently. Past assessments of fish stocks in Queensland's estuaries and coastal streams have usually been limited studies, fragmentary in geographic coverage, usually of short duration, and in some cases only focused on commercial fishery catches. This lack of information is of special concern for coastal streams in tropical north Queensland, where tourism and coastal development has placed pressure on fisheries resources.

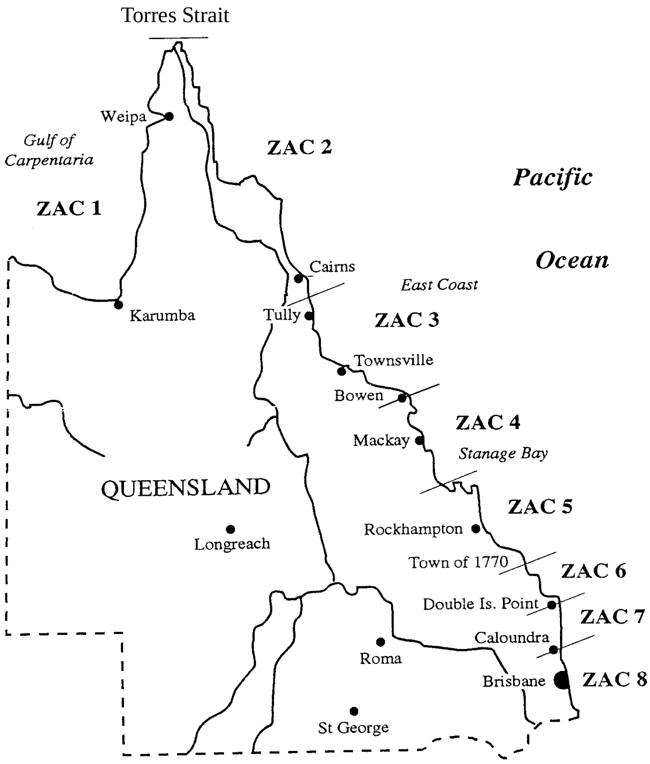
In 1996, the Queensland Government allocated funds for a program to improve the level of information on the fish stocks of Queensland's coastal streams. The "**Assessment of fish stocks in coastal streams"** initiative was undertaken between 1996 and 1999 by the then Department of Primary Industries (DPI) Fisheries Group (now Fisheries Queensland, a service of Department of Employment, Economic Development and Innovation (DEEDI)). The purpose of the initiative was:

- to provide better fisheries resources information to Queensland's fisheries managers for decisions on management and allocation of access to recreational, commercial and indigenous users of those resources and
- to provide information to be used as a basis for better protection of fisheries resources and habitats.

For the assessment, Queensland was divided into a North section (Sarina to the Northern Territory / Queensland border) and a South section (Sarina to the New South Wales / Queensland Border). The North section was further divided into four parts based on the boundaries of the then Queensland Fish Management Authority (QFMA) Zonal Advisory Committees (ZACs 1–4, Map 1). Priority coastal river systems in each northern ZAC region were chosen for detailed assessment through consultation with the local committee.

The selection process involved ZAC members ranking streams in their area according to outstanding fisheries resource issues, and a consideration of the available information about the resources. Highest priority was given to streams in close proximity to human population centres, in accordance with the initiative brief.

Within the Townsville region (ZAC 3) the highest priority for improved information on fisheries resources was given to the Bohle River just north of Townsville, and this report presents the findings of the studies that were subsequently undertaken during 1997 and 1998. The Townsville ZAC nominated the Bohle River as they believed it was a stream that required urgent investigation, identifying issues such as commercial and recreational fisher conflict, fish breeding grounds being threatened by high fishing pressure and pollution, the loss of important grunter and threadfin fishery, a $500,000 investment in boat ramp facilities and loss of barramundi nursery area.



Map 1 Queensland Zonal Advisory Committee (ZAC) areas.

The Bohle River was also attractive as a study location because of its proximity to the city of Townsville, and for the fact that no comprehensive fisheries resource surveys had ever been conducted in the system. The historical information about fisheries resources was restricted to a creel survey at five boat ramps in the Townsville area which included the Bohle River boat ramp (Jim Higgs, QFMA pers. comm. 1996) and a survey of fish stocks in the Borrow Pits, two permanent man made freshwater water holes in the flood plain of the Bohle River catchment within the Town Common (Perna 1999). In December 1998, Perna (1999) found 12 species of fish including three catadromous species, barramundi, milkfish and giant herring. Perna (1999) also reported two introduced species tilapia and mosquito fish, and noted the habitat of the Borrow Pits was poor quality although it supported a high number of fish species for the number of habitat types present.

This document brings together existing information on fisheries resources in the Bohle River region and its catchment. The information presented includes a description of the fisheries resources from fisheries independent surveys undertaken as part of the DPI initiative, fisheries dependant catch and effort statistics on the commercial and recreational fisheries from the CFISH and RFISH databases and Suntag database. The report is one in a series from the Coastal Streams Fish Stocks initiative.

Coastal stream description

Most of the coastline in the Townsville area, including the Bohle River, consists of sandy foreshores and broad intertidal flats with low and medium density seagrass beds (Ludescher 1997). The Bohle River has an extensive mangrove system and saltpans while coastal mangroves, beaches, rocky headlands and fringing reefs associated with the coastal islands (Magnetic Island, Rattlesnake Island and Herald Island) can also be found within a few kilometres of the river. A large portion of the following description of the Bohle River catchment is based on information from the Townsville and Thuringowa City Councils' Strategy Plan (TTSP) report series (TTSP 1996a, 1996b)

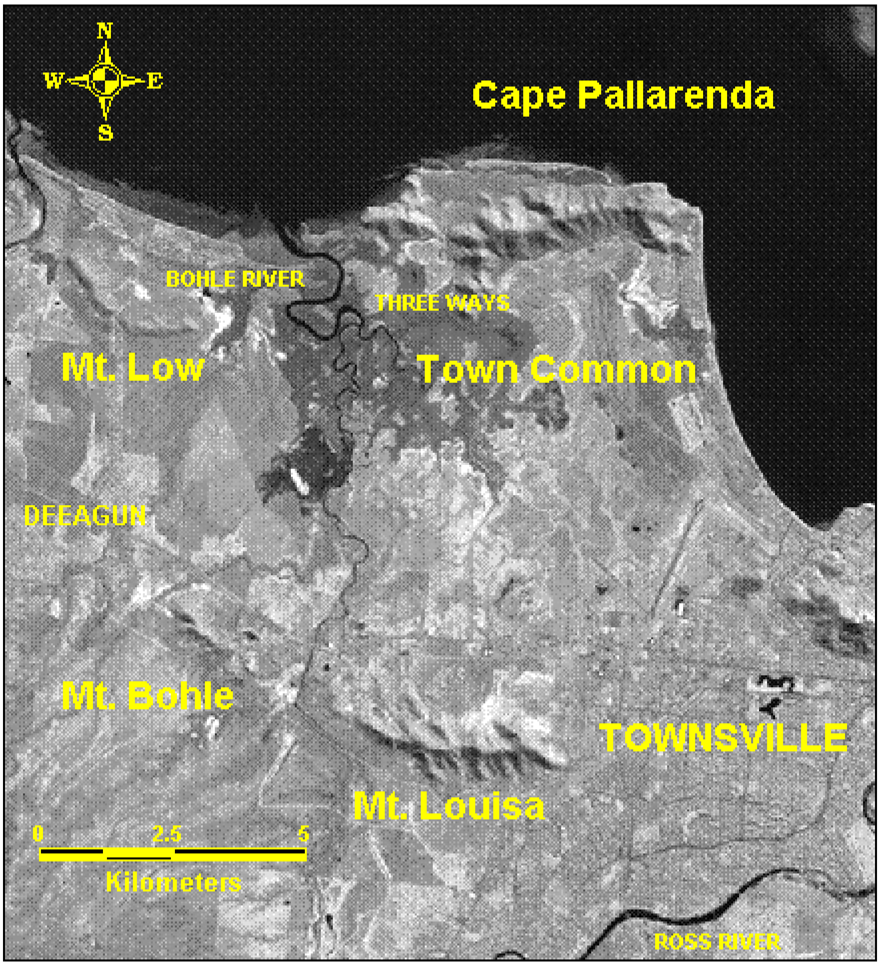
Location and topography

In 1996, Townsville had a population of 132, 667 people (Australian Bureau of Statistics 1997), and was a major regional industrial, tourism and public administration centre (Hornby 1998). The economy was based largely on defence services, mineral refining, agricultural commodity exports and tourism to the World Heritage listed Great Barrier Reef and Wet Tropics Rainforest.

The Bohle River is located in the dry tropics of north Queensland with the mouth of the river 14 km north-west of the Townsville Central Business District. The river flows approximately 30 km north from its source in the Hervey Range. The Bohle River drainage area is approximately 213 km^2 (TTSP 1996b) and forms part of the Black and Ross Rivers catchment (DPI 1993) which comprises seventeen different systems ranging in size from 19 km^2 (Christmas Creek) to 750 km^2 (Ross River) to (TTSP 1996b).

The Bohle River is bounded to the south by the Pallarenda Conservation Park and the Townsville Common Conservation Park. The townships of Bushland Beach and Mt. Low are located just north of the mouth of the river while sections of the upper Bohle River reach into industrial, developmental and residential suburbs of Townsville and Thuringowa (Map 2).

Soil surveys summarised by TTSP (1996b) show a variety of land systems in the Bohle River catchment including Old Plains and Old Plain Alluvials in the lower wetlands and Julago Volcanic Colluvials and Gilgai Clays in the mid ranges while the highlands into the Hervey Range are Granite outwash and Old Plain Alluvials. Apart from the Hervey Range in the south, and the mini peaks range to the north east, the Bohle River catchment is not bounded by large mountain ranges or hills. As such, in times of flood, river water may flow to other systems within the Ross River and Black River Catchments.



Map 2 Features of the Bohle River and catchment area.

The tides in the Bohle River are semi-diurnal with a mean sea level of 1.93 m, mean high water spring level of 3.07 m, mean high water neap level of 2.22 m, mean low water spring level of 0.73 m and mean low water neap level of 1.59 m (Queensland Department of Transport (QDoT) 1997, 1998). The highest astronomical tide is 4.01 m (QDoT 1997, 1998).

Nature conservation values

The Bohle River catchment has numerous recognised nature conservation values that relate to fisheries resources including, continuous wetlands habitat, fish habitat, high value fishery wetland and recreation sites for fishing (TTSP 1996b). Much of the land within the catchment is still in a natural form but significant areas have been degraded (see Pollution impacts on the Bohle River system, DPI 1993, TTSP 1996a).

As part of Townsville-Thuringowa Strategy Planning exercise, a Nature Conservation Draft Policy Paper was developed which identified the importance of the Bohle River catchment for Wetland Sites of Significance within the Townsville – Thuringowa Sub Region, and Sites of Regional Nature Conservation significance outside of existing reserves and protected areas in the Townsville – Thuringowa Sub Region. The details for these significant sites are given in Appendix 1, together with notations regarding fisheries resources management issues.

Cultural values for indigenous fishers

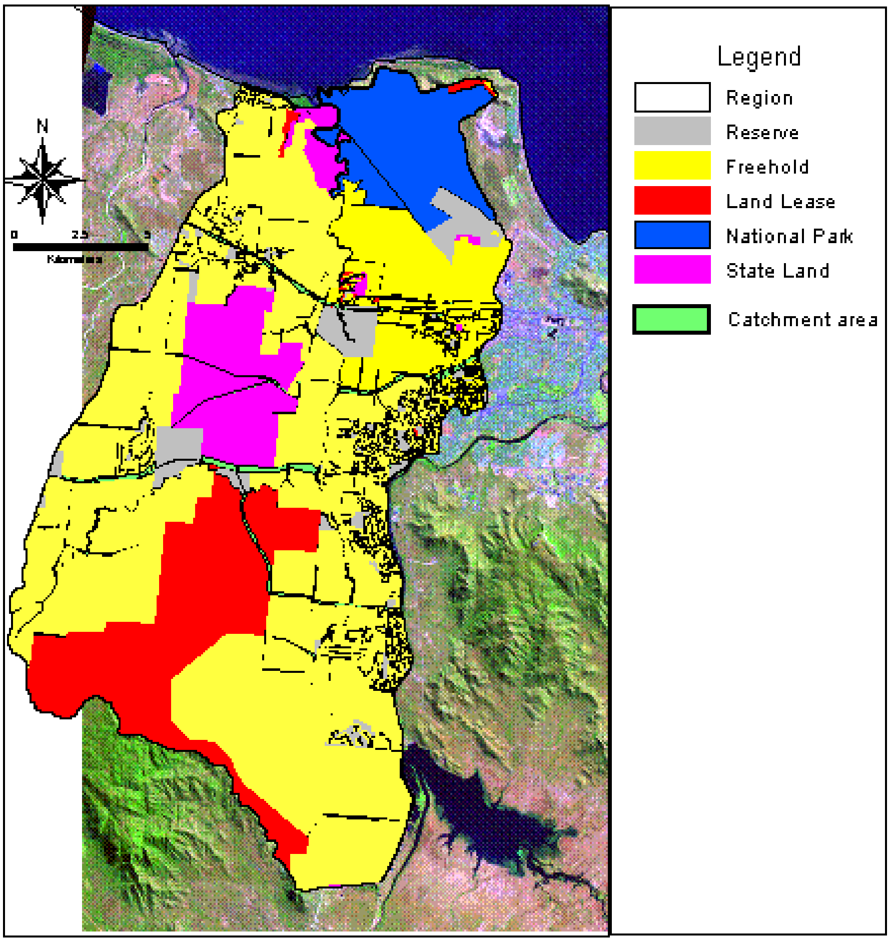
In 1996 Aboriginal and Torres Strait Islanders accounted for 4.9% (6116) of the Townsville population (Hornby 1998). Various aboriginal communities have had a long association with the Bohle River catchment and the Townsville region. A good summary of historic records of aboriginal cultures for the Herbert / Burdekin region can be found in Brayshaw (1990), however, she reports little information specific to the cultural values of the Bohle River from a fisheries perspective.

Information on the historical use of fisheries resources by indigenous people is limited to:

- "Middens consisting mainly of shellfish have been located at the southern end of Halifax Bay and within the Townsville Town Common Conservation Park. The midden within the common was carbon dated at 4200±300 years before present and was the oldest known in the area. Unfortunately this midden was lost during cyclone Althea in 1971."
- An appendix in Brayshaw (1990) lists many references from the historic literature to Halifax Bay in terms of fishing and hunting methods and other elements of material culture. However, little detail is available to indicate whether or not these relate specifically to the Bohle River catchment.

Land use and tenure

No detailed published studies were found on the current or historic land use of the Bohle River catchment. TTSP (1996a) state that for the Townsville – Thuringowa sub-region, the predominant land use outside urban areas is grazing with isolated areas of more intensive horticulture and sugarcane. Cattle grazing occurs in the upper catchment and has formed part of the weed management program of the Cape Pallarenda Conservation Park in the past.

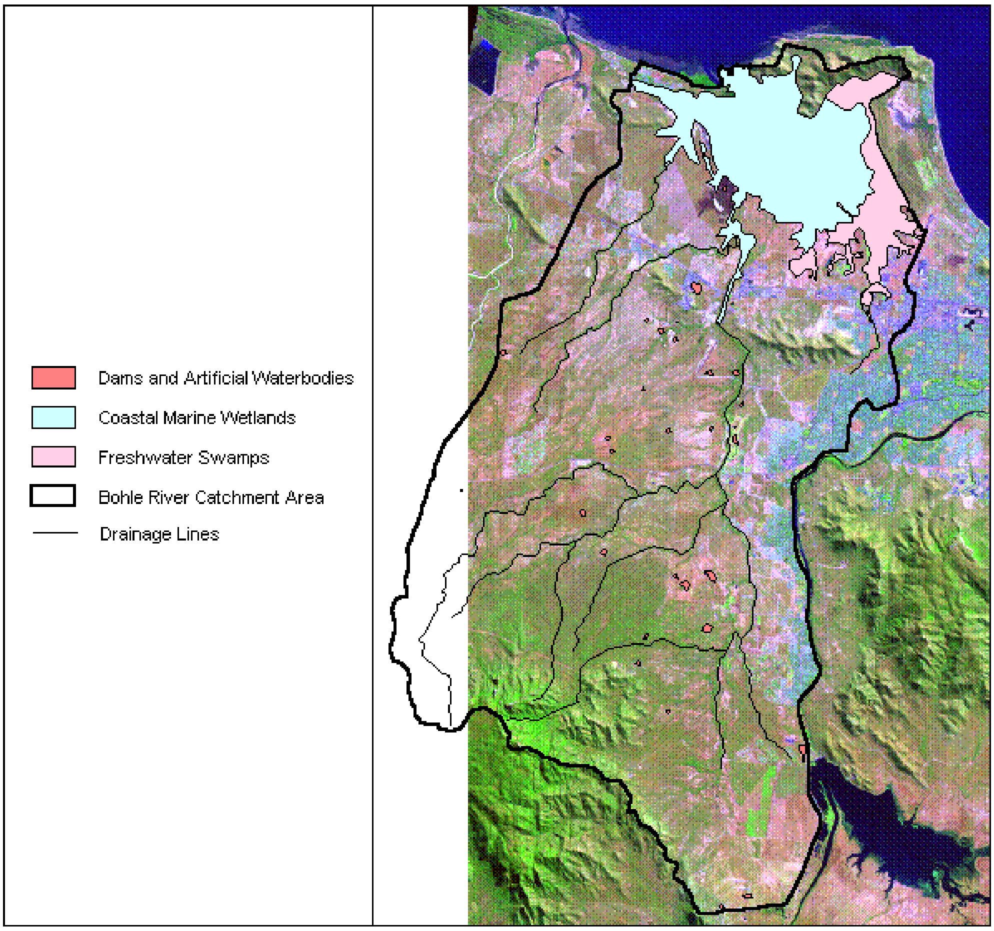


Map 3 Land tenure of the Bohle River catchment. Source: Department of Natural Resources 1998

Agricultural and grazing industry production in the catchment has facilitated the introduction of a variety of introduced and noxious species of plant to the area. Pastoral grasses such as para grass (*Brachiaria mutica*) have colonised the riparian and wetland habitats (TTSP 1996a). Other exotic species that have been reported in the Bohle River include guinea grass, rubber vine, prickly acacia, chinee apple, lantana, snake weed, pistia and water hyacinth (TTSP 1996a, Sinclair Knight Merz 1998). Riparian vegetation is still being cleared in the upper catchment (TTSP 1996a).

Within the Bohle River catchment, approximately 60% of the land is freehold (calculated from Department of Natural Resources 1998). Land tenure for the remainder of the catchment area includes National Parks, ≈4%, state land, ≈8%, lease land, ≈10%, and reserves, ≈4% (Map 3). Nearly 18 km^2 of marine wetland and 6.0 km^2 of freshwater swamps exist in the catchment with a further 0.5 km^2 of artificial water bodies (Map 4, adjusted from TTSP 1996a).

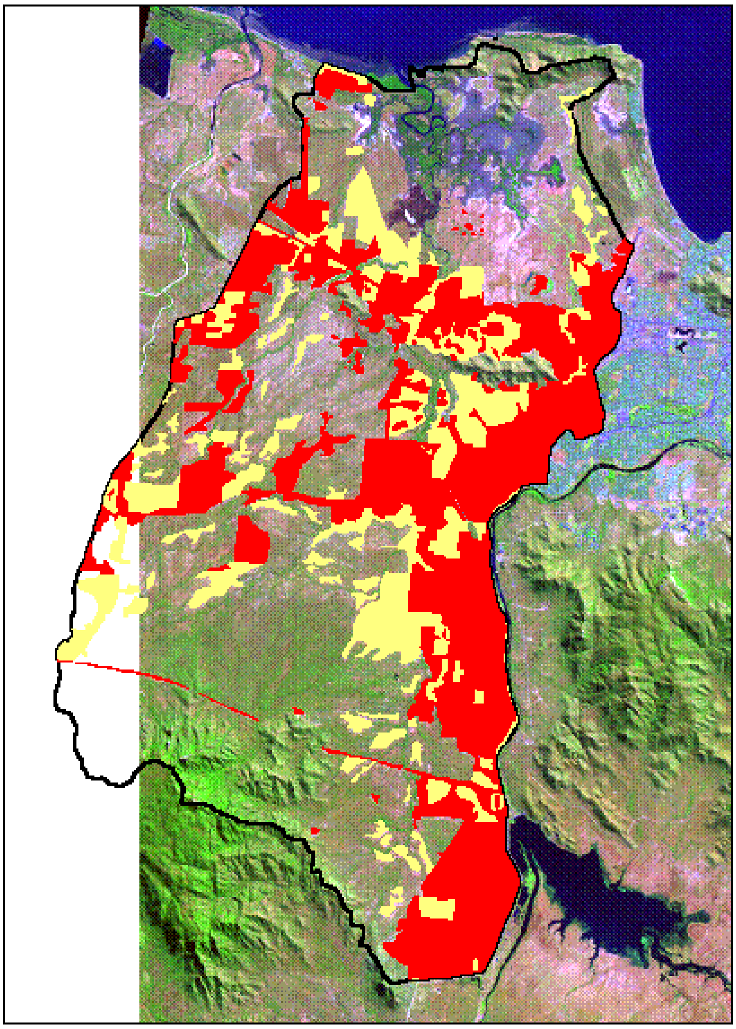
In November 1983, the Department of Primary Industries declared Fish Habitat Area, FHA 033-004A, in the Bohle River and surrounding foreshore area to provide long term protection of “critical” and “important” wetland habitats under S.120 of the *Fisheries Act 1994*.



Map 4 Freshwater and coastal marine wetlands of the Bohle River catchment.

Pollution impacts on the Bohle River system

The Natural Resources Working Group for the Townsville Thuringowa Strategy Plan (TTSP 1996a) investigated natural habitat quality in Townsville – Thuringowa sub-region. For the Bohle River catchment, most land area is rated Natural Habitat (≈58.6%) while a large proportion is Disturbed Habitat (≈13.8%) or Transformed and/or Degraded Habitat (≈27.6%, see Map 5).



Map 5 Natural habitat quality. Source Townsville-Thuringowa Strategy Plan 1996a. Uncoloured, red and yellow section indicated areas of natural Disturbed and damaged habitat respectively.

The major pollutants in the Bohle River waterway are sewage treatment plant discharge, urban and industrial run-off and agricultural run-off. Discharge from sewage treatment plants causes eutrophication in sections of the Bohle River (TTSP 1996a) through increased nutrient loadings (Sinclair Knight Merz 1998). Four sewage treatment plants together release around 12.455 mega litres per day of secondary treated sewerage into the river. Reuse of treated water or upgrades to tertiary treatment, are likely to reduce this discharge level in the next few years for at least the Condon sewage treatment plant (J. McCorkell, Thuringowa City Council pers. comm. 1999).

Storm water runoff from urban suburbs in the catchment have the ability to cause high sediment loads, scouring of the river bed and allow rubbish and other urban pollution to enter straight into the Bohle River (TTSP 1996a). This situation is exacerbated by erosion of the banks of the Bohle River from boat traffic, particularly in Stoney Creek which leads from the boat ramp to the main channel of the Bohle River (Vern Veitch, Sunfish pers. comm. 1999).

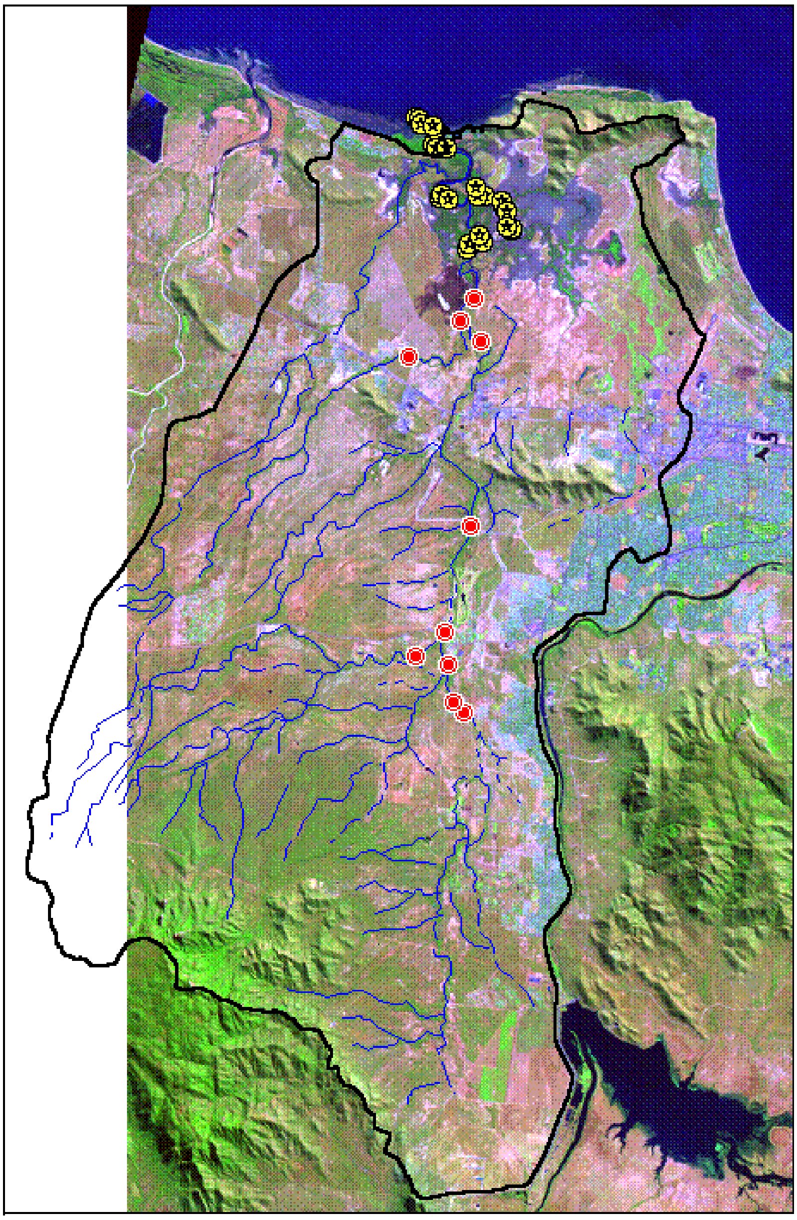
The close proximity of the industrial developments to the Bohle River wetlands has given rise to concerns about impacts on habitat quality (TTSP 1996a). In the industrial suburbs of the catchment, industrial pollutants can enter the Bohle River system via storm water run off and direct discharge.

Several extractive industries occur within the Bohle River catchment supplying gravel, rock, loam, sand, silica sand, soil and topsoil for Townsville. Four extraction sites for loam and four for sand occur within the riparian zone of the Bohle River. Cumulatively these industries have removed fish habitat area or reduced the quality of habitat that remains and have altered water quality by increasing the amount of land run off that enters the river, altered stream flow erosion and scour (TTSP 1996b).

Ongoing monitoring of stream water quality by the Environmental Protection Agency (EPA) occurs at several sites (Map 6) for the Bohle River. Data for the period 11/6/1997 to 4/8/1998 collected in this program and that collected by the EPA and the Townsville and Thuringowa City Council's water treatment plants is summarised in Table 1. These show significant departures from Australian and New Zealand Environment and Conservation Council (ANZECC) (1992) guidelines. Diminished water quality in the Bohle River from sewage pollution, industrial runoff and even the Hervey's Range Road dump has raised an ongoing issue (e.g. Townsville Sun 20 Jan 1999 p1, Appendix 2) regarding the quality of fish in the Bohle River.

Table 1 Water quality parametres in fresh and salt water in the Bohle River and Australian and New Zealand Environment and Conservation Council (ANZECC 1992) guidelines. Source of measured values includes Sinclair Knight Merz (1998), Townville City Council (1999a & 1999b), Environment Protection Agency (unpublished data) and this projects data.

Water Quality Parametre	**Range Measured in Freshwater**	**ANZECC Fresh Waters Guidelines**	**Range Measured in Marine Water**	**ANZECC Marine Waters Guidelines**
pH	3.75 – 9.60	6.5 – 9.0	6.20 – 9.33	< 0.2 unit change from the natural seasonal values
Turbidity	0 – 670 NTU	< 10% change from seasonal values	0 – 569 NTU	< 10% change from seasonal values
Dissolved Oxygen	0.0 – 15.4 mg/L	> 6 mg/L	1.3 – 20.3 mg/L	> 6 mg/L
Salinity	0.00– 0.73 ppt	No guidelines	0.20 – 40.0 ppt	No guidelines
Conductivity	0.000 – 1.695 mS/cm	No guidelines	0.000 – 74.400 mS/cm	No guidelines
Temperature	16.2 – 33.6 °C	< 2°C increase in normal temperature	17.9 – 34. 6 °C	< 2°C increase in normal temperature
Total Nitrate	0.32 – 36.05 mg/L	No guidelines	0.06 – 23.9 mg/L	No guidelines
Total Phosphates	< 0.01 – 12.00 mg/L	No guidelines	< 0.01 – 6.60 mg/L	No guidelines
Chlorophyll a?	0.601 – 53.047 μg/L	No guidelines	0.556 – 134.500 μg/L	No guidelines



Map 6 Water quality monitoring sites in the Bohle River Catchment. Source: Sinclair Knight Merz (1998), Townville City Council (1999a & 1999b), Environment Protection Agency (unpublished data). Blue lines are drainage lines, and the boundary of eth catchment is shown in black outline. Red dots indicate the location of Thuringowa City Council water quality sites while yellow starred circles are Coastal Streams water quality monitoring sites.

Fisheries of the Bohle River

History

Commercial fishery

The Bohle River has been fished commercial since the late 1800's and fish traps were used in the Bohle River until the 1950's (NQOHP ID12, 1A&B *In* Ludescher 1997). During this study, the Bohle River supported a commercial gillnet fishery, crab pot fishery and mullet and bait fishery (TTSP 1996b). Barramundi, blue threadfin and a range of estuary species are caught along the foreshores and in the river mouth with a total of 15 fish categories taken in this region. Mullet and baitfish are targeted on the foreshores of the river (TTSP 1996b) while only a low level of commercial crabbing occurs. Many species are fished commercially only when they are abundant during the year. For example barramundi are primarily targeted from February when the fishing season opens and / or when conditions of tidal flow and freshwater runoff are likely to generate high catch rates.

The Townsville branch of the then Queensland Commercial Fishermen's Organisation (QCFO) included in its membership just over 150 fishers. Other nearby branches included Lucinda and Bowen. The then QFMA's commercial catch logbook information database identified that in 1998, 24 boats recorded net catches in the fishing grid which includes the Bohle River (Grid J21, page 76), while 13 boats recorded crab landings from the area. These fishers worked 795 days in 1998, for a total catch of 98.9 tonnes worth $532 000. Commercial landings for the Bohle River area are discussed in greater detail later.

Seafood harvested from the Bohle River area is mainly sold locally, within the state and some interstate, however, in the past mullet roe has entered international markets (local wholesaler, pers. comm. 1999).

Control of licensed commercial fishery operations in the Bohle River area is imposed through regulations associated with the fisheries symbol in use (N1, N2, N7 netting licences and C1 crabbing licences in the Bohle River). Management measures include attendance regulations, gear restrictions, fish size limits, closed seasons and area closures and restrictions on methods used for the setting and collecting of nets as defined in the *Fisheries Act 1994* and *Fisheries Regulation 2008.*

The Bohle River falls within the Cleveland – Bowling Green Region Dugong Protection Area established in January 1998. The Cleveland section is classified Zone A, considered the most significant dugong habitat, where all commercial fishing using gillnets is banned with the exception of river set nets.

Commercial fishing tour operations

Fishing tour operators are classed as commercial fishers by the QFMA as they generate an income from fisheries resources, however, the fishery is based on recreational fishing clients. Commercial fishing tour operators have been operating in North Queensland since the 1960's (Kewagama Research 1990 in Ludescher 1997) and the industry has grown to cater for the increasing demand of tourist and specialist anglers. Only since 1996 have fishing tour operators been permitted by QFMA, and required to maintain a daily logbook of their activities as a condition of the permit. Up to five operators work from time to time in the Bohle River area. Summary catch data from the QFMA commercial fishing tour operator database was not available (J. Higgs QFMA pers. comm. 1999).

Anglers and crabbers fishing from commercial fishing tour vessels are governed by the same regulations as other recreational fishers.

Recreational Fishery

Recreational fishing has occurred in the area ever since European settlement in the mid 1860's and has values for a variety of reasons including, recreation and relaxation, nature based activity, sport and competition, social aspects and food for consumption. As the Townsville population grows and leisure activities are promoted (see Hornby 1998), recreational fishing is becoming increasingly popular in the region. A recent recreational fishing phone survey found that at least one person within 41% of households in Townsville fished in the past 12 months (Roy Morgan Research 1996). In recent years, there has also been a strong push to increase tourist numbers visiting the Townsville area specifically for fishing and the elusive big barramundi.

The Bohle River is very close to the main population centre of Townsville, and the local boat ramp has recently received a $500,000 upgrade, making it one of the best boating facilities in the region. The level of recreational fishing activity increased in Bohle River when the new boat facilities were completed in 1997 (J. Higgs, QFMA pers. comm. 1999).

Recreational fishing in the Bohle River is mainly conducted from boats because there is limited access for bank fishing. Fishing activity is concentrated at four main sites within the river, the river mouth which is the most heavily fished area then three upstream locations associated with deeper holes including the popular 'Three Ways' (see Map 2).

No information is available on the species targeted by recreational fishers in the Bohle River specifically, however, fishers in the Townsville area tend fish salt water more often than freshwater. When fishing they target barramundi, catfish, sooty grunter, yellowbelly and crayfish in freshwaters while targeting mud crab, barramundi, mackerel and mangrove jack in coastal waters (Roy Morgan Research 1996). Gear restrictions, bag limits and seasonal closures apply to all recreational fishers with crab pots and line fishing being the most popular gears used.

Indigenous Fishery

The Queensland *Fisheries Act 1994*, allows Aboriginal and Torres Strait Islander peoples to take fisheries resources or to use fish habitats under customary law. That is, fish may be taken for the purpose of subsistence, which includes ceremonial and kinship obligations as well as food (Australian Law Reform Commission 1986).

Historically, little is known about indigenous fishing in the Bohle River area. There are several references to fishing and fishing methods in Halifax Bay in Brayshaw (1990) and methods used included spearing and line fishing using hooks made of turtle shell and mother of pearl.

No formal survey has been conducted of the species targeted or the catch and effort of Aboriginal and Torres Straits Islands people in the Townsville region and very little has been done state-wide. Turner (1998) has recently developed a methodology to gain this information and the QFMA has undertaken to facilitate use of the survey kit in indigenous communities around Queensland (S. Helmke DPI pers. comm. 1999).

Fisheries management arrangements for the Bohle River

Management arrangements that applied to the Bohle River area in 1999 included area closures, seasonal closures, bag limits, size limits and fishing gear limitations. The EPA are also charged with managing the protected areas under their jurisdiction (National Parks, Marine Parks including joint management of the Great Barrier Reef and Wet Tropics areas), including enforcement of restrictions on fishing gear use and in strict attendance requirements while that gear is in use in Dugong Protection Areas (undertaken by Queensland Boating and Fisheries Patrol, QBFP).

Under the Queensland *Fisheries Act 1994* and the then *Fisheries Regulations 1995* there are regulations in place for the capture and take of fish for commercial or recreational purposes. The regulations stated in this report are correct at the time of writing (1999). It should be noted, however, that fisheries management regulations have changed since that time in response to various factors. Fishers should therefore contact their local QBFP for current regulations relating to the fisheries of the Bohle River area.

Licences

Commercial fishers require a licence to operate in Queensland waters. As part of licence conditions, operators must complete compulsory daily logbooks on their catch and fishing activities. Some information on participation demography, catch and effort in the recreational fishery has recently been obtained through a phone survey (Roy Morgan Research 1996) and from a network of volunteer recreational fishermen who provide logbook information on their fishing trips to fisheries managers.

Indigenous fishers using traditional methods are exempt from the provisions of the *Fisheries Act 1994.*

Closed fishing seasons

A closed season applies to the taking of barramundi in the Bohle River and along the whole east coast of Queensland between midday 1 November to midday 1 February of the following year. This closure is to protect the barramundi during their annual spawning season. Barramundi must not be targeted at this time and any captured incidentally during this period must be released. River set gillnets used by east coast commercial fishers are also banned during the barramundi closed season.

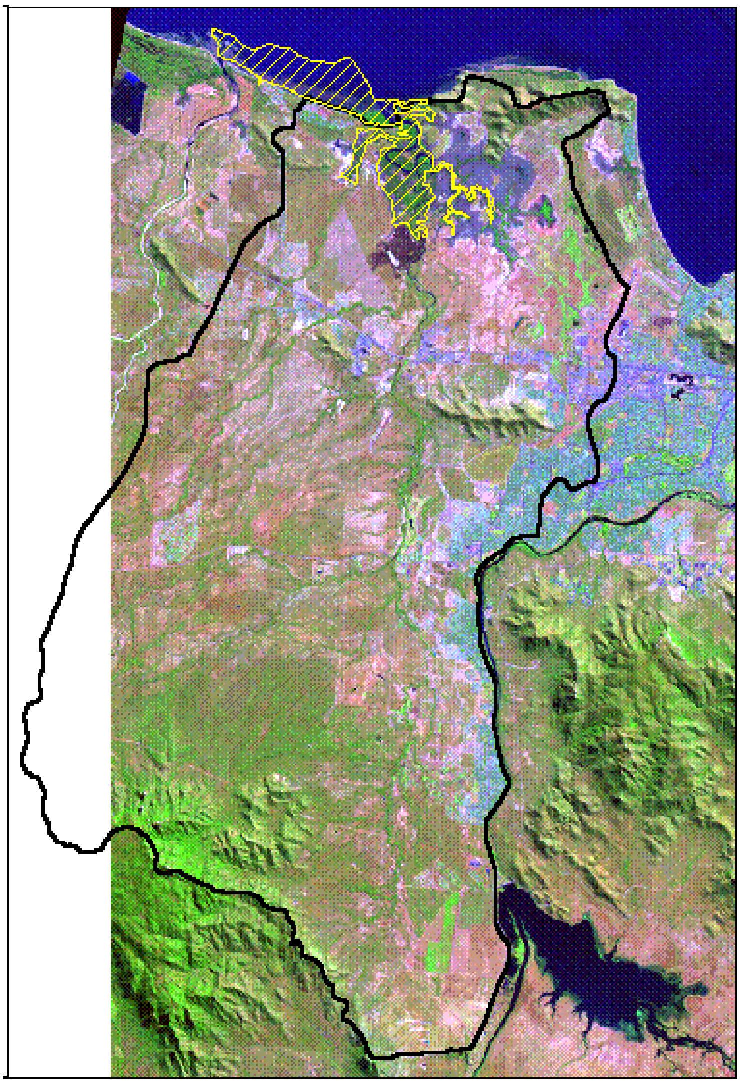
Area closures

Under the *Fisheries Regulation,* commercial fishing is not permitted in the freshwater reaches of the Bohle River. In the past, commercial eel trapping for the short-finned eel (*Anguilla australis*) has been conducted under licence in the near by Ross River Dam, but no licences have been issued for eel trapping in the Bohle River.

There are a range of protected areas established for the Bohle River catchment and adjacent area, including gazetted Fish Habitat Areas (FHA’s, Map 7), however, these are not fishing closures. Further discussion of protected areas can be found later in this document.

Bag limits

Bag limits have been applied to recreational and charter fishers to control the harvest of certain species. Bag limits ensure that all anglers have an equal opportunity to the share the fisheries resources available, and apply in both freshwater and marine waters. A list of the bag limits on fish and crab species found in the Bohle River can be obtained from the Queensland Boating and Fisheries Patrol.



Map 7 Fish Habitat Area in the Bohle River region is shown shaded in yellow. Source: DPI Conditions and Trend Unit 1999.

Size limits

In addition to bag limits, size limits were introduced by the QFMA to protect the juveniles of certain species and, in the case of barramundi and estuary cod, larger breeding fish as well. The minimum and maximum legal lengths are based on biological information and relate to size at maturity. The maximum size limit for barramundi (120 cm in 1998) was introduced to prevent large fecund females being removed from the population. All fishers must release fish below legal minimum size or above maximum legal size. Many fishing clubs and tour operators working the Bohle River have set minimum size limits above those required by law.

Commercial fishery

In the Bohle River, three different commercial net fishery licences may be used (N1, N2 and N7 bait net fishery) plus the C1 crab pot fishery licence. A detailed description of the gear restrictions and operating requirements pertaining to these commercial licences can be obtained from your local QBFP.

Recreational fishery

Gear restrictions on recreational fishers and fishers in tour groups in tidal and fresh waters of the Bohle River can be obtained from your local QBFP.

Protected areas of the Bohle River

The fisheries resources of the Bohle River catchment and wetland are protected by state, commonwealth and local Government legislation as described below.

Fish Habitat Area

Gazetted Fish Habitat Areas (FHAs) declared under the *Fisheries Act 1994* are a tool to provide long term protection of “critical” and “important” fisheries habitats. The Bohle River Fish Habitat Area (033-004A) was declared on 19 November 1983 (Map 7). The Bohle River FHA is classified as “Management B” category i.e. a Fish Habitat Area of major importance), and occupies an area of 1130 ha from within the Bohle River tidal area and foreshore area to the mouth of the Black River (Beumer *et al.* 1997). The Bohle River Fish Habitat Area was declared to protect its outstanding management features, fishery values and habitat types (Beumer *et al.* 1997) including:

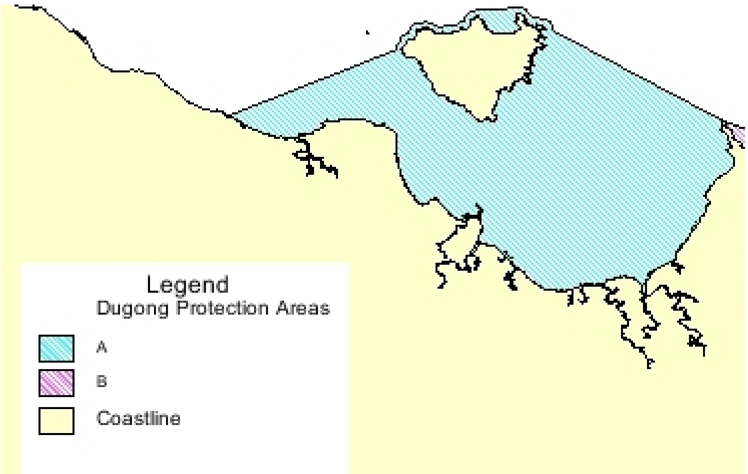
<u>Management Features:</u>	Estuarine and wetland buffer zone from urban development; controlled development adjacent to tidal wetlands
<u>Fishery Values:</u>	Commercial and recreational fisheries for barramundi, blue threadfin, bream, estuary cod, flathead, grey mackerel, grunter, mangrove jack, queenfish, recreational fishing, sea mullet, school mackerel, tiger prawns, banana prawns, blue legged, king prawns
<u>Major Habitat values:</u>	Extensive stands of mangroves, salt marsh and unvegetated clay pans along estuary.

Commercial and non-commercial fishing is permitted in a FHA. The FHA protects the habitat in the area, and any proposed modifications to the habitat must be deemed to be for the public good and be appropriately approved under Queensland planning legislation.

Dugong Protection Area

The Dugong, *Dugong dugon*, is listed as vulnerable to extinction in the Red Data Book of Threatened Species (IUCN 1996) and is recorded in the *Nature Conservation (Wildlife) Regulation 1994* as 'vulnerable wildlife'. In January 1998, the Queensland Government established a series of Dugong Protection Areas (DPAs) along the Queensland coast to help achieve the protection and recovery of dugong populations in Queensland (Department of Environment 1997).

The Bohle River is included in the Cleveland - Bowling Green Region Dugong Protection Area, which includes all the inshore waters in an area stretching from Black River to the north of Townsville south and east of Cape Bowling Green (Map 8). The waters between Black River and Cape Cleveland are classified as DPA Zone A, which is considered the most significant dugong habitat (Map 8).



Map 8 Cleveland - Bowling Green Region Dugong Protection Area.Source: Department of Employment, Economic Development and Innovation’s CHRIS (Coastal Habitat Resource Information System).

Townsville and Thuringowa Strategy Plan

In 1996, the Townsville and Thuringowa City Councils and the State and Commonwealth Governments cooperatively funded the production of draft policy papers to aid in the future planning of Townsville and Thuringowa's growth and development (TTSP 1996a, 1996b).

The Nature Conservation Policy document identified areas within the Bohle River catchment as being of high conservation value and biological diversity, and so should be protected. These areas were grouped under 2 headings, wetland sites of significance within the Townsville – Thuringowa sub-region and sites of regional Nature Conservation significance outside of existing reserves and protected areas in the Townsville – Thuringowa sub-region:

Wetland sites of significance within the Townsville – Thuringowa sub-region:

Eight wetland sites within the Bohle River catchment were identified: Stony Creek, Saunders Creek, the Bohle River and Mt. Louisa Creek in the Non-Perennial Creeks and Rivers category, the Mt. Saint John Swamps, Blakey's Crossing and the Town Common – Pallarenda in the Freshwater Swamps category, and Bohle – Pallarenda Estuaries and Coastal Swamps in the Coastal and Marine Wetlands section. The seagrass beds between Black and Bohle River were also identified as significant to the region.

The policy publication outlined the characteristics of each site including, the type of wetland and its classification (following Blackman *et. al.* 1992), the land system, principal values of the site and, management issues. Within the Non-Perennial Creeks and River category, concerns were raised about the flow-on effects of urban drainage including pollution, high sedimentation level due to lack of retention basins on major drains, exotic vegetation invasion and maintenance of riparian buffers during urban encroachment. Principal values of these sites were open spaces for recreation, wildlife corridors and fish habitat values.

Management concerns such as exotic vegetation invasion, poor water quality, lack of upstream retention basins, pollution and sewage were highlighted for the freshwater swamps of the Bohle River catchment. These areas have medium and high conservation value as water bird and fish habitat as recreation / eco tourism outlets, and act as nutrient retention basins for the high value estuarine complex of the Bohle River. The Bohle-Pallarenda Estuaries and Coastal Swamps were highlighted as complex wetland habitat for fish, birds and crocodiles, and the management issues raised included water quality, sewerage treatment, industrial and urban runoff and drainage problem in upper catchment, commercial and recreational fishing pressure and loam extraction from riparian zone.

Townsville Town Common Conservation Park

The Townsville Town Common Conservation Park is located on the east and south banks of the Bohle River and encompasses 3245 ha of wetland areas (Map 2). The park was established in 1937 and is protected under the *Nature Conservation Act 1992.*

The park provides permanent, semi permanent and ephemeral wetlands. An assessment of the fish populations in the Borrow Pits (two large pits excavated during the construction of the Townsville airport) undertaken in December 1998, found twelve species of fish including juvenile barramundi, and many tilapia (Perna 1999).

Fishery independent surveys of the Bohle River

Methods and Techniques

The methods developed for this study were designed to capture a nominated list of target fish and crab species of various sizes and in a variety of habitats. Barramundi (*Lates calcarifer*), king threadfin (*Polydactylus macrochir*), blue threadfin (*Eleutheronema tetradactylum*), mangrove jack (*Lutjanus argentimaculatus*), grunter (*Pomadasys kaakan* and *Pomadasys argenteus*), bream (*Acanthopagrus berda* and *Acanthopagrus australis*), tilapia (*Tilapia* spp.), jungle perch (*Kuhlia rupestris*) and mud crab (*Scylla serrata*) were selected as the target species by the project steering committee (made up of researchers from the habitat, freshwater and marine fisheries groups of DPI within Northern Fisheries Centre, Cairns), as they were considered to be exploited by all sectors of the fishing community. Tilapia were included in the list of target species as they are a declared noxious fish species and more information on their distribution and population ecology is required before strategies can be designed for their control or eradication.

Site Selection

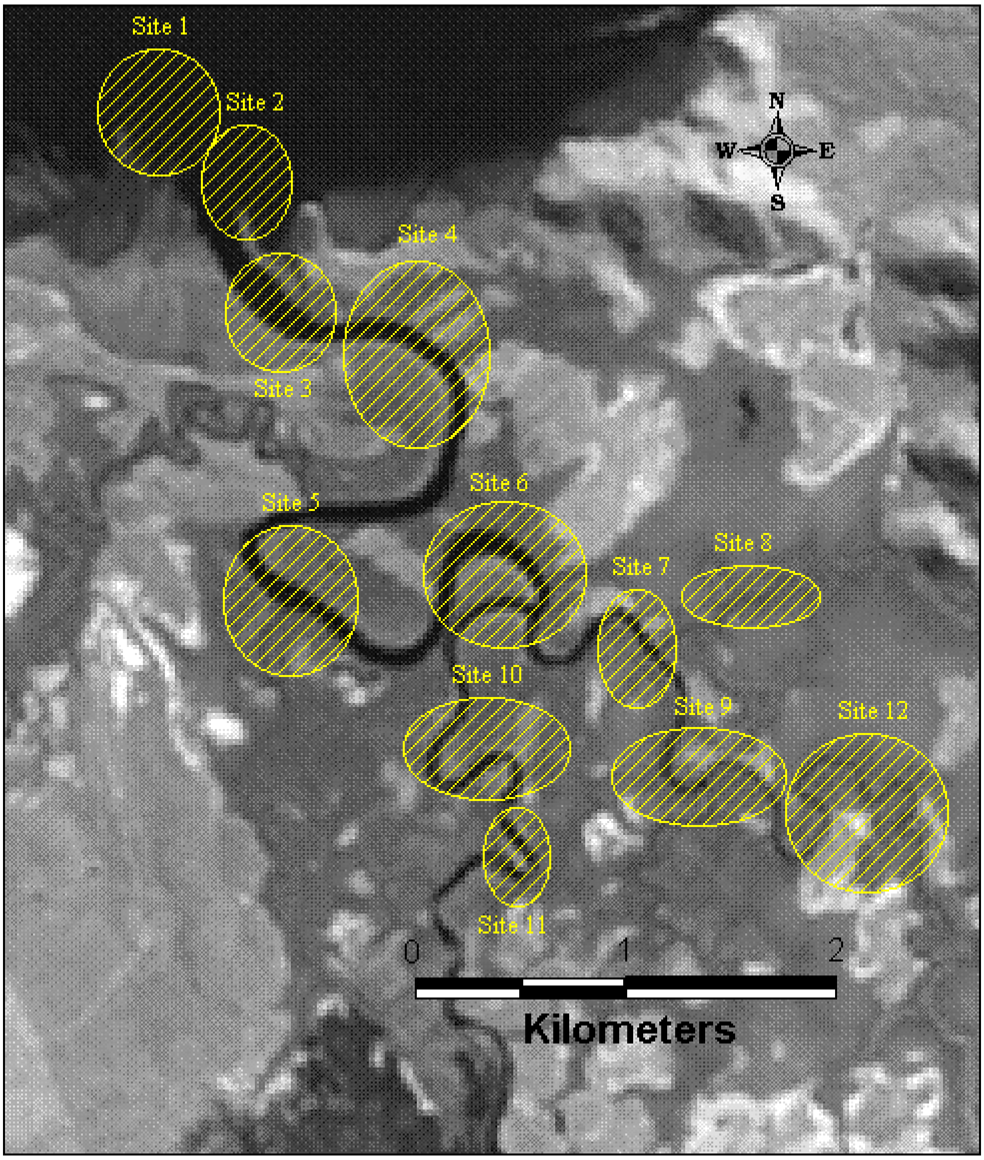
In order to maximise the catch of target species and therefore maximise the information from the research study, expert knowledge from recreational and commercial fishers about the distribution of target species through the year was obtained and used to select estuarine sample sites within the Bohle River. These fishers relayed knowledge of how to maximise catches of target species as well as hazards that might impact on the catching performance of sampling gear (such as areas of strong flow and submerged snags). Other factors considered when selecting survey sites included the need to locate sampling effort in as many different habitat types as possible throughout the Bohle River such as tributaries, the main channel and foreshore areas (Map 9). Sites also needed to be accessible and suitable for sampling at various tidal stages. Due to time constraints, only sampling techniques that would capture a large percentage of the target species while being time efficient would be adopted in this study. Set netting and crab potting were chosen as the primary survey techniques in the estuarine water as these techniques can capture over half of the of the target species. Fish traps and cast netting were identified as secondary techniques that would add to the value of the survey by targeting habitats and fish species not susceptible to gillnetting. Electrofishing was chosen for sampling freshwater reaches of the system. Electrofishing sites were selected based on accessibility for either backpack electrofishing (wading) or the electrofishing boat.

Pilot Study

A pilot study was conducted in the Bohle River during June 1997, prior to the commencement of the intensive fish and crab surveys. The pilot study allowed sampling and collecting methods to be trialled by the research team, permitted preliminary assessments of sampling sites within the systems, and helped team members gain some local knowledge of the areas. Site assessments involved evaluating the suitability of the site for set-netting and potting, and determining what constraints might impact on survey procedures at each site.

The fish fauna at eight sites (numbered 1, 2, 5-7 and 9-11 in Map 9) were sampled using 50, 100 and 150 mm stretched mesh gillnets. The exercise produced 40 fish species including six of the ten target species for a total of 477 fish of which 84 (17.6% of the total) were target species, and 64 (13.4%) were barramundi. All sites were retained for the intensive surveys and two additional locations (Sites 3 and 4, see Map 9) were added to sample the fish populations at the mouth of the river.

Mud crabs were surveyed at Sites 1, 2, 4, 5, 6, 9, 10 and 12 using ten Munyana© crab pots. Crabs were caught at all sites. Site 5 was replaced by Site 8 is all following intensive surveys due to poor catch rates at site 5.



Map 9 Survey sites in the Bohle River.

Observations by the research team during the pilot study revealed that there was substantial recreational use of the Bohle River. This information and the recognition that the tidal section of the river was quite small (such that the proposed gillnet fishing would interfere with other users of the river), suggested that future intensive surveys be designed to minimise the potential for conflict with other users of the waterway. Accordingly, all future surveys were planned around the following conditions:

1. A low flow regime over 4-5 days to allow maximum netting efficiency (neap tides)
2. Four to five days of similar tides i.e. time of change in tide and tidal range
3. A change of tide at or shortly after dusk towards the middle of the 4-5 day survey
4. Undertake the surveys during weekdays when boat traffic was at a minimum and
5. Advanced notification to the public of planned survey dates.

Fish surveys

Six surveys of the Bohle River were conducted between June 1997 and May 1998 at two monthly intervals. including; 11–13 June 1997, 8–13 September 1997, 16–22 November 1997, 21–23 & 26–27 January and 4–5 February 1998, 1–5 & 9–12 March 1998 and 5–7 & 21 May 1998. Information from the Bohle River pilot study 11-13 June 1997 is included in the intensive survey data analysis as the information generated in that survey was considered comparable to later research surveys. For all statistical analysis and presentation of results, data collected during the 4^{th} survey spanned two months, January and February 1998, due to flood flow conditions in the river. The data from these two months has been pooled as January 1998, to allow the data to be comparable to other surveys.

Three monofilament gillnets of 50 mm (2”), 100 mm (4”) and 150 mm (6”) stretched mesh size were set at each site surveyed. Fifty millimetre nets were 30 m long x 22 meshes deep, while 100 mm and 150 mm nets were variable in length and depth (up to 60 m in length) depending on the site being surveyed. On occasion these nets were “bundled” at one end to shorten the net when a smaller fishing area was available. These mesh sizes were selected to target a range of fish species and fish sizes. Nets were set before dusk then checked approximately hourly and where possible, fished until after a tide change had occurred or when the water level became too low to fish efficiently in that area. The time that the nets were fishing varied among sites and survey months, from 10.25 to 37.07 hours for three nets combined, depending on the tidal regime and site topography. Generally, all fish caught in the nets were cut free of the meshes, identified and measured to the nearest 5 mm fork length or total length before release. Fish that were difficult to identify to species level in the field were taken to the laboratory for positive identification. All target fish species except tilapia that were greater than 120 mm fork length were tagged with either a t-bar tag or a streamer tag (Hall print Series CS####) before release. Fish that suffered severe net damage were kept for laboratory analysis of gut contents, gender and reproductive staging, and aging. Reproductive maturity was macroscopically determined using the method of Nikolsky (1963). Sacrificed specimens of non-target species were used as crab bait for the mud crab survey to reduce waste and costs.

Up to ten sites on the Bohle River were surveyed using gillnets on any one survey trip. In January 1998 the DPAs were established. The research survey netting program continued with approval from QBFP and the then EPA with the condition that project staff remained within sight of the set nets to reduce the chance of meshing a dugong. To accomplish this, nets could not be set at Site 2 and Site 6 during the January 1998 survey, although Site 6 was recovered in subsequent surveys. The data that are missing for these sites have been regarded as missing values in subsequent analyses.

To increase the sampling efficiency of the program, the viability of cast nets and fish traps as survey tools was trialled in the Bohle River during the September 1997 intensive survey. Expanding survey operations to include these two techniques was undertaken to complement gillnet catch and to improve the range and sizes of fish species surveyed.

Fish trapping

Antillian Z-trap style fish traps of approximately 1.2 m length, 0.7 m width and 0.8 m height were used, with a straight entrance funnel and 37 mm (1.5”) stretched mesh (Figure 1, design is similar to that described by Sheaves 1995a). Traps were made collapsible for ease of handling and storage on board the research vessel and were baited with approximately 500 grams of Australian pilchards, *Sardinops neopilchardus,* per trap. Traps were left to soak for 24 hours per set with lifts every 12 hours. Bait was replaced after 24 hours or as required. Fish traps were placed beside complex habitat structures such as snags that could not be targeted using gillnets, except at Site 7, which was a low aspect mud bank.

Up to six fish traps were deployed in the Bohle River each day of the four surveys. Sites 4, 7, 9, 10 and 12 were sampled in September 1997, Sites 3, 7, 9, 10 and 12 in November, Sites 3, 4, 7, 9, 10 and 12 in January 1998 and Sites 3, 4, 6 and 12 in March 1998. Fish Traps were not available for the June 1997 survey and too few were in working order for the May 1998 survey.

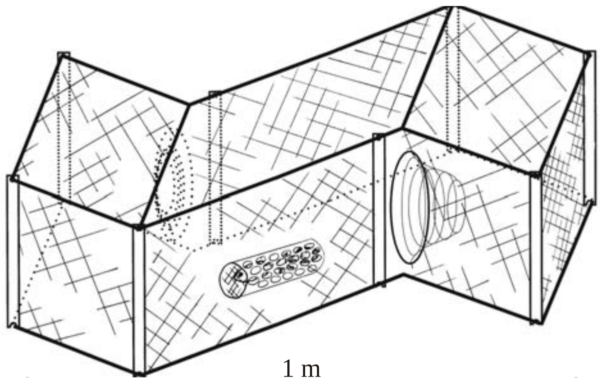


Figure 1 Diagrammatic presentation of a collapsible fish trap (Antillian Z-trap) used in this project.

Fish caught were emptied from the trap into a container of water on the boat while the catch as identified and measured to the nearest 5 mm fork length or total length before release. Fish that were difficult to identify to species level in the field were taken to the laboratory for positive identification. Target fish species were tagged with either a t-bar tag or a streamer tag (Hall print Series CS####) before release.

Cast netting

A 2.7 m and a 2.4 m drop nylon cast net with 25 mm mesh, were each used to make 10 casts at each gillnetting site (i.e. 20 casts per site). Cast netting was usually conducted after gillnets were retrieved, and was done within two hours of low tide in order to improve the fishing efficiency. As with gillnet fishing, fish samples that could not be identified in the field were kept for identification at the laboratory, while all other fish were released alive. It should be noted cast netting is an active sampling method can be “hit or miss” in nature and the level of skill of the operator and the habitat in which it is employed may affect the results. During this survey, cast net throws at each site were spread approximately evenly along a given stretch of river bank, and not focused on a particular habitat feature.

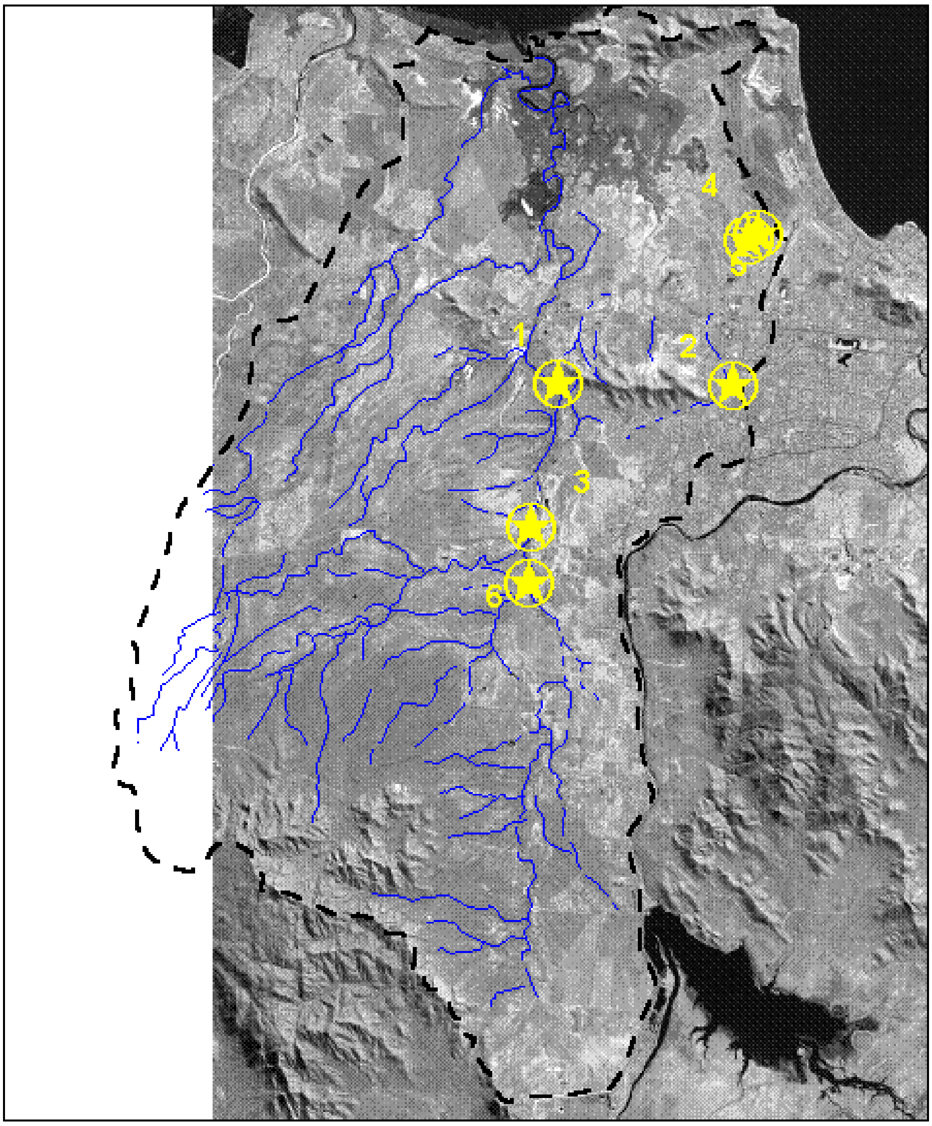
Cast nets were used to sample fish on four occasions in the Bohle River; Sites 1–7, 9 and 10 in September 1997; Sites 1–5 in November 1997; Sites 1–3, 5 and 7 in March 1998 and Sites 1–7 & 9 in May 1998. Cast netting was implemented on the second survey and was not possible during the January 1998 survey due to strong fresh water flows at the time.

Electrofishing

Freshwater fish surveys in the upper reaches of the Bohle River were conducted using a Smith-Root® Model 12 electrofisher, operated either from a 3.9 m aluminium dinghy or by backpack, and a generator powered 1000 V Smith-Root® Model 7.5 GPP electrofisher fitted to a 3.1 m V-nose punt. Electrofishing survey sites were chosen on accessibility, moderate to low water volumes and the suitability of water quality parametres to electrofishing (water conductivity less than 5 ms/cm).

A freshwater electrofishing survey of seven sites in the Bohle River catchment (Map 10) was conducted on 18–19 December 1997, prior to the wet season. Sites 4, 5 and the Borrow Pits on the Town Common, were re-sampled on 26 March 1998. Due to low water flows it was not possible to access many areas of the catchment. Electrofishing sites varied in size, depth of water and water quality. Survey time spent at each site and the area of waterway surveyed by continuous electrofishing was maximised, with the electrofisher (backpack or vessel) moving slowly along the banks to target fish in the shallower habitats (various aquatic vegetation, snags, paragrass and unvegetated areas). The open, deeper waters away form the banks were surveyed by regular crossovers from one bank to the other with the boat-mounted electrofishing unit operating. These crossover transects accounted for approximately one-fifth of the time spent electrofishing. Voltage output varied from 600 V to 800 V depending on the water conductivity. Approximately 4300 seconds (71.7 minutes) was spent electrofishing during the first survey in December 1997. The survey of the Borrow Pits in March 1998 ran for a total of approximately 7000 seconds (116.7 minutes).

Stunned fish were retrieved from the water using dip nets and allowed to recover in an aerated tank on board the vessel and were then examined at the end of the electrofishing run. Fish that could be positively identified on site were measured to the millimetre Fork Length (FL) or Total Length (TL) and released. Dead fish that could not be identified in the field were placed on ice for positive identification at the laboratory.



Map 10 Electrofishing sites in the Bohle River catchment.

Trailer counts

The number of trailers at the boat ramp was recorded during each visit as a relative measure of recreational fishing use of the area. It is acknowledged that the count of trailers is only indicative of effort as vessels may have fished other areas outside the Bohle River.

Crab surveys

Ten collapsible, round, Munyana© crab pots were set at up to eight estuarine survey sites during each bimonthly survey exercise. Sites 1, 2, 4, 6, 8, 9, 10 and 12 (Map 10) were regularly sampled. Sites 1 and 2 were omitted during the September 1997 survey due to poor weather, and Site 2 was missed in January 1998 because of logistic problems. Pots were set in the morning and checked every 12 hours over a 24-hour period. At each site pots were positioned approximately 150 metres apart and were deployed on both sides of the waterway near gutters and creek mouths. Baits (fish frames and butches bones) were checked every 12 hours and replaced as necessary.

Gender of all mud crabs caught was recorded along with carapace width (mm). Each crab was inspected for injury, deformity or obvious parasites and tagged between the abdomen and carapace using orange T-Bar tags (Hallprint model TBA-2) before release. Crabs were not tagged if their carapace width (CW) was less than 80 mm as Hill (1982) has shown in tank trials that some mortality occurs when tagging smaller crabs. Other affects of tagging with this technique and tag retention have not been established.

For the analysis of catch data, crabs were categorised as juvenile, sub-adult or adult depending on their sizes. Crabs with a carapace width less than or equal to 99 mm were classified as juveniles, crabs equal to or greater than 100 mm and less than 150 mm were classified as sub-adults, and crabs greater than or equal to 150 mm were classified as adults (Hill *et al.* 1982).

Water quality surveys

Measurements of conductivity (mS/cm), salinity (%), turbidity (NTU), dissolved oxygen (mg/L), temperature (^{o}C) and pH were recorded at each net position, at the furthermost downstream crab pot at each estuary survey site and at each electrofishing site. Parametres were measured using a Horiba U-10 water quality metre at 0.5 m below the water surface. Water flow was visually gauged and quantified as either, nil, slight, medium or high. Dissolved oxygen was converted from mg/L to a percentage using the following formula:

$$DO\% = DO\ mg/L \times 100 / \{14.3289-(0.3253*T)+(0.0032)*T^2\}$$

where DO is dissolved oxygen and T is temperature.

Data analysis

Descriptive statistics for fish catches, crab catches and water quality parametres were conducted and basic uni-variate analyses (ANOVAs, regressions) were undertaken on fish species and mud crabs. Least significant difference (LSD) was calculated for significant ANOVA results ($p = 0.05$) to determine among means differences in the data.

The Shannon - Wiener diversity index (H) (Zar 1984) was used to explore fish species diversity from the research gillnet catches at each netting site. Species evenness (J) ranges from 0 – 1 and was explored using the formula $J = H / H_{max}$. Species evenness provides a measure of dominance of any particular species over others (Zar 1984) and in a system where few species are numerically abundant and many species are represented by few animals, the species evenness would be closer to zero than one.

Crabs that were recaptured within the same site within 24 hours of being released were excluded from the number of crabs caught and analysis of size frequency. With various staff members involved with fish identification, it was found that the identification of *Platycephalus indicus* and *P. fuscous* was inconsistent and as both species were positively identified from the Bohle River their data have been pooled here (*Platycephalus* spp.). Also *Valamugil buchanani* and *V. georgii* often suffered the same fate, becoming *Valamugil* spp.

Target species

Captured fish that were not measured (various reasons), were excluded from calculation of percent of legal sized fish caught. Catch data from extra gillnets were excluded from comparison of mean length of target species across months. Catch rates for barramundi, king threadfin and blue threadfin, were based on gillnet data as 98% or more of fish of these species were caught using gillnets. Due to low sample number, catches of banded grunter, small-spot grunter, yellowfin bream and pikey bream from all collecting techniques was pooled for analysis. Catch per unit effort of gillnet catches was calculated as number of fish per hour fished including all net sizes cumulatively. Number of crabs per pot lift was used as a measure of catch rate as it was for fish traps.

One-way analysis of variance comparing sizes of fish and crabs among months was done before comparing sites in order to determine temporal independence of data collected. All assumptions of the one-way ANOVA were tested before analysis was completed.

Results and discussion

Research gillnetting surveys

A total of 2896 fish were caught in 951.1 hours fishing, with 57 species identified from 36 families. The overall catch rate from gillnets was 3.04 fish per hour fished. Fishing effort was not evenly spread across all sites and months and Table 2 shows the number of hours fished at each site, on each survey.

The size range of fish caught in research gillnets was from 70 to 1390 mm fork length (or total length where appropriate) with the majority (98%) being between 150 and 600 mm (Figure 2), and the mean size was 300 mm s.e. = 0.28 mm. The size distribution of fish that each mesh size caught overlaps with the next mesh size (Figure 2), this indicating that the gear sampled a wide range of size classes for the species caught.

Table 2 Gillnet effort (hours fished) recorded at each site for each month surveyed the Bohle River.

Site	June 1997	September 1997	November 1997	January 1998	March 1998	May 1998
1	10.62	16.12	15.48	11.08	15.02	18.67
2	10.25	11.98	10.37	0	0	0
3	0	18.80	16.97	16.60	16.97	21.03
4	0	19.32	18.08	13.57	14.75	19.15
5	25.42	19.30	20.92	12.95	17.48	11.12
6	24.10	19.25	22.47	0	16.43	16.42
7	23.10	21.27	20.08	11.63	18.48	17.62
9	23.38	18.37	24.92	14.30	17.75	16.88
10	19.38	20.92	0	37.07*	14.03	17.43
11	22.50	19.08	0	35.78*	14.85	17.28

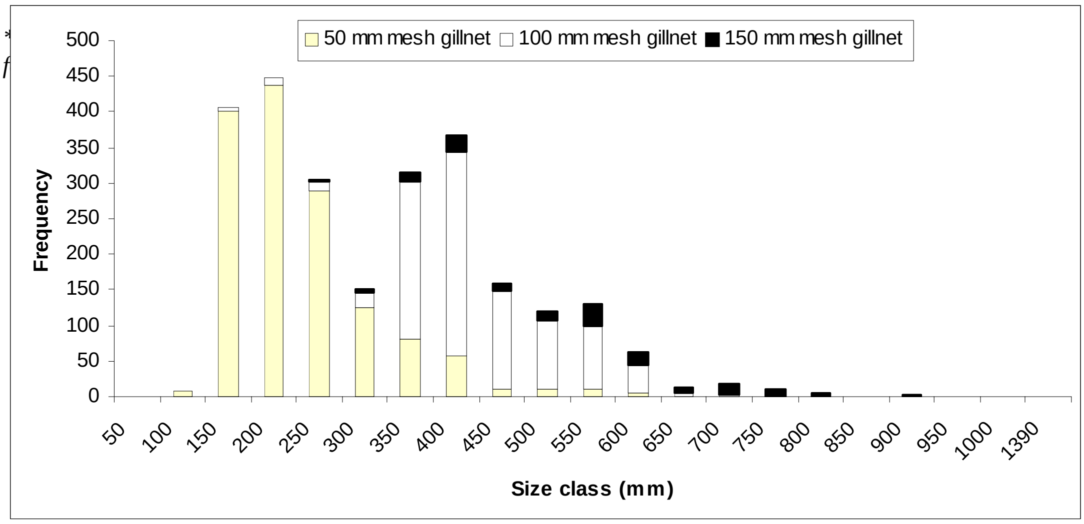


Figure 2 Size frequency distribution of gillnet catches during the Bohle River survey.

Most research gillnet catches were comprised of middle to surface water species with low catches of those species usually associated with structural complexity, such as bream, *Acanthopagrus* spp., and mangrove jack, *Lutjanus argentimaculatus*. This reflects the bias of the sampling gear toward highly mobile open water species.

Total species diversity (H) over the year averaged H = 2.45 and ranged from H = 1.52 at Site 9 to H = 2.54 at Site 3 (Figure 3). The patterns of species evenness closely followed that of diversity except at Site 2 (Figure 3), where very few fish were recorded. Mean fish diversity values at each site ranged from H = 1.13 to H = 1.87 (Figure 4) and was statistically significant (One-way ANOVA, F = 0.05, df = 50, p = 0.048). Gillnet efficiency at Site 10 was heavily affected by flow rate and reduced fishing efficiency was recorded on 3 of the five surveys at this site. This may account for the high variation in diversity recorded at this site. The low mean diversity at Site 2 and 9 may be related to habitat. Sheaves (1998) has shown diversity decreases as you move upstream which is supported here. Site 10 and 11 appear to contradict this pattern, however, the Bohle River splits at Site 6 with Site 10 and 11 being the main river while Sites 7 and 9 are within a major tributary offshoot that terminates much sooner than the main river (see Map 10).

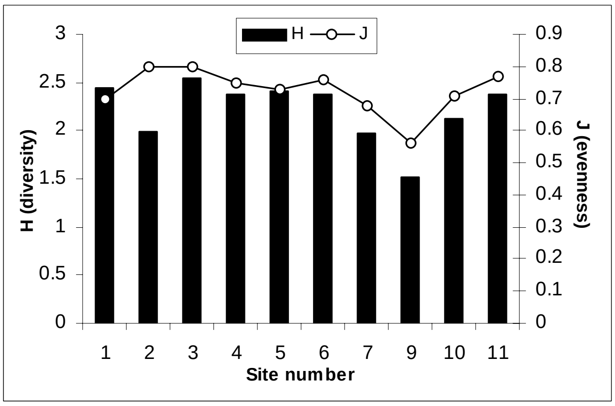


Figure 3 Total species diversity (H) and evenness (J) at each site in the Bohle River over the survey period.

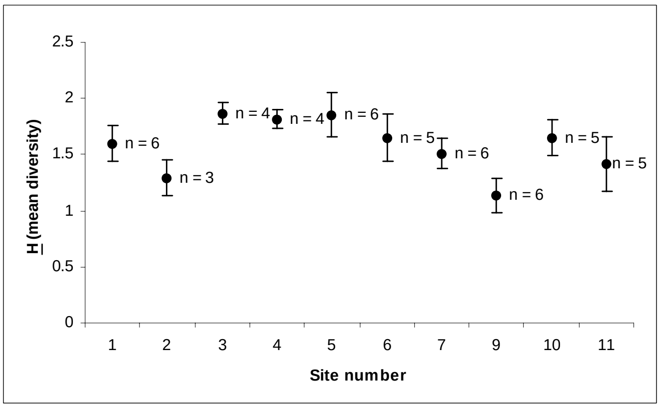


Figure 4 Mean species diversity (H) and standard error bars for each estuary site in the Bohle River survey. n = numbers of surveys completed at each site.

Diversity and species evenness of all gillnet catches also varied throughout the period of the survey from June 1997 (H = 2.44) to May 1998 (H = 1.85) as shown in Figure 5. Mean diversity for each survey ranged from H = 1.73 to H = 1.35 (Figure 6), but there were no statistically significant differences among survey trips (One-way ANOVA, F = 0.98, df = 50, p = 0.438). Blaber *et al.* (1985) and Robertson and Duke (1990) both report lower diversities in winter months, suggesting recruitment of juvenile fishes in summer enhanced diversity in those months. This pattern was not observed from the gillnet surveys of the Bohle River, however, both Blaber *et al.* (1985) and Robertson and Duke (1990) used small mesh nets, targeting smaller fish that would not have been sampled with the large mesh nets in this project.

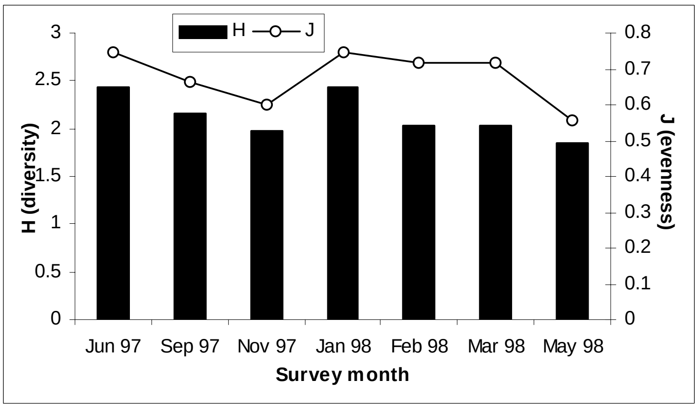


Figure 5 Species diversity (H) and evenness (J) recorded in gillnet catches each month the Bohle River was surveyed

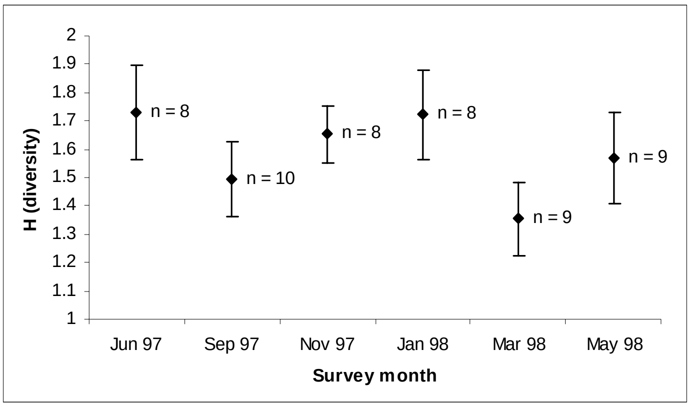


Figure 6 Mean species diversity (H) and standard error bars for gillnet catches each month during the Bohle River survey. n = numbers of surveys completed at each site.

Table 3 shows the catch rate of gillnets during each survey. Peak catch rates were recorded upstream at Site 9 in January 1998 (10.98 fish/hour) and May 1998 (9.89 fish/hour). June 1997 returned generally lower catch rates and also recorded lowest water temperatures. Catches in March 1998 would have been reduced by the large amount of freshwater run off and debris associated with recent rainfall event in the catchment affecting the fishing efficiency of the gillnets. Species contributing to catch rates in Table 3 can be see in Table 4 and Table 5 below.

Table 3 Number of fish caught per hour fished each estuarine survey site in the Bohle River between June 1997 and May 1998.

Site	**June 1997**	**September 1997**	**November 1997**	**January 1998**	**March 1998**	**May 1998**
1	0.85	5.46	0.97	3.79	2.93	4.66
2	0.88	1.00	3.18			
3		4.95	3.18	3.13	2.53	2.52
4		4.14	4.09	2.51	5.63	2.98
5	3.66	3.06	1.86	2.55	5.78	1.71
6	2.99	2.75	2.49		1.22	1.89
7	3.72	1.55	5.27	3.27	3.41	2.16
9	1.97	4.08	4.13	**10.98**	1.80	**9.89**
10	2.37	0.43		1.29	0.78	4.36
11	1.82	0.89		1.70	0.74	4.17

Table 4 shows the ten species with the highest catch rates in research netting surveys, including three baitfish families (Clupeidae, Mugilidae and Engraulidae), barramundi (Centropomidae) and catfish (Ariidae). One catch of bony bream, *Nematalosa come,* at Site 9 stands out in this data set and the catch rate of this species was generally high throughout the Bohle River.

A much more diverse catch was recorded during the Coastal Streams survey of Trinity Inlet, Cairns, where 95 species from 46 families were recorded from 2033 fish caught in 634 hours gillnet fishing (Helmke *et al.* 2000). However, Trinity Inlet is a much larger system than the Bohle River including a greater range of habitat types and being within the Wet Tropics, has a higher average rainfall. Beumer (1980) reports a small number of fish species from the Black and Alice Rivers neighbouring the Bohle River to the north, with fortnightly sampling over two years using a seine net and electrofishing apparatus producing just 41 species. Alternatively, Robertson and Duke (1990) report 128 species from Alligator Creek 12 km to the south east of Townsville using trap nets, seine nets and 18 mm-mesh gillnets to target much smaller fish than the present study.

Table 4 Catch rate (number of fish caught per hour fished) at each site for the ten species with the highest overall catch rate. Target species (see page 24) are highlighted in bold. One outstanding catch of Nematalosa come is also highlighted in bold.

Species	Family	1	2	3	4	5	6	7	9	10	11	Total
Nematalosa come	Clupeidae	1.13	0.03	0.59	0.74	0.81	0.43	0.60	**2.50**	0.51	0.28	0.83
Lates calcarifer	**Centropomidae**	0.10	0.00	0.33	0.55	0.41	0.17	0.58	0.77	0.27	0.30	0.38
Arius graffei	Ariidae	0.28	0.52	0.35	0.53	0.33	0.10	0.52	0.56	0.08	0.05	0.32
Arius argyropleuron	Ariidae	0.05	0.06	0.18	0.34	0.09	0.45	0.79	0.38	0.17	0.22	0.30
Liza subviridis	Mugilidae	0.06	0.00	0.25	0.27	0.25	0.10	0.24	0.30	0.22	0.00	0.21
Megalops	Megalopidae	0.03	0.00	0.04	0.15	0.23	0.16	0.08	0.00	0.03	0.00	0.08
Thryssa spp.	Engraulidae	0.25	0.00	0.23	0.16	0.02	0.02	0.01	0.03	0.01	0.00	0.07
Thryssa hamiltonii	Engraulidae	0.10	0.03	0.11	0.21	0.07	0.01	0.03	0.04	0.00	0.06	0.06
Mugilidae spp.	Mugilidae	0.01	0.00	0.01	0.08	0.03	0.15	0.05	0.05	0.05	0.08	0.05
Valamugil	Mugilidae	0.00	0.00	0.08	0.06	0.03	0.15	0.01	0.00	0.03	0.00	0.05

Catch rates of the top ten species varied from month to month (Table 5) although that of bony bream, *Nematalosa come,* was among the highest each month. Barramundi had the highest catch rate of all netted species in summer (January and March) 1998. Other species did not show a strong seasonal pattern in their catches although some irregular high catches were recorded.

Highest catch rates were obtained at Site 9 in January and May 1998 (Table 3). The May 1998 value was due to a large catch of bony bream at this site and the January 1998 figure was boosted by large catches of barramundi, *L. calcarifer*, bony bream, *N. come*, catfish, *A. graffei* and *A. argyropleuron,* and mullet, *L. subviridis* (Table 5).

Table 5 Catch rate each month of the survey for the ten species with the highest overall catch rate in the gillnet catches. Target species (see page 24) are highlighted in bold and peak catches are also highlighted.

Family	Species	June 1997	Sep. 1997	Nov. 1997	Jan. 1998	March 1998	May 1998
Clupeidae	*Nematalosa come*	0.48	**0.99**	0.52	0.56	0.51	**1.87**
Centropomidae	***Lates calcarifer***	0.33	0.33	0.09	**0.68**	**1.10**	0.14
Ariidae	*Arius graffei*	0.13	0.13	**1.28**	0.30	0.05	0.18
Ariidae	*Arius argyropleuron*	0.25	0.25	0.46	0.36	0.01	0.39
Mugilidae	*Liza subviridis*	0.36	0.36	0.12	0.31	0.13	0.14
Megalopidae	*Megalops cyprinoides*	0.21	0.21	0.05	0.06	0.14	0.01
Engraulidae	*Thryssa* spp.	-	-	-	0.06	0.02	0.35
Engraulidae	*Thryssa hamiltonii*	0.04	0.04	0.05	0.03	0.09	-
Mugilidae	*Mugilidae* spp.	0.04	0.04	-	0.07	0.03	-
Mugilidae	*Valamugil buchanani*	0.01	0.01	0.05	0.01	-	0.09

Baitfish catch rate

During the survey, the highest catches of baitfish were made in May 1998 (Figure 7) and at Site 9 (Figure 8). Overall, baitfish catch rates were lowest at Site 2 with Sites 6, 7, 10 and 11 producing less than 1 fish per hour fished. Catch rates of mugilids and clupeids were highest in the upstream areas (Sites 11 and 9 respectively). While engraulid catch rates were highest at the mouth of the river (Sites 1, 3 and 4). The poor results at Site 2 can be attributed to low sampling time at this site with small mesh nets (November 1997 survey only) and fouling of nets when used.

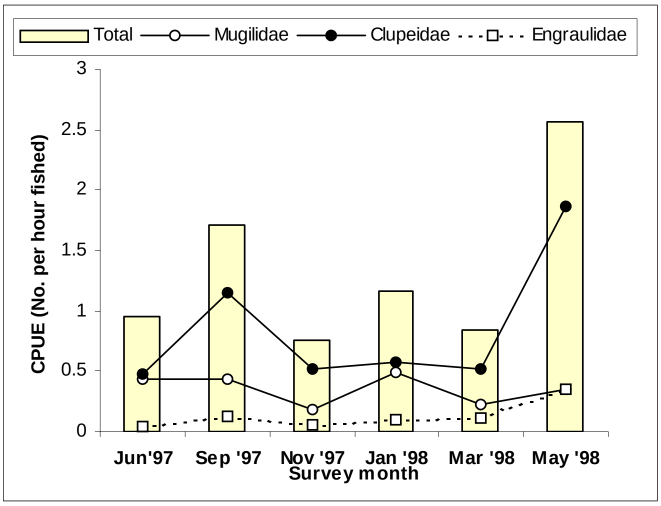


Figure 7 Number of bait fish caught per hour fished at each site during the Bohle River surveys.

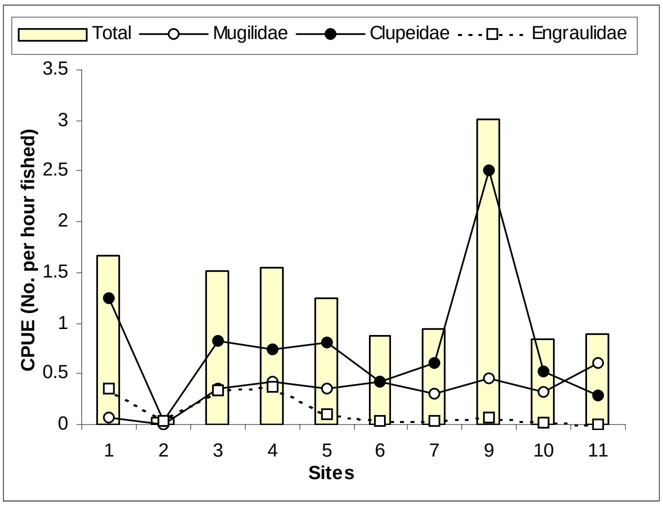


Figure 8 Number of baitfish per hour fished each month surveyed in the Bohle River.

Target species catch rates

Seven of the ten target species were caught using gillnets with barramundi the most commonly caught. The average, minimum and maximum size recorded for each target species can be seen in Table 6. No jungle perch, *Kuhlia rupestris,* or yellowfin bream, *Acanthopagrus australis* were caught in gillnets. The lack of jungle perch is not unexpected as they rarely enter saltwater and none were caught in freshwater surveys further up stream.

The low catches of several of the target species (grunter, blue threadfin, bream and mangrove jack) are note worthy although set gillnets are not optimal for catching bream and Lutjanidae species. Poor catches of grunter and threadfin may reflect sampling biases (gear bias, timing and location of sets) or reflect low population abundances in the Bohle River during sampling period.

Table 6 Details of gillnets catches of target species during the Bohle River survey.

Species	Common Name	CPUE	No. caught	Min Size (mm)	Max Size (mm)	Mean Size (mm)	Standard error
Acanthopagrus berda	Pikey bream	0.0011	1	240	240	240	-
Eleutheronema tetradactylum	Blue threadfin	0.0357	34	202	545	322	162.3
Lates calcarifer	Barramundi	0.3606	343	220	890	500	194.6
Lutjanus argentimaculatus	Mangrove jack	0.0011	1	340	340	340	-
Polydactylus macrochir	King threadfin	0.0400	38	250	730	506	190.2
Pomadasys kaakan	Banded grunter	0.0126	12	115	345	229	231.5
Pomadasys argenteus	Small-spotted grunter	0.0147	14	241	450	290	70.2

Cast netting survey

A total of 520 casts were made over the nine month sampling period from September 1997 to May 1998, capturing 860 fish specimens from 52 species and 27 families (Appendix 4). The most commonly caught families were Engraulididae, Clupeidae, Leiognathidae, Chandidae, Mugilidae and Tetraodontidae (Figure 9). A greater diversity of fish species was obtained by cast netting than with any other technique employed in the Bohle River survey. The overall species diversity in cast net catches was H = 3.1, and species evenness was also high, at J = 0.79.

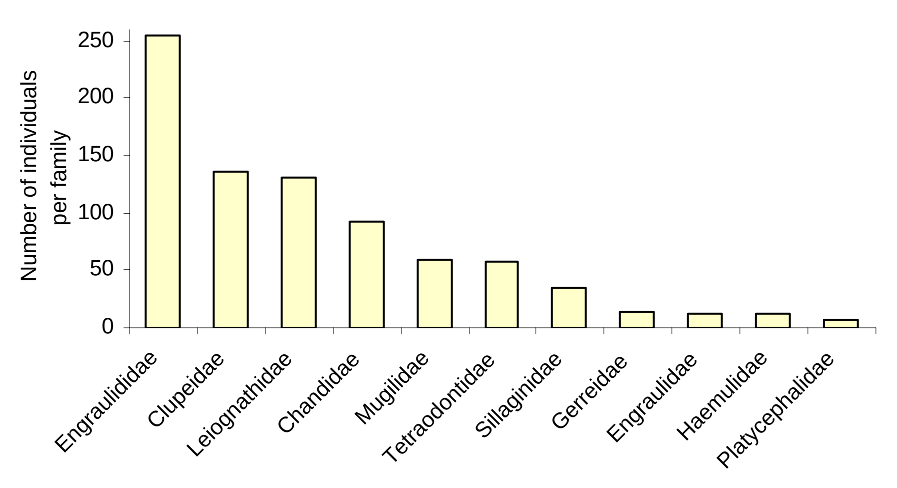


Figure 9 Number of individuals caught within each of the most frequently caught fish families in cast nets during the Bohle River survey.

Diversity among sites ranged from H = 2.56 for Site 4 to H = 1.77 at Site 10 (Figure 10). Species evenness followed a similar pattern to diversity and approached the maximum value of 1, at Site 4. The mean species diversity per survey was greatest at Site 5, 6 and 7 and ranged from H = 1.77 to H = 0.88 (Figure 11). Site 2, a low aspect sand bar at the mouth of the river, produced the lowest mean diversity. Within site variation was large (Figure 11) and may be attributed to the imprecise, “hit or miss” nature of cast netting surveys. Data should be interpreted carefully as the number of casts made at each site each month varied, from 64 casts at three sites in November 1997 to 185 cast at ten sites in September.

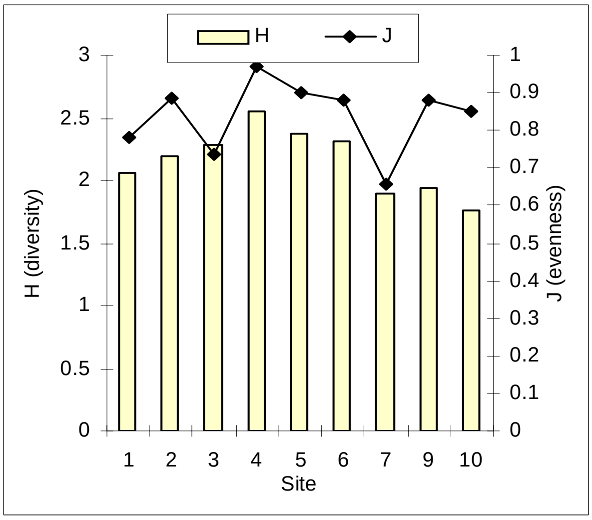


Figure 10 Species diversity (H) and evenness (J) recorded from cast net catches at each site in the Bohle River

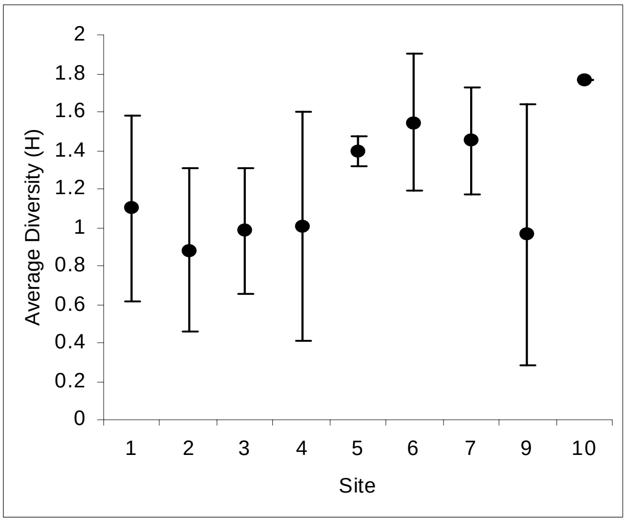


Figure 11 Mean species diversity (H) and standard error bars recorded from cast net catches at each site in the Bohle River

Monthly variation in overall species diversity ranged from H = 2.91 in May 1998 to H = 1.31 in November 1997 (Figure 12). This pattern was similar but more subtle for species evenness indicating fluctuations in diversity were due more to differences in the number of species than in species evenness. The average species diversity for sites over the survey period increased over time from H = 0.76 in November 1997 to H = 1.87 in May 1998.

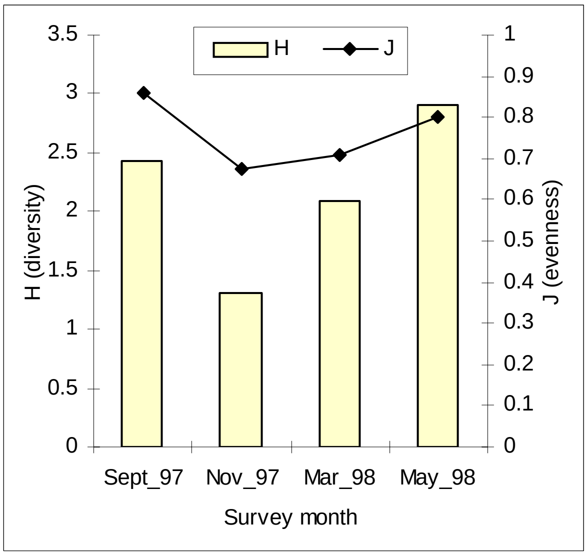


Figure 12 Species diversity (H) and evenness (J) recorded from cast net catches for each month sampled in the Bohle River

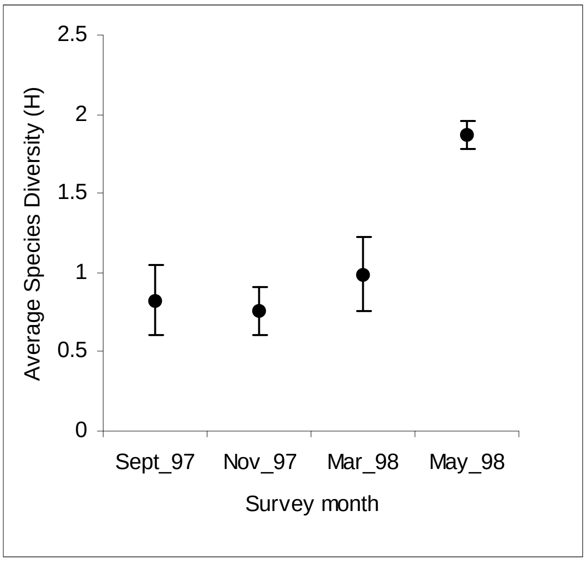


Figure 13 Mean species diversity (H) and standard error recorded from cast net catches for each month survey in the Bohle River.

The size of fish caught in cast nets ranged from a 10 mm long banded toadfish, *Marilyna pleurosticta* to a 470 mm barramundi, *Lates calcarifer,* although most of the catch (95%) measured 20 – 140 mm (Figure 14). The juveniles of target species comprised 3% of the catch, and the smaller sized fish were mainly toadfish or baitfish (engraulids, clupeids).

The cast netting survey technique caught mostly highly mobile, mid water species. A number of benthic species were also taken such as flounder, soles, tongue fish, stingrays and whiting (see Appendix 4) which were not caught with other sampling techniques. Altogether, 23 species were caught in cast nets only.

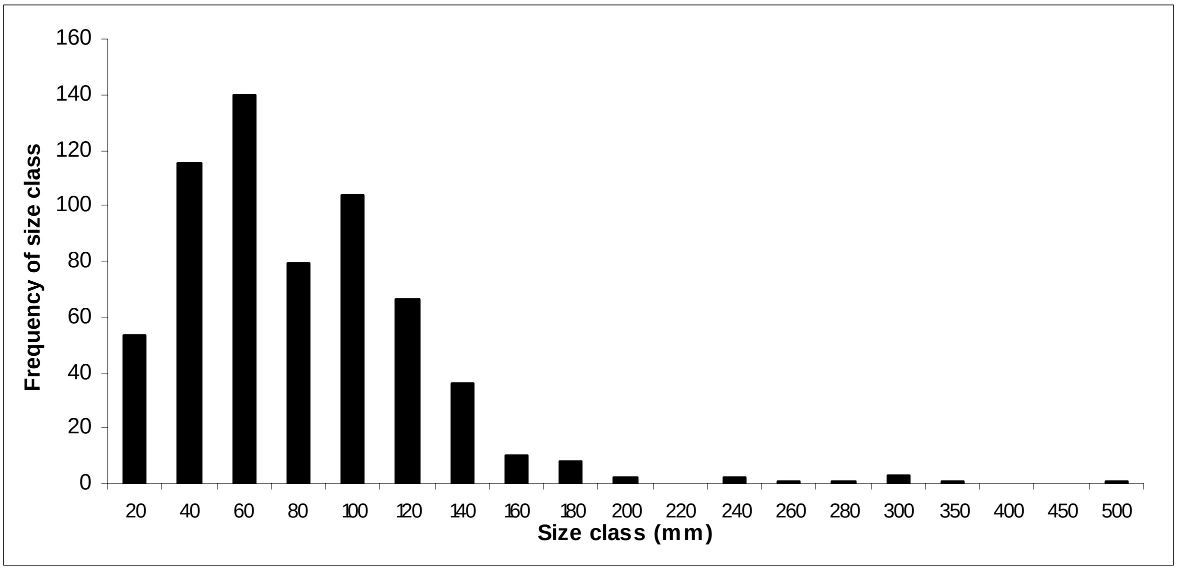


Figure 14 Size frequency distribution of cast net catches at Bohle River survey site.

Target species catches

Four of the ten target species were captured using cast nets. Six barramundi were caught at a size of 238–470 mm, which are approximately six months to two years old (Russell and Rimmer 1998). Four were tagged and released. The seven banded grunter, *Pomadasys kaakan*, caught measured 72–125 mm in length. These fish were most probably juveniles of less than 12 months of age (Bade 1989). Banded grunter were also caught in fish traps (see Table 7). Five spotted grunter, *P. argenteus,* were encountered during the cast net survey of May 1998 at a size of 88–145 mm. Three pikey bream, *Acanthopagrus berda*, were captured in cast nets at 93–135 mm in length. These specimens were caught at the mouth of the river where *Ceriops sp.* mangroves were falling into the water created structured habitat.

Bohle River fish trap survey

A total of 416 fish and crabs were caught in 139 trap lifts over four survey exercises, comprising 25 species (Table 7) from 15 families. Sheaves (1996) reported similar diversity (19 fish species) from 535 fish caught during a fish trapping exercise in Alligator Creek, 12 km to the south of Townsville. More than half the fish species in Table 7 were caught in Alligator Creek by Sheaves (1996) including the nine most numerous fish species. In a much larger study Sheaves (1998) reports 58 species caught in fish traps from three local streams, Cattle, Alligator and Barramundi Creeks, sampled once every three months over a two year period.

Trapping effort varied across surveys and sites, principally due to trap damaged or loss and non-replacement and care should be taken when comparing diversity and species evenness across sites or months. The number of lifts ranged from 19 at five sites in September 1997 to 40 at four sites in January 1998. Diversity was poorly correlated with number of fish traps lifts at each site ($r^2 = 0.025$, $n = 8$) and each month ($r^2 = 0.016$, $n = 4$), however, there were few data points available for the correlation analysis.

The overall diversity of fish species taken in fish traps was lower than that for either gillnetting, or cast netting (H = 2.29). This is likely because different components of the fish communities were targeted by each sampling method, with fish traps being the only technique that sampled in complex habitat structure (Sheaves 1992). Also, fish traps were only used on four of the six surveys which would have reduced the potential diversity of fish caught.

Individual site diversity values were high (Figure 15) except Site 7 which was a low aspect mud bank with lower habitat complexity. Species evenness among sites followed the pattern of species diversity (Figure 15) and diversity of fish species at a particular site overtime was markedly variable (Figure 16).

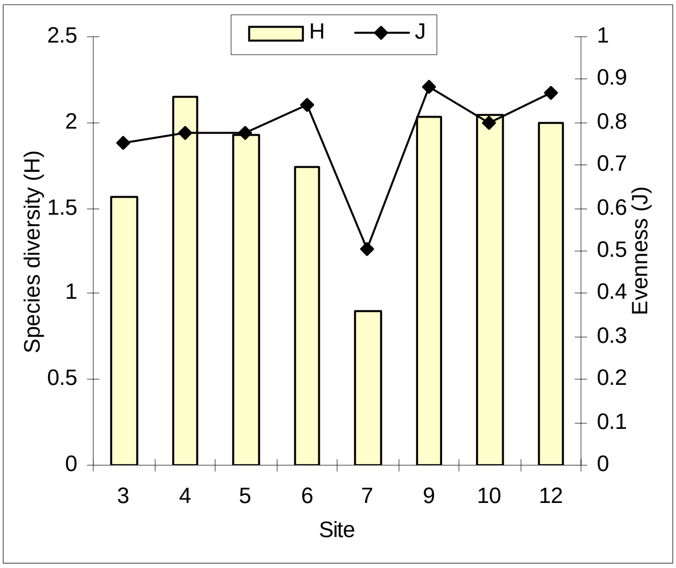


Figure 15 Species diversity (H) and evenness (J) for each site surveyed with fish traps in the Bohle River.

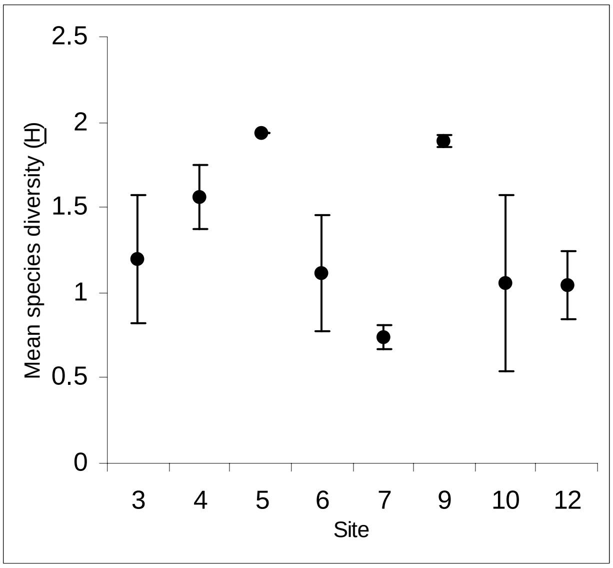


Figure 16 Mean species diversity (H) and standard error for each site surveyed with fish traps in the Bohle River

Over the four months surveyed using fish traps, species diversity at all sites combined fell from H = 2.16 in September 1997 to around H = 1.6 in March 1998 (Figure 17). This differs to patterns revealed by both gillnetting (Figure 5) and cast netting (Figure 12) perhaps highlighting the differences in application of the different sampling methods. Mean diversity at each site over time (Figure 18) showed a similar trend, however, the difference in numbers of trap lifts (effort) each month makes it difficult to compare these data.

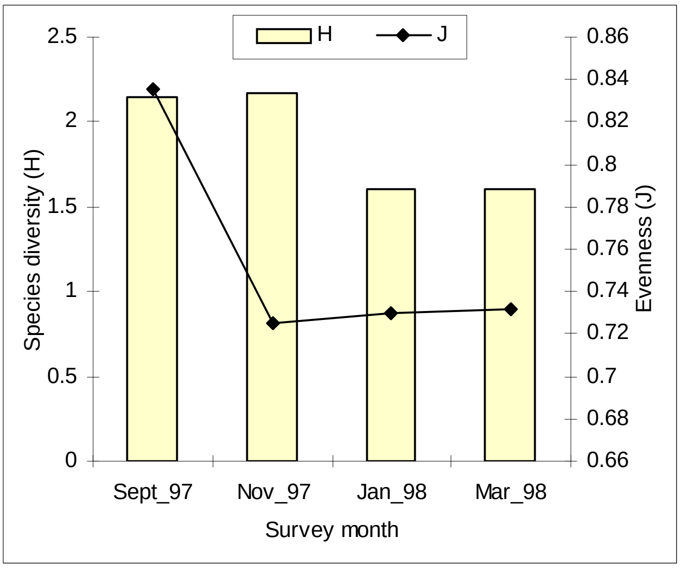


Figure 17 Mean species diversity (H) recorded from fish traps for each month surveyed in the Bohle River.

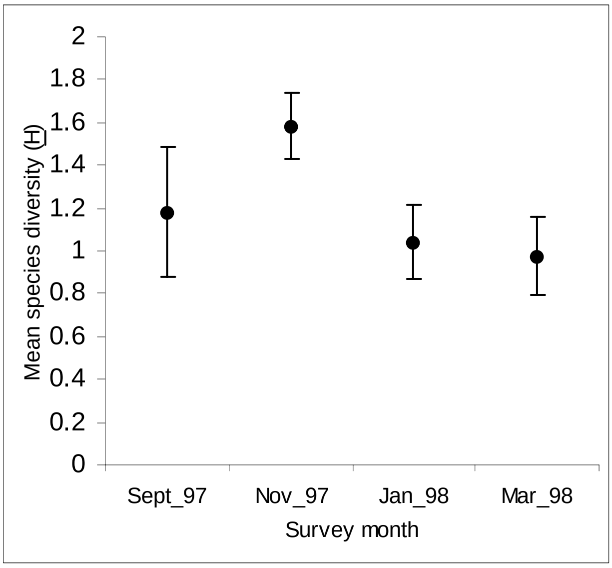


Figure 18 Species diversity (H) and evenness (J) recorded from fish traps for each month surveyed in the Bohle River.

The size of fish caught in traps ranged from 38–550 mm (Table 7) with an average of 191 mm with 75%, of fish between 100–200 mm long (Figure 19). The largest fish caught in fish traps were gold- and black-spot cods (*Epinephelus coioides* and *E. malabaricus* respectively). The smaller size classes were dominated by pikey bream, *Acanthopagrus berda*, yellowfin bream, *A. australis*, and mud crabs, *Scylla serrata*, although a large number of species were represented by only a few individuals.

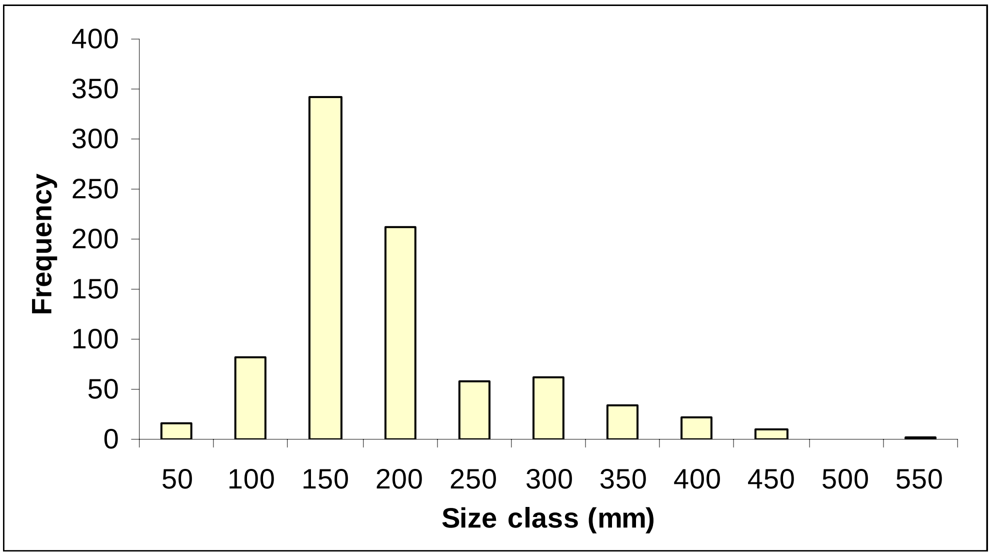


Figure 19 Overall size frequency histogram for fish trap catches

The overall catch rate of fish traps was 2.99 fish per trap lift (range 1.48–6.33 fish per trap lift) and the most frequently caught species were mud crab, *Scylla serrata*, pikey bream, *Acanthopagrus berda*, gold-spot cod *Epinephelus coioides*, Moses perch, *Lutjanus russelli*, and the striped puffer (Table 7). These five species were all trapped at each site on each survey occasion with two exceptions: Moses perch were absent in fish trap catches in January 1998 and gold-spot cod were not recorded in March 1998.

Fish trapping survey techniques caught mostly species that are associated with complex habitat. Prominent among the catch are ambush predators, such as the cods, *Epinephelus coioides* and *E. malabaricus*, mangrove jack, *Lutjanus argentimaculatus*, fingermark, *L. johnii*, stripey, *L. carponotatus* and flathead, *Platycephalus* spp. Cod caught would often regurgitate small bream (*Acanthopagrus* spp.) when removed from the traps indicating the presence of bream inside the traps may have also attracted cod species as well as the trap bait. Scavengers and opportunistic feeders were represented by mud crabs, *Scylla serrata*, sand crabs *Portunus pelagicus* and puffer fish, Tetraodontidae. Most of the other species caught in traps were omnivorous, schooling fish.

The upper size limit of trapped fish may reflect dimensional limitations of the gear with large fish excluded by entrance dimensions of the trap. Additionally, gold-spot cod (*E. coioides*) are known to migrate out of estuaries at around 330-500 mm in size and move offshore (Sheaves 1995b, Sawynok 1999 & 2000) which corresponds with the size of the largest gold-spot cod found in the Bohle River using all research survey techniques (Figure 20). Black spot cod (*E. malabaricus*) did not show the same size frequency distribution (Figure 20) indicating a difference in either estuarine stock structure or behaviour between these two species. Sheaves (1995b) reports *E. malabaricus* was more common than *E. coioides* in fish trap catches further upstream in Alligator Creek, north Queensland, while *E. coioides* was common in catches downstream. Sheaves (1995b) also indicated *E. malabaricus* may remain in estuaries longer than *E. coioides*, at least 8 and 5 years respectively, based on annuli (annual growth rings) in the fishes otoliths.

Table 7 Number of fish caught per pot lift, size range and average size of each species caught using fish traps in the Bohle River surveys. The six target species captured in traps are highlighted in bold.

Species	Common Name	No. Caught	No. Per Trap Lift	Average Size (mm)	Minimum Size (mm)	Maximum Size (mm)	Standard Error
Scylla serrata	Mud crab	104	0.75	131	66	169	0.23
Acanthopagrus berda	Pikey bream	82	0.59	133	80	220	0.34
Epinephelus coioides	Gold-spot cod	61	0.44	274	150	440	0.76
Lutjanus russelli	Moses perch	49	0.35	143	38	200	0.43
Arothron manilensis	Narrow-lined toadfish	26	0.19	144	65	200	0.61
Epinephelus malabaricus	Black-spot cod	22	0.16	277	135	420	1.98
Acanthopagrus australis	Yellowfin bream	16	0.12	145	115	195	0.54
Monodactylus argenteus	Butter bream	14	0.10	78	55	100	0.38
Marilyna pleurosticta	Banded toadfish	5	0.04	172	140	225	1.64
Batrachoididae sp.	Frog fish	4	0.03	209	160	305	3.27
Lutjanus argentimaculatus	Mangrove jack	4	0.03	141	115	170	1.19
Siganus lineatus	Rabbit fish	4	0.03	149	130	182	1.15
Arius graffei	Catfish	3	0.02	382	335	440	3.09
Lutjanus johni	Fingermark	3	0.02	284	250	338	2.70
Pomadasys argenteus	Spotted grunter	2	0.01	203	203	203	-
Pomadasys kaakan	Banded grunter	2	0.01	143	140	145	0.25
Portunus pelagicus	Sand crab	2	0.01	161	155	167	0.60
Sillago sihama	Northern Whiting	2	0.01	220	215	225	-
Thalamita crenata	Crab	2	0.01	70	70	70	5.36
Arothron hispidus	Stars-and-stripes toadfish	1	0.01	275	275	275	-
Liza subviridis	Mullet	1	0.01	210	210	210	-
Lutjanus carponotatus	Stripey	1	0.01	151	151	151	-
Platycephalus spp.	Flathead	1	0.01	510	510	510	-
Scatophagus argus	Scat	1	0.01	95	95	95	-
Stone crab	Crab	1	0.01	76	76	76	-

The highest catch rate in fish traps occurred in September 1997 (4.7 fish per lift), and the lowest in March 1998 (0.95 fish per lift, Figure 21). Highest catch rates were recorded at sites 4, 5 and 9 (Figure 22). Sampling effort in September 1997 and March 1998 was similar with 19 and 21 trap lifts respectively while January and November were sampled more thoroughly. Variation in sampling effort makes data interpretation difficult for the fish trap catches.

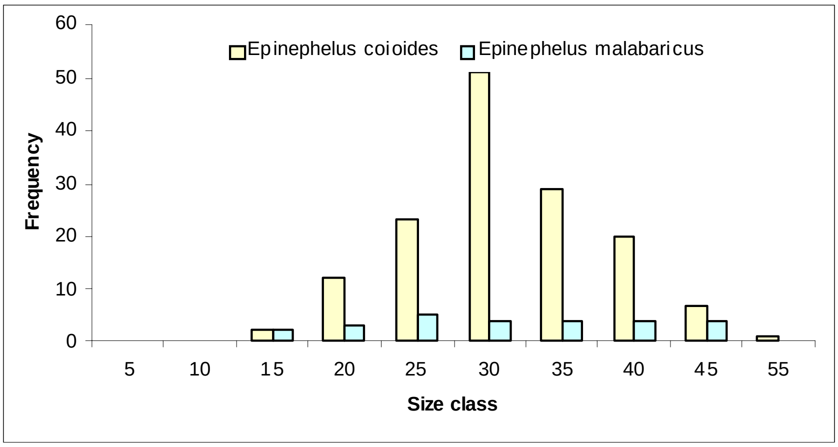


Figure 20 Size class (cm) distribution of gold-spot cod and black-spot cod in the Bohle River estuary.

Large variation was observed in the success of fish traps with just nine species recorded in March 1998 and only mud crabs recording a catch rate above 0.1 per trap lift, compared to September 1997 when nine of the 13 species encountered recorded catch rates above 0.2 fish per trap lift and mud crabs, gold-spot cod and Moses perch each recording catch rates above 0.5 per trap lift. Highest catch rates recorded were 6.3, 5.0 and 4.1 fish per trap lift at Site 5, 4 and 9 respectively (Figure 22). Varying catch rates of the four most prominent species, mud crabs, pikey bream, gold-spot cod and Moses perch had the most significant affect on the overall catch rates at each site. Fish traps at Sites 4 and 5 were set adjacent submerged snags, while fish traps further upstream at Site 9 were set both adjacent snags and in the middle of a narrow tributary (5-6 metres wide). Sheaves (1992) reports more fish and higher diversity caught in fish traps placed adjacent structure than in traps fishing less structured areas. While this was the principle behind setting fish trap adjacent snags in this study it is interesting to note high catch rates from Site 9 where not all traps were adjacent snags. Unfortunately the low sampling effort at Site 9 (8 trap lifts) and Site 5 (9 trap lifts) hinders interpretation of this data.

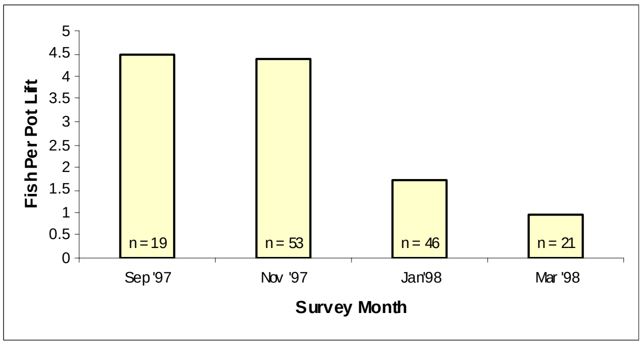


Figure 21 Overall catch rate for each month the Bohle River was surveyed with fish traps. n is the number of trap lifts.

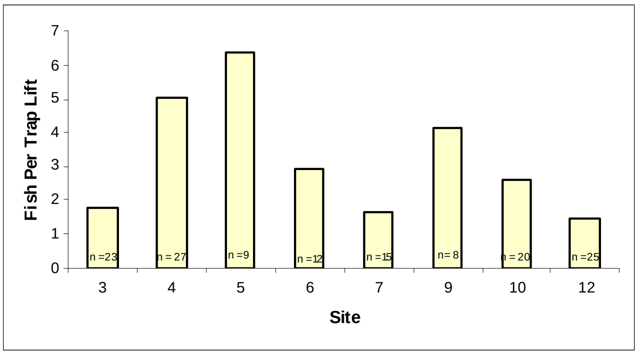


Figure 22 Over all catch rate for each site surveyed with fish traps in the Bohle River. n is the number of trap lifts.

Fish Trap target species catches

Six of the target species were caught using fish traps (Table 4), albeit in small numbers. Four mangrove jack specimens were recorded in traps over the whole survey period, a catch rate of just 0.03 fish per trap lift. They were juvenile fish of 115–170 mm size and were up to about 15 months of age (G. McPherson DPI Fisheries Group pers. comm. 1999). Mangrove jack were only encountered at up stream estuarine sites (Map 10). Importantly, these fish were only caught in January 1998 just after a major flood event which would have provided connectivity between their wetland nursery sites and the estuary.

Two specimens of spotted grunter, *Pomadasys argenteus* and banded grunter, *Pomadasys kaakan* were taken for catch rates of just 0.01 fish per trap lift. Grunter were caught only in November 1997, when banded grunter were absent from the cast net catches. The four specimens were juveniles around a year old based on work reported by Bade (1989) in the nearby Cleveland Bay.

Pikey bream (*Acanthopagrus berda*) and yellowfin bream (*A. australis*) recorded catch rates of 0.59 and 0.12 fish per trap lift respectively. Pikey bream were caught every month and every site through the survey period in large numbers (see page 56). Pikey bream specimens ranged from 80–220 mm, all below the legal size limit, 230 mm TL. In contrast, yellowfin bream were recorded from five of the eight sites sampled and ranged from 115–195 mm in length. Sheaves (1995a) has shown size selectivity in fish traps. A size frequency diagram of *Acanthopagrus* species caught during this his survey shows the Z-traps may be selective towards size classes from 80–250 mm for bream (Figure 23).

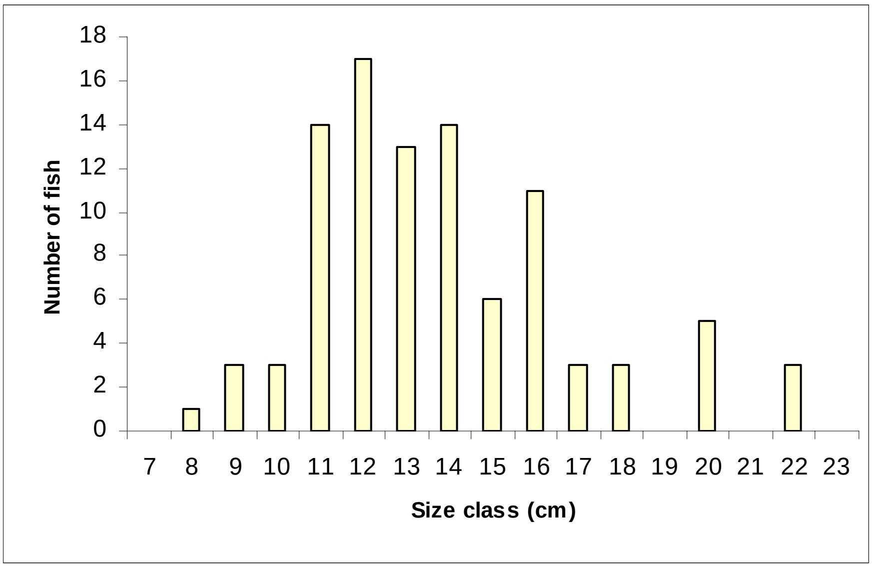


Figure 23 Size class distribution of Acanthopagrus species caught during the Bohle River fish trapping survey.

Mud crabs were the most commonly caught species in fish traps, recording an overall catch rate of 0.75 crabs per trap lift. Mud crabs were caught in each month surveyed and at every site. Catch rate of mud crabs in fish traps was higher than the highest catch rate of mud crabs in crab pots (0.63 crabs per pot lift recorded in March 1998, however the size range was similar at 66–169 mm and 64–189 mm for trap and pot catches respectively. The reason for higher catch rates using fish traps is unclear and may have been influenced by factors such as trap size, bait used and habitat targeted.

Target species catches

Before catches of barramundi can be discussed here the following should be noted. During the Townsville region floods on the 10–14th, January 1998 (see Rainfall data later), several cages of barramundi from an aquaculture venture in the Ross River, approximately 20 km south east along the coast, were destroyed releasing thousands of fish. Many of these fish washed up dead on Pallarenda Beach 8 km east of the mouth of the Bohle River, 10 km north-west of the Ross River. These fish appeared to be of two specific size classes namely 200–300 mm TL and 400–600 mm TL. Recreational anglers reported catching many barramundi around Pallarenda and the Bohle River in the weeks following the flood. Many of these barramundi had scale damage and severe ulcerous lesions where scales had been removed (Figure 24). It had been widely postulated that the scale damage of these fish occurred while flood waters washed fish against the side of their cages in the Ross River before their cages were destroyed. Hence, it can be assumed there was an unnatural addition to the Bohle River barramundi population from the unfortunate destruction of the barramundi aquaculture enterprise during January 1998 and several barramundi with scale damage and fungus were caught during gillnetting survey of the Bohle River during the January 1998 survey.

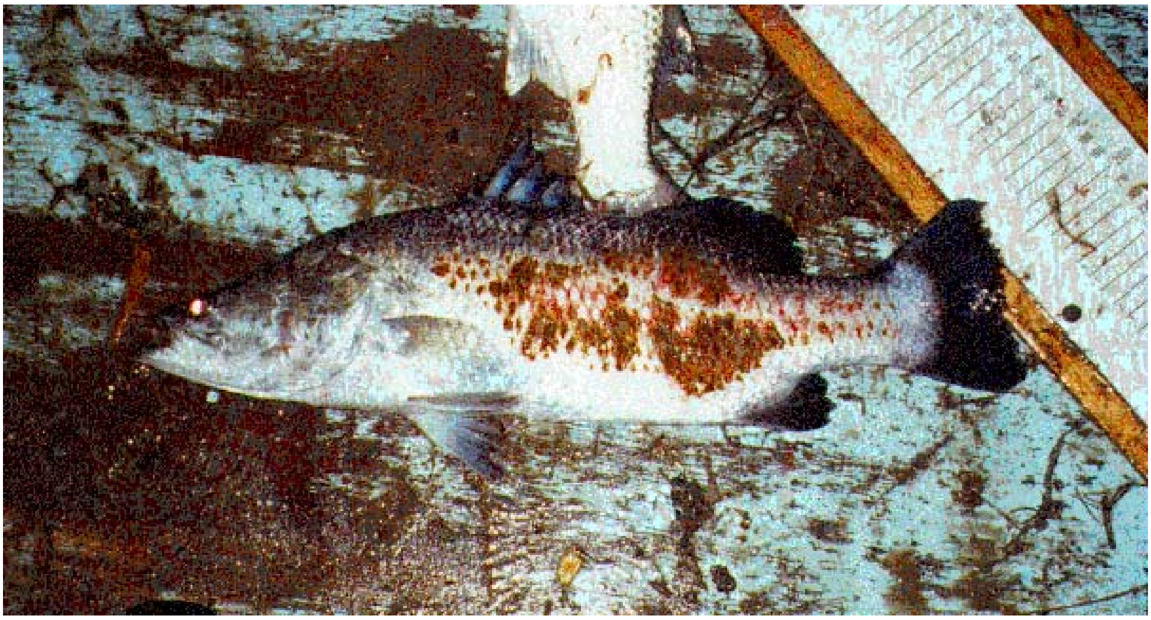


Figure 24 A barramundi caught during gillnetting survey of the Bohle River in January 1998 showing scale damage and ulcerous marks.

Barramundi (*Lates calcarifer*)

A total of 387 barramundi were caught and 369 were tagged before release during the twelve month Bohle River survey. Almost all (98.2%), were caught using gillnets. Information from barramundi, that were tagged and recaptured by recreational fishers, is discussed on page 97. Barramundi ranged in size from 220–890 mm TL which corresponds to an age span of less than a year old to about seven years old (Garrett and Russell 1982, Davis and Kirkwood 1984).

The size frequency distribution indicates the presence of a wide range of year classes in the catch (Figure 25). Most, 74.9%, barramundi caught were 400–600 mm TL, and 13.5% were of legal size (between 580 and 1200 mm TL) for this species. The relatively small contribution of fish greater than 600 mm TL may be due to a variety of reasons including size selectivity of gillnets, fish learning to avoid nets as they get larger, an unnatural peak in the 400 - 600 mm TL size classes from the fish that escaped from the nearby barramundi farm when the January floods came or reduced numbers of the size classes above 600 mm in the population due to migration, fishing pressure or other causes. Hall *et al.* (1998) discuss size selectivity of barramundi catches in gillnets and have shown that barramundi from 520 to 840 mm TL still had a greater than 25% chance of being caught in the 150 mm gillnets used by this project. This indicates size selectivity of nets may not be the cause of lower numbers of larger barramundi.

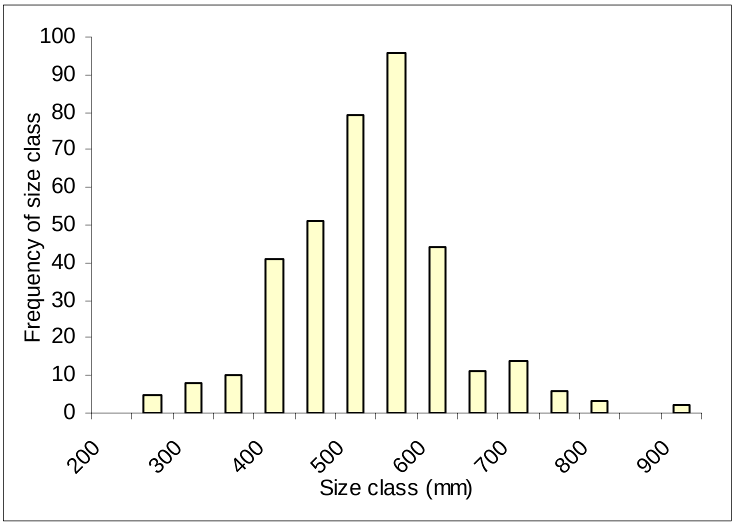


Figure 25 Overall size frequency distribution of barramundi caught in Bohle River survey.

Ley *et al.* (1999) has shown in estuaries around Townsville that fishing pressure can reduce the abundance of legal-sized barramundi, without impacting on the fish diversity of these systems. These authors also indicate that estuarine fish populations are dominated by juvenile or sub-adult forms which are seldom captured in large (150 mm) mesh nets as used by the survey team.

In this project, catch rates were highest in January and March 1998 (Map 11). This period also coincided with wet season flooding (see page 67) when barramundi are flushed from wetland swamps (Russell and Garrett 1983) and when barramundi escaped from the barramundi farm in the Ross River were being caught in high numbers (pers. obs.).

An analysis of mean size of barramundi caught did not detect any difference among sites (Figure 26, one-way ANOVA, df = 8, p = 0.448) however, differences were detected among months surveyed (one-way ANOVA, df = 5, p = 0.042). Figure 27 shows the mean size of barramundi caught in November 1997 was larger than other months with barramundi caught in January and March 1998 also being larger than those caught in June and September 1997.

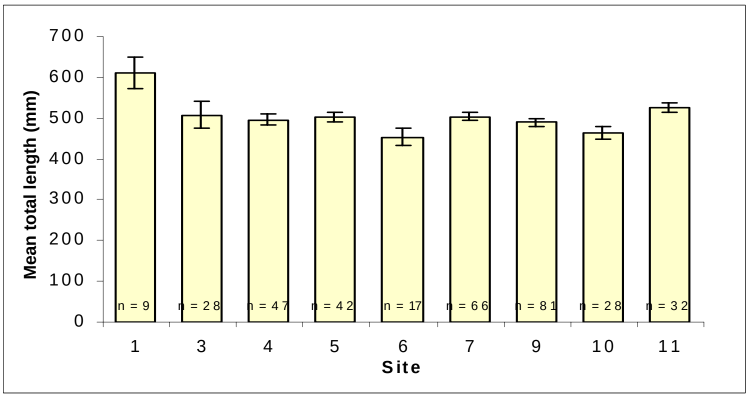


Figure 26 Average size of barramundi one standard error at each site surveyed in the Bohle River.

Catches of legal sized barramundi peaked in a March 1998 (Map 11) corresponding to peak catches in February and March for the commercial fishing industry (see page 85). Recreational fishing pressure was low during March 1998 (unpublished data), however, a large number of visitors to the Bohle River were recorded in early February 1998, a short time after the barramundi season opened, and on the Australia Day 1998 public holiday. This may indicate recreational fishers tend to fish when they have time to rather than when fish are being caught the most, although some fishers undoubtedly focus their effort on the start of the open season for barramundi.

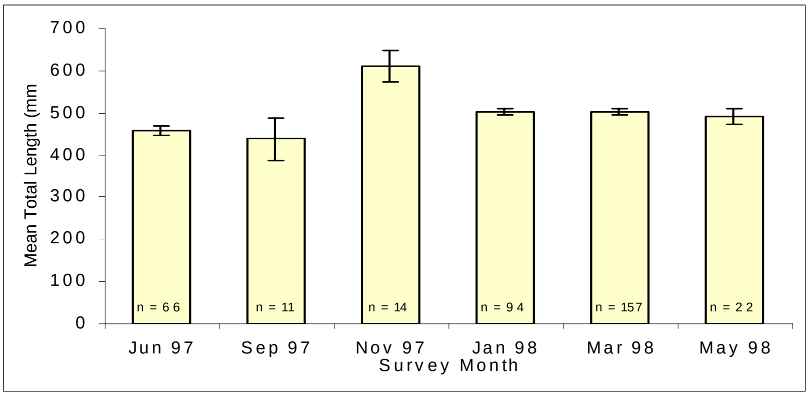
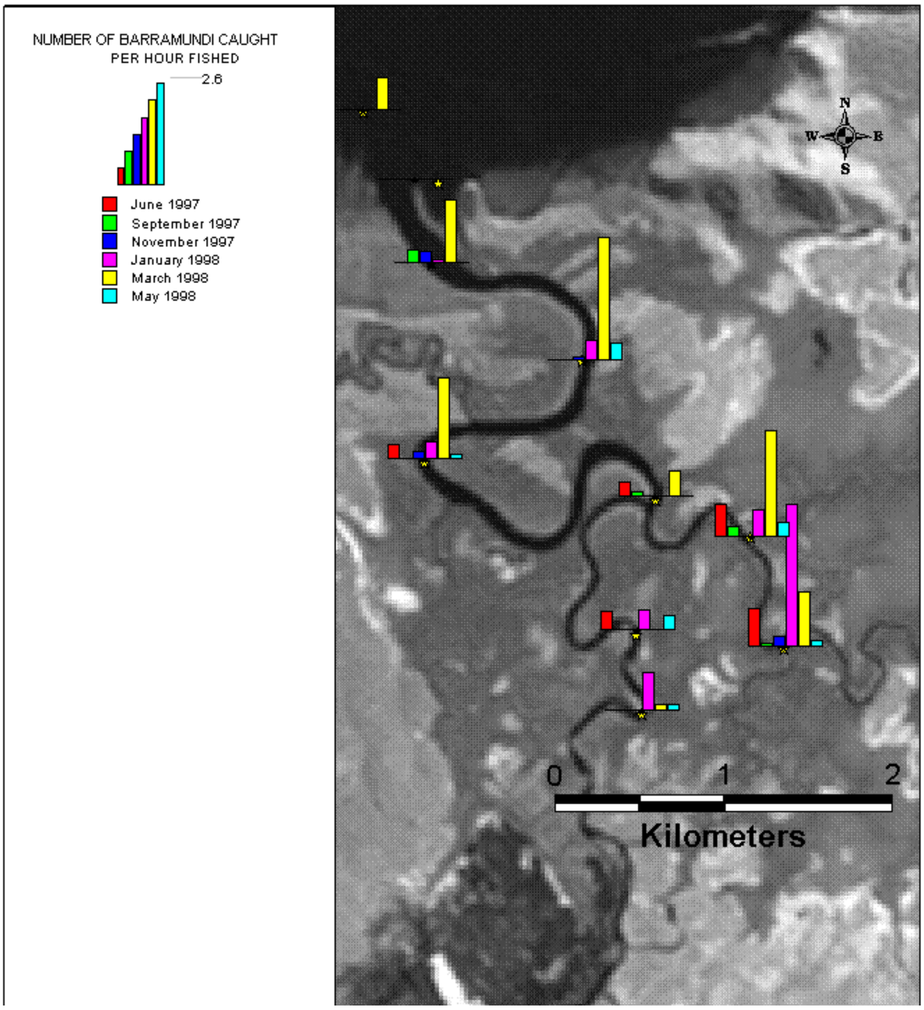


Figure 27 Average size of barramundi ± one standard error each month surveyed in the Bohle River.



Map 11 Distribution of barramundi catch rates from research gillnets in the Bohle River.

Mangrove jack (*Lutjanus argentimaculatus*)

Only five mangrove jack were caught during the 12 month study of which 4 were tagged. All were juveniles of 115 – 340 mm TL (G. McPherson, DPI pers. com. 1999) and all were less than the legal size 350 mm TL. Four fish were caught in fish traps at upstream sites 10 and 12 (Map 9) just following a major flood event. The other individual was caught in a gillnet set further downstream. Mangrove jacks are taken by recreational fishers using hook–and–line and lure fishing in the Bohle River (pers. obs.) but these techniques were not used in the survey.

King *threadfin* (*Polydactylus macrochir*)

Forty-three king threadfin specimens ranging from 250 – 730 mm FL (mean = 502 mm FL s.e.=188.1) were caught during the survey (Figure 28). Catch comprised fish approximately 1 – 6 years of age (Garrett 1998) and all were caught in gillnets. Of these 43 fish, 24 were tagged before being released, and none had been recaptured at the date of publication. Of the fish that died in the net most were immature fish (57%) while three were males and one was female.

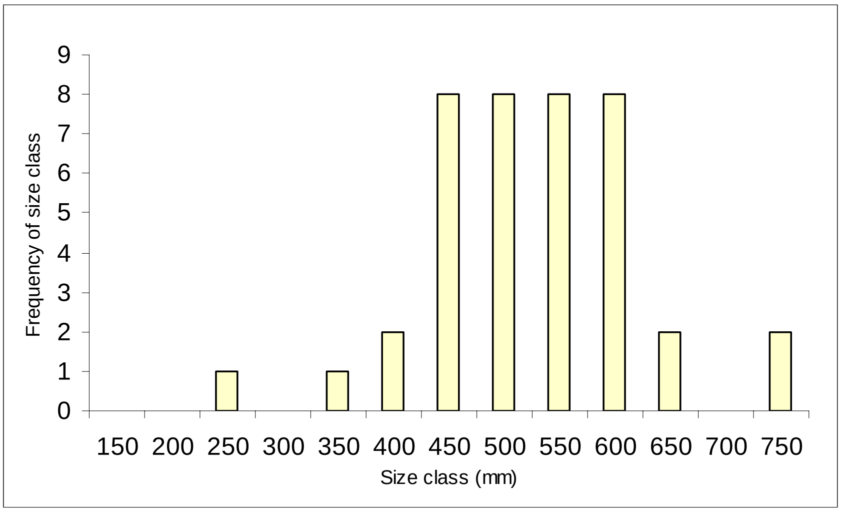
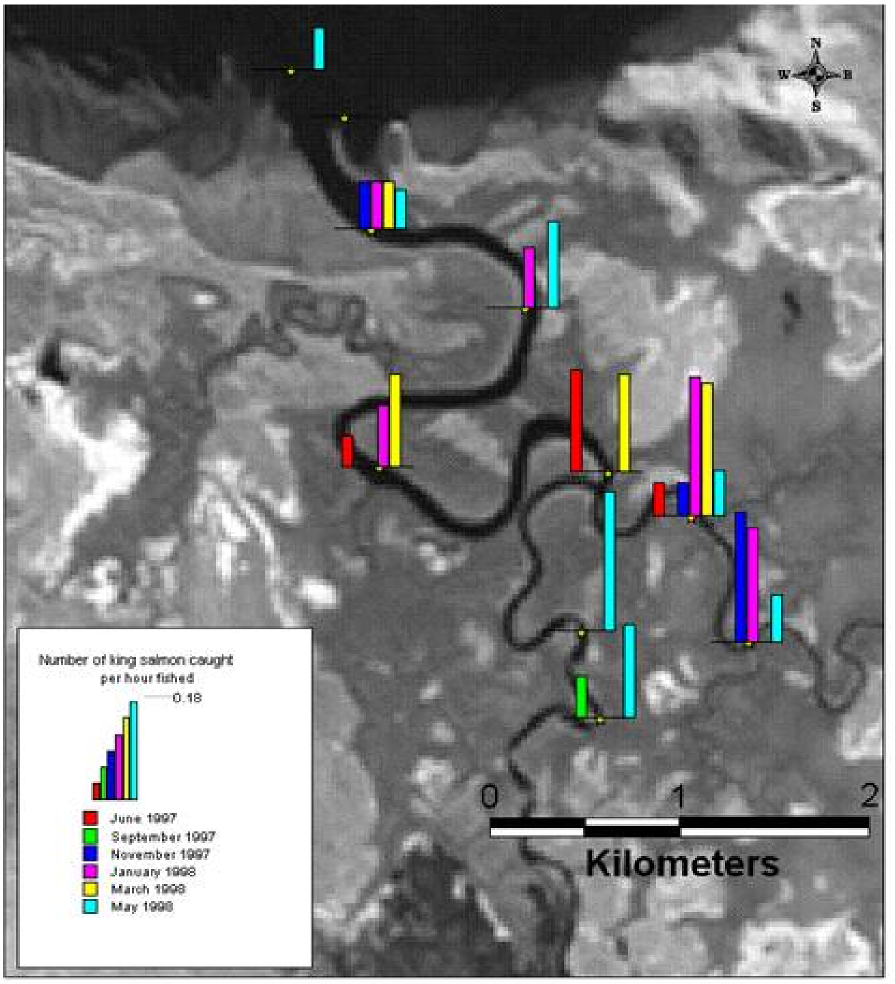


Figure 28 Overall size frequency of king threadfin caught in the Bohle River survey.

Captures were made throughout the river from foreshore to the upstream sites. Map 12 shows the best catches were upstream in 1998.

Mean size at each site surveyed remained constant (Figure 29) and a one-way analysis of variance did not detect any difference among sites (one-way ANOVA, d.f. = 8, p = 0.885). Figure 30 shows the mean size of king threadfin was highest in May 1998, however, no statistical difference was detected among months surveyed (one-way ANOVA, d.f. = 5, p = 0.100).

Of the 42 king threadfin for which a measurement was recorded, all but one were of legal size (400 mm total length). Catches of legal sized fish peaked in January, March and May 1998 corresponding to higher catches for the commercial fishing industry (see page 88).



Map 12 Distribution of king threadfin catch rates from research gillnets in the Bohle River.

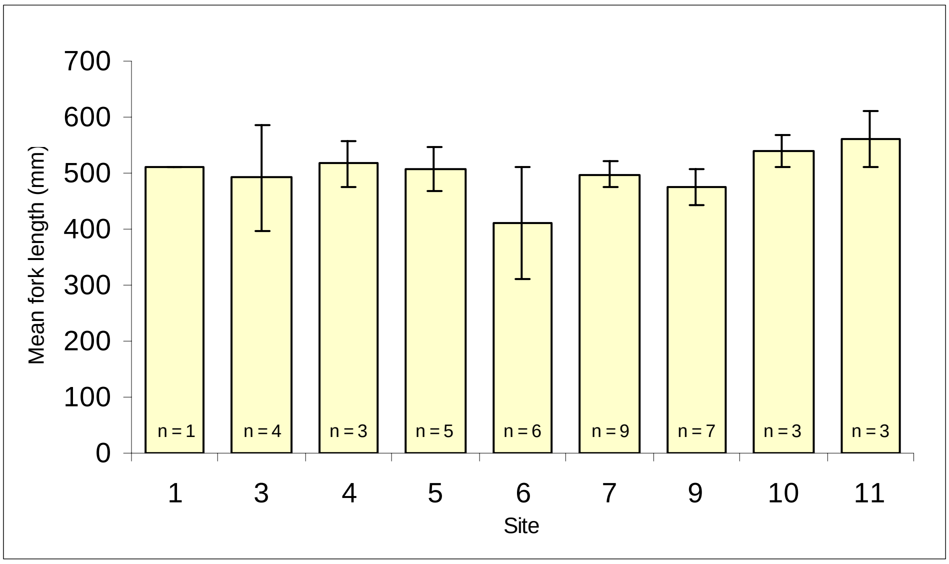


Figure 29 Mean size of king threadfin at each site surveyed in the Bohle River. Error bars are one standard error and indicate variation in size within each site.

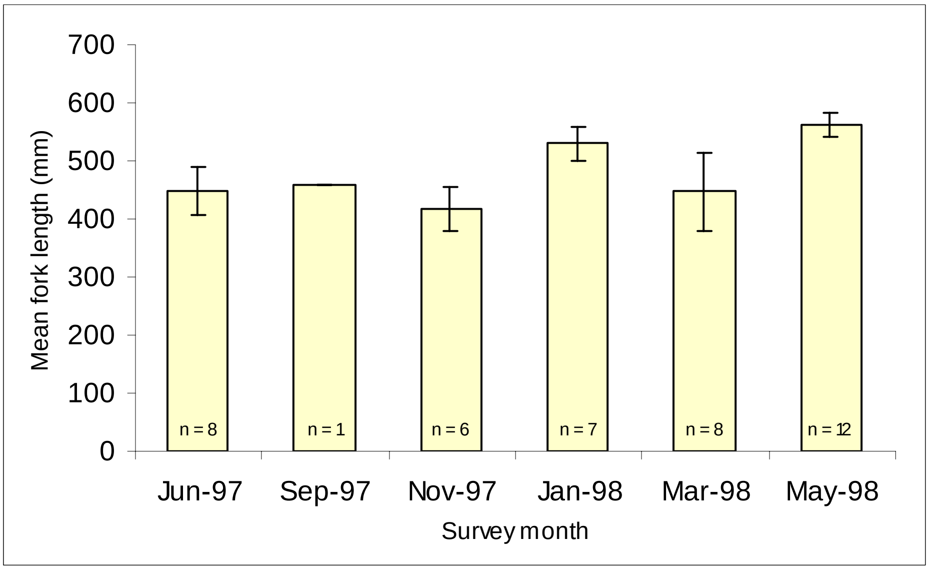


Figure 30 Mean size of king threadfin each month surveyed in the Bohle River. Error bars are one standard error and indicate variation in size within each month.

Blue *threadfin* (*Eleutheronema tetradactylum)*

A total of 35 blue threadfin were caught during the survey, and as with king threadfin, all were captured using gillnets. The fish ranged in size from 202 – 545 mm FL with a mean size of 325 ± 162.2 mm FL. Eight fish were tagged and released. The population sampled comprised an age group of less than a year old (all male) and age classes to 3+ year old, female fish (Stanger 1974 *In* Kailola *et al.*1993). As this species reaches sexual maturity at approximately 240 mm FL in the Townsville area (Stanger 1974 *In* Kailola *et al.*1993), about 85% of fish caught in this survey were likely to have been adult fish. Of 26 fish from 202 to 405 mm FL that were sampled, 65.4% were male, 26.9% were female and 7.7% could not be sexed macroscopically. One female fish was in spawning condition when caught. All sacrificed fish above 340 mm FL proved to be females, which is in agreement with the results reported by Stager (1974) who found females were between 280-720 mm FL (males 240-470 mm FL, hermaphrodites 250-460 mm FL). Nearly 23% of blue threadfin caught were of legal size.

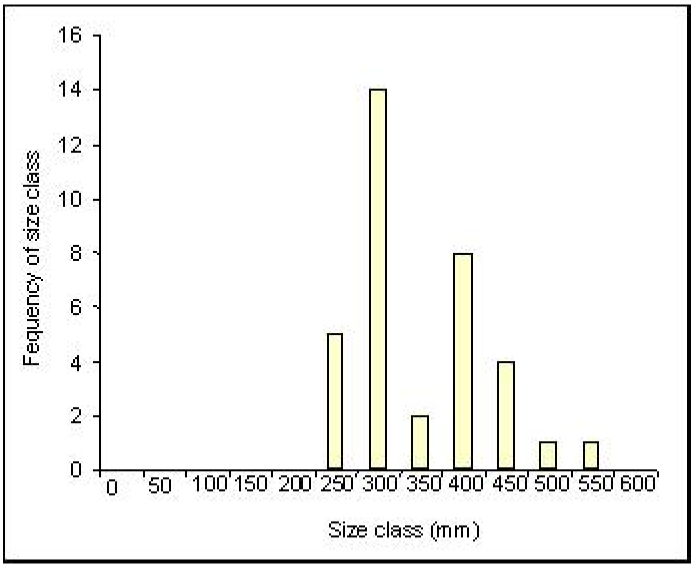
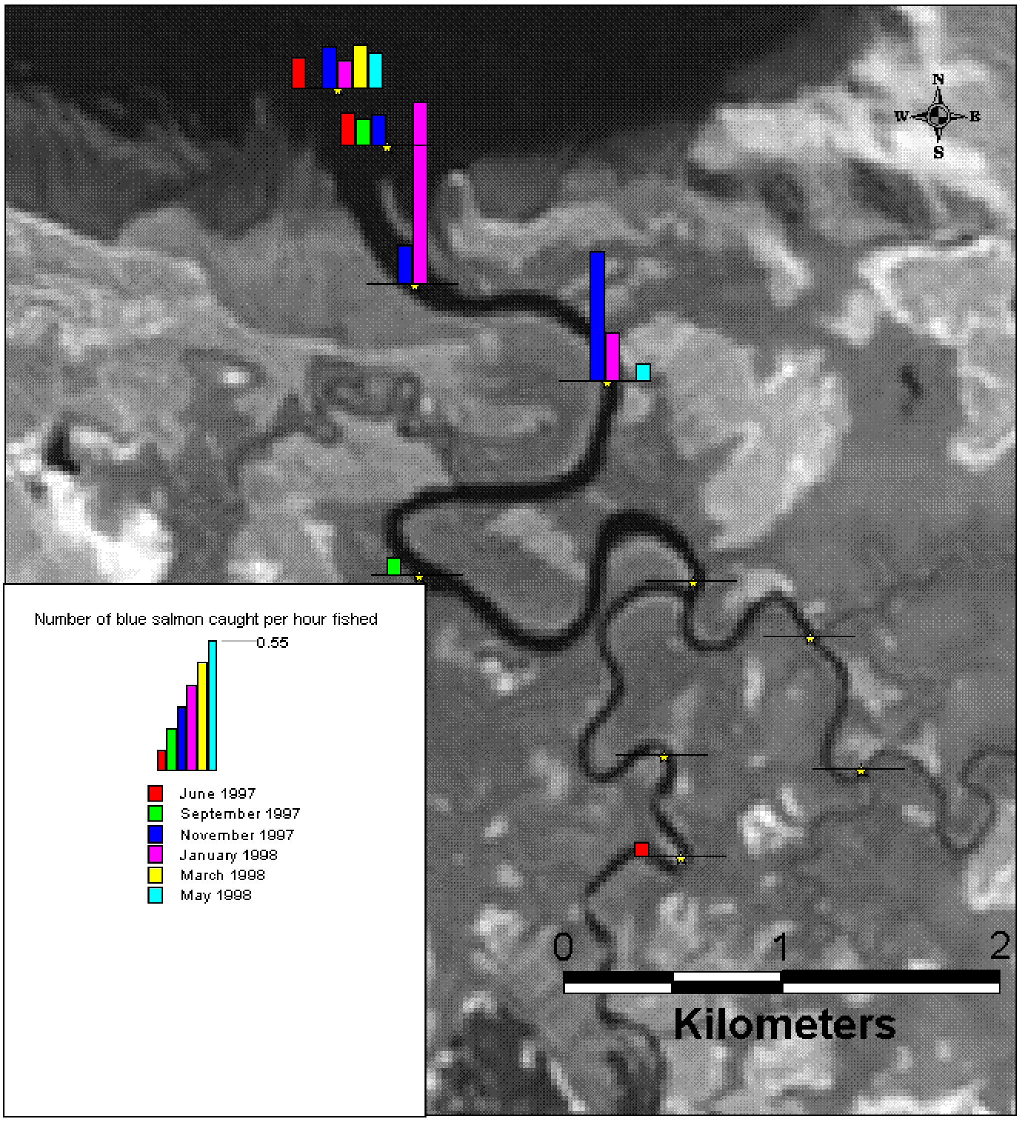


Figure 31 Size frequency distribution of blue threadfin caught in the Bohle River survey.

Very few blue threadfin were caught further upstream than Site 4, which is 1.5 kilometres from the mouth (Map 13). The peak catch rate of 0.56 fish per hour was recorded at the mouth of the river (Site 3) in January 1998 and the greatest numbers were recorded in summer months (January 1998 and November 1997) when this species spawns (Stanger, J.D. 1974 *In* Kailola *et al.* 1993). Although only 3 of the 23 blue threadfin that were caught were females. All were approaching spawning condition, as were all but 2 of the male fish, indicating a summer spawning period in this region. The local spawning locations for this species are unknown, however, one fish was running ripe (spawning imminent) and two others were close to spawning condition indicating they were caught close to an inshore spawning site. Small numbers of fish however, make conclusions difficult to draw. Small sample size prevents statistically testing for differences between site and fish size.



Map 13 Distribution of blue threadfin catch rates from research gillnets in the Bohle River.

Banded grunter (*Pomadasys kaakan*)

Twenty-four banded grunter between 68 and 450 mm TL (mean = 173 mm TL, s.e =217.2) were caught during the survey and thirteen were tagged and released. A recreational fisher reported one recapture although details were not available at the time of writing. The majority of fish were caught in cast nets and the 50 mm mesh gillnets and were between 72 – 450 mm TL. Although Bade (1989) found maturing banded grunter as small as 165 mm FL in Cleveland Bay he noted this minimum size was variable geographically (206 mm FL for Barramundi Creek in Bowling Green Bay to the south) and between the sexes with females maturing at a larger size. Bade (1989) reports that in Cleveland Bay 50% of the banded grunter observed were mature in the size class 191-200 mm FL. Hence, the majority of the banded grunter caught in this project were probably juvenile, while the five fish greater than 200 mm may have been mature (Figure 32).

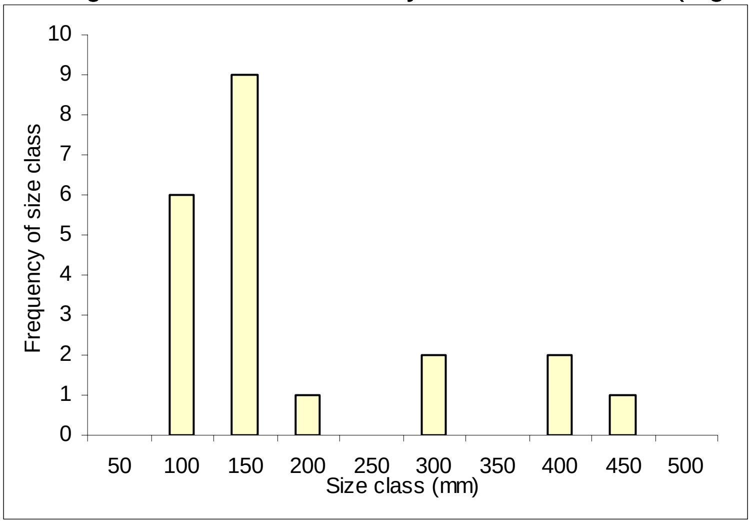


Figure 32 Size frequency distribution of banded grunter caught during the Bohle River survey.

Most banded grunter were caught at upstream Sites, 5-12 (Map 15), in May 1998. A 50 mm mesh gillnet set beside several snags along the bank at Site 6 in November 1997 produced the highest catch of banded grunter (six fish 125 – 158 mm TL). Only 4 fish were of legal size (300 mm TL). These fish were caught in March and May 1998 and were caught throughout the river from the foreshore, Site 1, to upstream areas, Site 10. Catch rates were very low throughout the survey with a maximum of 0.27 fish per hour fish for research gillnets.

Figure 33 shows the mean size of banded grunter was highest in March and May 1998, however, the low number of individuals caught precluded meaningful statistical analysis. Mean size at each site surveyed was highest at the foreshore site, Site 1 (Figure 34).

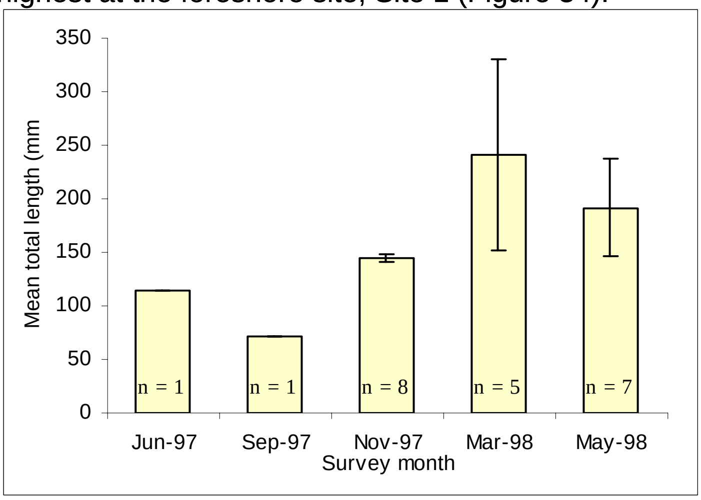
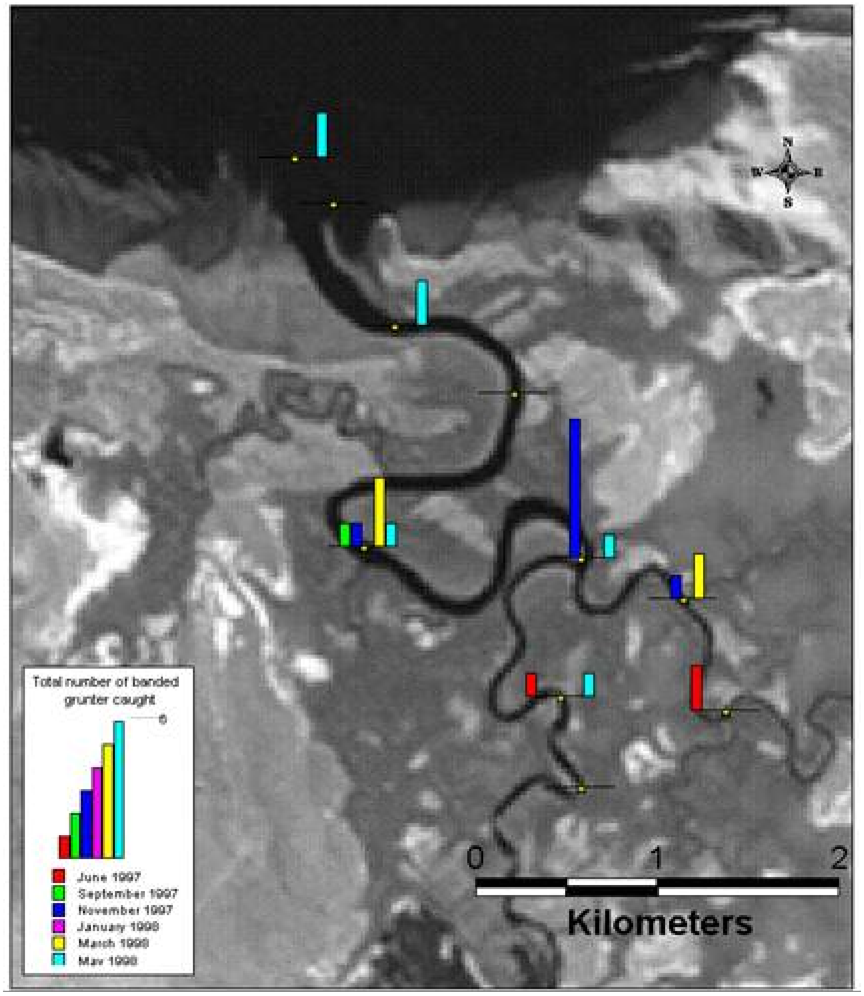


Figure 33 Mean size of banded grunter each month surveyed in the Bohle River. Error bars are one standard error.



Map 14 Distribution of banded grunter numbers caught during the Bohle River survey using all sampling methods.

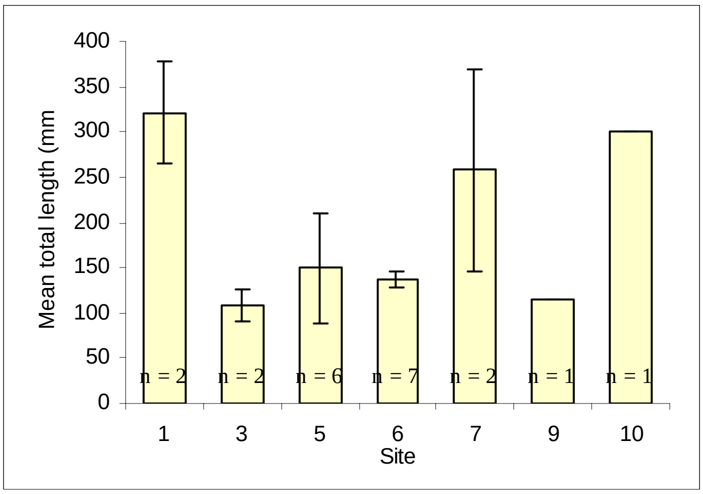


Figure 34 Mean size of banded grunter at each site surveyed in the Bohle River. Error bars are one standard error and indicate variability within each site.

Small-spotted grunter (*Pomadasys argenteus*)

Nineteen small-spotted grunter between 88 and 345 mm TL (mean = 232 mm TL, s.e. = 175.3) were caught during the survey. Thirteen small-spotted grunter were tagged before released and no recaptures have been reported as yet. Most fish (47.4%) were caught in 100 mm mesh gillnets including all four legal size fish (300 mm TL, *Fisheries Regulations 1995*). As with banded grunter, size at maturity for spotted grunter varies between location and sex (Bade 1989). Of the fish examined by Bade (1989), 50% of male and female fish in Cleveland Bay were mature at 181-190 mm FL and 201-211 mm FL respectively. This would suggest most of fish captured in this project would have been adult fish.

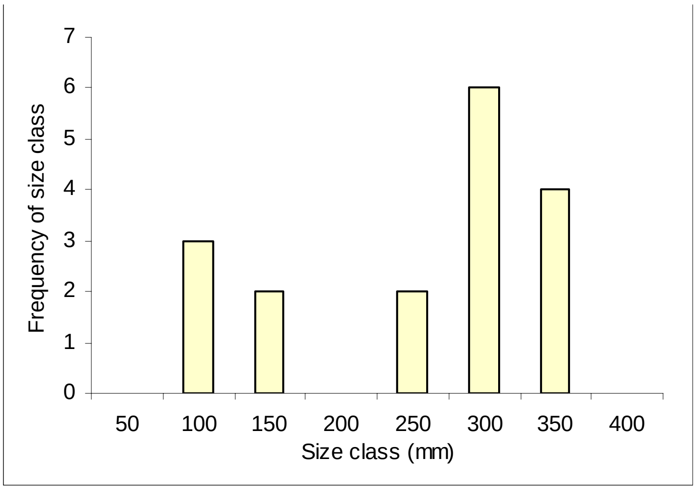
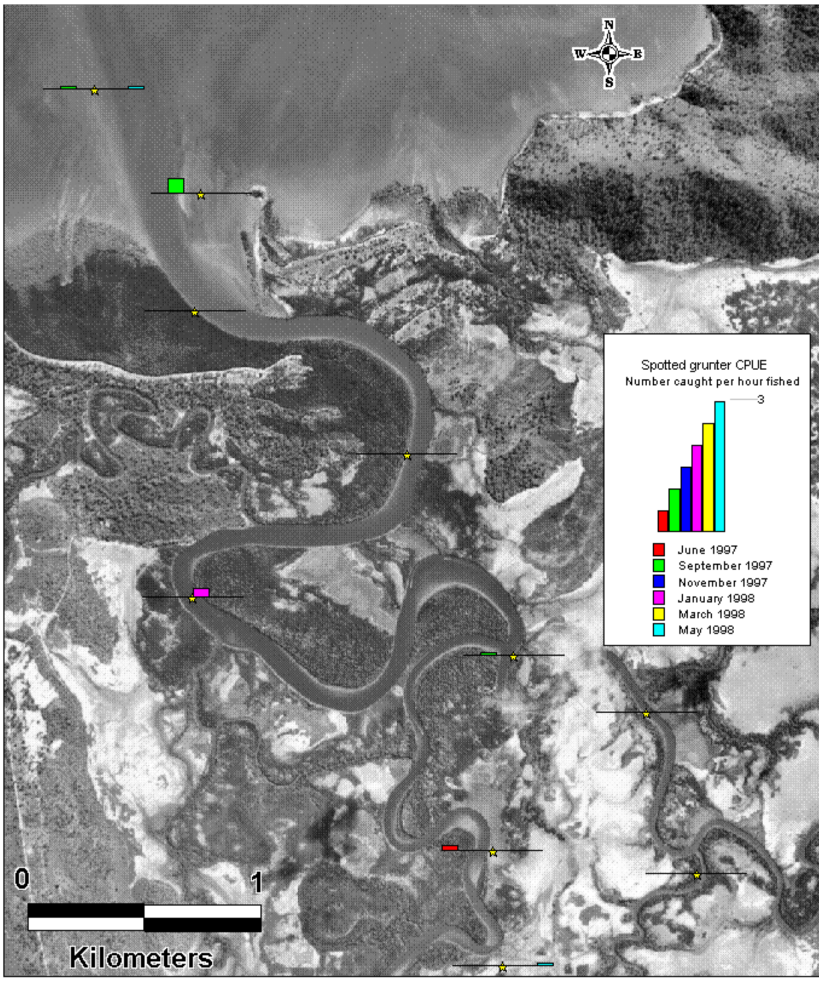


Figure 35 Size frequency distribution of small-spotted grunter caught in the Bohle River.



Map 15 Distribution of small-spotted grunter numbers caught in the Bohle River survey using all sampling methods.

Unfortunately, no comparison of fish maturity can be drawn between Bade's (1989) work and this study as all *P. argenteus* were released alive without determining level of maturity.

Small-spotted grunter were caught at sites all along the river, with the highest number (36.8%) taken in May 1997 (Figure 35). Legal sized fish were caught throughout the river (foreshore, middle and upper river). In the Bohle River area, grunter were landed by commercial fishers throughout the year with mean catches usually less that 2.5 kg per boat day. Commercial catches show little seasonality with peaks in March, August, and December

Yellowfin bream (*Acanthopagrus australis*)

Only 18 yellowfin bream were caught during the 12 month study, of which 12 were tagged. All but two fish were caught in fish traps. Fish ranged between 115–195 mm FL and were therefore all under the legal size limit of 230 mm. In Botany Bay, yellowfin bream reach maturity around 240 mm (State Pollution Control Commission 1981 *In* Kailola *et al.*1993) and Pollock (1985) has shown 40% of fish in the 170–215 mm FL size class were still juveniles in Moreton Bay. However, it has been suggested that growth is faster in warmer waters (State Pollution Control Commission 1981 *In* Kailola *et al.*1993) and fish may reach maturity at smaller sizes in the Townsville area. All fish caught in this study would have been juveniles. Fish traps are generally selective towards a particular size fish (see page 38) and perhaps large yellowfin bream were selectively excluded from the catch.

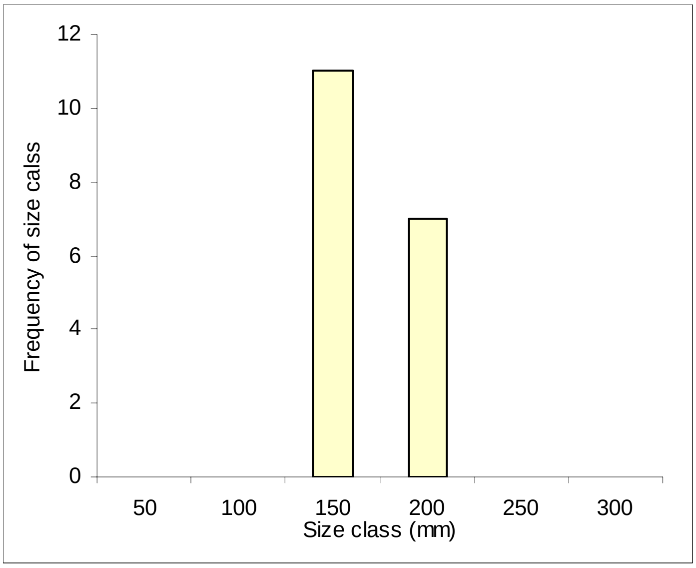
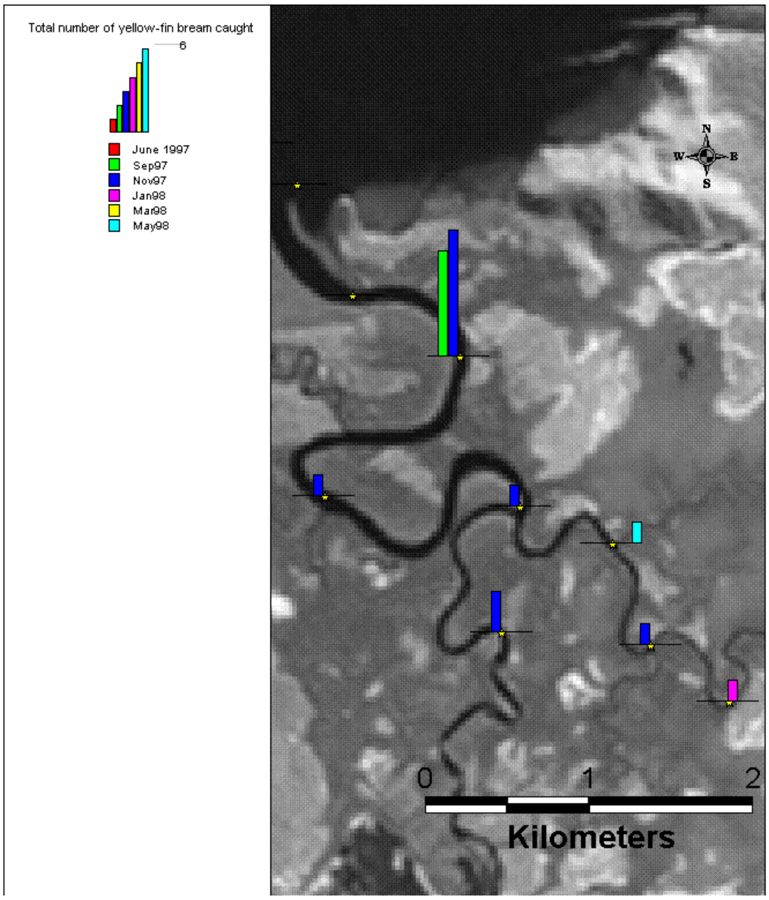


Figure 36 Overall size frequency of yellowfin bream (Acanthopagrus australis) caught in the Bohle River survey.

Most yellowfin bream were trapped in September and November 1997 and most came from Site 4 and upstream (Map 16).



Map 16 Distribution of yellowfin bream numbers caught in the Bohle River survey using all sampling methods.

Pikey bream (*Acanthopagrus berda)*

Pikey bream was the second most frequently caught target species, with 94 individuals caught over the twelve month survey. Sizes ranged from 80 to 240 mm FL (Figure 37) with a mean of 132 mm FL (s.e.= 63.5 mm). *A. berda* is a protandrous hermaphrodite reaching maturity at about 120 mm fork length and become female between 160 and 200 mm FL around Townsville (Tobin 1998). This means approximately 53.3% of the fish caught may have been sexually mature with 10.2 to 36.7% of these fish being female. Forty-two fish were tagged and released. Sheaves (1995a) discusses the effect of fish trap dimensions on the size of fish caught in the trap (see page 38), and this may account for the very low representation in the catch of bream that were either larger or smaller than the mean size.

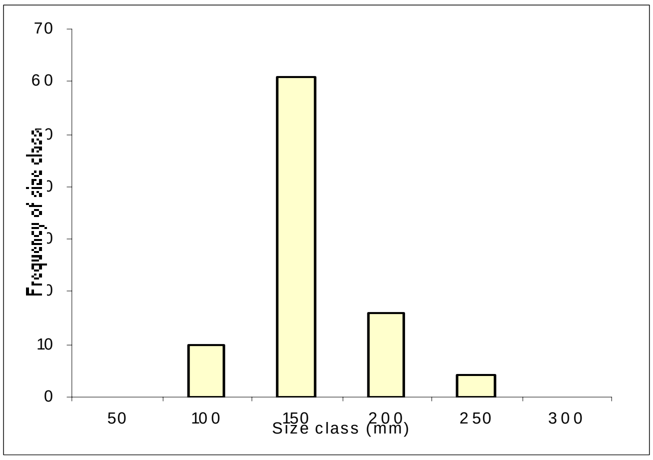
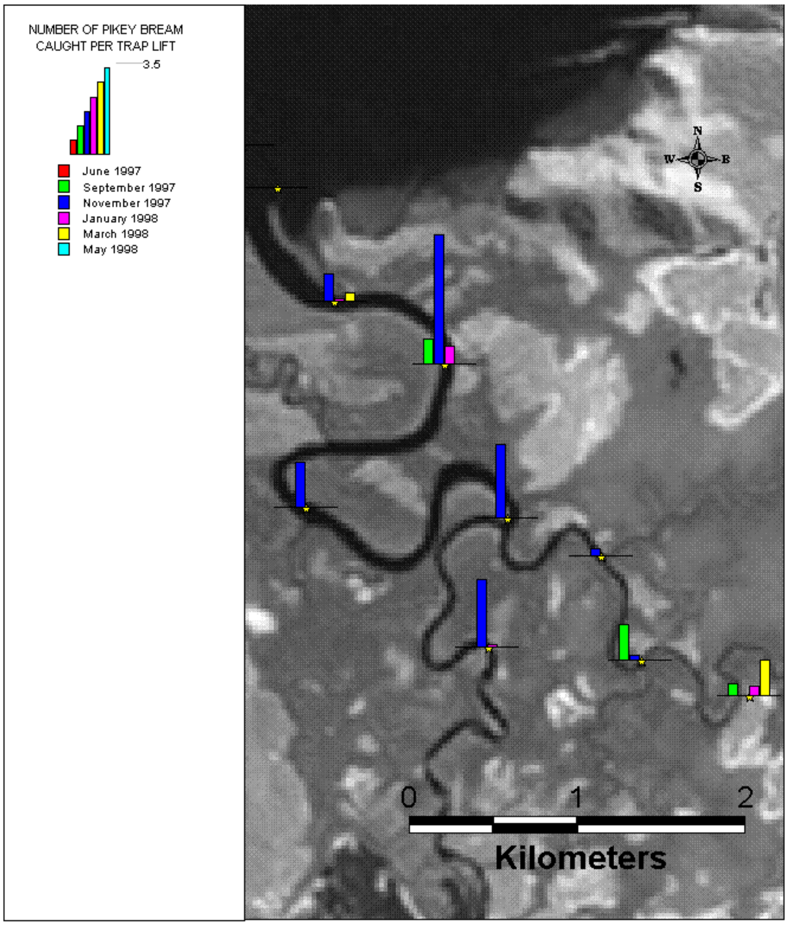


Figure 37 Overall size frequency distribution of pikey bream caught during the Bohle River surveys.



Map 17 Distribution of pikey bream numbers caught during the Bohle River surveys.

Most bream were caught in fish traps (88.3%) and crab pots (8.5%). The only legal sized fish (240 mm FL) was caught in a 150 mm mesh gillnet. Map 17 shows highest catch rates of pikey bream were recorded in November 1997 from fish trap catches, which is also when fish trapping effort was greatest. The majority of fish were caught in the middle section of the river (Map 17). Lowest catches were recorded at Site 7 (n = 1) and Site 9 (n = 3) which were also low in structural complexity. This supports Sheaves (1996) postulation that structurally complex habitats such as snags play an important role in estuarine communities.

Figure 39 shows the mean size of pike bream was highest in May 1998, however, no statistical difference was detected among months surveyed (one-way ANOVA, d.f. = 5, p = 0.671). Mean size at each site surveyed remained constant (Figure 38) and a one-way analysis of variance did not detect any difference among sites (one-way ANOVA, d.f. = 7, p = 0.822).

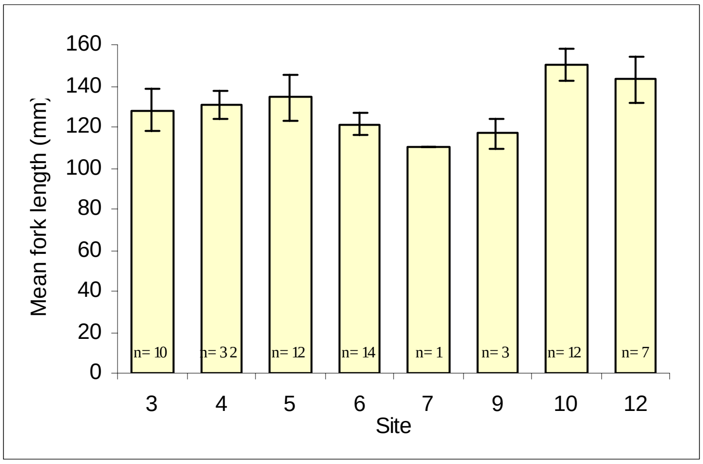


Figure 38 Mean size of pikey bream at each site surveyed in the Bohle River. Error bars are one standard error.

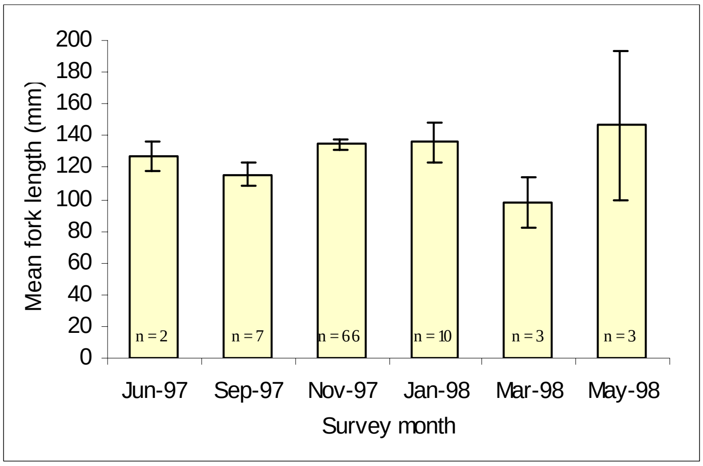


Figure 39 Mean size of pikey bream each month surveyed in the Bohle River. Error bars are one standard error.

Tilapia (*Oreochromis mossambicus*)

Tilapia were recorded in the estuarine waters (n = 2) as well as the freshwater areas of the Bohle River catchment. In the estuarine waters, both tilapia were taken in the upper reaches of the Bohle River: a 195 mm FL specimen in a crab pot at Site 12 (see Map 9) on 22 January 1998, and a 410 mm FL fish in a 150 mm gillnet at Site 11 (see Map 9) on 5 May 1998. On both occasions heavy rains had fallen in the catchment and probably flushed out the tilapia. To the best of the authors' knowledge there are no permanent marine or brackish water populations of tilapia in the Bohle River region (as at 1999).

Tilapia were the second most prominent species caught during the freshwater surveys of the Bohle River catchment with fish caught ranging from 5 mm to 350 mm in total length. The prominence of this species in the upper catchment and it presence in the lower estuary is indicative of the level of tilapia infestation of this catchment. This is especially true when one considers that the vast majority of tilapia seen while electrofishing evaded capture. The capacity of the Bohle River catchment to maintain such a population of tilapia raises concerns over the health of upper catchment area. Concerns may also be raised over the affect of tilapia on native species in the system, however, at present there is no direct evidence of tilapia competing or predating on native species in Australia (A. Webb pers.comm.1999). Webb (1994) also reported tilapia, *Oreochromis mossambicus*, at seven sites he sampled in the Bohle River in 1992, five years before this project started.

Jungle perch (*Kuhlia rupestris*)

No jungle perch were encountered during the project surveys of the Bohle River. This species has been seen on the downstream side at the base of the downstream weir (Aplin Weir) in the neighbouring Ross River catchment (Jim Tait, Centre for Tropical and Freshwater Research, pers. comm. 1999) but was not recorded above the Weir (Webb 1994). Perna also reported *Kuhlia rupestris* in the Leichhardt, Saltwater and Hencamp creeks 22.5 – 37.5 km to the north of the Bohle River catchment and St Margaret's Creek 50 km to the south. The absence of jungle perch from the Bohle River catchment area may be due to lack of permanent water holes or sufficient freshwater flows with the pristine water quality this species requires. Alternatively, sampling may not have been targeted in the locations were jungle perch occur in this system.

Mud crabs (*Scylla serrata*)

During the survey of the Bohle River a total of 757 mud crabs were caught. More male crabs (413) were retrieved from the pots than females (335), resulting in an overall sex ratio of 1.23:1. The male bias in pot catches is likely to result from aggressive male crabs excluding females from the crab pots (Williams and Hill 1982).

Figure 40 shows the sex ratio of males to females within each size class is clearly dominated by male crabs in size classes less than 150 mm, however this relationship is reversed for size classes above 150 mm. This pattern has been observed elsewhere in Queensland (Helmke *et al.* 2000, Williams and Hill 1982, Perrine 1979). Because crab pots are known to be selective towards large crabs and towards male crabs (William and Hill 1982), it is likely that the proportion of male crabs ≥ 150 mm carapace width present in the Bohle River population is lower than the data suggest. Possible causes for low densities of legal mud crabs include heavy fishing pressure, natural predation biased toward adult male crabs and reduced catchablilty of adult male crabs due to parasitic infestation (Hashmi and Zaida 1964, Perrine 1979, Mounsey 1990, Knuckey *et al.* 1995). It is likely that fishing pressure plays an important role in the Bohle River.

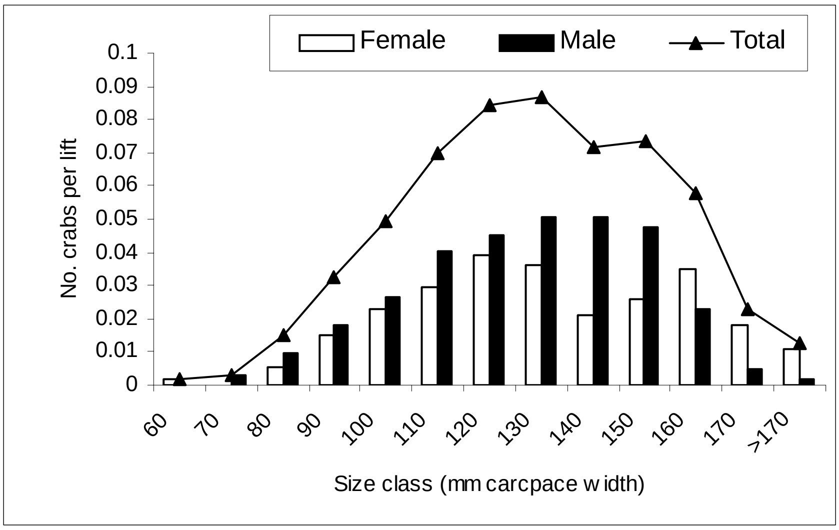


Figure 40 Number of crabs per pot lift for each size class over the survey period and differentiated by sex.

Male crabs dominated the sex ratio of pot catches at most study sites (Figure 41). The reason for the high proportion of female crabs at Sites 1 and 8 is unclear. Female crabs were scarcest in pot catches in November 1997 (Figure 42), perhaps due to movement out of the river to offshore spawning grounds (Hill 1994). If so, the Bohle River crab migration occurs much earlier than in the Northern Territory (Knuckey *et al.* 1995) but may be similar or later than that in the Gulf of Carpentaria (Hill 1994).

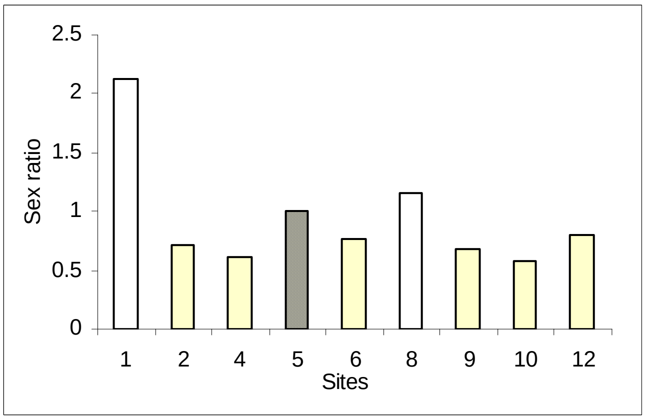


Figure 41 Number of female crabs for each male crab at each site in the Bohle River. Male dominant site. Female dominant site. Site 5 had a 1:1 sex ratio.

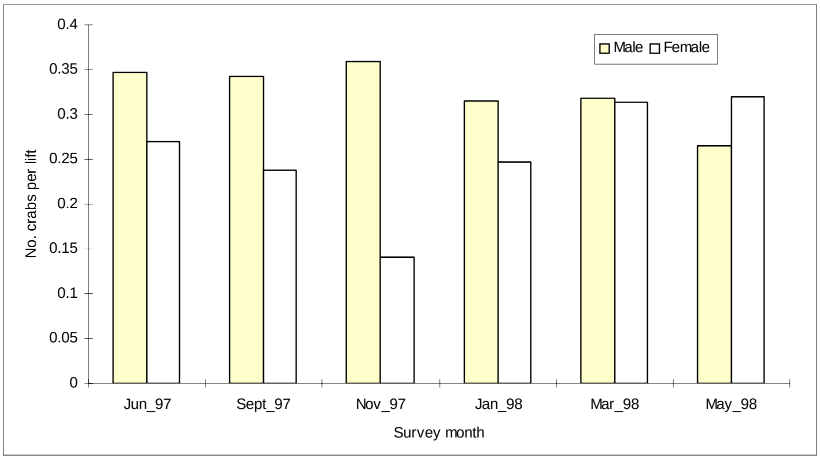


Figure 42 Sex ratio of crabs observed each survey month.

Size distribution

Crabs from 30–189 mm carapace width (CW) were caught in the research potting program. The average size of crabs caught over the 12 month survey period was 124.2 mm (s.e. = 0.09) and on average, females tended to be larger than males, 127.7 mm and 123.6 mm respectively (one-way ANOVA, n = 880, df = 1, p = 0.012). Figure 40 reveals that male crabs have a size frequency distribution skewed to the right, peaking around the 130 and 140 mm size classes but then dropping off sharply in size classes above the 150 mm legal size limit for this species. This pattern may be the result of selectivity of crab pots against juvenile crabs which primarily occupy intertidal areas (Hill 1982) not targeted during the research potting exercise and through exclusion by larger male crabs (Williams and Hill 1982). Fishing pressure on the larger size classes in the population likely explains the sharp decrease in males in the upper size classes.

Figure 40 shows that catches of female crabs resulted in a bi-modal size distribution with peaks in the 120 mm and 160 mm size classes. This is a pattern that has been observed in crab surveys in other Queensland east coast streams (e.g. Trinity Inlet, Helmke *et al.*2000) and elsewhere (Williams and Hill 1982). The reasons for this bimodality are unclear. It may be that females are under-represented in pot catches when they become sexually mature (around 120 mm, Hill 1982), due to migration offshore in the breeding season (Hill 1994) or the onset of male territorial behaviour as they mature in those size classes. Males should dominate catches throughout the size classes; although it is possible not all larger female crabs migrate away from the system as part of the breeding population. Hill (1994) reported female crabs caught in trawlers offshore (presumably on a spawning migration) up to 209 mm in size suggesting larger female crabs do still breed or at least participate in breeding migrations. It is possible that larger females, >160 mm, outnumber larger male crabs due to fishing pressure and are thus caught in higher numbers above this size class. More detailed research of the behaviour of mud crabs around crab pots is required to understand these data.
The average size of male crabs each month was relatively uniform (Figure 43) although crabs caught in January 1998 were smaller than those caught in June 1997, September 1998 and May 1998, with those caught in May 1998 being larger than any other month (Figure 43, One-Way ANOVA, n = 744, d.f. = 5, p = 0.026). Females were also similar in size each month (One-Way ANOVA, n = 333, d.f. = 5, p = 0.121) except May 1998 when crabs caught were larger than any other month except September 1997 (LSD, Figure 43). No statistically significant difference was observed among months for the average size of males crabs (One-Way ANOVA, n = 411, d.f. = 5, p = 0.057) although crabs caught in January 1998 were smaller than all other months except March 1998 (LSD, Figure 43).

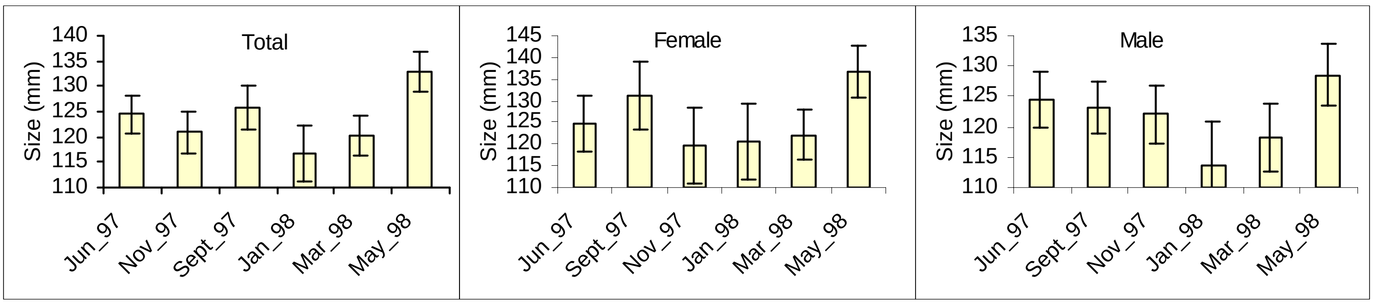


Figure 43 Average size for male, female and total crabs at each study site ±95% Confidence Interval.

The average size of crabs caught differed among sites (One-Way ANOVA, n = 744, d.f. = 8, p < 0.001) with crabs on the foreshore site (Site 1) being larger than at other sites (Figure 44). Crabs at Site 12, 8, 4 and 9 were smaller than those from Site 2 and 6 and crabs from Site 10 were larger than those from 12 and 8 (LSD). Mean size of both male and female crabs differed among sites (Figure 44, One-Way ANOVA, n = 333, d.f. = 8, p = 0.002, One-Way ANOVA, n = 411, d.f. = 8, p < 0.026 respectively). Male crabs were larger at Site 2 than most other sites, while those from Site 8 were smaller than those caught at Site 1, 6 and 10 (LSD). Female crabs were larger at Site 1 than any other site with those from Site 12 smaller than those from Site 10 and 6 also (LSD).

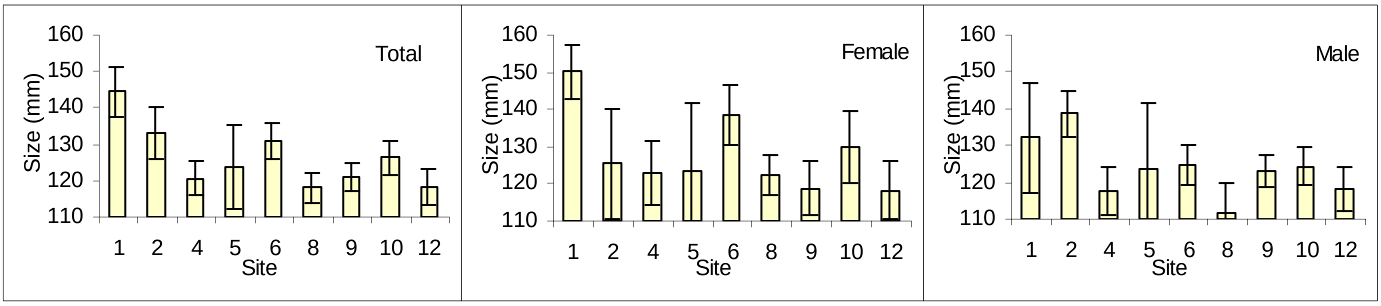


Figure 44 Average size for male, female and total crabs at each month surveyed ±95% confidence interval.

Catch per unit effort (CPUE)

From 1283 pot lifts, the total catch rate for the survey was 0.59 crabs per pot lift, ranging from 0.76 crabs per pot lift at Site 8 to 0.32 crabs per pot lift at Site 2 (Figure 45). Generally, the catch rate of male mud crabs were higher than catch rates of females crabs. Catch rates of legal mud crabs were low at all sites and lower than that reported for Trinity Inlet (Helmke *et al.* 2000) and the Murray and St. Helens Creeks (Lunow and Garrett unpublished).

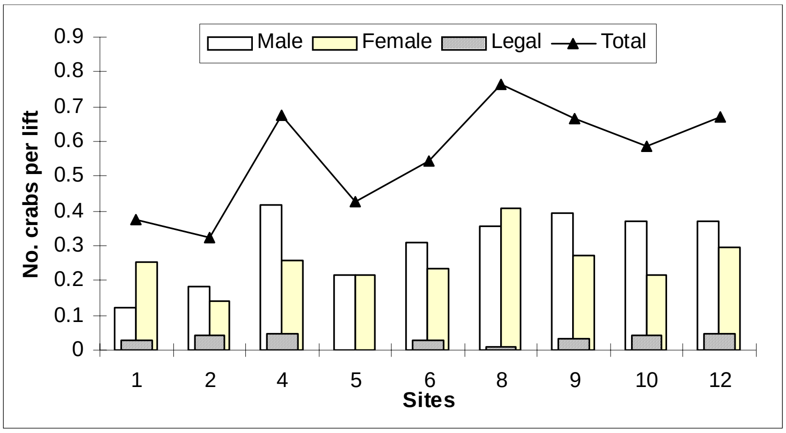


Figure 45 CPUE for male, female, legal and total crabs at each study site.

Male crabs dominated the juvenile and sub-adult size classes at most sites with females dominating the adult size classes (Figure 46). The catch rate of sub-adult crabs (100 - 149 mm CW, Hill 1982) was higher than for juveniles or adult crabs at all sites except at Site 1 (Figure 47) where adult crabs dominated the catches, in particular, adult female crabs (Figure 47). Williams and Hill (1982) have shown catchability of crabs increases linearly with size up to 140 mm for male crabs and 150 mm for female crabs. This may explain why the catch rate for juveniles is low in the present study. However, Williams and Hill (1982) reported the probability of capture for larger crabs remained around 30-35%, except for male crabs of 170 mm, for which probability of capture was reduced. If this was the case in the Bohle River then the lower catch rate of adult crabs indicates fewer crabs in this population were above the 150 mm size class. Also note that the sub-adult size class spans a greater range of sizes than the than the adult size class. Crabs are classed as sub-adults if they are in the range from 100-149 mm, while adults are crabs above 150 mm. The largest crab captured was 189 mm so the range of sizes for sub-adults and adult crabs was 50 mm and 39 mm respectively.

The high catch rate of adult crabs at Site 1 was driven by the highest catch rate of adult female crabs recorded, 0.19 crabs per pot lift. The high catch rate of adult females at this site may indicate favouritism for this exposed foreshore environment, or perhaps be due to female crab movements in and out of the estuary associated with an offshore spawning migration. Alternatively, fishing pressure on this site may have skewed the sex ratio and size class distribution in favour of larger female crabs.

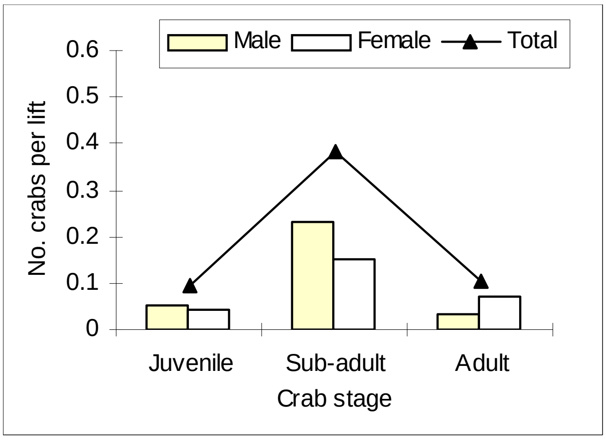


Figure 46 CPUE for the developmental size classes caught in crab pots during the Bohle River survey.

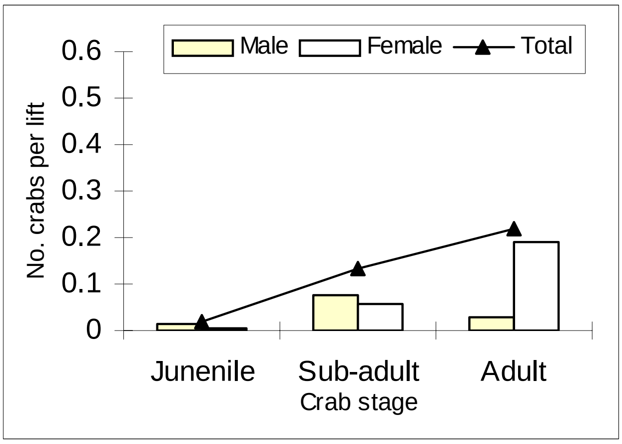


Figure 47 Number of crabs per pot lift at Site 1 for juvenile, sub-adult and adult size classes

Male crabs were caught more often than female crabs in every month except May 1998 (Figure 48). Over the duration of the survey the catch rate for female mud crabs varied much more than did the catch rate for male crabs (Figure 48).

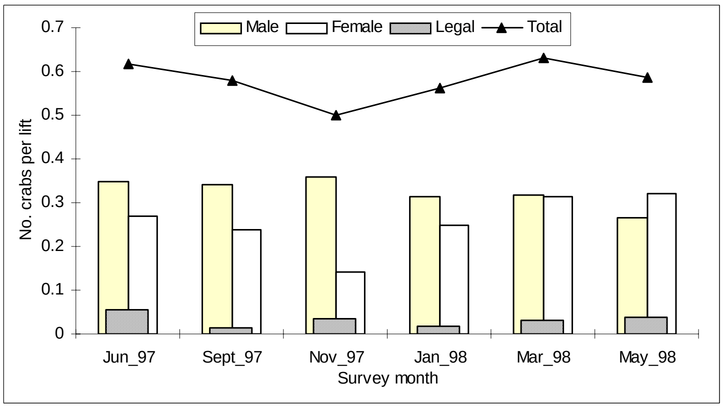


Figure 48 Monthly catch rate (number per pot lift) for male, female, legal and total crabs at each month surveyed.

While sub-adults crabs were the most frequently taken component of mud crabs catches (Figure 49) the pattern of catches of all three crab developmental stages were very similar at all sites each month (Figure 49). Catch rates of sub-adult crabs increased with distance upstream especially for the male crabs (Figure 50).

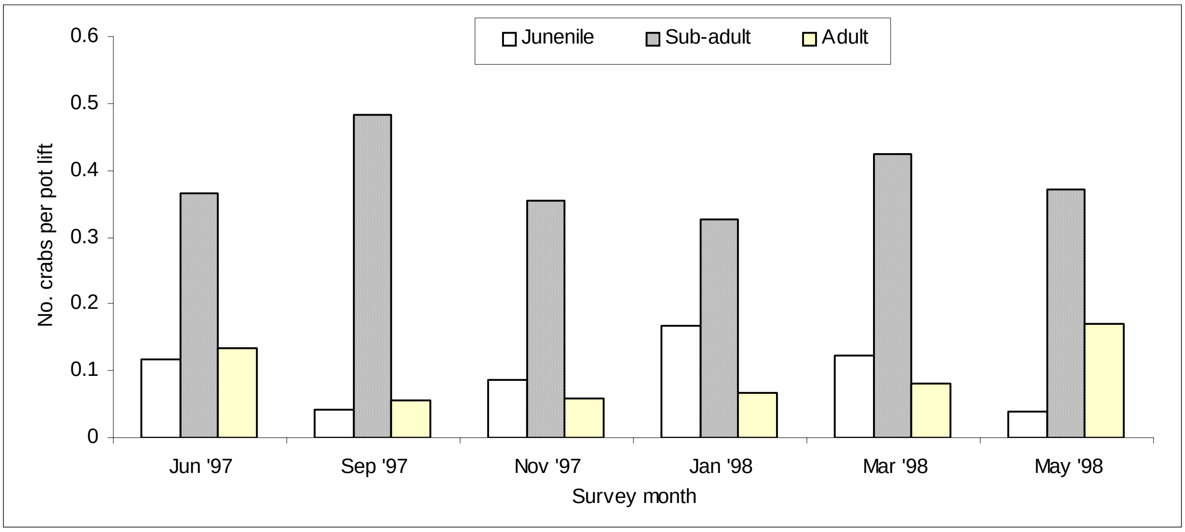


Figure 49 Number of crabs per pot lift each month for juvenile, sub-adult and adult size classes.

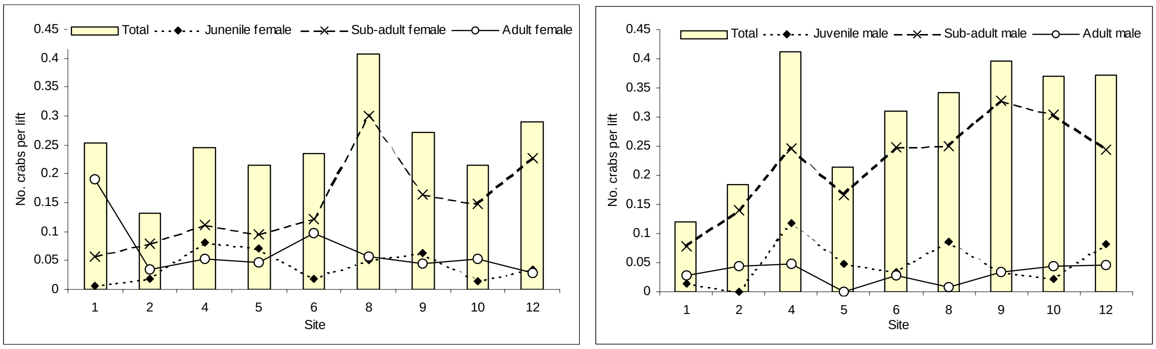


Figure 50 Number of crabs per pot lift at each site and for each survey divided by sex and developmental stage.

Tagged mud crab program

During the Bohle River survey, a total of 697 crabs were tagged and by June 1999, 88 crabs (12.6%) had been recaptured. Sixty-three recaptures (9.0%) were made by the survey team and 25 (3.6%) were reported by recreational fishers. Thirty-four tagged crabs were recaptured within 24 hours of release (32 by project staff and 2 by recreational fishers). Of the 378 male crabs tagged 15.1% were recaptured while only 8.9% of 316 tagged female crabs were recaptured.

The longest a tagged crab was at liberty was 397 days, and the shortest was just 9 hours. The average length of time a recaptured crab was at large was 43.78 days with crabs at large more than 1 day averaging 71 days at large before recapture. Mean times at large were different for male (23.5 days) and female crabs (55.0 days) (unpaired t-test, $p = 0.04$). However, mean time at large for male (84.7 days) and female (46.7 days) crabs at large for more than 1 day were not statistically different (unpaired t-test, $p = 0.10$) indicating male crabs tend to be recaptured within 24 hours more often than females.

Table 8 Direction of movement by recaptured mud crabs of male, female and undetermined sex.

Direction of Movement	Number of Male Crabs	Number of Female Crabs	Sex Undetermined	Total
Downstream	21	12	2	35
Upstream	12	4	-	16
No Movement	21	12	1	34
Other	3	0	-	3

Of the 88 crabs recaptured to date, most either moved downstream from the release point (40%) or didn't move at all (39%, Table 8). Sixteen tagged crabs (18%) moved upstream after release, the vast majority being male crabs. Two male crabs moved both downstream and then upstream again into a tributary close to the mouth of the Bohle River (Table 8, Other). One male crab tagged at the mouth of the river moved east to the mouth of the next creek while another male crab moved downstream, out of the Bohle River system and north 82 km to Gentle Annie Creek. These were they only instances where crabs tagged in the Bohle River were recaptured in other systems.

Growth and growth rate

A growth event in the Bohle River crabs was deemed to be a change in carapace width between tagging date and recapture date of ≥ 10 mm. Ten millimetres was chosen as the cut off line by looking at the growth data (Figure 51) and identifying a significant size class increase. This figure is conservative in that it is slightly less than the smallest growth increment reported by Heasman (1980).

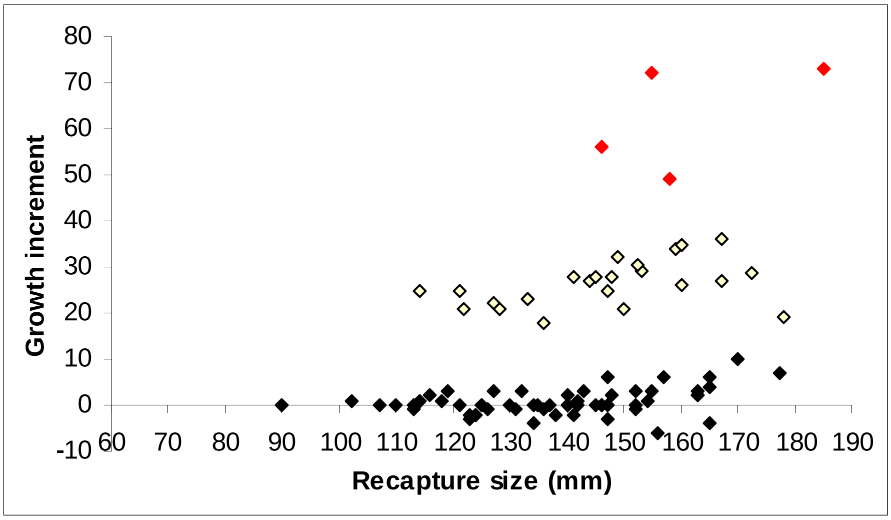


Figure 51 Size of recaptured crabs and their growth increment. Different colours indicate number of moults while at large. Black = no moults, black outline = one moult and red = two moults.

Of the 88 tagged crabs recaptured, 28 (31.8%) had moulted since release (51.9% of the crabs at large more than 1 day, 62.2% of the crabs at large more than 1 week) and of these, four had moulted at least twice. Ten female crabs recorded growth with one moulting at least twice, while 18 male crabs recorded growth, three of which had moulted at least twice.

Inter-moult growth increment varied widely from 18 to 36 mm, with a mean of 26.3 mm, for the first moult (n = 24) and 49 to 73 mm, with a mean of 62.5 mm, for the second moult (n = 4). Such a large variability in growth may be indicative of the variability in condition (health) of the crabs when they moulted or errors in measuring the crab. Hill (1975) reports single growth increments of 19 to 28 mm for thirteen recaptured crabs from two South African estuaries. Hill (1975) also reports a growth increment from 40-43 mm from three crabs that moulted twice, a much smaller increment than that observed in the Bohle River. Recaptured crabs from Hill's (1975) work are from the same size range as recaptured crabs from the Bohle River (100–180 mm). Therefore, mud crab growth increments may vary geographically among mud crab populations, perhaps depending on the maximum size attained in a given population and environmental conditions.

Figure 51 shows the variation in growth increment increased with the recapture size of the crab. This suggests that some factor, such as condition of the crab, may influence the size of the growth increment in a particular moult. The variation in growth of crabs that had not moulted between release and recapture (growth <10 mm) also increased with increasing crab size. This indicates error in measurements of crabs carapace width increases with the size of the crab and would be around ± 5 mm (see Figure 51).

Growth Rate

The following growth rates need to be considered carefully as the nature of crab growth is not continuous but incremental (Hill 1982). The average growth rate for crabs that had moulted at least once was 0.412 mm per day (n = 28). The maximum growth rate was recorded at 0.79 mm per day and the minimum was 0.11 mm per day. Female crabs grew faster than males on average, 0.49 mm and 0.37 mm per day respectively, but there is no statistical difference (unpaired t-test, p = 0.075). Growth increment was not dependant on initial size of the crab (r^2 = 0.007).

Movement of mud crabs in the Bohle River

One male crab averaged a speed of 500 m/day during the 164 days it was at large. This crab travelled downstream and out of the mouth of the Bohle River and continued north to be recaptured in Gentle Annie Creek in the northern section of Halifax Bay. Although this is the only record of this magnitude of movement in the Bohle River, a similar distance was travelled at approximately the same speed by a female crab tagged in Murray Creek (see Lunow and Garrett unpublished).

It is possible that both crabs' migration is just one type of movement behaviour. It is also possible that both crabs were recaptured either on route or returning from a spawning event, however, no evidence of the female being in berry was obtained. Hill (1994) also recorded male crabs found offshore in a similar location to female crabs in berry and assumed to be on a spawning migration.

Of the 88 mud crabs that were tagged in the Bohle River and subsequently recaptured, 87 (99%) had moved an average of 826 metres from the release site, with those crabs at large more than 1 day moving 1,231 metres on average. A single mud crab moved 82 km in the 164 days it was at liberty. Coincidentally, this crab also recorded the highest growth increment (112 to 185 mm = 73 mm). Male crabs tended to be more mobile than female crabs (moving an average of 971 and 595 metres respectively, see Figure 52a and Figure 52b) but the difference was not statistically significant (unpaired t-test, p = 0.317). Males were three times more likely than females to move more than 1.5 km. A large degree of site fidelity was also observed. Seventy five percent of crabs caught more than 1 day after being tagged did not move more than 1.5 km from the tagging site even though crabs were, on average, at large for 71 days, indicating, at least superficially, a high degree of at least short term site fidelity.

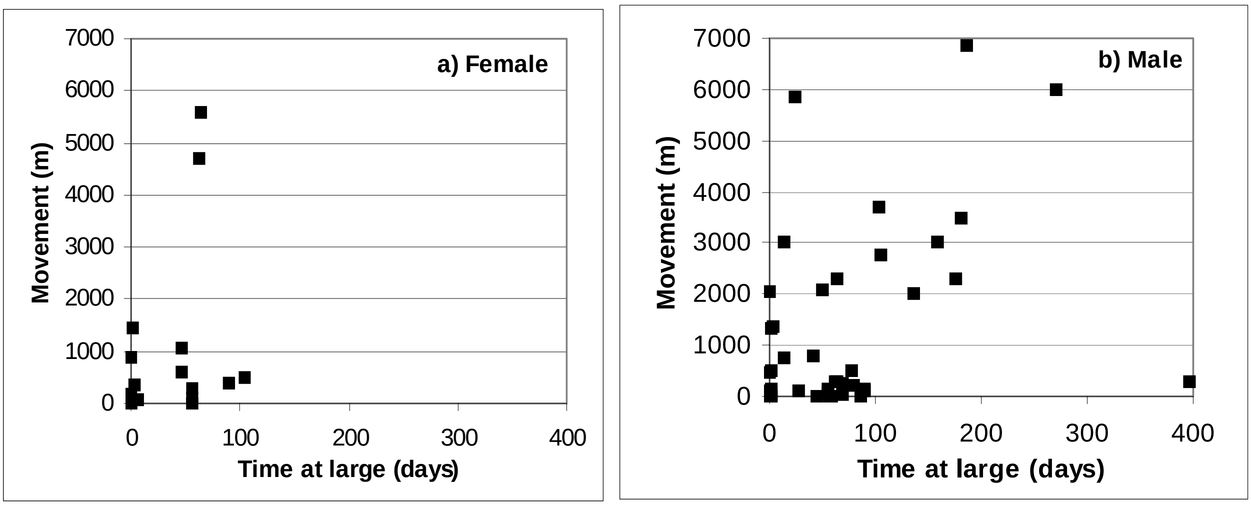


Figure 52 Distance moved by a) female and b) male crabs compared to the time they spend at large. One large movement of 82 km was omitted from figure b to aid in presentation of data.

There seems to be at least 3 types of movement patterns:

- site fidelity, less than 1.5 km, where crabs may be moving within some home range,
- mobile crabs, 1.5 – 7 km, that move throughout the creek (tend to be males more than females).
- large migratory movements out of the system (for spawning or other reasons).

Rate of movement

To look at the rate of movement of mud crabs, all crabs that had not moved in the time they were at large were removed from the data. Of the remaining recaptures (n = 55) the smallest recorded movement was 20 m while the largest was 82 km. The overall average rate of movement of crabs (± 1 standard error) was 166 (± 47.9) m per day. There was no difference in the mean rate of movement of males and female crabs, 148 (± 52.8) m and 232 (± 122.2) m per day respectively (unpaired t-test, $p = 0.43$). A maximum rate of movement of 4,429 m per day was recorded for one male crab at large just 11 hours. Hill (1978) observed several tagged crabs hitting top speeds of similar magnitude 3552 - 4512 m per day which may suggest this crab was moving at top speed for an extended period of 11 hours. Being the only record of this type of movement the data point was removed from the above analysis of mean rate of movement. The next fastest crab was a female that had travelled at 1661.5 m per day for the time she was at large (Figure 53). Care should be taken in interpretation of these rates of movement as the straight line distance between tag and recapture sites, and the time at large was used to estimate an average minimum speed travelled by the crabs. The actual amount of movement and distance travelled by each crab, while it was at large, is not known and therefore the calculated rate of movement is likely an underestimate.

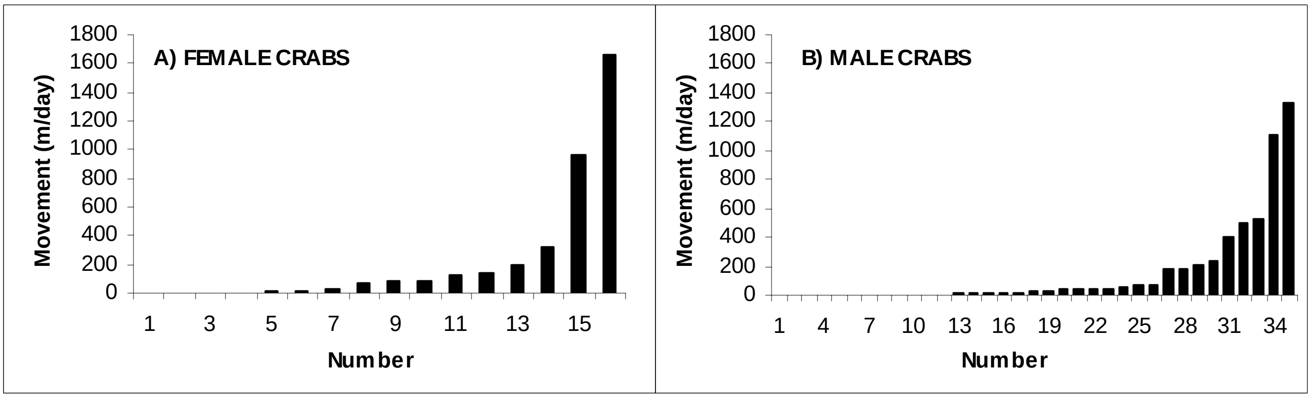


Figure 53 Speed of movement by A) female and B) male mud crabs.

*Table 9 for Size (mm carapace width) of copulating male and female crabs caught during the Bohle River surveys. * Soft shelled crab.*

Date captured	Size of male crab	Size of female crab
13 June 1997	154	110
13 June 1997	142	103
13 June 1997	161	111
11 September 1997	150	126
12 September 1997	153	115
12 March 1998	142	113
12 March 1998	138	103
5 May 1998	141	118*

Five pairs of copulative crabs were caught during the Bohle River surveys, three pairs during the first survey in June 1997 and two pairs in the next survey in September 1997. In each case the male was larger than the pre-moult female crab (Table 1). Two of the copulating male crabs were later recaptured but no females were recaptured. Neither of the recaptured males had moulted or moved from the site they were originally tagged at. One male was recaptured within 24 hours while the other was at large 56 days.

Estuarine Water Quality

Water quality parametres measured in the Bohle River showed marked variation during the surveys (Table 10). Of particular note are the low dissolved oxygen concentrations which on average were less than the ANZECC (1992) guidelines for marine water. Also, several very high turbidity measures were recorded associated with a major flood event in the catchment in summer 1998 (see *Rainfall* below). The turbidity and dissolved oxygen probes proved inaccurate on a number of occasions (recording error values, -10, or failing to reach a stable value) and suspect data was not recorded.

Table 10 Range and average value of all water quality parametres recorded in the estuarine waters of the Bohle River and Australian and New Zealand Environment and Conservation Council (ANZECC 1992) guidelines for marine water.

Water Quality	**Bohle River Mean ± s.e.**	**Range**	**ANZECC Guidelines (Marine Water)**
Water	28.13 ± 0.17 °C	22.0 – 33.3°C	< 2°C increase in normal temperature
pH	7.79 ± 0.02	6.82 – 8.53	< 0.2 unit change from the natural seasonal
Turbidity	56.1 ± 6.5 NTU	1.5 – 569 NTU	< 10% change from seasonal mean
Dissolved oxygen	5.35 ± 0.15 mg/l	1.3 – 11.3 mg/l	> 6 mg/l
Dissolved oxygen	68.6 ± 1.9%	17.2 – 141%	> 80-90%
Conductivity	39.22 ± 1.13	0.57 – 64.6	No guidelines
Salinity	2.53 ± 0.08 ppt	0.02 – 40.00 ppt	No guidelines

Rainfall

The monthly rainfall for 1997 and 1998 in the Bohle River catchment shows highest levels occurred in January 1998 during a massive flood event (Figure 54). Generally the monthly figures follow the average monthly rainfall pattern for 1871-1998 with December 1997 and April and May 1998 having above average falls (Figure 54). The average rainfall for the Bohle River is 1146 mm per year, with above average rainfall recorded in 1997 and 1998, 1462 and 1993 mm respectively (Rainman Data 1999).

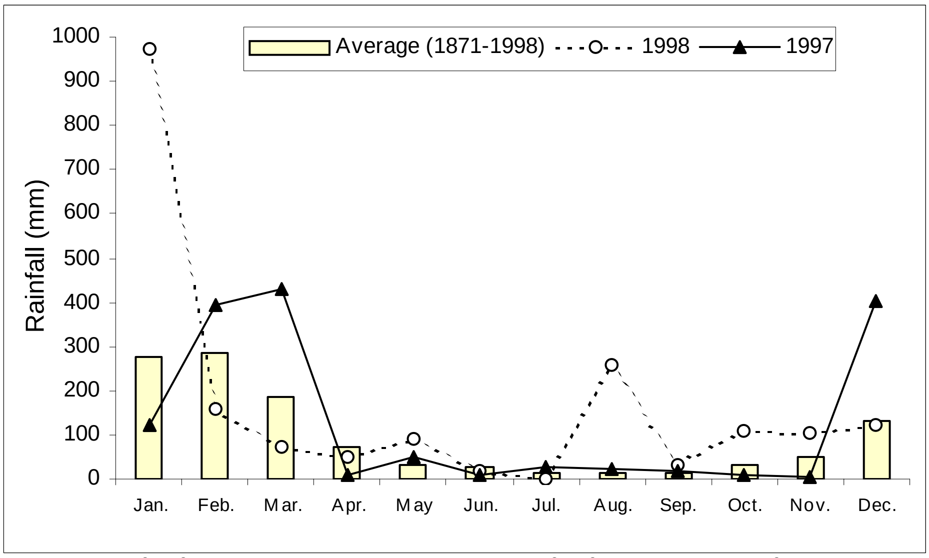


Figure 54 Average monthly rainfall for 1871 - 1998 and total monthly rainfall for 1997 and 1998 for the Townsville airport. Source: Bureau of Meteorology and Rainman® data for Townsville AMO composite.

Salinity

The mean salinity for the Bohle River over the survey period was 2.53 ± 0.08 ppt and ranged from 0.02–40.00 ppt (Table 10). At individual survey sites, salinity fluctuated during the sampling period, with a peak in November 1997 and a minimum recorded in January or March 1998 (Figure 55). Salinities remained low from January to May 1998, as freshwater entered the system after above average rainfall (Figure 54).

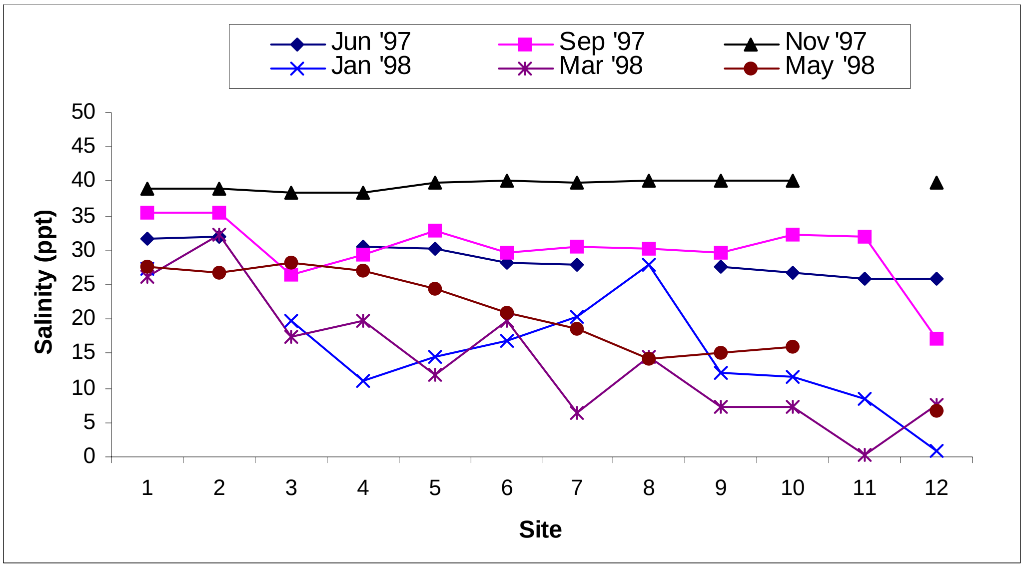


Figure 55 Average salinity recorded at the twelve survey sites during surveys of the Bohle River.

pH

During the survey period average pH for the Bohle River was 7.79 ± 0.02 (Table 10), and ranged from 6.82 to 8.53. pH values slowly decreased from the mouth upstream (Figure 56) which is typical of tropical estuarine environments (Boto and Bunt 1981). Acidity levels in January 1998 fluctuated markedly, probably because of high rainfall and a loss of buffering usually provided through higher salinities.

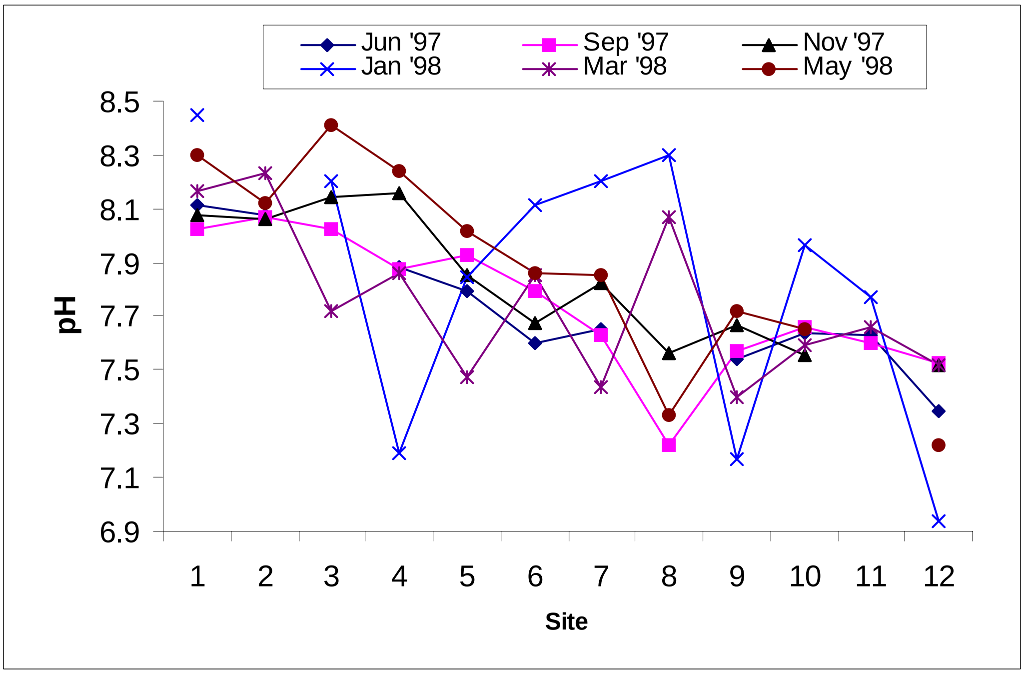


Figure 56 Average pH recorded at the 12 survey sites on the Bohle River.

Water Temperature

The average surface water temperature for the Bohle River was 28.13 ± 0.17 °C (Table 10). Temperature showed a marked seasonal pattern, increasing steadily into the summer months then varying among sites after January 1998 (Figure 57) under the influence of freshwater run-off and the approach of winter.

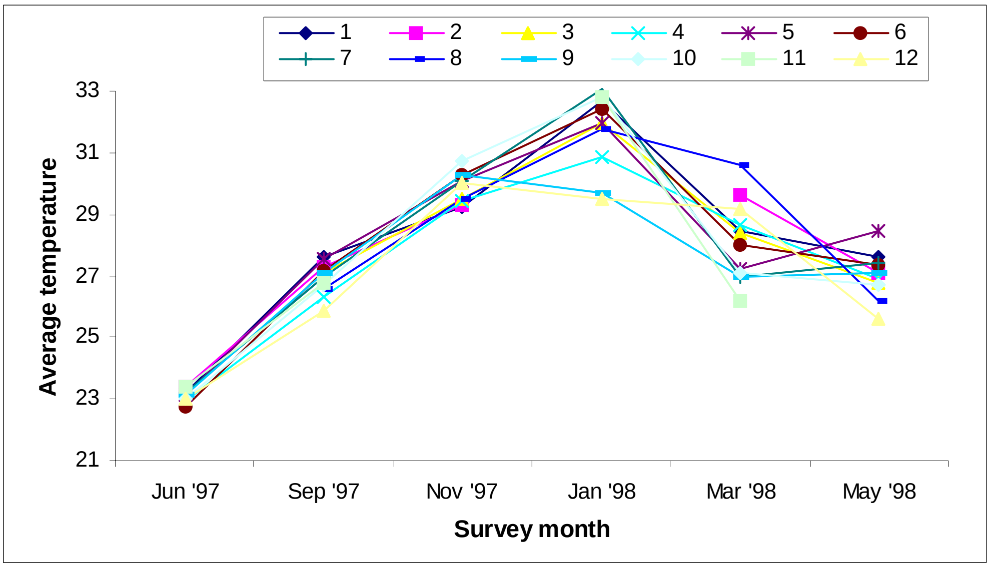


Figure 57 Average surface water temperature recorded during survey of the Bohle River.

Dissolved oxygen

The mean dissolved oxygen level recorded in the Bohle River survey was 5.35 ± 0.15 mg/l, low by ANZECC (1992) standards. Levels ranged substantially from 1.3 mg/l in January 1998 to 11.3 mg/l in August 1997 (Table 10, Figure 58). Dissolved oxygen displays an inverse relationship to water temperature with a decrease in concentration in the warmer summer months and an increase after January 1998 as the waters cooled (Figure 58). Recorded values of dissolved oxygen showed little variation among sites for each month except September 1997. In September, two groups of values are discernible being the downstream sites (Site 1-6) and the upstream sites (Sites 7-12). The levels of dissolved oxygen were lower for the upstream sites, which is typical of tropical estuaries (Boto and Bunt 1981), while the well mixed and more tidally influenced downstream waters have relatively high levels of dissolved oxygen. Figure 54 shows that by September 1997 there had been little rainfall for five consecutive months. This means there would have been little flow in the upstream sites perhaps resulting in the observed distribution of dissolved oxygen concentrations.

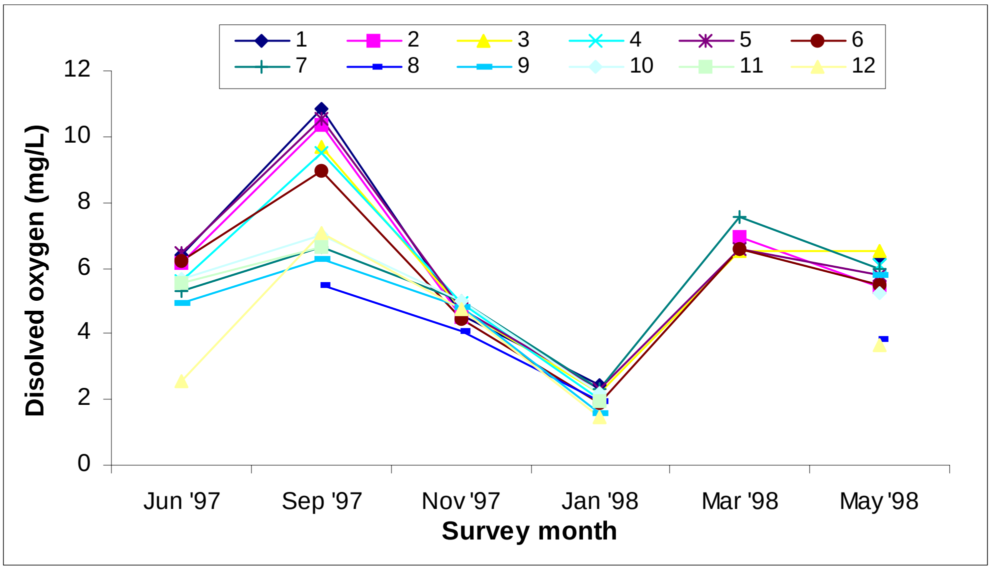


Figure 58 Average dissolved oxygen levels recorded during survey of the Bohle River.

Water temperature, salinity and biological activity directly influence the concentration of dissolved oxygen in aquatic environments, with potentially high variations in concentrations being recorded over a single diurnal cycle. This is seen more frequently in tropical estuaries where a combination of high flow events and collective changes to the catchment from urban expansion and agriculture causes higher than normal nutrient loading of creeks and rivers. Water quality reports from each of the four sewerage treatment plants discharging into the Bohle River indicate that the increased nutrient level the plants cause are minimal or insignificant compared to other sources of nutrient input (Sinclair Knight Merz 1998, Townville City Council 1999a and 1999b).

Dissolved oxygen concentrations reported here are in mg/L. A more biologically meaningful measure would be percent saturation of oxygen in the water. For example, the figure 4 mg/L is often quoted as the biological limit or threshold of dissolved oxygen for barramundi, however, as temperature affects dissolved oxygen levels this figure becomes unreliable. Percentage saturation takes temperature into account thereby providing a better measure of water quality and oxygen available to the animals in the water.

In the Bohle River, dissolved oxygen ranged from 17.2% at Site 12 in January 1998 to 141% at Site 4 in September 1997 with a mean (± s.e.) of 68.6 (± 1.9)%. More than 30% of sites sampled had dissolved oxygen concentrations less than 60% saturation. Around 40% of sites were in the moderate range between 60 and 80% saturation with a small number of sites (11%) being super saturated (> 100%).

Russell *et al.* (1998) report much higher average percent oxygen concentrations for wet tropical streams including 92.96%, 93.5% and 77.17% for the Daintree River, Saltwater Creek and Mossman River respectively. Russell and Hales (1997) report saturation levels of 86.6%, 72.2% and 80.74% for Liverpool Creek, Maria Creek and the Hull River respectively while Russell *et al.* (1996a) report an average saturation of 86% fro the Russell and Mulgrave catchment. However, Russell *et al.* (1998) do report dissolved oxygen similar to the Bohle River of and 72.88% for the Mowbray River while Russell *et al.* (1996b) report an average dissolved oxygen saturation of 70 ± 6% for the tidal reaches of the Moresby River. This indicates the levels in the Bohle River are generally lower than streams in the Wet Tropics. Unfortunately, little data is available in percent saturation for comparison in the semi-dry or dry tropics of Queensland.

Turbidity

Mean turbidity for the Bohle River was high, 56.12 ± 6.52 NTU. Values recorded were extremely variable, ranging from 1.5 – 569 NTU (Table 10, Figure 59). Peak turbidity was recorded during January and March 1998 after flooding events and while substantial freshwater flows were occurring in the river. The extreme levels of turbidity observed in the Bohle River demonstrate well the levels of run-off associated with heavy rains during the Wet Season and action of intense flow events to mobilise fine sediments. These periods of high turbidity are confined to strong run-off / rainfall events.

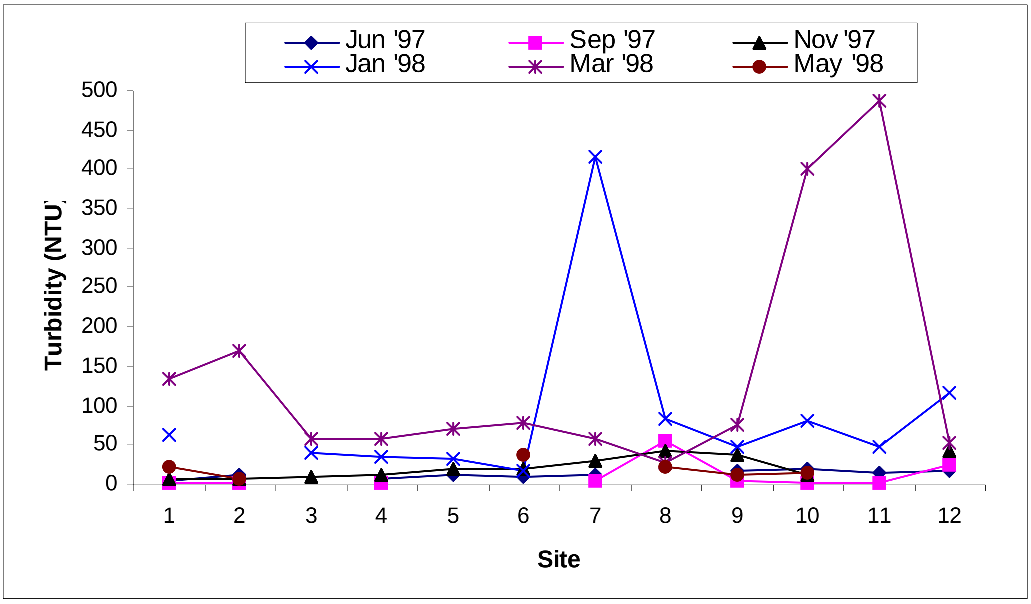


Figure 59 Average levels of turbidity recorded during surveys of the Bohle River.

Freshwater fisheries resource surveys

Electrofishing surveys took place at seven freshwater sites in December 1997 and March 1998 (Map10). Five hundred and twenty seven fish from at least 15 species were observed during approximately 2.75 hours of electrofishing in the Bohle River. Although eleven barramundi were sighted during electrofishing operations, only a single juvenile specimen (340 mm TL) was captured.

*Table 11 Species, number of fish observed and size range of captured fish during the electrofishing survey in the Bohle River. Sizes given are fork lengths or total lengths as appropriate. Exotic species are denoted *.*

Species name	Common name	Number	Size range (mm)
Ambassidae spp.	Glass perchlet	34	10.0 – 40.0
Ambassis agassizi	Agassiz's glass perchlet	7	23.0 – 42.0
Anguilla reinhardti	Long-finned eel	17	100.0 – 580.0
Craterocephalus stercusmuscarum	Fly-specked hardyhead	3	40.0 – 45.0
Gambusia affinis	Mosquito fish *	15	14.0 – 32.5
Gerres filamentosus	Spotted silver-belly	2	79.0 – 80.0
Hypseleotris compressa	Empire gudgeon	247	20.0 – 80.0
Lates calcarifer	Barramundi	10	340.0
Leiopotherapon unicolor	Spangled perch	30	58.5 – 163.0
Megalops cyprinoides	Tarpon / oxeye herring	13	10.20 – 23.50
Melanotaenia splendida splendida	Australian rainbowfish	29	15.0 – 70.0
Nematalosa come	Saltwater bony bream	4	165.0 – 305.0
Oreochromis / Tilapia spp.	Tilapia *	98	5.0 – 350.0
Poecilia reticulata	Guppy *	14	10.0 – 30.0
Selenotoca multifasciatus	Butterfish	2	120.0 – 134.0

Water quality conditions prevailing at the time of operations (Table 12) were not ideal for electrofishing surveys. The recorded high values of conductivity and surface water temperature can diminish the effectiveness of electrofishing operations. Sediments at several of the freshwater sites (Sites 1, 3, 4, 5 and 7) consisted mainly of organic debris, which is highly conductive and disrupts the electric field produced by the electrofisher (Zalewski and Cowx 1990). The water was often too deep or too turbid to see fish species that may have been affected by the sampling gear, particularly benthic species. In the Borrow Pits, freshwater Sites 4 and 5, the width of the water body (approx. 100 m each) enabled the more mobile nektonic and epibenthic species to swim out of the range of the weak electric field e.g. several barramundi were seen easily swimming out of the electric field. Less than optimal water quality conditions resulted in the electrofishing unit cutting out regularly which would have affected sampling efficiency. Lack of experience using the equipment also affected its value as a survey tool.

Water quality

The pH levels varied at freshwater sites, from 6.12 to 7.9 (Table 12). Dissolved oxygen levels were variable but generally low ranging from 0.25 to 8.30 mg/L. At the time of sampling (summer), surface water temperature was high, 28.6 to 33.6°C. Turbidity was variable and ranged from 16 to 400 NTU. No water flow was observed during the surveys of freshwater Sites 4 and 5 while flow was slight to medium at the remaining sites. Conductivity was high at all sites, ranging from 0.203 to 1.000 ms/cm, except Site 3 which was 0.057 ms/cm. Dissolved oxygen also recorded it lowest value at Site 3, 0.25 mg/l.

Table 12 Water quality values encountered during electrofishing surveys in the Bohle River system, in December 1997 and March 1998. Units are given in the Methods section. Electrofidshing sites are displayed on Map 10, page 28. DO = Disolved Oxygen

Site	Date	pH	Conductivity	DO mg/	DO %	Turbidity	Flow Rate	Salinity	Surface Water Temperature
1	18/12/1997	6.92	0.261	1.03	14.1	400	Slight	0.01	31.0
2	18/12/1997	7.10	0.203	2.37	33.8	243	Slight-med	0.00	33.6
3	18/12/1997	6.12	0.057	0.25	3.3	16	Slight-nil	0.00	29.3
4	26/03/1998	6.97	0.255	4.80	62.8	17	nil	0.00	28.6
4	19/12/1997	7.90	1.000	2.67	36.7	68	nil	0.04	31.4
5	26/03/1998	7.51	0.432	8.30	116.	352	nil	0.01	32.5
5	19/12/1997	7.51	0.774	2.72	37.7	113	nil	0.03	31.8
6	19/12/1997	7.30	0.460	2.73	37.1	32	Slight	0.01	30.7
7	19/12/1997	7.09	0.370	1.64	21.9	23	Slight	0.01	29.8

ANZECC (1992) guidelines for water quality parametres in freshwater indicate water quality at the sites electrofished in the Bohle River is poor. Only at one site did dissolved oxygen reach or exceed the suggested 6 mg/L minimum recommended. Low salinities and high conductivities also indicate heavy organic loading of the water at these sites. Poor water quality in this catchment is probably caused by a variety of anthropological factors but some consideration should be made for the ANZECC (1992) guidelines which are not strictly designed for dry tropics streams. Dissolved oxygen is also displayed in Table 12 as percent saturation. This is to provide comparison with previous work by Russell *et al.* (1996a), Russell *et al.* (1996b), Russell and Hales (1997) and Russell *et al.* (1998). All of these studies found much higher average levels of dissolved oxygen saturation highlighting the poor quality of water in the Bohle River, however, all the aforementioned studies were of streams in the higher rainfall, wet-tropics as apposed to the semi-dry tropical Bohle River.

Species diversity was highest at Sites 4 and 5, the Borrow Pits. Diversity was lowest at Site 3, where the dissolved oxygen concentration was lowest. The evenness of diversity varied strongly among sites, indicating a high variability in numbers of individuals captured within each taxa at the different sites (Figure 60). Helmke *et al.* (2000) reported higher numbers of fish (3154) and species (24) from Trinity Inlet while Hogan and Graham (1994) report a variable number of species, 13 – 30 species, in different creeks within the Herbert River flood plain. Both the Trinity Inlet and the Herbert River flood plain are larger catchments then the Bohle River catchment and are in the Wet Tropics. Both these factors typically contribute to a higher diversity than smaller catchments in the wet-dry tropics (Pusey *et al.* 1995). Low diversity in the Bohle River may be natural and result from low average rainfall with seasonal high intensity flows and the small physical size of the catchment or due to anthropological factors which could strongly and quickly reduce habitat quality and quantity (e.g. urban and industrial run-off, encroachment of housing and industrial industries into the catchment, water treatment discharge, introduction of exotic plant and fish species etc.). Karr (1981) has suggested a procedure to assess the biotic integrity of an area using descriptions for all components of the fish community, and according to his scheme, the indicative calculation reveals the biotic integrity of the Bohle River must be rated as fair-to-poor. More information is required to refine this preliminary estimate.

Exotic and noxious species

Three exotic taxa were captured in the survey: tilapia, guppies and mosquito fish. Tilapia and guppies were present at all sites apart from Site 6 where guppies were absent. Mosquito fish were only recorded at Site 4 (one of the Borrow Pits). Over 90 tilapia were captured, however, the effect of their presence on the diversity of fish fauna in the catchment could not be determined as no information is available on the diversity of the catchment before tilapia were introduced.

Species of commercial and recreational importance

Barramundi and long-finned eels were the only species of commercial net fishery importance that were captured. Barramundi, and to a lesser extent, spangled perch and tarpon are of recreational importance to local fishers. Many of the remaining species captured (Table 11), are common in the home aquarium trade. The smaller fish species encountered (e.g. Glassfish *Ambassis agassizi;* bony bream *Nematolosa come*) form an important part of the prey food of the recreationally and commercially important species such as barramundi (Dunstan 1959, Merrick and Schmida 1984).

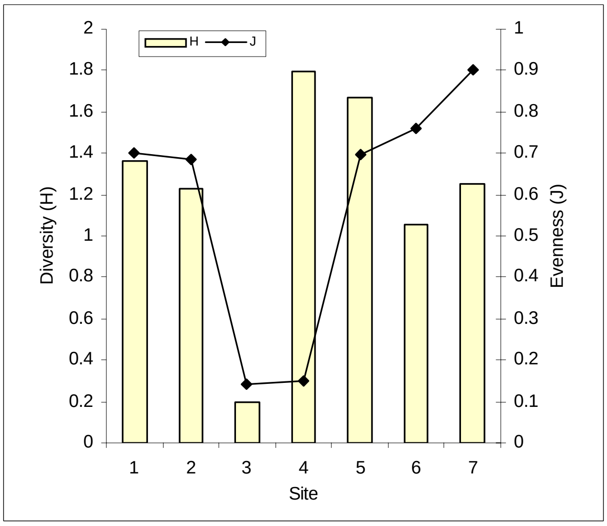


Figure 60 Species diversity and species evenness at the electrofishing sites within the Bohle River catchment.

Rare species

Fish range in their ability to tolerate a wide range in water quality parametres, for example tilapia are a tolerant species that can survive in wide range of salinities, oxygen levels and temperatures while jungle perch are sensitive to small variation in water quality. During the electrofishing surveys in the Bohle River, no rare or sensitive fish species were recorded. Perna (1999) lists ten species that he expected to occur in the Bohle River catchment but that, based on previous surveys in the region (Perna 1995, Perna *et al.,*unpublished, and James 1998), he did not locate in his survey of the fish fauna in the Borrow Pits. Only two of these ten species, the silver biddy *Gerres filamentosus* and the fly-specked hardyhead *Craterocephalus stercusmuscarum*, were identified during the broader scale electrofishing surveys of the Bohle River catchment undertaken by this Coastal Streams project.

Fishery dependent information on fishery resources

Introduction

Understanding the impacts of fishing pressure on a fished resource comes from understanding the dynamics of the fishery. Understanding commercial and non-commercial use of the fisheries resources of the Bohle River is essential to this process. Several sources of data were available on resource use in the Bohle River by commercial fishers, commercial tour operators and recreational fishers.

As part of licensing requirements, commercial fishers must provide details of their catch and effort into logbooks, which is collated by the QFMA into the CFISH database. CFISH contains records of commercial catch and effort since 1988. Commercial tour operators are also required to complete logbooks on their catch and effort since permits were introduced to the fishery in December 1995. This information is also stored in the CFISH database.

Recreational fishing throughout Queensland is much more difficult to assess because recreational fishers do not require a license or fishing permit and therefore have no catch or effort reporting requirements placed on them. Instead, the QFMA implemented a program of recreational fishing surveys throughout Queensland (Queensland Fisheries Management Authority (QFMA) n.d.a). This survey was first conducted in 1996-97 (QFMA n.d.a) and another survey is currently underway. Although not directly providing information on total recreational catch and effort, survey data can be extrapolated to obtain estimates for the entire Queensland population. Information on angler catches and on fish movements can also be obtained from the Australian National Sportsfishing Association, Suntag database (B. Sawynok, pers. comm. 1999). This database, dating back to 1986, holds records of fish tagged and recaptured in the Bohle River. There is little effort information associated with the data, but Suntag is rectifying this situation and has introduced catch and effort data collection for members of Australian National Sportsfishing Association (Queensland) willing to participate.

Indigenous fishers also make use of fisheries resources in the Bohle River, however, no information exists on the indigenous catch and effort for this river. Addressing this lack of data was investigated as part of the project brief and a joint exercise with DPI, EPA and Balkanu Development Corporation was instigated to develop methods for community based indigenous subsistence fishing surveys (Turner 1998). The procedure was trialled in the Trinity Inlet as part of the project development.

Fishery dependent information is available from many sources and at a small cost relative to that obtained through fishery independent surveys. Assessing fisheries resources using fishery independent techniques provides information on resources not available to or accessed by the fishery, and to validate fishery dependent data. Together, research information and fishery derived data can give a synthesis of detail about resource condition and trends over times, as well as quantifying the demands from the various sectors in the fishery.

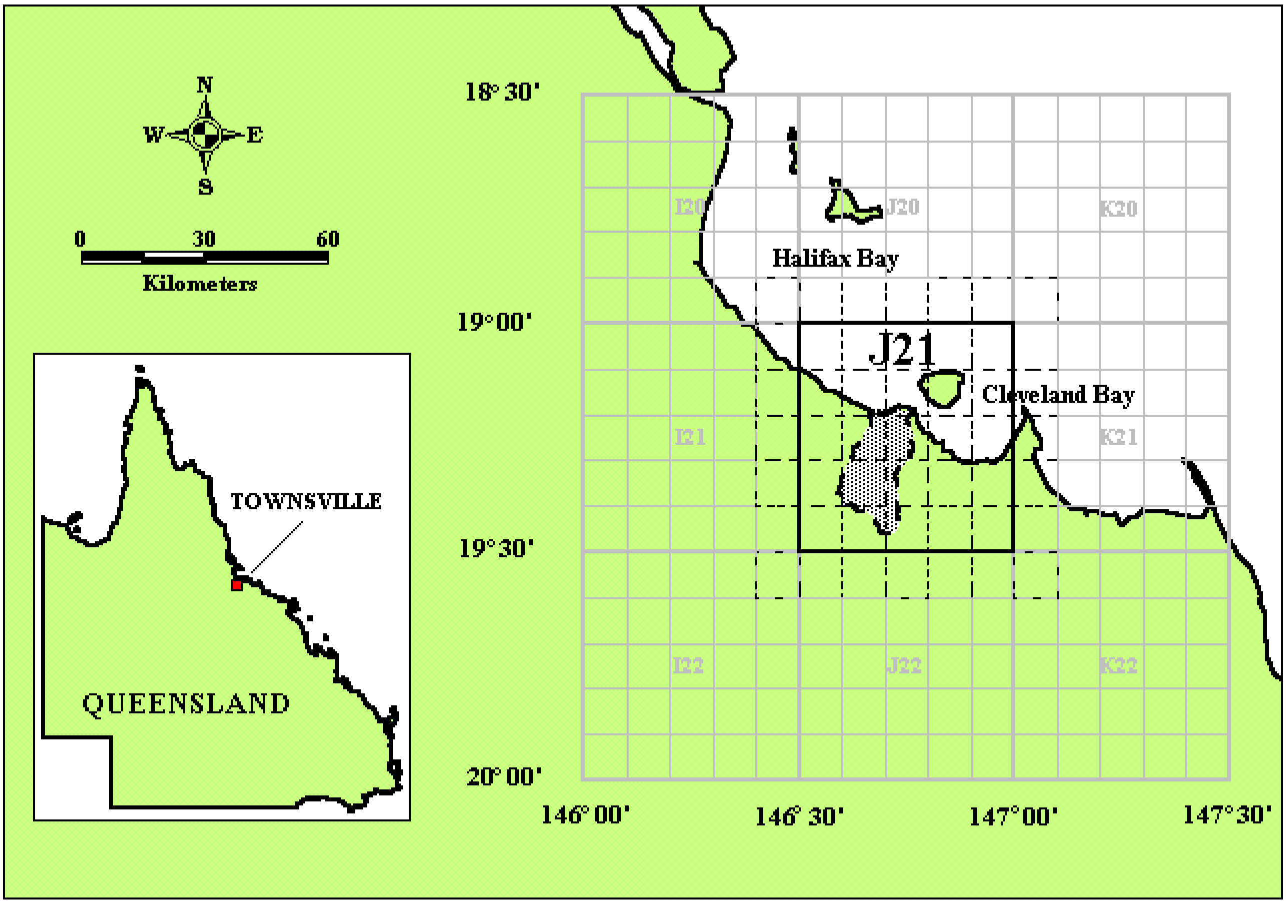
This section of the report presents information on commercial, commercial tour operator and recreational catch in the Bohle River and surrounds.

Methods

Commercial harvest fishery

Historic catch records for the commercial inshore set mesh, line and crab fishery in the Bohle River area were extracted from the QFMA CFISH mixed database for nine years from January 1990 to June 1999 (by Sue Helmke, DPI). The data set extracted contained three different logbook formats (mixed – 1990 to 1993, and net/crab and line fisheries – both are 1992 to 1999) which were combined to make a continuous database. Information recorded by commercial fishers includes catch (species and weight) and effort (date, type and quantity of gear used).

The commercial logbook records contained in CFISH are structured into 30' grids of latitude and longitude (Map 18). Spatial information of finer detail, usually 6' grids, are sometimes provided, however, the 6' grid information is not consistently available for any one area. Very little information was provided at the finer scale for the Bohle River, so data from within the 30' grid 'J21' was pooled for analysis. Consequently, catch and effort data were drawn from the area encompassed by the four points 19°00'S, 146°30'E; 19°00'S, 147°00'E; 19°30'S, 146°30'E and 19°30'S, 147°00'E, which includes the southern end of Halifax Bay and the northern end of Cleveland Bay (Map 18). In this larger 30' grid there are twelve commercially fished estuaries in addition to the Bohle River. Therefore, the data can not be used to imply any reference solely to the commercial catch in the Bohle River.



Map 18 Fishing Grid J21 used in the extraction of commercial logbook data for the Bohle River area. The Bohle River catchment area is shown.

The extracted CFISH data set was reviewed to filter out inappropriate data before analysis. Limitations and difficulties associated with the analysis of CFISH data are discussed by Magro *et al.* (1996, 1997). Difficulties experienced in using the Grid J21 data set included: numerous common names for individual species codes leading to mis-identification and broad taxonomic identification of catch; a number of species codes without corresponding species names; codes starting with 0 had the 0 removed (e.g. 019000 was converted to 19000) in order to allocate a corresponding species, and an unrealistically high catch of crabs recorded by one fisher every day over a 30 day period. In the later case it was assumed to be a bulk data problem where a months catch has been accidentally entered each day of that month. This extra data was removed before analysis was done.

Data from the line fishery (1992-1999) were excluded as the additional effort applied in this fishery would have made the interpretation of overall CPUE analysis extremely difficult, and because estuarine fish species are not targeted by this fishery {less than 1% of the total catch recorded for each estuarine species, except garfish (2.7%) was taken by line fishing}.

Beam Trawl data were excluded from the mixed fishery information set as no finfish species were recorded in the catch. However, Trawl data were not excluded from the net/crab fishery data set because reported mesh size and net lengths were similar to those for inshore gillnets and the species caught were estuarine fish species. Catch records from the net/crab fishery relating to nets greater than 600 m in length were also excluded as these nets are not permitted close to shore (*Fisheries Regulation 1995*). The resulting data set for analysis contained information from both the mixed and net/crab fisheries, and included ten fishing methods (Table 13). It is important to note that fishing effort for different fisheries is not directly comparable as different fishing methods and gear are used (Table 13).

*Table 13 Fishing methods whose catch statistics were included in analysis of commercial fishing logbook data for grid J21. * denotes fishing methods that could only be identified as a net, similar in dimensions to that of a gillnet.*

Fishery Code	Fishery Method
Mixed	Line fishing
Mixed	Gillnetting
Mixed	Crab pot
Mixed	Beam trawling
Net/Crab	Anchored gillnetting
Net/Crab	Gillnetting
Net/Crab	Drifting gillnetting
Net/Crab	2*
Net/Crab	34*
Net/Crab	54*

To make analysis more applicable to the Bohle River estuarine fishery, catch records of fish that were not estuarine species, or where species of catch was classified as either “fins” or “skins” were also omitted. Species removed from the analysis were, coral trout *Plectropomus maculatus*, red emperor *Lutjanus sebae*, sandy sweetlip *Lethrinus choerorynchus*, red throat emperor *Lethrinus chrysostomus* , grassy sweetlip *Lethrinus fletus*, snapper or squire *Pagrus australis* and the categories of fish “emperor unspecified”, “parrot fish unspecified”, “sweetlip unspecified”, “mixed reef A” and “mixed reef B”. A list of species categories and the best possible taxonomic differentiation available for those categories is shown in Appendix 7.

Fish catch was measured in tonnes or kilograms live weight and was calculated by multiplying recorded catch weight by a QFMA weight conversion factor (whole =1, trunks =1.4, gutted fish =1.1, fillets =2.0) after Magro *et al.* (1996). For mud crabs, 49 of the 1767 records from the net/crab fishery listed quantities only as numbers. Following Margo *et al.* (1996), catch weight was estimated for these 49 records by assuming 1 crab =1 kg.

Effort expended in the mixed and net/crab fishery was calculated in terms of boat days. It was assumed that records where no end date was supplied were one day fishing trips. Duplication of effort across different fishing methods was reduced by grouping boat number and operation date when calculating total effort.

For species other than barramundi and mud crabs, annual and monthly catch per unit effort (CPUE) values were calculated for each species based on the summed catch (kg) for each species and the total effort (boat days) expended in the mixed and net/crab fishery. For barramundi, any recorded effort expended during the barramundi closed season was excluded from analysis while mud crab effort was calculated from only those boat days where mud crabs were caught. Average monthly CPUE for species is the average of monthly CPUE in each month from 1990 to 1998. A confidentiality agreement between commercial fishers and QFMA states that data set where fewer than five fishers recorded a catch must not be accessed from CFISH (L. E. Williams, DPI pers. comm.). In the following analysis, * denotes where data have been omitted in concordance with this agreement.

The Gross Value of Production (GVP) of the fishery was calculated from catches recorded in CFISH and an approximated value of each species ($ per kg) derived in consultation with fish wholesalers throughout Queensland (L.E. Williams, DPI pers. com. 1999).

Commercial tour operator fishery

During the 1990's, fewer than five commercial tour operators operated in grid J21, including the Bohle River. Therefore, due to the confidentiality of the logbook data (as discussed above), information on the catch and effort of this fishery is not available for analysis.

Recreational fishery

No quantitative historical information exists for recreational fishing in the Bohle River. During the study, recreational fishing information for the Bohle River was obtained from the Queensland Fisheries Management Authority's RFISH database and the Suntag database.

As a measure of recreational use of the Bohle River, the number of vehicles and vehicles with boat trailers attached was recorded at the Bohle River boat ramp each time the research team entered or left the water (~0700 hrs, ~1200 hrs, ~1800 hrs and ~2400 hrs). This resulted in several records (2-6) being collected for each day during the bimonthly survey period from 16-11-1997 to 22-05-1998.

In order to get an estimate of average use of the boat ramp, weighted means were used. This also allows results to be comparable with data previously collected by James Cook University.

QFMA RFISH database information

Information in RFISH was based on 1997 logbooks compiled by recreational fishers that volunteered during a telephone survey by QFMA. Recreational fishers provide the following details for each fishing trip they go on:

- date fished
- fishing location (usually local name for fishing spot only)
- species caught
- number of fish kept
- number of fish released
- hours spent fishing.

Research officers at the QFMA provided summarised information from RFISH on the number of trips recorded, the number of each species kept, the number of each species released and on total fishing effort for the Bohle River. Some RFISH species categories were grouped to facilitate species–by–species analysis. ‘Crab’ and ‘mud crab’ categories were combined into ‘mud crab’ while ‘grunter’ and ‘javelin fish’ became ‘grunter’. Care should be used when viewing these data as the number of lines used by each fisher has not been taken into account and may affect the catch rates calculated.

Suntag information

Recreational fishing information was also obtained from the Australian National Sportsfishing Association’s Suntag database, coordinated by InfoFish Services, Rockhampton in the form of fish tag and recapture details for the period 1986-1998. The database includes information on:

- date fished
- fishing location (in 1 km grids)
- species caught
- fish size (total length)

The tag-recapture information was used to generate data on fish growth, time at liberty and movement within the Bohle River and between the Bohle River and neighbouring river systems. Information extracted from the database on recaptured fish included:

- tag number
- angler
- species
- recapture location
- movement direction
- fish size (total length)
- distance moved.

Only one record of a recaptured fish, a barramundi, was caught by a commercial fisher. Effort for the Suntag data was estimated by summing the number of days that fish were tagged. Care should be taken in interpreting this data as the effort calculated does not account for the recreational fishing effort applied in the Bohle River where fish were not tagged or when multiple fishers were fishing.

Indigenous fishery

No information was available of the indigenous fishery in the Bohle River, however, Turner (1998) have recently developed a technique for collecting such information.

Results

Commercial harvest fishery

Total Commercial Catch

For the period 1990 to 1998 the annual commercial catch from the inshore gillnet and crab pot fishery in grid J21 varied between 66 tonnes of product in 1992 and 142 tonnes in 1997, with a mean of 92 tonnes (Figure 61). The GVP over that time was approximately $4.5 million including more than $500 000 in 1998. Effort applied to the fishery declined from over a thousand boat days in 1991 (31 boats) to around 800 in 1998 (24 boats, Figure 62). It is important to note that fishing effort for different fisheries is not directly comparable as different fishing methods and gear are used (Table 13).

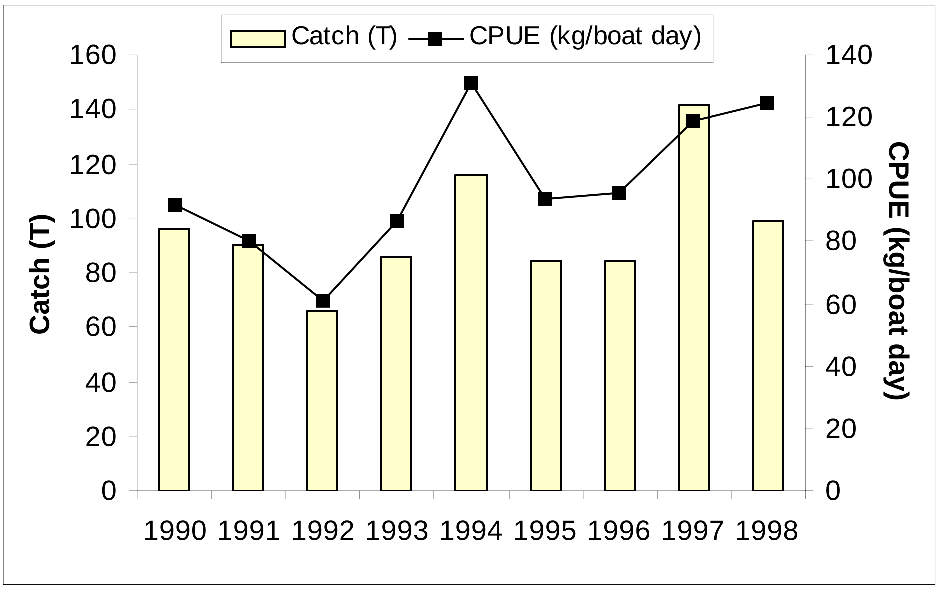


Figure 61 Annual catch and CPUE for the inshore gillnet and crab pot fishery in Grid J21.

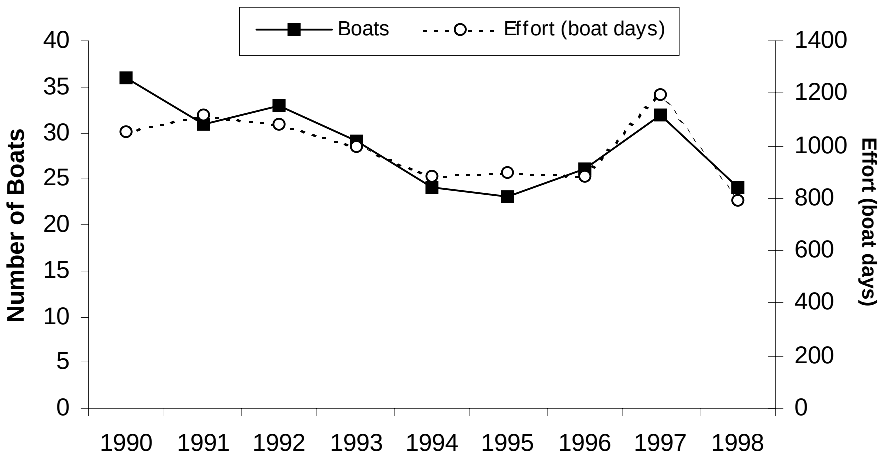


Figure 62 Total number of boats and fishing effort (boat days) for the inshore commercial fisheries in Grid J21 between 1990 and 1999.

High catch rates recorded in 1994 may be attributed to high CPUE of blue threadfin (see p 86) while mackerel and shark landings were reasonable (see below). In 1997 mackerel, shark and grunter catches were high while in 1998 barramundi, mud crab, grunter and mackerel catch rates were high. Effort was also reduced in 1998 while landings were generally high providing an increase in CPUE. Catch rates are discussed for each of the target species below.

An increased level of fishing effort recorded in 1997 may be attributed to fisher reaction to a proposed DPA which was proposed for this area in August 1997. Figure 62 shows that the number of boats working in Grid J21 rose from 25 to 32 in 1997. Fishers may have been trying to maximise the value of their authorities before the Cleveland Bay DPA was legislated in January 1998. A close look at monthly effort applied in this fishery after June 1997 when the DPA was first proposed does indicate an increase in effort compared to previous years. The mean number of days fished for the period from July-December from 1990-1996 (± 95% Confidence Interval) was 488.6 (± 65.9) days while the number of days fished in the same period in 1997 was 649. With the introduction of the DPA in 1998 and restrictions on net fishing activities there is a fall in effort to the lowest level recorded in the nine year period (24 boats and 795 days, Figure 62). Interestingly, however, there is no notable corresponding drop in landings recorded for 1998 (Figure 61).

Commercial catch was classified into 19 different species categories, although the actual number of species within these categories is unknown. Between 1990 and 1998, grey mackerel contributed 29% of the overall catch, shark was 23% mullet-unspecified 10%, barramundi 9%, blue threadfin 9% and queenfish 6% (Figure 63).

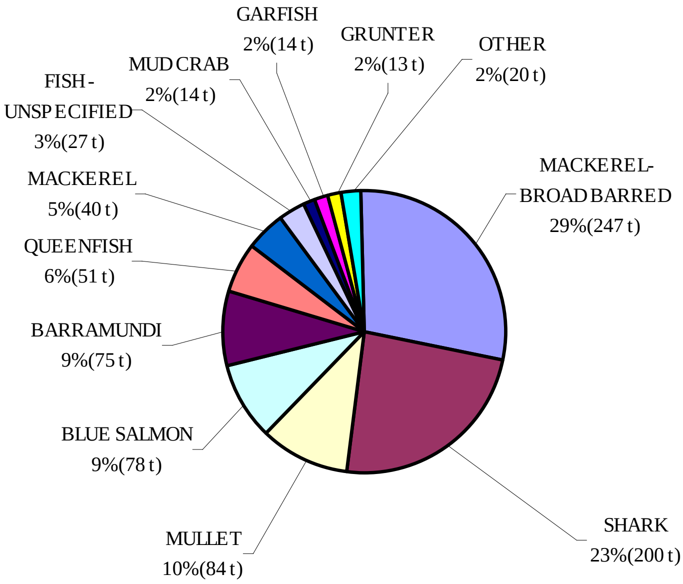


Figure 63 Total commercial catch (percentage and total tonnes in parenthesis) from Grid J21 for 1990 to1998 using the species categories of CFISH.

The relative importance of the catches of the different species varied from year to year. The commercial catch of shark and grey mackerel dominated the annual catch from 1990 to 1998, averaging 20 and 27 tonnes per year respectively over this period (Figure 64). Highest catches of shark and grey mackerel were both reported in 1997. In 1998, catches of grey mackerel remained high (Figure 64) even though effort was reduced (Figure 62). Each year mullet unspecified, blue threadfin, barramundi, queenfish, and mackerel unspecified featured prominently in the top five species after shark and grey mackerel (Figure 64). The “fish-unspecified” species category consists mostly of incidental catch and / or by-catch from the inshore gillnet fishery (L.E. Williams, DPI pers. comm. 1999), and landings averaged three tonnes per year, although large catches were made in 1993 and 1997 at six and seven tonnes respectively (Figure 64).

Detailed catch statistics from the commercial fishery in the Bohle River area were available for barramundi, blue threadfin, king threadfin, grunter, bream and mud crabs, although grouped categories (such as *Pomadasys kaakan* and *P. argenteus* into “grunter unspecified”) made analysis difficult. The catch in kilograms and catch per unit effort (CPUE) measured in kilograms per boat day, calculated both monthly and yearly, are presented for these target species. Information available for mangrove jack and bream was limited due to the confidentiality agreement between QFMA and commercial fishers (discussed above).

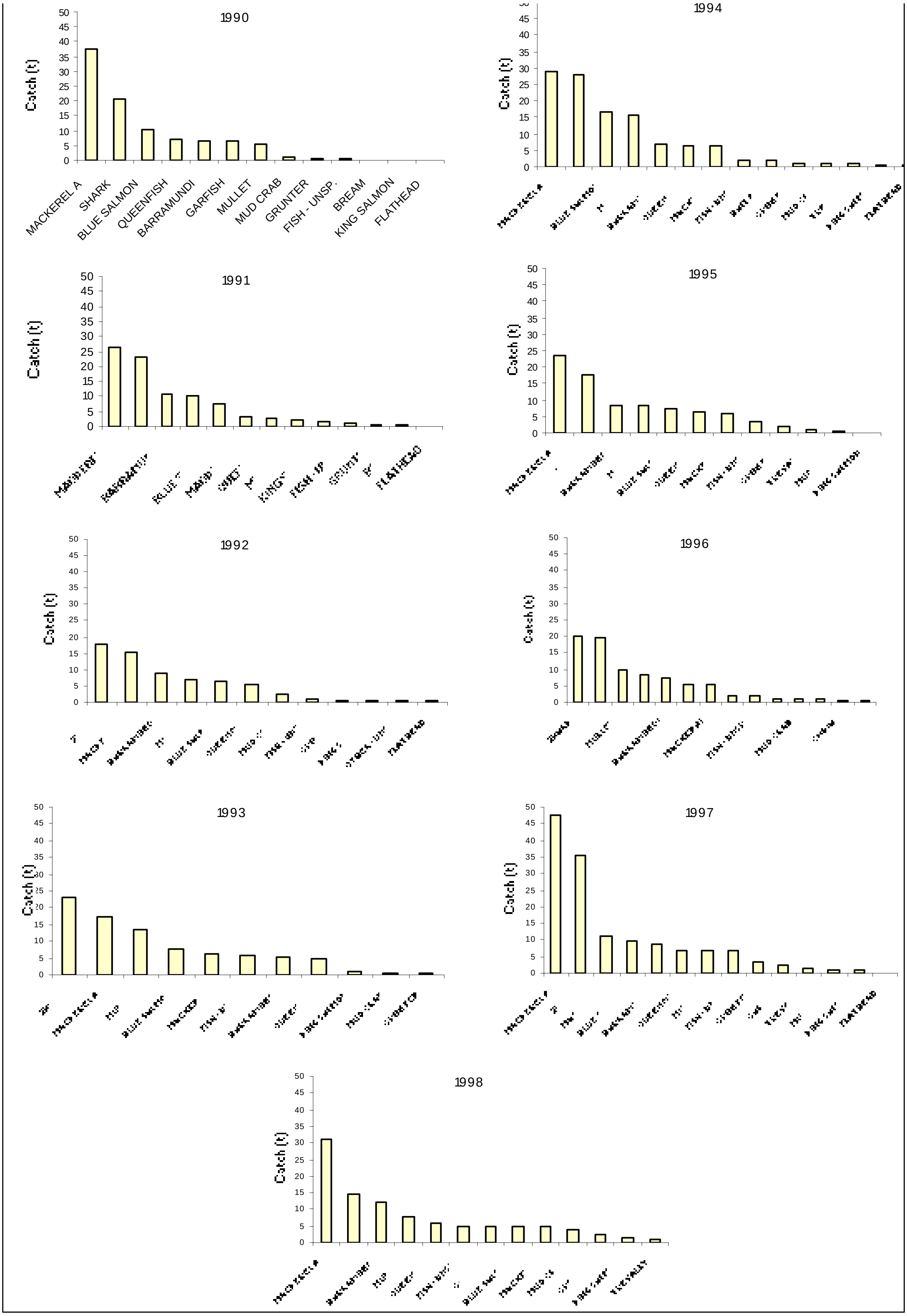


Figure 64 Commercial catch tonnes (t) for Grid J21 from 1990 to 1998. Mackerel A is grey mackerel, Mackerel B is Spanish mackerel and Unsp. Is unspecified.

Barramundi (*Lates calcarifer*)

Barramundi is a valuable commercial estuarine species in the Bohle River area, being the fifth most important species by weight (9% of the total commercial catch for the nine years 1990-1998, Figure 63) and the third most important species by dollar value, ≈$530 000. A total of 12.3 tonnes was landed in 1998 for a GVP of around $86 000. The catch of barramundi is sold within Queensland and interstate with the local fishers receiving $6.50 /kg for whole fish and $12.00 /kg for fresh and frozen fillets in the 1998 season (Townsville wholesaler, pers. comm.).

The annual catch of barramundi varied from 5.1 tonnes in 1993 to 12.3 tonnes recorded in 1998 (Figure 65) with an average of 8.4 tonnes per year from 1990 to 1998. Catch rate has increased in recent years from 5.5 kg per boat day in 1993 to 17.1 kg per boat day in 1998.

Helmke *et al.* (2000) reported similar catch rates of barramundi from Trinity Inlet (Cairns), ranging from approximately 5 to 18 kg per boat day for 1990-1998. Williams (1997) reported higher catch rates ranging from 24 to 37 kg per boat day for the East Coast barramundi fishery, however, Williams' calculated effort for this fishery only from those days where barramundi were landed (L. E. Williams, pers. comm. 1999). While Williams' method may under-represent effort targeted at this species, the effort level calculated in this report may be an over-estimation, so, the results should be viewed as trend indicative only. Helmke *et al.* (2000) reported the same peak in landings of barramundi in Trinity Inlet that occurred in 1991 and 1998 in the Bohle River area (Figure 65), and Williams (1997) reported a state wide peak in production in 1991.

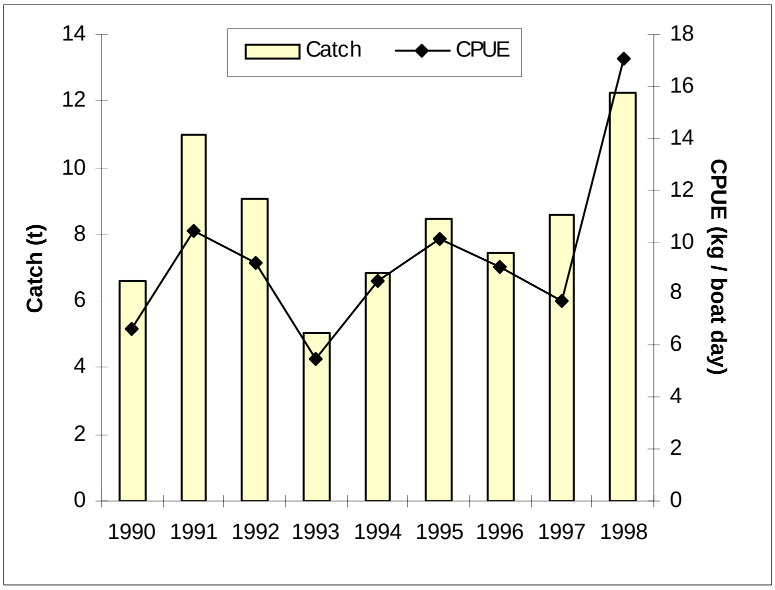


Figure 65 Barramundi catch (t) and CPUE (kg per boat day) in the Townsville area form 1990 to 1998

Direct correlation of annual barramundi landings for Grid J21 with annual total rainfall recorded for the Bohle River catchment was reasonable but not statistically significant (correlation coefficient r = 0.63, F = 4.63, df = 1, 7, p = 0.068). Peverell *et al.* (1998) reported that increased water turbidity in estuaries during high flow events improved the catchability of barramundi in the Queensland barramundi fishery and Dunstan (1959) also reported a direct positive correlation existed between river flow and barramundi catches.

Williams (1997) found annual wet season rainfall influences adult spawning success and juvenile recruitment of barramundi, therefore it is reasonable to expect rainfall should also affect barramundi catches although a time lag factor is important to allow juvenile fish to grow and recruit into the fishery. Barramundi are not expected to reach a size at which they can enter the fishery until there third year of life (Russell and Rimmer 1998), so a time lag of at least three years and a subsequent rainfall event may produce the best correlation between rainfall and landings.

However, during periods of several consecutive dry years (i.e. more than three years), correlation between rainfall and barramundi landings could be expected to be more complex. That is, barramundi that would be of legal size may not be able to escape from their freshwater nursery areas and become available to the fishery until a flood event occurs. For example, fish spawned during the 1990 season when there was a peak in rainfall (Figure 66) might not be available to the local fishery until after the 1997 rainfall event. This is probably a major contributing factor to the success of the 1997 and 1998 season seen in Grid J21 (Figure 65 and Figure 66). The timing and volume of rainfall would also affect the relationship between rainfall and barramundi landings as rainfall late in the season may be too late for barramundi spawned early in the spawning season while too little rain may not allow access to and from all nursery wetland areas. Another complication is the likelihood of a fish kill, usually following the first rainfall even after a dry spell, that reduces oxygen concentration in the water and can kill a large number of fish in the affected area.

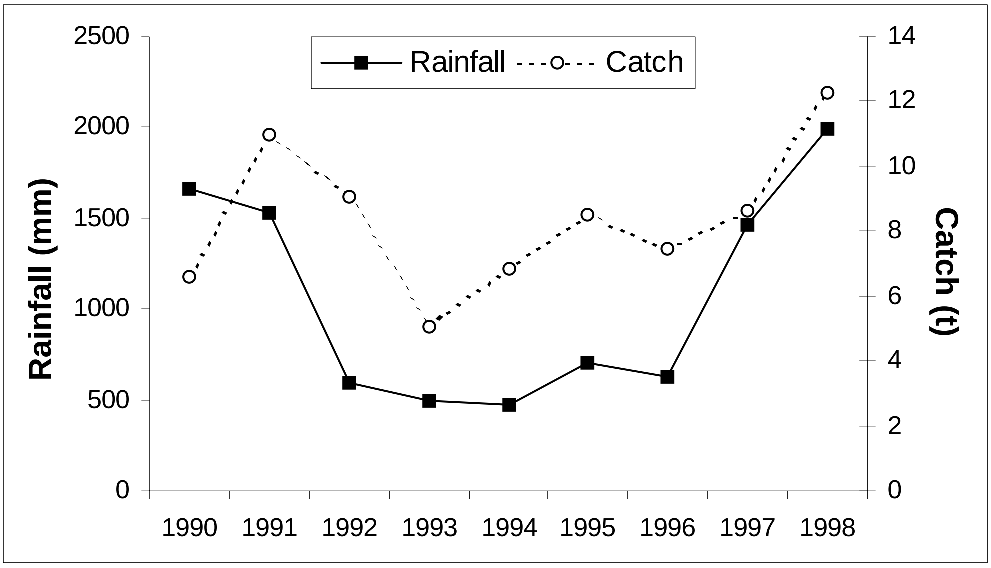


Figure 66 Total annual rainfall recorded for the Bohle River catchment and commercial landings of barramundi for 1990 to 1998. A time lag of one year was applied to the rainfall data (that is, rainfall data displayed for 1991 is the quantity of rain that fell in 1990).

Recruitment of barramundi is a further consideration and unknown factor in this equation. Barramundi caught in Grid J21 may have recruited from other areas such as the wetlands associated with the Burdekin River to the south Thus, rainfall in the Burdekin catchment might be a major contributing factor to barramundi landings in Grid J21. More work in recruitment and movement of barramundi would be required to determine the extent and importance of recruitment of barramundi from other areas into Grid J21.

With the effort applied by the commercial fishery during the barramundi season closure removed from the total effort calculated the pattern of total effort applied to the barramundi fishery (Figure 67) remained the same as for the whole fishery (see Figure 62). A general slow decline in effort from 1050 boat days in 1991 to 719 boat days in 1998 can be seen in Figure 67. The peak of 1117 days in 1997 may have been caused by increased net fishing activity before DPAs were introduced in January 1998.

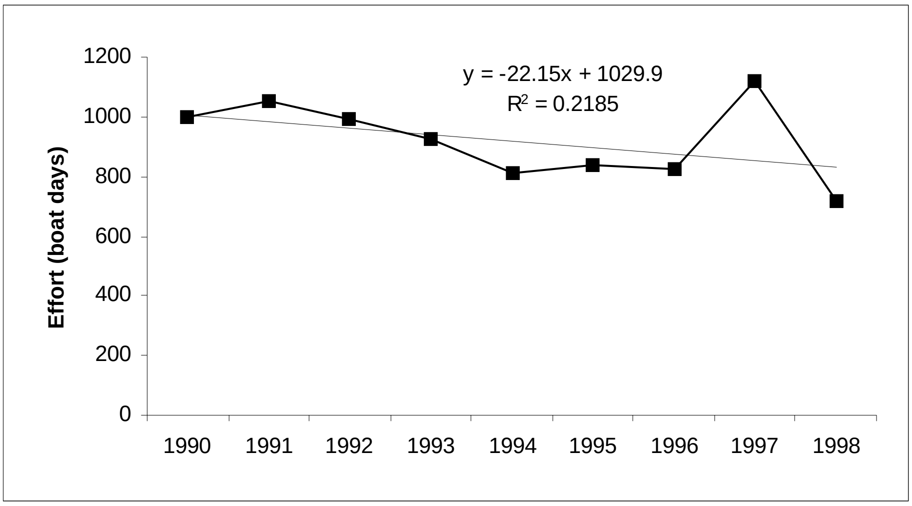


Figure 67 Effort (boat days) applied by the commercial fishery in the Bohle River, excluding the season closure for barramundi.

There is a strong seasonal influence on the commercial catch of barramundi with the greatest catches occurring from February to April when fresh water flows are typically highest (Dunstan 1959) and at the opening of the barramundi fishing season (Figure 68). The decrease in catch for barramundi during the winter months may be attributed to lower rainfall and freshwater flow in the stream during these months (Dunstan 1959), diminished levels of fish activity in cooler water (Gary Ward, Queensland Commercial Fishermen's Organisation, pers. comm., 1981), diminished foraging movements with reduced freshwater flows in winter (B. Sawynok, Suntag pers. comm., 1999), their dispersal from the usual fishing grounds as water temperatures drop (Margo *et al.*1997), and increasing water clarity as rainfall events become less frequent, all of which reduce catchability in gillnets (Peverell *et al.*1998).

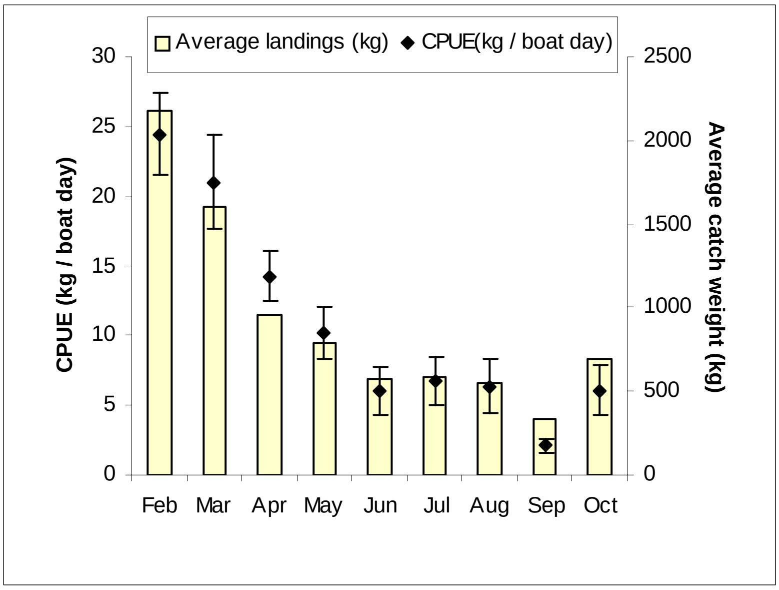


Figure 68 Average monthly commercial catch (kg) and CPUE (kg per boat day) of barramundi in the Townsville area, over the period 1990-1998.

Blue Threadfin (*Eleutheronema tetradactylum*)

Blue threadfin is a valuable commercial estuarine species in the Bohle River area, being the fourth most important species by weight (9% of the total commercial catch for the nine years 1990-1998, Figure 63) and the fourth most important species by dollar value, ≈$313 000. The average GVP for blue threadfin from 1990-1998 was $35 000 each year while the dollar value returned by this component of the fishery dropped to around $19 000 and a total of 4.7 tonnes in 1998. The catch of blue threadfin is sold locally, within Queensland and interstate with the local fishers receiving $3.00 /kg for whole fish and $5.00 /kg for fresh and frozen fillets in the 1998 season (Townsville wholesaler, pers. comm. 1998).

Commercial landings of blue threadfin varied from year to year with a strong peak in 1994. The average annual landings from 1990 to 1998 were 8.7 tonnes per year and ranged from 4.7 tonnes in 1998 to 16.4 tonnes in 1994 (Figure 69). The fall in annual catch in 1998 was mirrored by a fall in recorded effort from an average 988 boat days for the period 1990-1998 to 795 days in 1998, however catch rate was also down in 1998. The drop in both catch and effort in 1998 may be attributed to the introduction of DPAs in this area and the restriction on offshore and foreshore netting activities, however, the cause of the drop in catch rate is not understood but may reflect the lower densities of this species within estuaries (as compared to the densities from both estuaries and foreshores pooled together in years prior to the DPA closures). The CPUE in 1994 of 18.6 kg per boat day was more than double the average for the 1990-1998 period. This finding is consistent with that of William (1997) who reported a higher catch and a peak CPUE for this species in the East Coast fishery in 1994. The dynamics of blue threadfin catches are not well understood and Williams (1997) suggests sea water temperature, salinity and near shore productivity may be factors influencing this fishery.

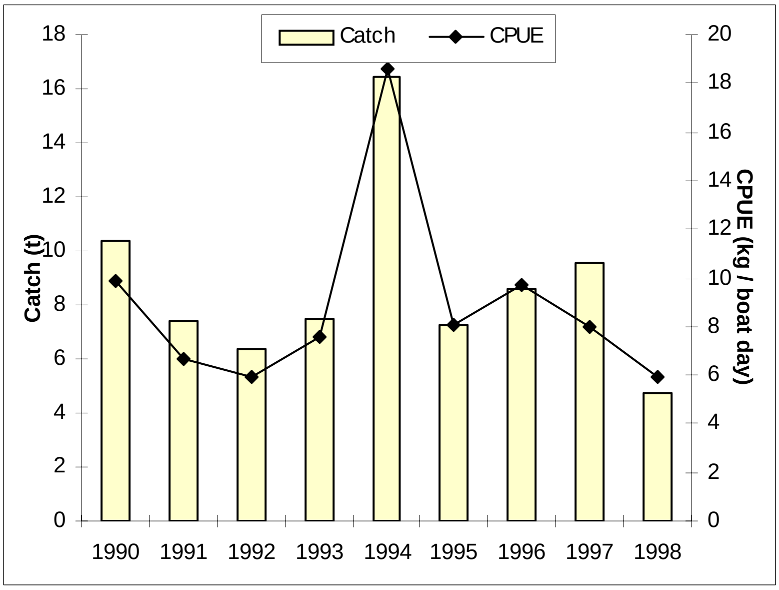


Figure 69 Blue Threadfin catch (t) and Catch per unit effort (CPUE kg / boat day) in the Townsville area from 1990 to 1998.

In the Townsville area, blue threadfin are caught mainly in the autumn and winter months (Figure 70). The elevated catch levels and catch rates in mid year is likely the result of fishers targeting this species when they are seasonally abundant (Stanger 1974). The catch rate of blue threadfin increases at the time of year that catch rate drops away for barramundi, suggesting catches of these two species complement each other in maintaining income for local fishers throughout the year. It is interesting to note there seems to be an inverse relationship between blue threadfin landing and rainfall, however, this potential relationship requires further investigation.

The large variation in CPUE for November correlates to a single large catch recorded for that month in 1994. Although landings recorded each month in 1994 were higher than the average landings recorded for each month from 1990-1998, more than 45% of the years landings were recorded in November alone. The reason for this exceptional catch remains unclear.

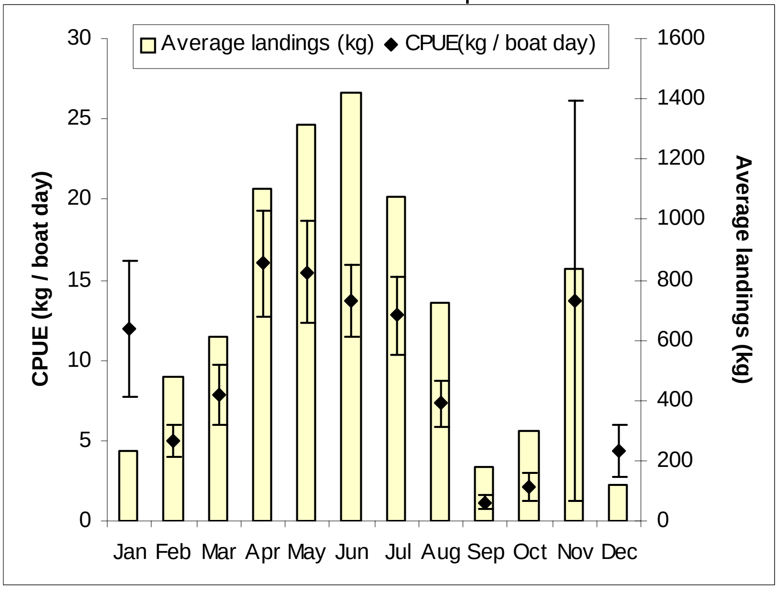


Figure 70 Average monthly commercial catch (kg) and catch per unit effort (CPUE kg per boat day) of blue threadfin in the Townsville area, over the period 1990 to1998.Error bars are one standard error indicating the variation in CPUE each month.

King Threadfin (*Polydactylus macrochir*)

Landings of king threadfin vary markedly from year to year over the period 1990 to 1998, and ranged from 135 kg in 1995 to 1565 kg in 1991 (Figure 71). King threadfin accounted for just 1% of the total commercial catch for the nine years 1990-1998 (Figure 63), and was the eleventh most important species by dollar value, ≈$28 000. A total of 1.25 tonnes was landed in 1998 for a GVP of around $5 000. The catch of king threadfin is sold locally, within Queensland and interstate with the local fishers receiving $3.50 /kg for whole fish and $6.00 /kg for fresh and frozen fillets in the 1998 season (Townsville wholesaler, pers. comm. 1998).

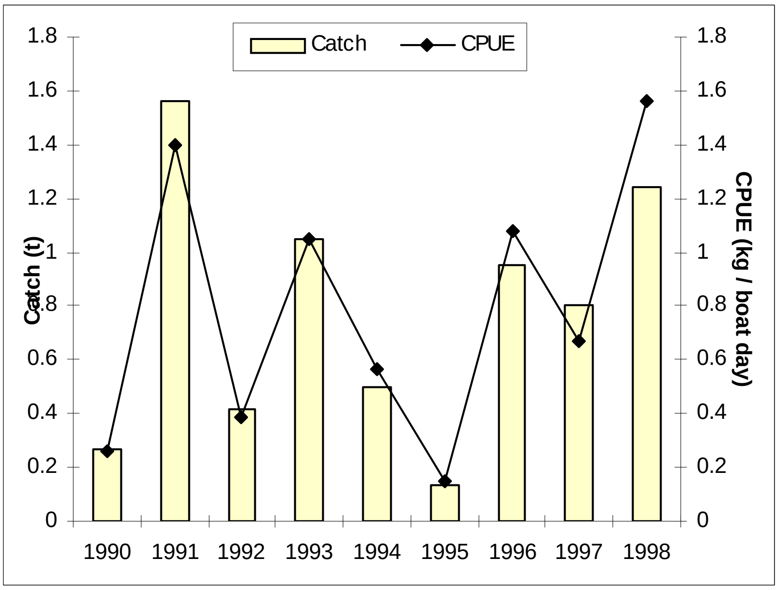


Figure 71 King threadfin catch (t) and catch per unit effort (CPUE kg per boat day) from the Townsville area from 1990 to1998.

King threadfin catch and catch rate peak in February and August (Figure 72). This pattern is similar to that of barramundi (Figure 68), indicating elevated catches and catch rates of king threadfin early in the year may be the result of increase effort targeted at the more valuable barramundi at that time of year. Alternatively, king threadfin may be more abundant at this time of year than at other times. Helmke *et al.* (2000) reports peak catches of king threadfin from December to March in Trinity Inlet near Cairns while the best catches are later in the year, April – May , around Tully (R. Garrett, pers. obs. 1999). King threadfin are generally not targeted in the Townsville area (various local commercial fishers, pers. comm. 2000).

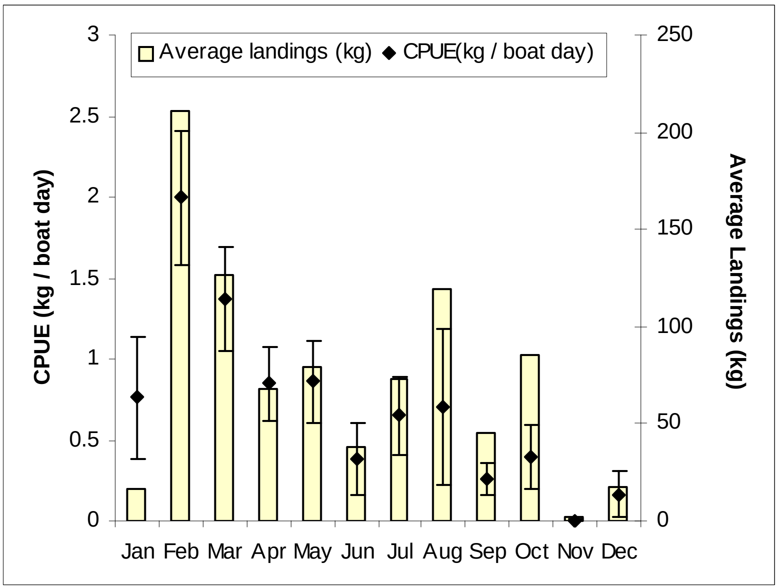


Figure 72 Average monthly commercial catch (kg) and catch per unit effort (CPUE kg per boat day) of king threadfin in the Townsville area, over the period 1990 to 1998.

Grunter (*Pomadasys argenteus and P. kaakan*)

Grunter is in the top ten fish groups in the Townsville area by dollar value over 1990-1998: Local wholesalers pay $3.75 for frozen fillet, $3.50 whole fish and fresh whole supplied by local fishers (Townsville wholesaler, pers. comm. 1999). In 1998, the GVP for grunter was around $12 000 which is well above the average for 1990-1998 of around $7 300. The reported annual grunter catch increased from 0.5 tonnes of fish in 1990 to 3.3 tonnes in 1997, with a rapid increase in catch rate since 1993 (Figure 73). Grunter are usually caught as a by product while targeting more commercially important species such as barramundi (Williams 1997). Much of the increase in landings may be attributed to more of the catch being identified as grunter in the commercial logbook records and less being recorded in the fish-unspecified category or may be in response to increased value of this species and therefore increased targeting of this species.

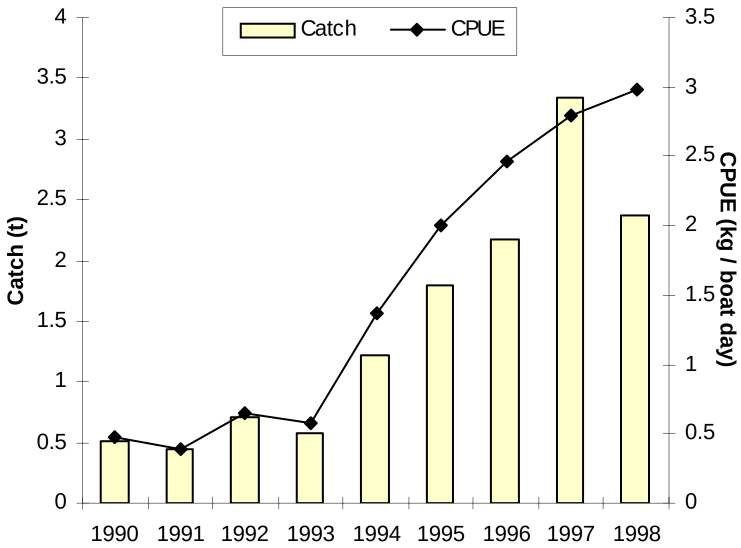


Figure 73 Grunter catch (t) and catch per unit effort (CPUE kg per boat day) from the Townsville area from 1990 to 1998.

Catch rates for grunter peak in autumn and August – October in the Townsville area (Figure 74) which is similar to the April and September peak catch rates reported by Helmke *et al.* (2000) for the Trinity Inlet at Cairns. Monthly landings followed a similar pattern to catch rates through the year (Figure 74). Grunter are often caught as a by product of gillnetting targeted at other more valuable species such as barramundi or schooling species that may be caught in larger numbers such as blue threadfin (Williams 1997), which may explain some of the variability in recorded catches.

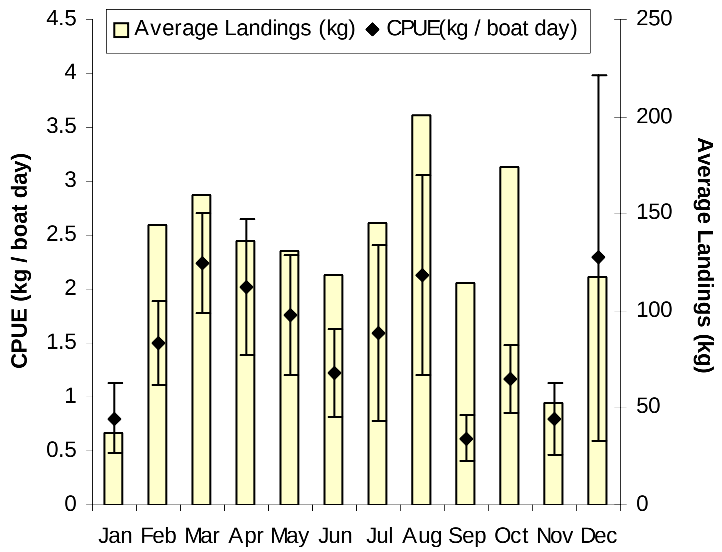


Figure 74 Average monthly commercial catch (kg) and catch per unit effort (CPUE kg per boat day) of grunter in the Townsville area over the period 1990 to1998.

Bream (*Acanthopagrus berda* and *A. australis*)

Only in 1990 and 1991 did more than five fishers record catches of bream from within Grid J21 (Figure 75), making analysis of catches over time impossible. No landings of bream were recorded at all in the area in 1995. Like mangrove jack, bream are an incidental catch for gillnet fishers and are often be recorded in log sheets as “fish unspecified”. Landings in 1990 and 1991 were around 250 and 450 kg of product, respectively.

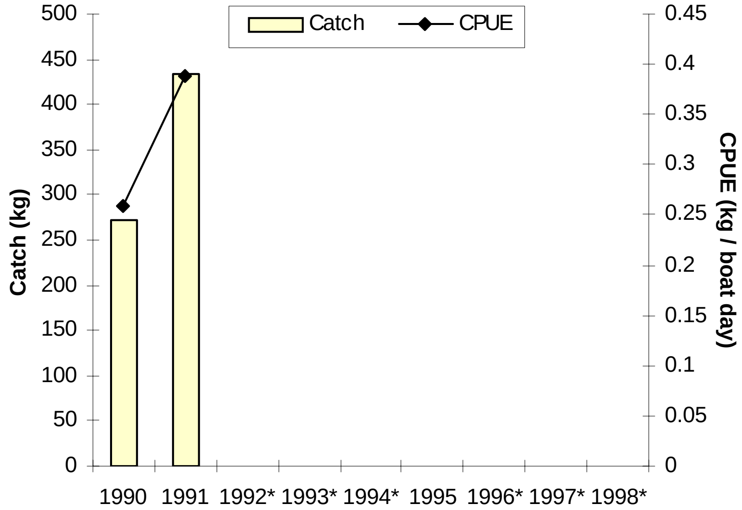


*Figure 75 Bream catch (kg) and catch per unit effort (CPUE kg per boat day) in the Townsville area from 1990 to 1998. Years when five fishers or fewer reported landings of bream are denoted *; and data for these years are not available for analysis.*

Between 1990 and 1998, the highest catch rates for bream were recorded in March as was the highest landings (Figure 76) but catch and catch rate varied markedly from month to month. This variability is indicative of the incidental nature of bream catches in the commercial fishery. No data are shown for January or November as less than five fishes have recorded landing in these months between 1990 and 1998. No landings were reported in either September or December.

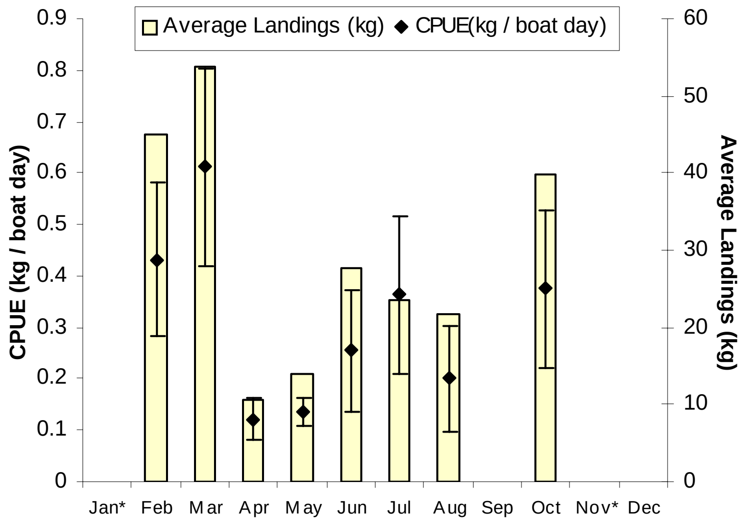


*Figure 76 Average monthly commercial catch (kg) and catch per unit effort (CPUE kg per boat day) of bream in the Townsville area for 1990 and 1998. Years when five fishers or fewer reported landings of bream are denoted *; and data for these years are not available for analysis*

Mud Crab (*Scylla serrata*)

Mud crab was the fourth most important CFISH species category in the local estuarine commercial fishery by dollar value in 1998. The mud crab catch was valued at around $146 000 over the period from 1990-1998, averaging $16 000 a year. In 1998 the GVP for mud crabs jumped to around $40 000 and landings in 1999 already exceeding the total for 1998 (CFISH database, June 1999). Local wholesalers buying mud crabs from local fishers in 1998 paid $10 /kg for a live crab (Townsville wholesaler, pers. comm. June 1999) making mud crab the most valuable species by weight taken in the inshore mixed and net/crab fishery for 1990-1998. Mud crabs are sold on the local and interstate markets as live or chilled whole crabs.

Over 1990-1998, annual landings of mud crabs varied from around 600 kg in 1993 to around 3700 kg in 1998 (Figure 77). The low catch levels from 1993 to 1996 correspond with low levels of effort in this area (Figure 78). In 1998, catches jumped by almost 200% above the eight year average (1265 kg) to around 3700 kg, and catch rate also increased dramatically (Figure 77) indicating an enhanced availability of crabs.

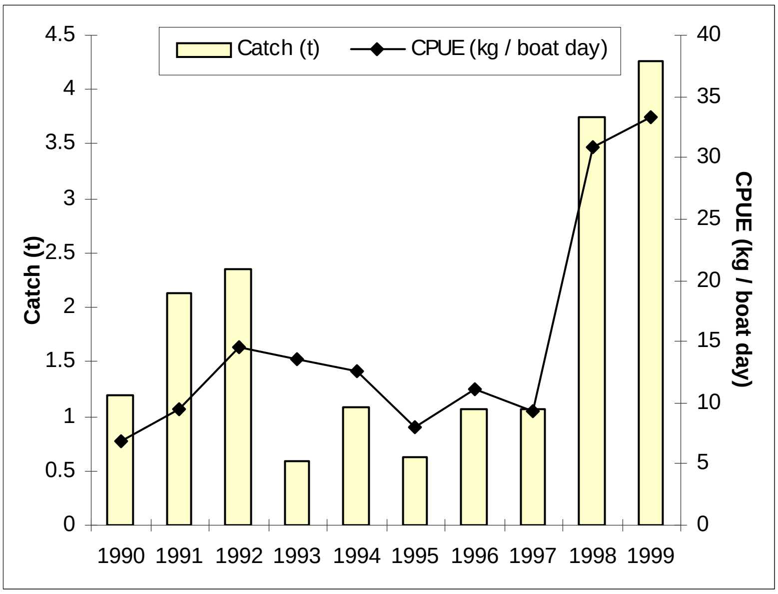


Figure 77 Mud crab catch (t) and catch per unit effort (CPUE kg per boat day) for1990 to June 1999 in the Townsville area

From 1993 to 1999, effort in the crabbing fishery has slowly risen from 43 boat days to 128 boat days (Figure 78). A maximum of 14 fishers recorded mud crab landings from the area in 1990 and 1997 (Figure 78). An increase in the number of boats and fishing effort in 1997 may be a result of fishers relying more heavily on their crab authorities and less on their gillnetting authorities. Data for 1999 are incomplete and should be considered carefully.

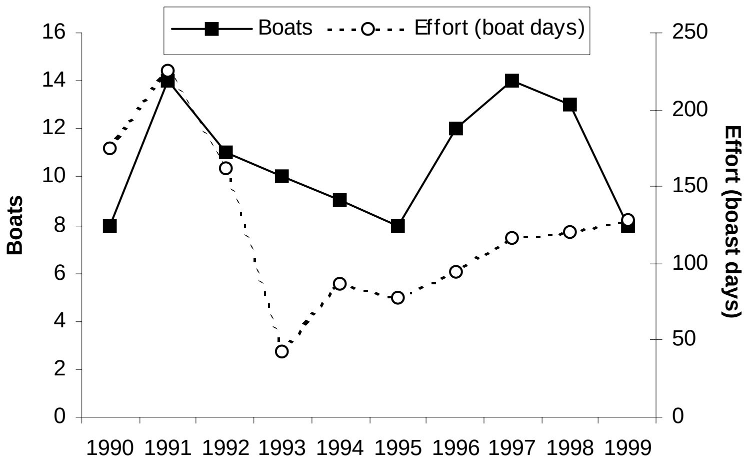


Figure 78 Number of boats and fishing effort (boat days) for the mud crab commercial fishery in Grid J21 between 1990 and 1999.

There is a strong seasonality in mud crabs catches with most landings recorded during the wet season between November and March (Figure 79). Hill (1982) reported similar seasonality in crab landings for the Queensland mud crab fishery, however, Helmke *et al.* (2000) reports a March to July peak in catch rates and landings for the Trinity Inlet.

Research catches of legal sized mud crabs in the Bohle River (see Figure 48) produced peak catch rates of crabs in June 1997, when commercial landings are usually low (Figure 79). Both commercial landings and research surveys recorded lowest catch rates in September, however, research surveys recorded low catch rates in January when commercial landings are generally much higher. Differences in January may be due to the amount of fresh water in the system after a major flood event on 1998 (see Rainfall). As only one years data is available from research surveys it would be presumptuous to say the differences between commercial and research catches was due to anything more than yearly variation in catches or differences in fishing techniques.

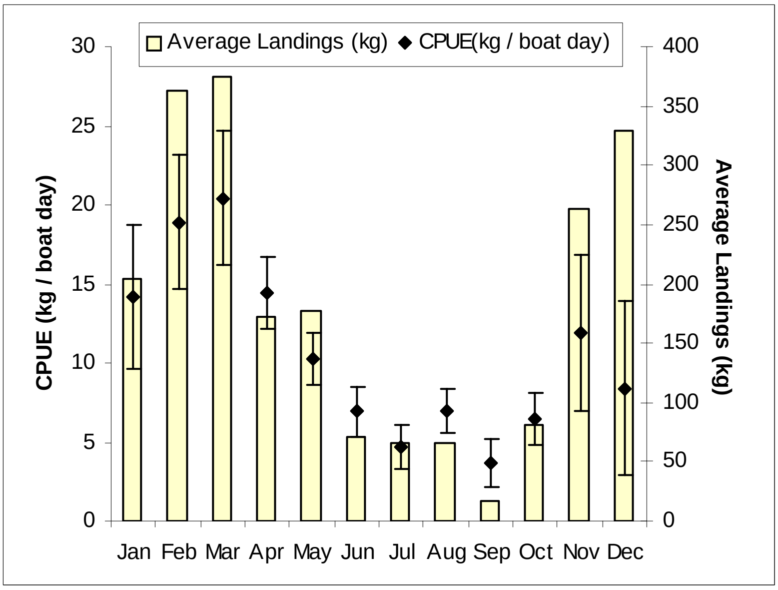


Figure 79 Mud crab average monthly commercial catch (kg) and catch per unit effort (CPUE kg per boat day) in the Townsville area for 1990-1999.

Recreational fishery

QFMA RFISH data

Specific information on recreational fishing in the Bohle River is available through QFMA's RFISH database. Recreational fishers reported catching 18 types or categories of fish in the Bohle River in 1997 (subsequently condensed into 16 categories because of overlap, e.g. grunter and javelin fish). Catch data were provided by 16 fishers from 27 fishing trips, with 175.3 hours fishing time recorded for 25 of these trips. Unfortunately, this is a limited data set and can not provide a comprehensive understanding of recreational fishing in the Bohle River.

The average length of each fishing trip (effort) was 5.16 hours (s.e. = 1.06 hrs). A total of 267 fish and crabs were caught resulting in an overall catch per unit effort of 1.5 fish or crabs per hour fished. This is a slight over estimate of the actual catch per unit effort as there were two trips where effort was not recorded.

Three species categories, grunter, bream and mud crabs, accounted for 77.9% of the recorded catch (Table 14). Of the 267 fish caught in total, 68.2% were released (Table 14) with the reason for release being recorded as either undersized, tagged or unwanted (J. Higgs, QFMA pers. comm.). All catfish, barramundi, flathead, butter bream, perch and stone fish were released, and all the fingermark (1) and whiting that were caught were kept. The 1997 QMFA state-wide survey indicated approximately 46.2 million fish were captured with 53% of fish released (Higgs 1999). The same survey estimated that in the Northern Statistical Division (Townsville) the release rate was 57.8%. This indicates that the release rate of 68.2% for the 16 fishers that recorded catches in the Bohle River is above average. Excluding released fish, the average catch per unit effort for fish kept from the Bohle River was less than 0.5 fish or crabs per hour fished, during the 27 trips recorded.

While bream, mud crab and barramundi were among the most numerous fish caught in the recreational fishing logbooks and in the fisheries independent research surveys, the species most frequently caught by recreational fishers, grunter did not feature as prominently in the research catches. Mangrove jack were as prominent as barramundi in the RFISH records (Table 14), compared with their virtual absence in the research surveys. This highlights the species specific selectivity of different fishing methods (targeting) and gear types used by various sectors of the community. Species such as mangrove jack, which are much more susceptible to line fishing, would be under-represented in abundance data if only catch information from netting surveys are considered; a broad range of gear types is necessary to sample the fish fauna.

Table 14 Number and percentage of fish kept and released for each category of fish recorded in the RFISH database for the Bohle River in 1997. Source: QFMA RFISH database, Brisbane, 8 June 1999.

Common Name	Species Name	Number Kept	Number Released	Total	Total	Kept	Released
Grunter	*Pomadasys* spp.	33	68	101	37.8%	32.7%	67.3%
Bream	*Acanthopagrus* spp.	22	62	84	31.5%	26.2%	73.8%
Mud crab	*Scylla serrata*	6	17	23	8.6%	26.1%	73.9%
Trevally	Carangidae	2	7	9	3.4%	22.2%	77.8%
Whiting	Sillaginidae	9	0	9	3.4%	100.0%	0.0%
Catfish unspecified	Ariidae	0	8	8	3.0%	0.0%	100.0%
Mangrove jack	*Lutjanus argentimaculatus*	5	2	7	2.6%	71.4%	28.6%
Barramundi	*Lates calcarifer*	0	7	7	2.6%	0.0%	100.0%
Mullet	Mugilidae	4	1	5	1.9%	80.0%	20.0%
Flathead	*Platycephalus sp.*	0	4	4	1.5%	0.0%	100.0%
Black-tip reef shark	*Charcharinus sp.*	2	2	4	1.5%	50.0%	50.0%
Cod	*Epinephelus* spp.	1	1	2	0.7%	50.0%	50.0%
Butter bream	*Monodactylus argenteus*	0	1	1	0.4%	0.0%	100.0%
Fingermark	*Lutjanus johnii*	1	0	1	0.4%	100.0%	0.0%
Moses perch	Lutjanidae	0	1	1	0.4%	0.0%	100.0%
Stone fish	Scorpaenidae	0	1	1	0.4%	0.0%	100.0%

Suntag Fish Tagging and Recapture Information

Suntag recreational tagging data was extracted on the 22 July 1998 and included fish tagged between 20/8/86 and 30/4/98 and fish recaptured between 12/2/1990 and 13/6/98. Details of 1115 fish from 24 species tagged by 89 fishers in the Bohle River were received. Of the 1115 fish, 263 (23.6%) were tagged by project staff during the fishery independent study. For the following analysis of recreational fish tagging, the fish tagged during research surveys have been removed from the data set. Figure 80 shows the number of days where anglers recorded tagging fish (fisher days: effort) is low from 1986 until 1994, from when it increased until 1997. The number of fisher days is again low in 1998 because of the incompleteness of the database for that year. There were probably several fish recaptured in the Bohle River by a commercial fishers, however, only one recapture was reported, being a barramundi.

The number of fish tagged in the Bohle River correlates well with the effort units recorded (Parametric correlation, r = 0.8619). However, it is difficult to determine trends in catch rates of fish from these data as not all fish caught were tagged, and effort information is not available for days when no fish were tagged or caught.

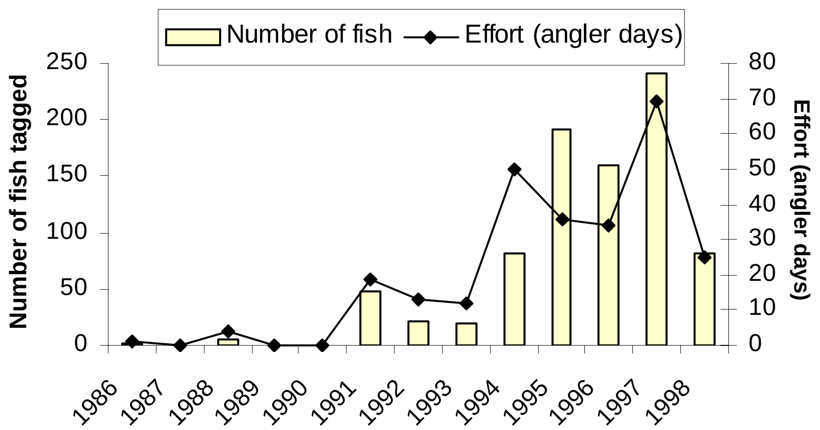


Figure 80 Number of fish tagged each year from 1986 to 1998 in the Bohle River and corresponding fishing effort in angler days.

In terms of concentrations of fishing activity in the Bohle River, 89 (10.4%) of all records, identified the location as just the river while the remainder were more specific. Most fish, 563 (66.1%), were tagged at the mouth of the Bohle River and locations approximating Site 4, 5 and 6 (Map 10) accounted for 7.3%, 3.3% and 5.0% of tagged fish records respectively. The pattern of tagged fish numbers is closely related to effort (Figure 81). Figure 81 highlights the general pattern of recreational fishers targeting the downstream section of a river (U77, V77, V75 and U76, for grid locations see Map 19).

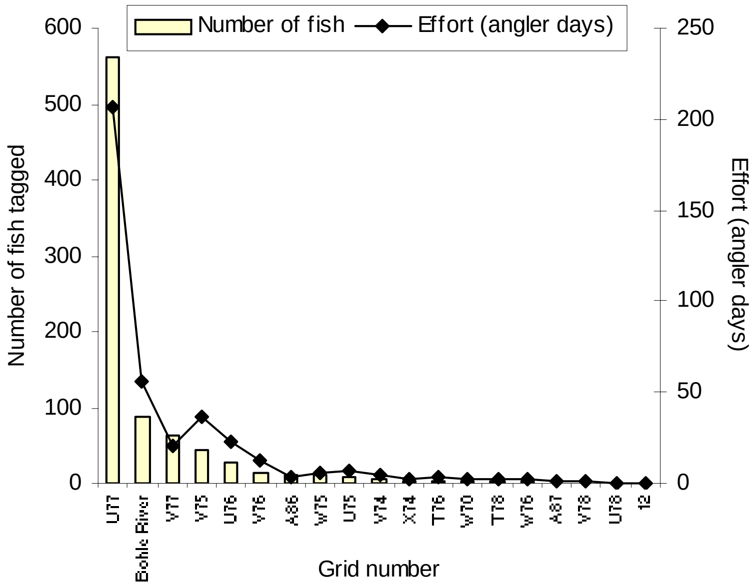
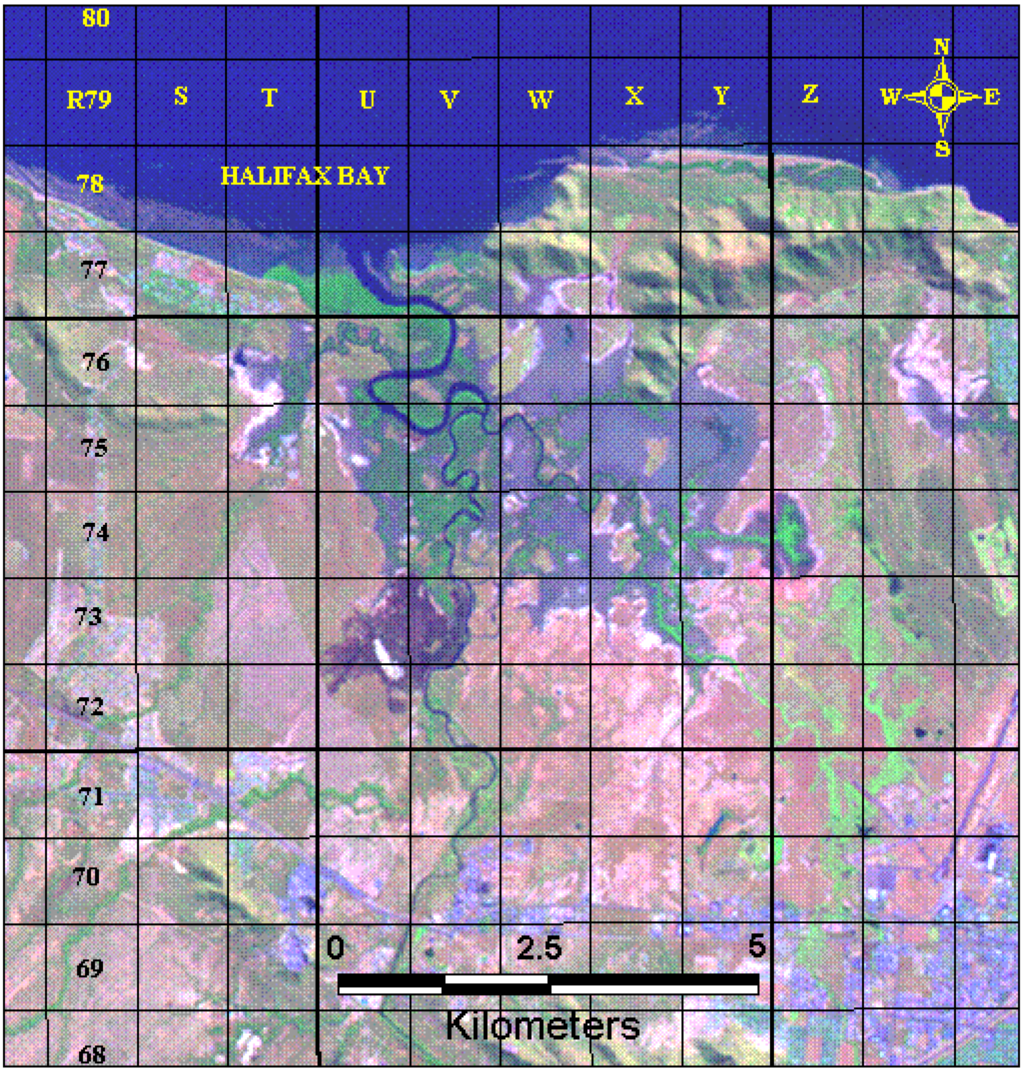


Figure 81 Number of fish tagged within each grid in the Bohle River and the effort (number of angler days) within each grid. For location of grids see Map 19

Pikey bream, barramundi, banded grunter and gold-spot cod were the most frequently tagged fish in the Bohle River, comprising 34.4%, 26.1%, 17.3% and 5.5% respectively of the total number of fish tagged by recreational anglers (Figure 82). Barramundi, pikey bream and gold-spot cod were also the most numerous of the 24 tagged species that were caught during the research surveys. Barramundi, queenfish and grunter are in the top 10 species for both commercial (see Figure 63, page 81) and recreational fishing (see Table 14, page 94). Mud crabs are a prize species in the local recreational fishery (QFMA 1996), however, this species does not occur in the Suntag data set as mud crabs are generally not tagged by recreational anglers. The tagging catch record depicted in Figure 82 shows that most species were taken in only low numbers, a pattern also demonstrated in research catches.

The top four tagged species were caught in highest numbers at the downstream sites (grids U77, V77, U75), which received the largest proportion of effort (Figure 81).



Map 19 Sunfish grid locations for Halifax Bay and the Bohle River. Source: InfoFish services.

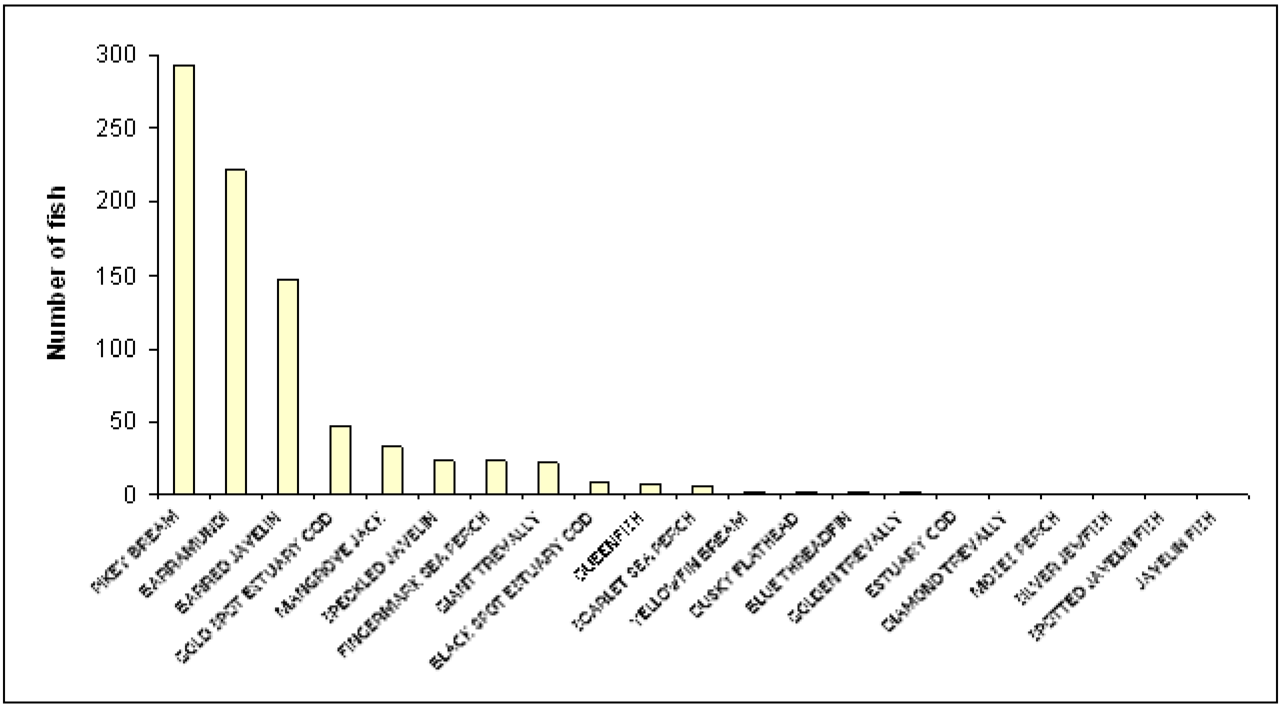


Figure 82 Total number of each species tagged in the Bohle River between 1986 and 1998. Barred javelin is Pomadasys kaakan, spotted javelin is P. argenteus and javelin fish are Pomadasys. sp.

Specimens of barramundi were the largest sized fish tagged, closely followed by queenfish (Figure 83). These two species also had the largest size range (Figure 83). The legal size of barramundi is 580 mm indicating that a portion of legal barramundi caught by recreational fishers were tagged and released when they could have been kept for consumption. Fourteen percent (119) of all fish that were tagged and released were of legal size. The catch and release ethic that is established in many fishing clubs would account for many of these fish while other fish would be released as a consequence of fishing clubs having their own minimum size that is slightly greater than the actual legal size, as well as fish surplus from species subject to a bag limit. The high release rate suggests that tag and release behaviour is widespread in the Bohle River fishing community and elsewhere (e.g. 35% in Trinity Inlet, Helmke *et al.*2000). However, the behaviour of fishers contributing to the Suntag database may well not be representative of recreational fishing.

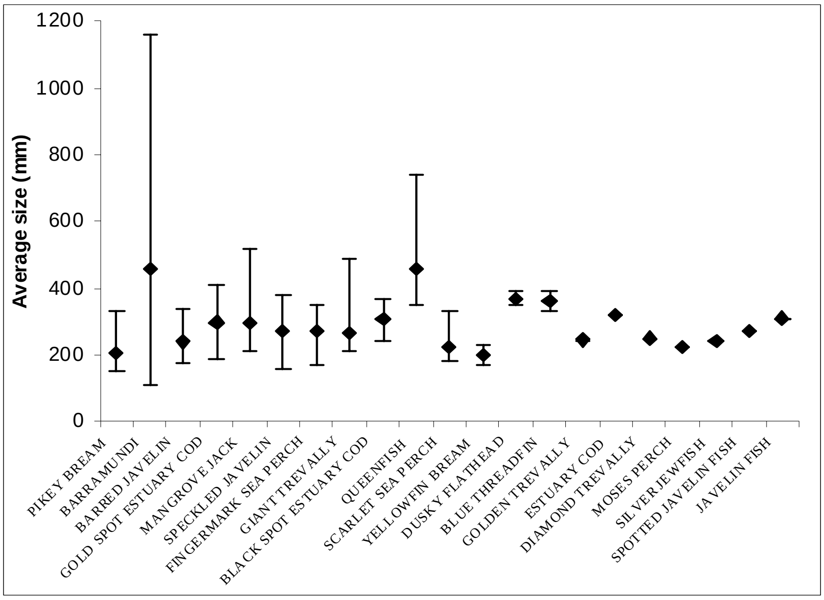


Figure 83 Average size of fish tagged by recreational anglers in the Bohle River 1986–98. Error bars show minimum and maximum sizes for each species. Barred javelin is Pomadasys kaakan, spotted javelin is P. argenteus and javelin fish are Pomadasys sp.

Although there was no statistically significant difference in the size of fish caught by recreational fishers or during research surveys (ANOVA, d.f. =29, F value = 121.67, p = 0.244), the average size of fish tagged and released by recreational fishers was usually larger than the average size of the same species captured during the research survey (Table 15), with barramundi and silver jewfish the only exceptions. Size ranges in Table 15 show strong overlap indicating these two fishing groups catch similar components of the population.

Movement of tagged fish in the Bohle River

Of 1115 fish tagged in the Bohle River, movement details were available from the 89 tagged fish that were recaptured including four fish (4.5%) that had moved into the Bohle River from release sites. Of the recaptured fish 57 individuals were tagged within the Bohle River (Table 16). To date, no fish tagged in the Bohle River have been recaptured outside of the Bohle River, however, four immigrations were found including two barramundi, a mangrove jack and a grunter which had moved 70, 125, 20 and 65 km respectively. All fish moved north from the Burdekin River, Bowling Green bay or Kissing Point. The large distance covered by the grunter in just 31 days makes the information suspect but not impossible (Sawynok 1999)

Most recaptured fish (57 or 64.0% of all recaptures) moved less than 1 km from their release points (Table 17), while 21 (23.6%) fish moved a kilometre or more in the time they were at large. There was insufficient information to calculate movement for 11 (12.4%) of the recaptures. Eight species were represented in recaptured fish from the Bohle River (Table 17) with barramundi (43 specimens or 48.3%) the most prominent.

Table 15 Comparison of the average size and size range of species tagged by recreational fishers and those caught during the fisheries independant survey. DPI = fishery independant survey results.

Species	Suntag		Research Surveys		Difference in mean length (mm)
	Mean (mm)	Range (mm)	Mean (mm)	Range (mm)	
Pikey bream	205.3	150-330	132.4	80-240	73.0
Barramundi	456.6	110-1160	493.5	220-890	-36.9
Banded grunter	239.0	175-340	173.5	68-450	65.6
Gold-spot cod	298.2	185-410	280.5	150-440	17.7
Mangrove jack	297.1	210-520	180.8	115-340	116.3
Spotted grunter	272.1	160-380	231.8	88-345	40.3
Fingermark	271.4	170-348	254.5	90-338	16.9
Giant trevally	263.6	210-490	251.0	88-365	12.6
Black-spot cod	306.7	240-370	272.8	135-420	33.9
Queenfish	457.5	350-740	400.4	290-720	57.1
Scarlet sea perch	224.3	180-330	-		-
Yellowfin bream	200.0	170-230	1440	115-195	56.0
Dusky flathead	366.7	350-390	184.3	65-510	182.4
Blue threadfin	360.0	330-390	324.5	202-545	35.5
Golden trevally	245.0	240-250	-	-	-
Estuary cod	320.0	320	-	-	-
Diamond trevally	250.0	250	-	-	-
Moses perch	225.0	225	142.0	38-200	83.0
Silver jewfish	240.0	240	328.3	200-374	-88.3
Small spotted grunter	270.0	270	-	-	-
Grunter	310.0	310	-	-	-

Table 16 Direction of movement of recaptured tagged fish.

Movement	Number	% of recaptures	% of all fish tagged
Within the Bohle	75	84.3	6.7
From other areas	4	4.5	0.4
Insufficient data	10	11.2	0.9

Table 17 Number of each species recaptured in the Bohle River and the distance they moved.

Species	Movement			Insufficient Information	Total
	< 1 km	1 – 5 km	>5 km		
Barramundi	19	15	2	7	43
Banded grunter	2			1	13
Black spot cod	3				3
Fingermark		2			2
Giant trevally	1				1
Gold-spot cod	8			3	11
Mangrove jack	1		1		2
Pikey bream	23	1			24
Total	57	18	3	11	89

Growth of tagged fish in the Bohle River

Of the 89 fish recaptured, in the Suntag program, seven indicated negative growth while at large (i.e. were smaller when they were recaptured than when they were tagged), which may be the result of measurement errors in the field such as different length measures being recorded (i.e. fork length instead of total length). Records for another 11 fish were insufficient to calculate growth, while five recaptured fish were at large less than one day. Fifteen fish exhibited zero growth, and 51 fish recorded positive growth, while being at large for more than one day.

Growth rates were only calculated for this later subset and ranged from 0.02 to 1.43 mm/day (Figure 84). Barramundi grew an average of 0.53 mm/day, which is the same rate reported by Russell and Rimmer (1998) for barramundi in the Johnstone River, some 250 km further north. Growth rates for gold-spot cod, banded grunter, fingermark and mangrove jack are only available from two or fewer fish and are therefore of little value. Pikey bream and black-spot cod had 10 and seven useable data points respectively. Sheaves (1995b) reports a growth rate of 0.26 mm per day for black-spot cod (n = 63) from local estuaries, slightly lower than that reported here of 0.38 mm per day. The slow growth rate of pikey bream reported here, 0.12 mm per day, is actually much faster than that reported by Tobin (1998) for pikey bream from local estuaries to the north and south of the Bohle River. Growth rates calculated from Tobin's (1998) plots of fork length and age indicate fish growth around 0.01-0.03 mm per day for fish over 150 mm in length.

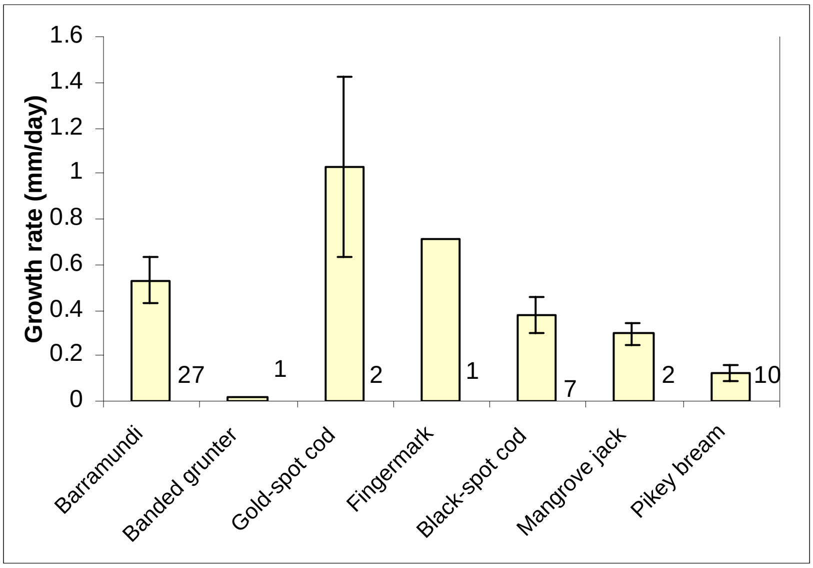


Figure 84 Average growth rate (mm per day) of species recaptured. Bars labelled with the number of fish used in the calculation of growth rate. Error bars are one standard error and indicate the variation around growth estimates.

Time at liberty

Tagged mangrove jack, barramundi, banded grunter and pikey bream were all at large for more than 150 days on average with the remainder of fish at large less than 82 days on average (Figure 85). The maximum time at large recorded for a tagged fish in the Bohle River Suntag data set was 1276 days (3.5 years) for a barramundi that grew 460 mm and was caught within 1 km of where it was originally tagged.

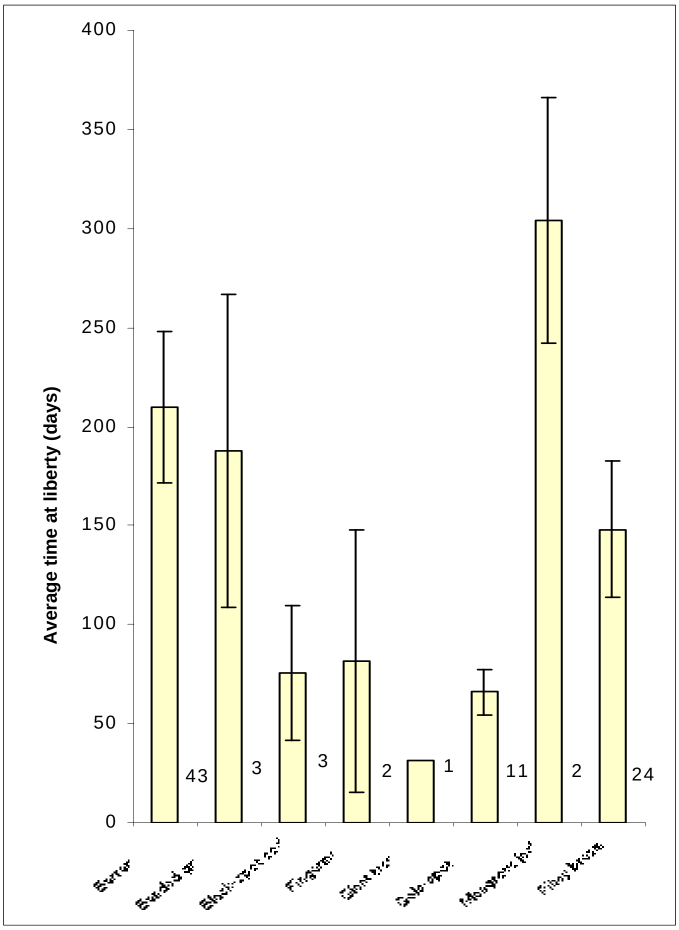


Figure 85 Average time at large for each species recaptured and the number recaptured. Numbers of observations are also shown. Error bars are one standard error and indicate variation in time at liberty for each species.

Trailer counts

A total of 82 observations of visitors at the Bohle River boat ramp were made from 16-November 1997 to 22-May 1998 (first month in summer to the first month winter). Data was collected on 28 weekdays (n = 72), on four weekend days (n = 8) and on one public holiday (n = 2). The maximum number of visitors (defined as a single car – with or without a boat) on any one day was 25 cars on the Australia Day public holiday on 26 January 1998 (Figure 86). In the 33 days of observations, at least 230 visitors were recorded.

Most visitors (95%) went boating during day light hours (6:30 a.m.–8:00 p.m., Figure 86). On 60% of survey days, 5 visitors or fewer were counted at the ramp, compared with 30% of records indicating 5-10 visitors and 10% of records indicating more than 10 visitors. On two different survey dates in March 1998 there were no cars at the boat ramp during daylight hours. The highest number of visitors recorded was during daylight hours at around 9:30 a.m. More people used the boat ramp during the weekend days than on week days, with the mean number of visitors being 14.20 and 5.89 respectively.

During the survey, the mean number of visitors at the Bohle River boat ramp each day was 7.18 visitors. Because most observations (87%) were made during weekdays visitor numbers on weekends is likely to have been under represented. To accommodate this, weighted means were used to calculate an overall usage of the boat ramp (Higgs, J. QFMA pers. comm. 1999), based on the maximum number of trailers recorded on any one day. The resulting weight mean was 8.21 visitors a day.

Conclusion

The Bohle River drains a small catchment area in close proximity to a high population centre, which generates many anthropological impacts, pressures and influences on the catchment and its natural values. Urban and industrial encroachment, reduced water quality in some sections of the upper catchment, the removal of riparian vegetation, the invasion of noxious fish and plant species and high fishing pressure would have a substantial cumulative influence on the fisheries resources of this catchment. However, no historical information is available on the Bohle River fisheries resources to allow the affects of these impacts to be quantified. This report provides the first such information and is a baseline for future surveys of the fisheries values of the Bohle River. As an extension of this project, the Queensland Government has implemented a long-term monitoring project of fisheries resources of select streams throughout Queensland. The long-term monitoring project will monitor species such as barramundi, mud crabs and freshwater fishes on an annual basis providing information on the long-term trends of fisheries resources in Queensland waters.

The fisheries resources in the Bohle River include substantial barramundi, mud crab, baitfish, catfish, gold spot cod and bream populations with less substantial populations of other species targeted by fisheries resources user groups, such as blue and king threadfin. Effort applied to the fishery from the commercial gillnetting sector appears to be slowly declining through time while the effort applied by the commercial crabbing sector is slowly increasing. The effort applied by the local recreational fishery, although unquantified, is believed to be increasing dramatically, emphasising the need to address the lack of information on this aspect of the fishery.

1. Water quality

Water quality records from a variety of sources have depicted a huge range in most parametres measured. While large variation in water quality parametres would be expected in an estuarine environment, large variability was also found in the upper catchment. In the lower catchment concern is raised about the low dissolved oxygen values recorded, often being well below the ANZECC (1992) guidelines. In the upper catchment, levels of dissolved oxygen were consistently below those recommended for maintaining the environmental value of a watercourse by ANZECC (1992). High variation in turbidity, high conductivity and low pH are also cause for concern. If the water quality values recorded in this survey are representative of the actual conditions in the upper Bohle River then improvements from programs to rehabilitate the upper catchment and to control run-off and discharges into the stream are likely to benefit the fisheries value of the catchment.

2. Upper catchment fish communities

The Bohle River catchment is a small area that has few permanent freshwater water holes existing within it and would be classed as a semi-dry tropical catchment having low average rainfall (1146 mm). Accordingly, diversity was found to be low (15 species) in the freshwater reaches of the Bohle River catchment with only one specimen of one target species being caught. Barramundi were observed only at the Borrow Pits which was the site of highest diversity in the catchment, while noxious species, particularly tilapia, were common at all sites. The poor suitability of water quality parametres (high turbidity and conductivity) to electrofishing techniques highlights the need to use a variety of techniques to sample this habitat. The authors suggest future surveys include seine, dip and gillnetting as well as fish traps and line fishing to obtain a more substantial species list and information on population structure. More intensive sampling using a range of capture techniques should be undertaken to determine the distribution and population structure of barramundi, and other species, throughout the freshwater reaches of the Bohle River. Blakey's Crossing within the Royal Australian Air Force tenure is one location not surveyed during this project, which the authors strongly recommend be included in any future work.

3. Presence of noxious and exotic fish species

Three introduced fish species were captured during the freshwater survey: mosquito fish, guppies and tilapia. The presence of introduced species is of concern, particularly when coupled with the fact no rare or intolerant freshwater species were recorded. Karr (1981) has suggested a procedure to assess the biotic integrity of an area using descriptions for all components of the fish community, and according to his scheme, the indicative calculation reveals the biotic integrity of the Bohle River must be rated as fair-to-poor. More information is required to refine this preliminary estimate.

4. Value of the Bohle River fisheries resource.

With an average commercial fishery production of around half a million dollars a year going directly into the local economy and employing a substantial number of fishers, the local inshore crab and net fishery is a major resource in the Townsville economy. Both the commercial and recreational fishery provide regional economy through purchasing of gear, fuel, bait and maintenance of vessels etc. Commercial fishing tour operators are also providing directly for the local economy, while adding to the attractiveness of Townsville as a tourist destination. However, the importance of the recreational and chartered fishing tour fisheries to local economy has not been quantified and high numbers of boat trailer counts recorded by this project indicate this may be substantial.

5. Public perception of the commercial fishery

Multi-sector use of fisheries resources has led to animosity among user groups in a number of locations in Queensland. In the Bohle River this animosity has not generated any major upheavals such as the closure of Trinity Inlet to commercial fishing in Cairns, however, there is a general ill regard for gillnets in creeks among recreational fishers due to the increased competition for target fish species. Although it is understandable, this increased competition may cause some animosity, the importance and value of the local commercial fishery appears to be under emphasised in the public arena. If not addressed this issue may become a major cost to the local commercial fishery.

6. The Cleveland Bay Dugong Protection Area

Both catch and effort were high in the months between the announcement of the DPAs and the implementation date. However, at this early stage, the establishment of the Cleveland Bay Dugon Protection Area appears to have had little affect on the catch produced in the area (since implementation) even though fishing effort has reduced. Continued monitoring of the commercial landings in this area may allow a more detailed understanding of the effects of DPAs on the local fishery.

7. Iconic species

Barramundi and mud crabs are iconic species in north Queensland for the commercial fishing industry, recreational fishers and the chartered fishing tour industry. Commercial catches of these species do not indicate a need for change in management techniques with 1998 producing both the highest landings and highest catch rate seen in nine years. Research surveys found good numbers of barramundi in the estuarine portion of the Bohle River, with many size and year classes accounted for, however, the largest and smallest size classes were not encountered. The lack of larger barramundi may simply be the result of size selectivity of sampling gears used. Low numbers of smaller size classes would be of concern, however, smaller size classes of barramundi are usually found in the freshwater reaches of the upper catchment where research surveys using electrofishing many not have had the capacity to sample this species effectively. More work needs to be done in order to understand the juvenile barramundi population and emigration and immigration, to and from the Bohle River.

Being catadromous fishes, barramundi rely on freshwater lagoons and swamps for a portion of their life cycle. Although the wetland areas within the Bohle River catchment have remained reasonably stable in size in recent years, the quality of these wetlands has been deteriorating with exotic and noxious plant and fish species becoming established (para grass, tilapia, guppies etc.). In order for these wetlands to continue to function as valuable fisheries resources the establishment of exotic species needs to be halted and reversed through rehabilitation initiatives.

Mud crab landings from the commercial fishery have dramatically increased in the local area in 1998 and 1999 with a slow continual increase in fishing effort since 1993. Research surveys indicate a good population of crabs with a low proportion of legal crabs, probably resulting from fishing pressure. A low public (recreational fishery) return rate of tagged crabs (3.6%) from the research survey may indicate a high population of crabs, an apathy towards returning tagged crab information among the users of this resource or perhaps people rarely returning information on recaptured crabs not of legal size and sex. A high level of site fidelity displayed from tag returns indicates local populations may be prone to seasonal overfishing. Some level of long distance movements between streams indicates genetic mixing occurs between streams.

8. Information required

In order to make informed decisions on managing a fisheries resource, information of the catch and effort of all sectors of the fishery are required. Only limited information is available on the recent catch and effort of the local recreational sector of the fishery, while no historical information is available. No information is available, current or historical, on the catch and effort of the indigenous sector of the fishery. These issues need to be addressed.

More detailed and more reliable information is required from the CFISH database under the custodianship of QFMA. Some level of validation or quality assurance of data and data entry is required in order to use the data in a meaningful manner. The CFISH database is not completely accurate and care is required in use of the data extracted. If finer scale information on commercial catch could be obtained, fisheries resources could be assessed on a catchment by catchment basis allowing perhaps the most informative scale of decision making.

In this report the value of the local fishery was estimated using an approximate dollar per kilogram value for each species multiplied by the tonnage caught each year. In order to determine the value of fishery production more accurately, detail is required on the value of each species and how that value varies through time and across different wholesalers. With this information economist may be able to determine and improve the economic viability of local fisheries. There is a desperate need for more economic information on recreation and charter fishing and the flow on benefits of all sectors to the community.

9. Standardisation of recreation fishing data

Suntag, QFMA RFISH and charter fishing tour operators each collect some level of information on recreational fishing catch and effort. If these three sources of information were to standardise their approach to collection of effort data as well as catch data, fisheries management bodies would gain access to catch rates of species which we otherwise have no information on, e.g. mangrove jack, flathead, whiting and fingermark.

10. Future research surveys

It is important that research surveys be conducted at regular intervals to provide fishery independent information for comparison with the fishery dependent information that is being collected from the commercial, charter and recreational fisheries. An ideal situation would exist if a 12 month research survey of fish and crabs stocks could be conducted every three to five years. This would provide comparable data to what has been collected during this study.

Reviews of commercial fishery logbook data, available recreational fishery information and any future information on the indigenous fishery sector should be conducted annually.

Implications for management

Several catadromous species were found in the Bohle River including commercially and recreationally important species such as barramundi and mangrove jack. Russell and Garrett (1983) have established the linkage between freshwater, estuarine and coastal aquatic environments for these species. It is important for resources sustainability that these links be maintained and that critical fisheries habitats be identified and protected from impacts within the catchment. For example, if exotic plant species are allowed to continue to prosper in the catchment, eventually choking freshwater wetlands, this would reduce the available nursery habitat for barramundi and mangrove jack (among other species) and could affect the replenishment of fish stocks in the Bohle River and neighbouring systems. Habitat restoration including the replanting of riparian vegetation may reduce such impacts.

A lack of information on current and historical catch and effort of the indigenous and recreational fishing sectors reduces the ability of management bodies to make informed management decisions. The indigenous sector of the fishery may be addressed using the survey techniques developed by Turner (1998). While QFMA’s RFISH program can describe catch statistics for the recreational fishery, it does not address the effort applied by this fishery, nor will it obtain information on historic catch and effort information.

Caution must be exercised with regard to local populations of blue threadfin, king threadfin and possibly grunter. These species were not captured in large numbers in the Bohle River area and their populations may be in danger (or naturally low). Careful consideration of this point should be made when planning management strategies between now and when research surveys can establish what the natural population levels are for these species in this area.

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Appendices

Appendix 1 Wetland Sites of Significance with the Townsville – Thuringowa Sub Region (Source Townsville-Thuringowa Strategy Plan 1996a, 1996b)

Habitat Type	Location	Principle Conservation Values	Management Issues
Non-perennial Creeks and Rivers	• Stoney Creek • Saunders Creek • The Bohle River • Mt. Louisa Creek	• Open spaces for recreation • Wildlife habitat/corridors • Fish habitat • Upper catchment for high value estuarine wetland	• affect of urban drainage including pollution, high sedimentation level due to lack of retention basins on major drains • exotic vegetation invasion • maintenance of riparian buffers during urban encroachment • excessive fire regime • loam extraction • riparian vegetation removal • erosion in upper catchment
Freshwater Swamps	• Mt. St. Johns Swamps • Blakeys Crossing • Town Common – Pallarenda	• Med-high conservation value principally as bird and fish habitat • Recreation / eco tourism / education / scenic amenity • Nutrient retention basin • Catchment for high value estuarine complex.	• exotic vegetation invasion • poor water quality • lack of upstream retention basins • pollution and litter • sewerage • industrial and urban catchment • requires grazing to control weeds • Fire regime too hot
Coastal and Marine Wetlands	• Bohle – Pallarenda estuaries and coastal swamps.	• Complex wetland habitat (many types) for fish, birds and crocodiles	• Water quality • Sewerage treatment • Industrial and urban run off • Land reclamation and drainage problem in upper catchment • Commercial and recreational fishing pressure • Loam extraction from riparian zone
Seagrass Beds	• Black – Bohle River	• Nursery and feeding grounds for commercial and recreational fish and crustacean species (Coles *et al.*, 1989) • Feeding grounds for vulnerable dugong and marine turtles	• High suspended solids due to port dredging and coastal run off, • habitat impacts due to trawling, • Gillnet fishing in areas of dugong abundance • Coastal development, • potential for heavy metal pollution from port operations and industrial development in coastal catchments

Sites of regional Nature Conservation significance outside of existing reserves and protected areas in the Townsville – Thuringowa Sub Region: Four sections of the Bohle River catchment are highlighted under “Principal Values and Planning Implications for Sites of Regional Nature Conservation Significance”:

- The Bohle Mouth and Wetland Buffer
- Bohle Plain Leasehold (Bruce Highway to Hervey Range Road)
- Bohle Plain Leasehold(Hervey Range Road to Pinnacles) and
- The Bohle Wetland Catchment

In summary the principal values stated for these areas are:

- Natural habitat buffer adjoining high value wetland/fishery wetland area
- Representation of Old Plains Landsystem in a near coastal setting
- Two endangered, one vulnerable and five ‘Of concern’ regional ecosystems
- Last remaining example of Mt. Low beach vine thicket
- Wetland habitats supporting commercial and recreational fisheries
- Diversity of habitat types
- Connectivity between habitat types including regional connectivity and proximity to Bohle Plains leasehold areas to the south
- Relative integrity of habitat
- Habitat connectivity south to Hervey Range via Saunders and Stoney Creeks or via other leasehold plains area.

Appendix 2 This article from the SUN newspaper dated 20 January 1999 is just one example of the ongoing water quality issue in the Bohle River.

Classifieds 4722 4466 Wednesday, January 20, 1999 60¢ where sold

MUCK RIVER

Dump polluting the Bohle

By DEBBIE McLENNAN

SUNFISH NQ is calling on builders and the Thuringowa City Council to clean up the badly polluted upper reaches of the Bohle River.

Many amateur anglers refuse to fish the upstream reaches of the river because they're afraid the fish and crabs may be tainted.

Recent rainfall has flushed river pollutants into the bay, jeopardising marine life.

At the same, Sunfish NA deputy chairman Vern Veitch claims time it leached pollution from the Hervey's Range Road dump and caused runoff from building sites and industrial areas to flow into the river.

High sediment levels and pollutants from the dump and construction sites washing into waterways was evidenced by the discolouration of the river, he said.

"Drive past the Bohle River on the new Dalrymple Road extension and you can quite clearly see the river looks like milk coffee," Mr Veitch said.

"All this muck and sediments is depositing in Halifax Bay and will ultimately have a destructive effect on marine life."

He said he had personally monitored the river quality for about 10 years but had not seen it looking this bad.

"We can't keep using the ocean as one big wheelie bin," Mr Veitch said.

Recent felling of trees growing in the river itself near the Dalrymple Road crossing was further pollution of the river and a potential hazard in case of flood, he said.

"I don't know who cut down all the trees but they've just left them in the river to wash down stream next big flood rain."

Practices such as covering sites and foreign materials with the mesh-like cloth as used by the main roads department should be enforced by local councils to prevent pollution of waterways, he said.

"The amount of algae growing in the river on rocks suggests there is also a high nutrient content in the river," Mr Veitch said.

"People just need to be aware that lot of accounting to do over the discharge of effluent into the river.

"I'm absolutely disgusted at the way the whole river environment has been handled," he said.

However Thuringowa City Council Water Supply and Sewerage engineer Col Phillips said the plant was bound to conduct regular tests of the Bohle River to monitor if the plant's practices had any effect on the river's ecosystems.

He said the monthly tests would culminate in an end-of-year report due soon.

While the plant concentrated tests on the impact of the sewerage plant's practices, traces of heavy metals and nutrients from other sources such as the dump and building sites may be picked up, Mr Phillips said.

"Our testing is fairly comprehensive and accurate so I feel confident that if there is pollutants from other sources the tests would pick it up," he said.

Department of Environment and Heritage senior environmental officer Jeremy Taylor said Mr Veitch's claims may be based on more than fiction.

He said the proximity of the Bohle River to the Thuringowa dump on Hervey's Range Road and construction of housing estates near the Dalrymple Road extension river crossing indicated runoff and leaching into waterways was possible.

He said discharge from the Thuringowa City Council sewerage treatment plant was monitored by the Thuringowa City Council.

However he said murky, turbid looking water was not unusual this time of the year.

He said the department made monthly tests

Appendix 1 Size range, average size, number and CPUE of all species caught in cast net survey of the Bohle River.

Family	Species	Common Name	Average	Max	Min	Number	Standard error
Sparidae	*Acanthopagrus berda*	Pikey bream	11.17	13.50	9.25	3	1.244432
Chandidae	*Ambassis gymnocephalus*	Glass perchlet	3.15	4.65	1.50	41	0.143193
Chandidae	*Ambassis interuptus*	Long-spined glass perchlet	3.85	5.40	3.00	4	0.567891
Chandidae	*Ambassis nalua*	Glass perchlet	6.87	9.80	4.05	20	0.336844
Chandidae	*Ambassis vachellii*	Vachelli's glass perchlet	4.06	5.10	2.85	9	0.235915
Tetraodontidae	*Arothron manilensis*	Toadfish	16.50	16.50	16.50	1	
Soleidae	*Aseraggodes rautheri*	Sole	10.50	10.50	10.50	1	
Carangidae	*Caranx ignobilis*	Lowly trevally	9.90	11.00	8.80	2	1.1
Tetraodontidae	*Chelonodon patoca*	Milk-spotted toadfish	5.17	7.75	1.50	21	0.48443
Cynoglossidae	*Cynoglossus sp.*	Tongue-sole	3.55	4.40	2.70	2	0.85
Leiognathidae	*Gazza minuta*	Common-toothed ponyfish	5.55	5.60	5.50	2	0.05
Gerreidae	*Gerres abbreviatus*	Short silver-belly	6.50	6.50	6.50	1	
Gerreidae	*Gerres oyena*	Silver-belly	7.25	8.80	4.90	6	0.535879
Gobiidae	*Glossogobius biocellatus*	Mangrove goby, Sleepy goby	4.45	4.45	4.45	1	
Hemiramphidae	*Hemiramphidae* spp.	Garfish	10.00	10.00	10.00	1	
Clupeidae	*Herklotsichthys castelnaui*	Herring	8.92	14.00	8.00	49	0.15734
Clupeidae	*Herklotsichthys koningsbergeri*	McCulloch's herring	8.50	8.50	8.50	1	
Centropomidae	*Lates calcarifer*	Barramundi	31.26	47.00	23.80	5	4.121602
Leiognathidae	*Leiognathus decorus*	Ponyfish	5.40	6.45	3.35	11	0.270338
Leiognathidae	*Leiognathus equulus*	Common ponyfish	3.52	6.50	1.50	77	0.162356
Leiognathidae	*Leiognathus splendens*	Black-tipped ponyfish	6.74	8.00	5.47	2	1.265
Mugilidae	*Liza subviridis*	Greenback mullet	9.09	19.50	3.00	21	1.002283
Mugilidae	*Liza vaigiensis*	Diamond-scaled mullet	4.80	4.80	4.80	1	
Lutjanidae	*Lutjanus johni*	Fingermark	9.00	9.00	9.00	1	
Lutjanidae	*Lutjanus russelli*	Moses perch / fingermark bream	12.07	15.50	9.20	3	1.840592
Tetraodontidae	*Marilyna pleurosticta*	Banded toadfish	6.62	14.50	1.00	30	0.714761
Clupeidae	*Nematalosa come*	Saltwater bony bream	8.94	18.00	5.50	27	0.687875
Cynoglossidae	*Paraplagusia bilineata*	Rock Sole, rough back sole, Double lined sole	12.30	12.30	12.30	1	
Platycephalidae	*Platycephalus fuscus*	Dusky flathead	23.00	23.00	23.00	1	
Platycephalidae	*Platycephalus indicus*	Bar-tailed flathead	15.20	17.30	13.80	3	1.069268
Pleuronectiformes	*Pleuronectiformes* spp.	Soles, left and right eyed flounders, tounges	7.67	10.50	6.00	3	1.424001
Haemulidae	*Pomadasys argenteus*	Small-spotted grunter	10.96	14.50	8.80	5	1.094463
Haemulidae	*Pomadasys kaakan*	Large-banded / golden grunter	8.76	12.50	6.80	7	0.723147
Bothidae	*Pseudorhombus* spp.	Deep-bodied Flounder	9.00	9.00	9.00	1	
Clupeidae	*Sardinella albella*	White sardinella	9.85	9.85	9.85	1	
Scatophagidae	*Scatophagus argus*	Spotted scat	10.17	11.50	9.00	3	0.726483
Scombridae	*Scomberoides lysan*	Queenfish	9.70	10.50	9.00	5	0.254951
Scatophagidae	*Selenotoca multifasciata*	Striped scat	6.00	6.00	6.00	1	

Appendix 1 Cont. Size range, average size, number and CPUE of all species caught in cast net survey of the Bohle River.

Family	Species	Common Name	Average	Max	Min	Number	Standard error
Siganidae	*Siganus* spp.	Spinefoot	8.40	8.40	8.40	1	
Sillaginidae	*Sillago ciliata*	Sand whiting	12.33	13.50	11.00	3	0.726483
Sillaginidae	*Sillago sihama*	Northern whiting	13.88	17.20	9.00	19	0.45271
Sphyraenidae	*Sphyraena* spp.	Barracuda, sea pike	31.75	34.50	29.00	2	2.75
Dasyatididae	*Stingray*	Stingray	18.50	18.50	18.50	1	
Engraulidae	*Stolephorus sp.*	Anchovy	4.14	5.70	3.70	7	0.276765
Belonidae	*Strongylura strongylura*	Spottail needlefish	26.80	26.80	26.80	1	
Terapontidae	*Terapon jarbua*	Crescent perch	7.80	8.10	7.50	2	0.3
Tetraodontidae	*Tetractenos hamiltoni*	Toadfish	6.93	8.50	5.20	4	0.675
Engraulidae	*Thryssa hamiltonii*	Hamilton's anchovy	7.23	13.80	3.20	25	0.694773
Tetraodontidae	*Torquigener sp.*		5.00	5.00	5.00	1	
Toxotidae	*Toxotes chatareus*	Archerfish	6.00	6.10	5.90	2	0.1
Mugilidae	*Valamugil buchanani*	Buchanan's mullet	9.29	13.00	1.00	20	0.702719
Mugilidae	*Valamugil georgii*	Fantail	6.14	8.70	3.90	5	0.980102

Appendix 4 List of species captured in the Bohle River, North Queensland, using all sampling techniques during the fisheries independent research surveys.

No.	Species	Common name	Family name	Family common name
1	*Acanthopagrus australis*	Silver bream / yellowfin bream	Sparidae	Porgies
2	*Acanthopagrus berda*	Pikey bream	Sparidae	Porgies
3	*Aetobatus narinari*	Eagle ray	Myliobatidae	Eagle rays
4	*Ambassis agassizi*	Agassiz's glass perchlet	Ambassidae	Glass perchlets, asiatic glassfishes
5	*Ambassis gymnocephalus*	Glass perchlet	Ambassidae	Glass perchlets, asiatic glassfishes
6	*Ambassis interruptus*	Long-spined glass perchlet	Ambassidae	Glass perchlets, asiatic glassfishes
7	*Ambassis nalua*	Glass perchlet	Ambassidae	Glass perchlets, asiatic glassfishes
8	*Ambassis vachellii*	Vachelli's glass perchlet	Ambassidae	Glass perchlets, asiatic glassfishes
9	*Anguilla reinhardti*	Long-finned eel	Anguillidae	Freshwater eels
10	*Arius argyropleuron*	Sea catfish	Ariidae	Sea catfishes
11	*Arius graffei*	Sea catfish	Ariidae	Sea catfishes
12	*Arothron hispidus*	Toadfish	Tetraodontidae	Puffers
13	*Arothron manilensis*	Toadfish	Tetraodontidae	Puffers
14	*Aseraggodes rautheri*	Rauther's sole	Soleidae	Soles
15	*Batrachoididae sp.*	Frog fish	Batrachoididae	Frog fish
16	*Belonidae sp.*	Longtom	Belonidae	Needlefish / Longtoms
17	*Carangoides hedlandensis*	Trevally	Carangidae	Jacks and pompanos
18	*Caranx ignobilis*	Lowly trevally	Carangidae	Jacks and pompanos
19	*Carcharhinus leucas*	Bull shark / river whaler	Carcharhinidae	Requiem sharks
20	*Chanos chanos*	Milkfish	Chanidae	Milkfish
21	*Chelonodon patoca*	Milk-spotted toadfish	Tetraodontidae	Puffers
22	*Chirocentrus dorab*	Wolf herring	Chirocentridae	Wolf herring
23	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead	Atherinidae	Silversides
24	*Cynoglossus sp.*	Tongue sole	Cynoglossidae	tonguefishes
25	*Drepane punctata*	Sicklefish	Ephippidae	Spadefishes, batfishes and scats
26	*Dussumeri sp.*	Herring / sardines	Clupeidae	Herring / sardines
27	*Eleutheronema tetradactylum*	Blue threadfin	Polynemidae	Threadfins
28	*Elops australis*	Giant herring	Elopidae	Tenpounders
29	*Epinephelus coioides*	Gold-spot cod / estuary cod	Serranidae	Sea basses: groupers and fairy basslets
30	*Epinephelus malabaricus*	Black-spot cod	Serranidae	Sea basses: groupers and fairy basslets
31	*Favonigobius sp.*	Gobie	Gobiidae	Gobies
32	*Freshwater shrimp*	Freshwater shrimp		Freshwater shrimp
33	*Gambusia affinis*	Mosquito fish	Poeciliidae	Livebearers
34	*Gazza minuta*	Common-toothed ponyfish	Leiognathidae	Slimys, slipmouths, or ponyfishes
35	*Gerres abbreviatus*	Short silver-belly	Gerreidae	Mojarras
36	*Gerres filamentosus*	Spotted silver-belly	Gerreidae	Mojarras
37	*Gerres oyena*	silver-belly	Gerreidae	Mojarras
38	*Glossogobius biocellatus*	Mangrove / sleepy goby	Gobiidae	Gobies

Appendix 4 Cont. List of species captured in the Bohle River, North Queensland, using all sampling techniques during the fisheries independent research surveys.

No.	Species	Common name	Family name	Family common name
39	*Gobiidae sp.*	Goby	Gobiidae	Gobies
40	*Herklotsichthys castelnaui*	Herring	Clupeidae	Herrings, shads, sardines, menhadens
41	*Herklotsichthys koningsbergeri*	Herring	Clupeidae	Herrings, shads, sardines, menhadens
42	*Hypseliotris compressa*	Empire gudgeon	Eleotridae	Sleepers
43	*Lactarius lactarius*	False trevally	Lactariidae	False trevallies
44	*Lagocephalus sp.*	Puffer	Tetraodontidae	Puffers
45	*Lates calcarifer*	Barramundi	Centropomidae	Snooks
46	*Leiognathus decorus*	Ponyfish	Leiognathidae	Slimys, slipmouths, or ponyfishes
47	*Leiognathus equulus*	Common ponyfish	Leiognathidae	Slimys, slipmouths, or ponyfishes
48	*Leiognathus splendens*	Black-tipped ponyfish	Leiognathidae	Slimys, slipmouths, or ponyfishes
49	*Leiopotherapon unicolor*	Spangled perch	Terapontidae	Grunters, tigerperches, thornfishes
50	*Leptobrama muelleri*	Beach salmon	Leptobramidae	Beach salmon
51	*Liza subviridis*	Greenback mullet	Mugilidae	Mullets
52	*Liza vaigiensis*	Diamond-scaled mullet	Mugilidae	Mullets
53	*Lutjanus argentimaculatus*	Mangrove jack	Lutjanidae	Snappers
54	*Lutjanus carponotatus*	Stripey	Lutjanidae	Snappers
55	*Lutjanus johni*	Fingermark	Lutjanidae	Snappers
56	*Lutjanus russelli*	Moses perch / fingermark bream	Lutjanidae	Snappers
57	*Marilyna pleurosticta*	Banded toadfish	Tetraodontidae	Puffers
58	*Megalops cyprinoides*	Tarpon / oxeye herring	Megalopidae	Tarpons
59	*Melanotaenia splendida splendida*	Australian rainbowfish	Atherinidae	Silversides
60	*Monodactylus argenteus*	Diamond-fish / butterfish	Monodactylidae	Moonfishes or fingerfishes
61	*Mugil cephalus*	Sea mullet	Mugilidae	Mullets
62	*Nematalosa come*	Saltwater bony bream	Clupeidae	Herrings, shads, sardines, menhadens
63	*Nibea soldado*	Silver jewfish	Sciaenidae	Drums or croakers
64	*Oreochromis / Tilapia sp.*	Tilapia	Cichlidae	Cichlids
65	*Opiocara porocephala var. darwinensis*	Spangled gudgeon	Eleotridae	Gudgeons
66	*Paraplagusia bilineata*	Rock sole	Cynoglossidae	Tonguefishes
67	*Platycephalus fuscus*	Dusky flathead	Platycephalidae	Flatheads
68	*Platycephalus indicus*	Bar-tailed flathead	Platycephalidae	Flatheads
69	*Pleuronectiformes sp.*	Soles, left and right eyed flounders, tounges	Pleuronectiformes	Flat fishes
70	*Poecilia reticulata*	Guppy	Poeciliidae	Livebearers
71	*Polydactylus macrochir*	King threadfin	Polynemidae	Threadfins
72	*Pomadasys argenteus*	Small-spotted grunter	Haemulidae	Grunts
73	*Pomadasys kaakan*	Large-banded / golden grunter	Haemulidae	Grunts
74	*Portunus pelagicus*	Sand crab	Portunidae	Swimming crabs
75	*Pseudorhombus elevatus / arsius*	Left-eye flounder	Bothidae	Left-eye flounders
76	*Rhinobatos typus*	Shovelnosed ray	Rhinobatidae	Shovelnosed rays

Appendix 4 Cont. List of species captured in the Bohle River, North Queensland, using all sampling techniques during the fisheries independent research surveys.

No.	Species	Common name	Family name	Family common name
77	*Sardinella albella*	Herring	Clupeidae	Herrings, shads, sardines, menhadens
78	*Scatophagus argus*	Spotted scat	Scatophagidae	Scats
79	*Sciaenidae sp.*	Jewfish	Sciaenidae	Jewfish
80	*Scomberoides commersonnianus*	Queenfish	Carangidae	Jacks and pompanos
81	*Scomberoides lysan*	Double-spotted queenfish	Carangidae	Jacks and pompanos
82	*Scomberoides tol*	Needleskin queenfish	Carangidae	Jacks and pompanos
83	*Scomberomorus semifasciatus*	Grey mackerel	Scombridae	Mackerels, tunas, bonitos
84	*Scylla serrata*	Mud crab	Portunidae	Swimming crabs
85	*Selenotoca multifasciata*	Striped scat	Scatophagidae	Scats, Butterfishs
86	*Siganus lineatus*	Golden-lined spinefoot	Siganidae	Rabbitfishes
87	*Siganus sp.*	Spinefoot	Siganidae	Rabbitfishes
88	*Sillago ciliata*	Sand whiting	Sillaginidae	Smelt-whitings
89	*Sillago sihama*	Winter whiting	Sillaginidae	Smelt-whitings
90	*Sphyraena barracuda*	Giant barracuda	Sphyraenidae	Barracudas
91	*Sphyraena jello*	Slender barracuda	Sphyraenidae	Barracudas
92	*Sphyrna lewini*	Hammerhead shark	Sphyrnidae	Hammerhead, bonnethead shark
93	*Stolephorus sp.*	Anchovy	Engraulidae	Anchovies
94	*Strongylura strongylura*	Spot-tailed needlefish	Belonidae	Needlefish / Longtoms
95	*Terapon jarbua*	Crescent perch	Terapontidae	Grunters or tigerperches, thornfishes
96	*Tetractenos hamiltoni*	Toadfish	Tetraodontidae	Puffers
97	*Thalamita crenata*	Thalamita crenata	Portunidae	Swimming crabs
98	*Thryssa hamiltonii*	Hamilton's anchovy	Engraulidae	Anchovies
99	*Torquigener sp.*	Pufferfish	Tetraodontidae	Puffers
100	*Toxotes chatareus*	Archerfish	Toxotidae	Archerfishes
101	*Tripodichthys angustifrons*	Triplespine	Triacanthidae	Triplespines
102	*Valamugil buchanani*	Buchanan's mullet	Mugilidae	Mullets
103	*Valamugil georgii*	Fantail	Mugilidae	Mullets
104	*Zabidius novemaculeatus*	Shortfinned batfish	Ephippidae	Spadefishes, batfishes and scats

Appendix 5 Mean size and size range of each species caught during the Bohle River surveys.

Species	Average	Maximum	Minimum	Number
Acanthopagrus australis	14.4	19.5	11.5	18
Acanthopagrus berda	13.2	24	8	91
Aetobatus narinari	45.0	45	45	1
Ambassid sp.	23.6	4	1	34
Ambassis agassizi	3.24	4.2	2.3	7
Ambassis gymnocephalus	3.1	4.65	1.5	41
Ambassis interruptus	3.9	5.4	3	4
Ambassis nalua	6.9	9.8	4.05	20
Ambassis vachellii	4.1	5.1	2.85	9
Anguilla reinhardti	24	58	10	17
Arius argyropleuron	34.5	48	19	299
Arius graffei	33.3	50	12.5	296
Arothron hispidus	29.8	32	27.5	2
Arothron manilensis	15.1	22.5	6.5	29
Aseraggodes rautheri	10.5	10.5	10.5	1
Batrachoididae sp.	23.6	30.5	16	10
Belonidae sp.	42.5	46	39	2
Carangoides hedlandensis	18.8	21.8	17	3
Caranx ignobilis	25.1	36.5	8.8	8
Carcharhinus leucas	76.0	90	70	5
Chanos chanos	24.1	24.7	23.5	2
Chelonodon patoca	5.5	12	1.5	22
Chirocentrus dorab	45.6	57.5	30	20
Craterocephalus stercusmuscarum	4.25	4.5	4	3
Cynoglossus sp.	3.6	4.4	2.7	2
Drepane punctata	24.1	30.5	19.5	4
Dussumeri sp.	25.0	25	25	1
Eleutheronema tetradactylum	32.5	54.5	20.2	35
Elops australis	27.8	36.5	23	6
Epinephelus coioides	28.1	44	15	105
Epinephelus malabaricus	27.3	42	13.5	36
Favonigobius sp.	2.8	2.85	2.7	2
Gambusia affinis	2.38	3.25	1.4	15
Gazza minuta	5.6	5.6	5.5	2
Gerres abbreviatus	6.5	6.5	6.5	1
Gerres filamentosus	7.95	8	7.9	2
Gerres oyena	7.3	8.8	4.9	6
Glossogobius biocellatus	4.5	4.45	4.45	1
Herklotsichthys castelnaui	8.9	14	8	49
Herklotsichthys koningsbergeri	14.1	18	8.5	29
Hypseleotris compressa	3.86	8	2	247
Lactarius lactarius	31.4	37.5	25.25	9
Lagocephalus sp.	30.0	43	17	2
Lates calcarifer	49.3	89	22	371
Leiognathus decorus	5.4	6.45	3.35	11
Leiognathus equulus	3.7	10	1.5	79

Appendix 5 Mean size and size range of each species caught during the Bohle River surveys Cont.

Species	Average	Maximum	Minimum	Number
Leiognathus splendens	7.9	10.2	5.47	3
Leiopotherapon unicolor	9.76	16.3	5.85	30
Leptobrama muelleri	23.3	31	20	22
Liza subviridis	23.2	56.5	3	218
Liza vaigiensis	50.2	67	4.8	14
Lutjanus argentimaculatus	18.1	34	11.5	5
Lutjanus carponotatus	15.1	15.1	15.1	1
Lutjanus johni	25.5	33.75	9	5
Lutjanus russelli	14.2	20	3.8	55
Marilyna pleurosticta	8.4	22.5	1	37
Megalops cyprinoides	36.1	49	10.2	79
Melanotaenia splendida splendida	3.7	7	1.5	29
Monodactylus argenteus	7.8	10	5.5	14
Mugil cephalus	39.1	51	19	36
Nematalosa come	14.4	30.5	5.5	690
Nibea soldado	32.8	37.4	20	8
Opiolara porocephala var. darwiniense	19.6	19.7	19.5	2
Oreochromis / Tilapia sp.	8.2	41	0.5	100
Paraplagusia bilineata	12.3	12.3	12.3	1
Platycephalus sp.	18.4	51	6.5	8
Poecilia reticulata	1.6	3	1	14
Polydactylus macrochir	50.2	73	25	41
Pomadasys argenteus	23.2	34.5	8.8	17
Pomadasys kaakan	17.3	45	6.8	21
Portunus pelagicus	12.3	16.7	1	112
Pseudorhombus elevatus/arsius	9.0	9	9	1
Rhinobatos typus	39.0	39	39	1
Sardinella albella	9.9	9.85	9.85	1
Scatophagus argus	16.0	28.5	8	10
Sciaenidae sp.	28.7	39	17	11
Scomberoides commersonnianus	40.0	72	29	58
Scomberoides lysan	9.7	10.5	9	5
Scomberoides tol	19.3	20.1	18.5	3
Scomberomorus semifasciatus	29.1	49	22	41
Scylla serrata	12.5	18.9	3	885
Selenotoca multifasciata	12.6	19	6	4
Siganus lineatus	14.8	21	8.4	6
Sillago sp.	14.9	27	3.8	44
Sphyraena barracuda	139.0	139	139	1
Sphyraena jello	44.0	44	44	1
Sphyrna lewini	47.0	51	42	8
Stingray	18.5	18.5	18.5	1
Stolephorus sp.	4.1	5.7	3.7	7
stone crab	7.0	8.6	6	10
Strongylura strongylura	28.2	29.5	26.8	2
Terapon jarbua	11.7	19.5	7.5	3
Tetractenos hamiltoni	6.9	8.5	5.2	4

Appendix 5 Mean size and size range of each species caught during the Bohle River surveys Cont…

Species	Average	Maximum	Minimum	Number
Thalamita crenata	7.0	7	7	2
Thryssa hamiltonii	16.7	22.5	3.2	76
Torquigener sp.	5.0	5	5	1
Toxotes chatareus	19.6	26.5	5.9	7
Tripodichthys angustifrons	21.4	24	18.5	3
Valamugil buchanani	19.4	45	1	65
Valamugil georgii	6.1	8.7	3.9	5

Appendix 6 Commercial catch species categories.

Species Code	Species	Common name	Total catch	Mean Annual Catch
Barramundi	*Lates calcarifer*	Barramundi	65.7655	7.307277778
Bream - bony	*Nematalosa come*	Bony bream	0.735	0.081666667
Crab - Mud	*Scylla serrata*	Mud crab	19.3215	2.146833333
Fish - Bait	Mugilidae spp., Clupeidae spp. & Engraulidae spp.		4.136	0.459555556
Fish - Unspecified	MIXED FISH FAMILIES		19.948	2.216444444
Grunter - unspecified	*Pomadasys argenteus*	Small spotted grunter	5.815	0.646111111
	Pomadasys kaakan	Banded grunter		
Mullet - Unspecified*	Mugilidae spp.	Mullet	79.699	8.855444444
	Mugil cephalus	Sea mullet		
Queenfish	Scomberoides spp.	Queenfish	40.7284	4.525377778
Shark - Unspecified*	*Carcharhinus tilstoni*	Australian blacktip shark	168.5185	18.72427778
	Carcharhinus limbatus	Common blacktip shark		
	Carcharhinus sorrah	Spot-tail shark		
	Carcharhinus cautus	Nervous shark		
	Carcharhinus amblyrhynchos	Grey reef shark		
	Negaprion acutidens	Lemon shark		
	Rhizoprionodon acutus	Milk shark		
Threadfin - Blue	*Eleutheronema tetradactylum*	Blue threadfin	71.258	7.917555556
Threadfin - King	*Polydactylus macrochir*	King threadfin	2.155	0.239444444
Trevally - Unspecified	Caranax spp.	Trevally	3.158	0.350888889