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*The Influence of Fitzroy River Freshwater Discharge on Fishery Catch Rates in Central Queensland Waters.*

J. R. Platten

## 1 Introduction:

It has long been perceived by fishers that marine fisheries are positively influenced by periodic freshwater flows. The statement that "drought on the land means drought on the water" would appear to have some basis in fact (see below). The current proposals to build several major water impoundments on the Fitzroy river (Central Queensland) would appear to raise several issues of particular relevance to the Great Barrier Reef Marine Park.

It is the intention of this document to indicate that the flood outflows of this river have considerable influence on the Great Barrier Reef Marine Park and to suggest that the Great Barrier Reef Marine Park Authority should take urgent steps to ensure that the links between river outflow and the ecology of the park are maintained.

## 2 Background:

The influence of river outflow on several marine fisheries and habitats has been established and the negative effects of stream impoundments preventing stream discharge have been well documented.

### *a) River plumes have considerable influence on offshore habitats*

The production of continental shelf and estuarine waters would appear to be linked to nutrient flow associated with freshwater inflow. Asleem (1972) concluded that outflow from the Nile river in northern Africa prior to the construction of the Aswan high dam transported nutrients as far as Lebanon and Cyprus.

The high turbidity of the Mississippi river in North America inhibits plankton development, however when the turbid plume meets with the clear water of the Gulf of Mexico the high levels of nutrient result in vastly accelerated planktonic growth (Grimes and Finucane, 1991).

Govoni et al (1989) found that the densities of larval fish were much greater at the front of the plume than inside or outside the plume itself.

Larval King Mackeral in the plume would appear to have higher growth rates than those of other Gulf of Mexico waters (Devries et al, 1990).

In New Zealand, larval crab *(Munida gregaria)* aggregations have been noted on the edges of river plumes and headland fronts (Zeldis and Jillett, 1982).

Richardson (1981) found that the spawning of the northern anchovy *(Engraulis mordax)* was linked to the Columbia river plume.

b) **Fishery catch rates can be significant indicators of environmental effects and are often influenced by river outflow.**

Drinkwater (1987) and Drinkwater and Frank (1988) list several correlations between freshwater inflows and fisheries production. For example in Norway the catches of

Northern Cod (*Gaddus* spp.) are related to rainfall events some 11 years earlier, probably reflecting the time taken for recruits to enter the fishery.

**c) Similar to the positive effects of freshwater discharge there is evidence that reduction of flow associated with impoundments have significant negative influences.**

The population of striped bass of the San Francisco bay region (North America) have been reduced to critically low levels associated with a reduction to 36% of original water inflow (Williams,1989, Anon., 1989).

Asleem (1972) records a significant drop in phytoplankton and zooplankton production associated with with construction of the Aswan dam on the Nile. The average weight of sardines declined by 15% and catches fell to below 10 % of the levels before this dam was built (White, 1988). Wadie and Razek (1985) also documented a drop of 75% in shrimp catch associated with the dam.

Quarishee (1988) records that the shrimp catch of the Indus river of Pakistan declined to 10% of the original levels associated with construction of dams and weirs. Each construction was associated with a corresponding decline.

Weisburg and Burton (1993) established that fish growth and feeding were enhanced following increases in water releases from the Conowingo dam (Maryland United States of America).

**d) Australian species and habitats have been shown to be influenced by river flow.**

In Australia the influence has largely been described in an anecdotal manner, although some evidence has been described amongst certain prawn species. Glaister found a positive correlation between catches of the school prawn (*Metapenaeus macleayi)* and outflow of the Richmond and Clarence rivers. Ruello (1973) established a similar link in the Hunter river. Staples (1985) established that rainfall positively influenced the recruitment of Banana prawns (*Penaeus merguiensis)* in the South Eastern Gulf of Carpentaria. Thorrold and McKinnon (1995) suggested a positive relationship between larval fish assemblages and river plume exists in the central Great Barrier Reef lagoon.These authors found that the movement of the plume offshore probably translocated certain species offshore and the high biomass of zooplankton within the plume is likely to positively influence recruitment of some species.

Similarly several species eg the Barramundi, *Lates calcarifer* have been shown to rely on freshwater discharge to allow landlocked fish access to saltwaters and juvenile fish to move to freshwater nursery areas (Dunstan 1959). The flooding of rivers has been shown to trigger reproductive behaviour in several catadromous species (eg Australian bass *Macquaria novemaculeata*, Harris,1986). As a result the recruitment of several species is directly correlated with river flows (eg Australian bass, Harris,1988).

Mangrove forests and their exported productivity would appear to rely on deposition of nutrient with sediment, similarly the growth rates of mangrove trees is positively influenced by reductions in salinity apparently associated with the reduction in energy needed to eliminate or exclude salt from their tissues (see Saenger 1996).

The massive riverine plume associated with rivers such as the Burdekin and Fitzroy in 1991 (see Wolanski and Jones, 1981,McKinnon and Thorold 1993) would suggest that they should have considerable influence on fish populations even if indirectly.This is particularly relevant since these rivers flow through dry tropical environments, which have relatively few other freshwater outflows.

The physical effects of the 1991 flood of the Fitzroy river are documented in Byron (1992). Among several significant effects noted are an immense export of nutrient and major phytoplankton blooms within the GBR marine park.

e) **The link between fishery catch rates and river flow in Queensland.**

Until relatively recently there has been little catch data maintained over a sufficient length of time to establish a clear link with changes in climate and stream flow cycles.

The commencement of the QFISH database maintained by the Queensland Fisheries Management Authority in 1988 has enabled shorter term links to be investigated, but longer term relationships can only be analysed using fishing competittion information collected from recreational fishing clubs.

The catch statistics of Gladstone's Yaralla Offshore Fishing club are described below. The usefulness of this data lies in that it provides a moderately controlled sampling measure, with all participants bound by rules in regard to the time spent fishing and the methods utilised . There is also a motivation to accurately record and store catch information. The data are available over a sufficient length of time to allow a useful comparison over a range of river flow regimes.

Higgs (1993) carried out an analysis of the trends in recreational fishing club catch data for Barrier Reef waters, but investigated no links with climatic or river discharge data.

**The results below attempt to demonstrate that**:

1- There is a direct link between marine fisheries catch rates of Central queensland and river outflow

2- That this is indicative of an ecosystem wide relationship that may well be of considerable significance to the Great Barrier Reef marine park

## *2 Analysis Methods*

To estimate the apparent extent of any correlation between catch rates and river discharge the following methods were used.

Catch data were collected from two main sources:

**A) Recreational Fishing Clubs**

The Gladstone based Yaralla Fishing Club provided data for the period 1977 to 1995 based on catches from the Capricorn/Bunker group. Over this period the club visited reefs between Llewellyn Reef ($23^0$ 42'S,$152^0$ 10'E) and Haberfield Shoal ($23^0$ 5'S,$151^0$ 43'E). Each trip consists of a 2 day weekend excursion with anglers fishing for approximately 10 hours per trip. Typically fishing is carried out in daylight from vessels from 10m to 17m in length. In almost all cases the vessels were allowed to drift across patch reefs in depths between 12 and 25m. Fishing is carried out with nylon handlines using baits of fish, squid or cuttlefish.

Fish are weighed and counted shortly after capture (usually less than 2 hours after capture) and information is kept on tally sheets. Anglers are assigned points using the formula:

Points = Total weight of fish (kg) x 10 + number of fish

Hence 10 fish weighing 40 kg would score 40 x 10 +10 = 410 while 30 fish weighing 20 kg would score 20 x 10 + 30 = 230 .

This results in a motivation to catch larger fish, and in fact many participants return smaller (but legal size) fish.

The maximum number of anglers on each trip is set at 10.
Trip data is recorded as individual catches and usually as total trip catch in kg and total numbers of fish caught along with the numbers of anglers participating. No information has been stored on species composition of catches, though discussions with long term participants suggest that Tusk fish *(Choerodon spp.)* and Red Throat Emperor *(Lethrinus spp.)* make up the bulk of the catch with significant numbers of common Coral Trout *(Plectropomus leopardus)* and Hussar *(Lutjanus adetti)* on some trips. This view is reinforced by the study by Thwaites (1994) of the log books of charter fishing vessels. In most cases the area fished and the prevailing wind and sea conditions are also recorded.
Data in this investigation was stored on Microsoft Access and analysed to date in a relatively simple manner though Microsoft Excel.
Data are expressed as:
a) the average number of fish caught per angler per trip calculated from the total number of fish caught divided by the total number of participants,
b) the average weight of fish caught per angler calculated by dividing the total mass of the catch by the number of fishers,
and
c) the average size of the fish was determined by dividing the total weight of fish by the number of fish caught.

## B) Commercial Catch Data

Information analysed was supplied by the Queensland Fisheries Management Authority from the QFISH database. They were provided for several 30 minute grids encompassing the Fitzroy River mouth and adjacent waters, the Capricorn/Bunker group and reef areas immediately offshore from the Burdekin river, ie $23.5^0$ - $24^0$ S, $151^0$ - $151.5^0$ E , $23^0$ - $23.5^0$ S , $151.5^0$ - $152^0$ E,
$23.5^0$S - $24^0$ S, $152^0$ - $152.5^0$ E and $19^0$-$19.5^0$ S, $148^0$ - $148.5^0$ E.
All estimates of catch are expressed in estimated kg of whole fish calculated from the mass of the landed product multiplied by a factor dependent on the state of the landed fish (fillet, gutted, headed and gutted etc).
The methods used for capture is dependent on the species involved. Prawn species were exclusively taken from beam or otter trawls, reef species largely by handlining. Data was also supplied on the number of boat days and the number of boats involved in the catch.
Catch per unit effort was calculated as the total catch in kg for each species divided by the number of boat days used in making the catch.
Catch estimates exist for the years 1988 to 1995, although Mapstone (1995) suggests that the estimates for 1988 may be less reliable than for later years because of initial difficulties in establishing the database. While the data provides estimates for comparing any effect on particular species, it does not give any indications of the number of fish involved in the catch. This can be important in cases where increases or decreases in condition factor (weight compared to length) can mask trends in catch rates. For example if the number of kg of product landed increases, this may indicate an increase in numbers of fish caught or the same number of bigger fish taken.

## C) Stream Discharge

Stream discharge estimates were supplied by the Department of Natural Resources as follows:
i) Fitzroy River
The discharge was supplied as estimated total stream discharge in megalitres for the Fitzroy River at the Gap. In some cases (for example in times of high flood) the discharge was provided as a reliable but not precise estimate. However the data should be reliable enough to show the effect of stream discharge if taken at an error of ± 10000 megalitres per annum. Data was utilised as an annual total for comparison with catch data.
ii) Burdekin River
The increased flow of the Burdekin meant that discharge was provided in gigalitres.
The discharge was measured at Clare approximately 60 km from the coast. In the years 1988 - 1995 the data is considered reliable to ± 1 gigalitre. Data was utilised usually as an annual total for comparison with catch data.

**D) Establishing a Correlation**

For the purpose of the initial simple analysis the average catch per unit effort (cpue) of each year for the data sets was calculated and compared with the annual discharge figures, using the calculation of the correlation coefficient. $\rho_{x,y} = \mathrm{Cov}(x,y)/\sigma_x . \sigma_y$ where $\mathrm{Cov}(x,y)=1/n \, {}^n\Sigma_{j=1}(x_j-\mu_x)(y-\mu_y)$. The level of significance was then ascertained by comparison with a table of the coefficient in Bishop (1976).

## *2 Results*

To date a desk top analysis of the relationship between the catch rates of recreational and commercial fishers and the river discharge from the Fitzroy and Burdekin rivers suggest a significant link.
A similar analysis of correlations with cyclone occurrence, wind strength and direction gave no evidence of significant correlations.
a) Yaralla Offshore Fishing Club
Data exist reliably over 18 years, covering several flood events of the river.
There is a significant increase in the number of fish caught per person per trip associated with each flood event.
Initial analysis would suggest that there is a close mathematical correlation between these catch rates and river discharge (see fig 1). There is no such link with the catch in kg of fish per person per trip.
The correlation does not establish a causative relationship, but analysis demonstrates that the positive influence on catch rates decreases with distance from the Fitzroy mouth. This suggests that the cause or causes is/are probably closely associated with this river's outflow (see figs 2-4).
Additionally, the subsequent 2-3 years after a flood are characterised by declines in catch rates smaller than would be expected from the correlation with river discharge. This suggests some residual beneficial effect.
As might be expected in these offshore waters the correlation becomes less significant in years of lower river flow with the most noticeable effects occurring in years with annual flow greater than 5-10 GL.

b) Commercial Data

It would appear that commercial data, although over a shorter time frame, demonstrate a similar correlation.

i) Capricorn Bunker group

An apparent link can be observed with Coral Trout (*Plectropomus spp.)* , Cod (Serranidae- *Epinephelus spp.*predominately) , Pearl Perch (*Glaucosoma scapulare*) , Hussar (*Lutjanus adetii*) , Snapper (*Chrysophrys auratus*) , Eastern King Prawn (*Penaeus plebejus*) and Moreton Bay Bugs (*Themus orientalis*) in that catch rates increased with increased river outflow.

As with the recreational data, the link becomes much less apparent with increasing distance from the Fitzroy River.

See figs 10- 12.

The influence of river flooding on species other than those outlined above cannot be dismissed since the data is only recorded in kg of fish taken, not in the number of fish caught, so that fewer larger fish (say 1-2 years after flooding) could weigh more than a greater number of smaller fish. The recreational data showed no correlation for kg/angler/trip and showed an increase in average size of fish after each flood. It may be that other species may be affected but not readily demonstrate the relationship.

iii) Reefs offshore from the Burdekin River

Initial analysis of catch rates of three species suggests that a relationship may exist with Red Throat Emperor (*Lethrinus spp.)* and Coral Trout *(Plectropomus spp*) ( see figs )

To date analysis has been only on a simple basis, advanced statistical techniques have not been utilised, and there has also been no attempt to delineate the influences on correlations (eg the apparent residual effect which seems evident in years following flood events).

However the apparent correlation in two independent sets of data, for a range of species and habitats, for fisheries involving different capture techniques and across two widely separated locations suggest that a significant process and influence may be involved.

## *3 Possible Causes of the relationship*

A desk top study such as this cannot determine definitely the causes of such an influence, however some inferences can be suggested.

The usual interpretation of variations in catch rates is that they are related to changes in stock abundance linked to recruitment variations or changes in mortality. In line fisheries, other influences such as fish feeding intensity and hook avoidance behaviour can also be involved.

The immediacy of the increase in catch rates with only relatively short time lags until catch rates rise, suggests that recruitment of fish to the fishing areas could be influenced by the flood events, (as has been shown to occur in prawn species), as fish are translocated by the effects of flood waters.

The results are also consistent with an increase in feeding intensity of the line caught species. The current information on reef species such as coral trout suggests that they do not readily move far once recruitment from larval stages has occurred.

Possibly the best explanation is that prawn species move offshore associated with river flooding and finfish feeding is enhanced by river outflow.

## *4 Implications of the Relationship*

a) The Effect of Floods on Ecosystems of the GBR Marine Park

These data suggest that the outflows of the Fitzroy and Burdekin rivers significantly influence GBR waters.

I Species Involved

The species affected occur at several trophic levels (Prawns to Coral Trout) suggesting that the influences may be present across the food web.

As described above two main explanations exist to explain changes in catch rates. The implications of each is considered below:

i) If a change in feeding intensity of finfish is indicated:

The fact that the recreational information and data related to several of the commercial species is derived from line fisheries, may point to significant changes to feeding patterns. This suggests that considerable influence may be applied to both predator and prey species.

An increase in stream flow was shown by Weisburg and Burton (1993) to increase the intensity of feeding in several species. The effects of this was to increase the growth rates of these fish. Tagging data from Fitzroy river Barramundi suggest that growth rates are significantly slower in years of smaller stream flow (W. Sawynok, pers comm). Similarly it is the perception of several local commercial fishers that the coral trout of the Capricorn Bunkers grow faster than those of the Swains reefs (beyond the influence of the Fitzroy). The study of Thwaites (1994) is the only study which records the average size of fish from the Capricorn /Bunkers and Swains reefs. This study suggests the average size of coral trout of the Capricorn/Bunkers is larger than those from the Swains.

Analysis of the recreational data above, suggests that the average size of fish increases after a flood event (see fig ), although it is impossible to tell if this reflects increased growth rates or the taking of larger species.

It is thus at least possible that the growth rates of fish in the Capricorn Bunkers are positively influenced by the Fitzroy floods.

ii) If an offshore movement of species is caused

The offshore movement and hence recruitment of Banana prawns is well known and the success of Gulf of Carpentaria trawl fisheries has been linked to rainfall and river flooding. The results above suggest an offshore movement of king prawns is possibly linked to river flow also.

These apparent movements must influence offshore predatory species as well as the fishery and may also be related to the life cycle and reproduction of each prawn species.

While this desktop study can only speculate on the importance of such flows the worldwide data suggest that any effects which reduce river outflow are likely to have negative consequences.

II Nutrient flow

Nutrient flow from rivers to offshore areas would appear a very significant factor in dry tropical environments. Without these nutrients the ecosystem's productivity is significantly reduced (see Asleem (1972)).

O' Neill, Byron and Wright (1992) reported the plume from the Fitzroy river in 1991 reaching as far south as Masthead Is. and Heron Is.. Similarly Preker (1992) recorded significantly lower water salinities at Heron Is. associated with the flood.

Brodie and Mitchell (1992), reported very high levels of nitrogen, and phosphorous associated with the Fitzroy river flood plume. They also found evidence of extensive phytoplankton blooms (20 times normal chlorophyll-a values in water sampled).
Thus the Fitzroy certainly influenced the nutrient and planktonic regime of the Capricorn Bunkers in 1991.
O'Neill et al (1992) suggest that the movement of the riverine plume so far to the south east is unusual, and that the effect of river outflow is unlikely to influence the Capricorn Bunkers very often. The results of this study suggest that the effects may be more common than they suggest if the catch rate effects above are correlated to the effects of riverine plumes. However even if their suggestions are correct there would still be considerable movement of nutrient into the marine park to the north of the river.
b) The Effect of Dams on Offshore Ecosystems
Current considerations of environmental flow releases from dams does not appear to consider the link with offshore areas. Most investigations on releases would appear to focus on instream ecological maintenance.
If a similar approach is taken with Fitzroy catchment dams significant negative implications may result for the GBR marine park.

Summary of findings
1 Fitzroy river floods would appear to positively influence catch rates of commercial and recreational fishers within the marine park.
2 This is likely to be indicative of a significant effect on the ecosystem of the marine park from the Fitzroy mouth to the Capricorn Bunker group.
3 The construction of large dams on the Fitzroy river catchment is likely to impact on this apparent influence.
4 The world wide consequences of dam building indicate that they can adversely affect offshore ecosystems in the dry tropics.
5 The present system of water allocation from dams does not consider offshore effects.

Recommendations for the Consideration of the Marine Park Authority.

1 That the authority investigate further the influence of the Fitzroy river on the southern GBR marine park as a matter of urgency.
2 That the authority take careful cognisance of the likely environmental costs to the waters of the GBR marine park of any Fitzroy river dam.
3 That the authority look carefully to any water allocation from dams to ensure maintenance of the apparent links between flood outflow and offshore ecosystems.
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Harris 1986 or 1988

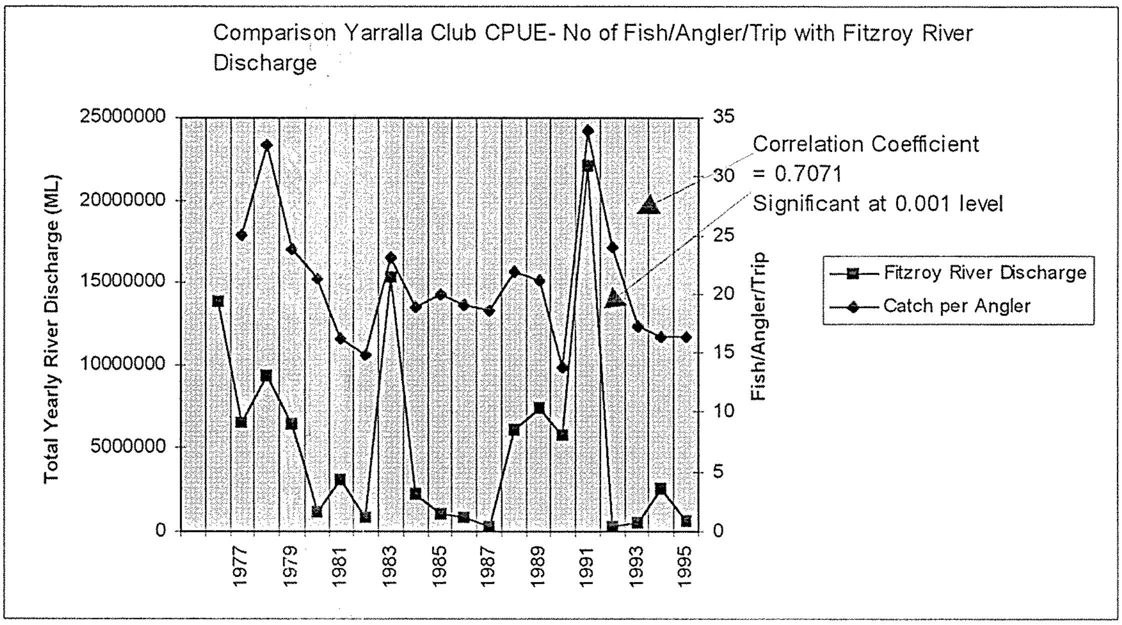



Figure 1 Comparison of Fitzroy river discharge and catch rates of the Gladstone based Yaralla fishing club.

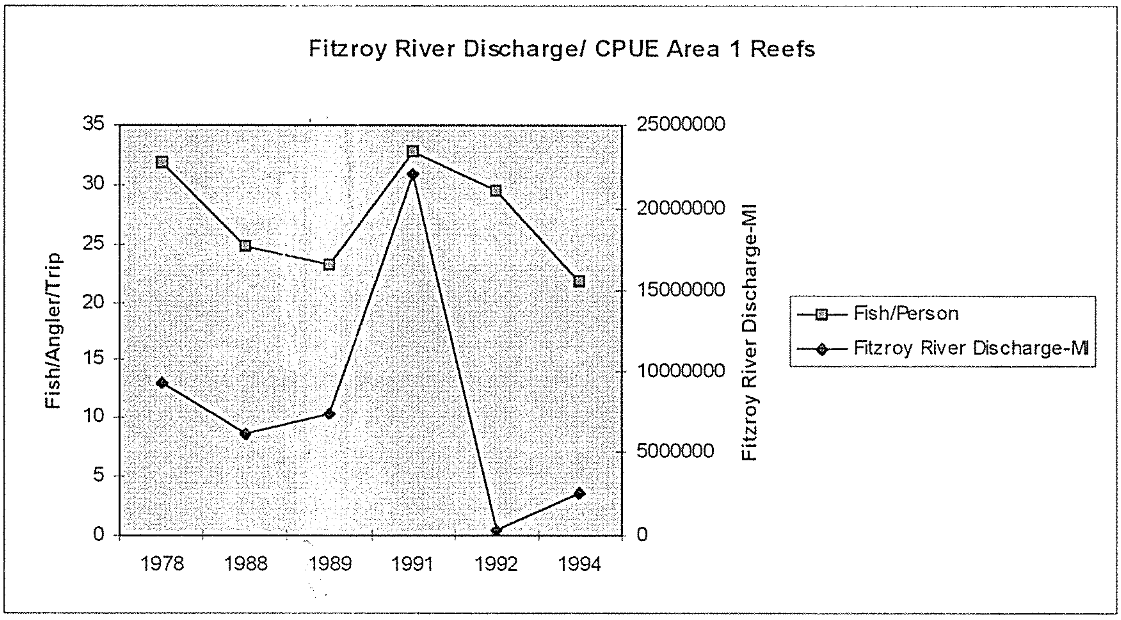



Fig 2 Area 1 Reefs- Douglas and Habberfield Shoals Closest to Fitzroy river

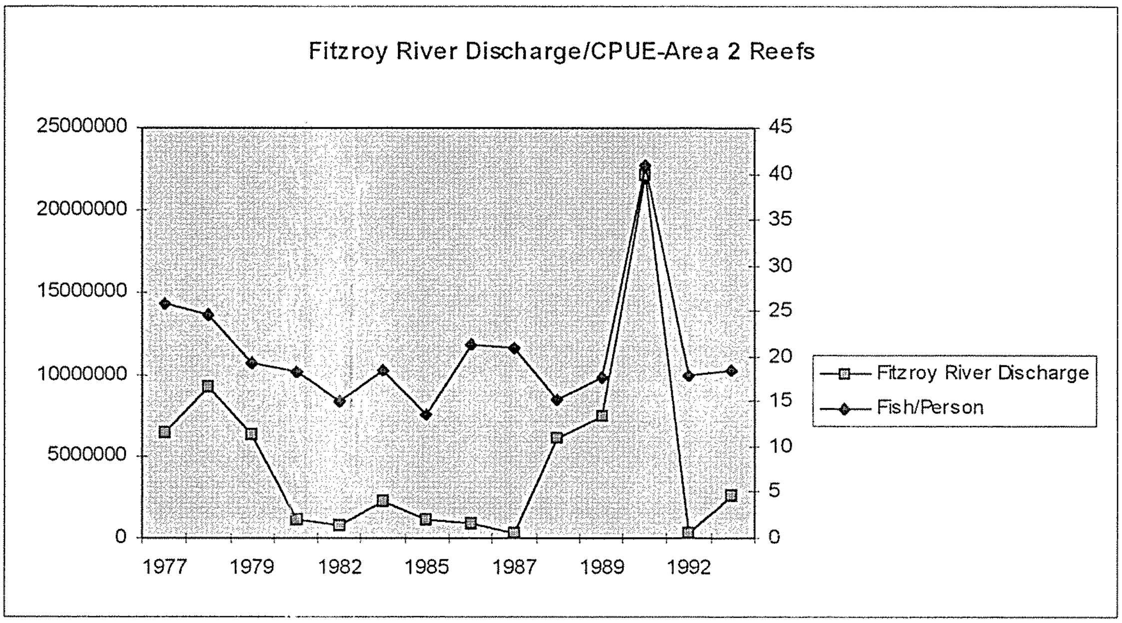



Fig 3 Area 2 Reefs- Wilson, Bloomfield, Tryon and Wreck

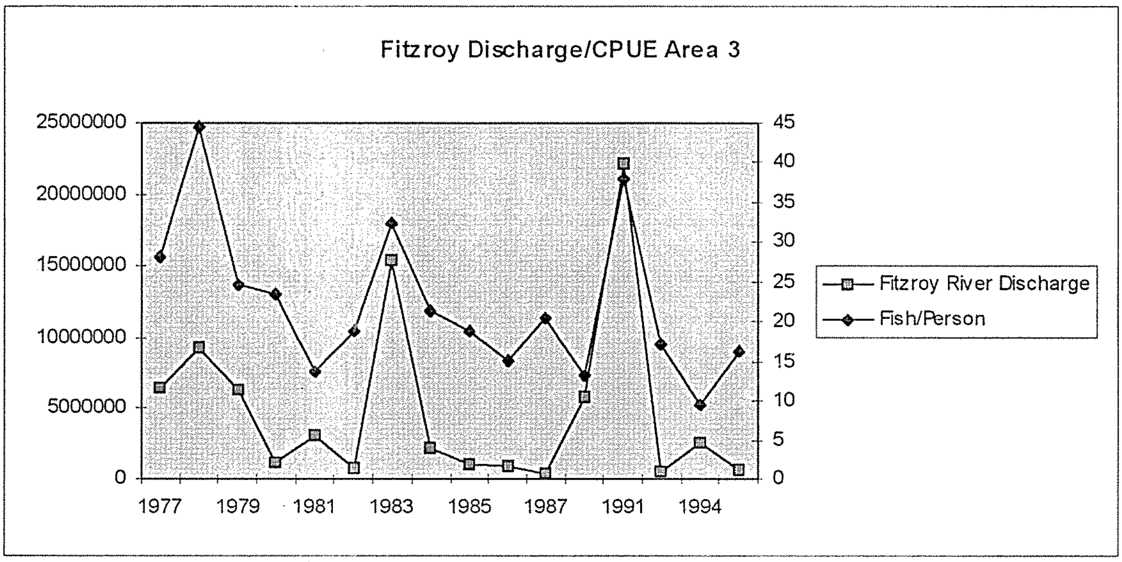



Fig 4 Area 3 Reefs-Sykes,One Tree,Heron and Wistari

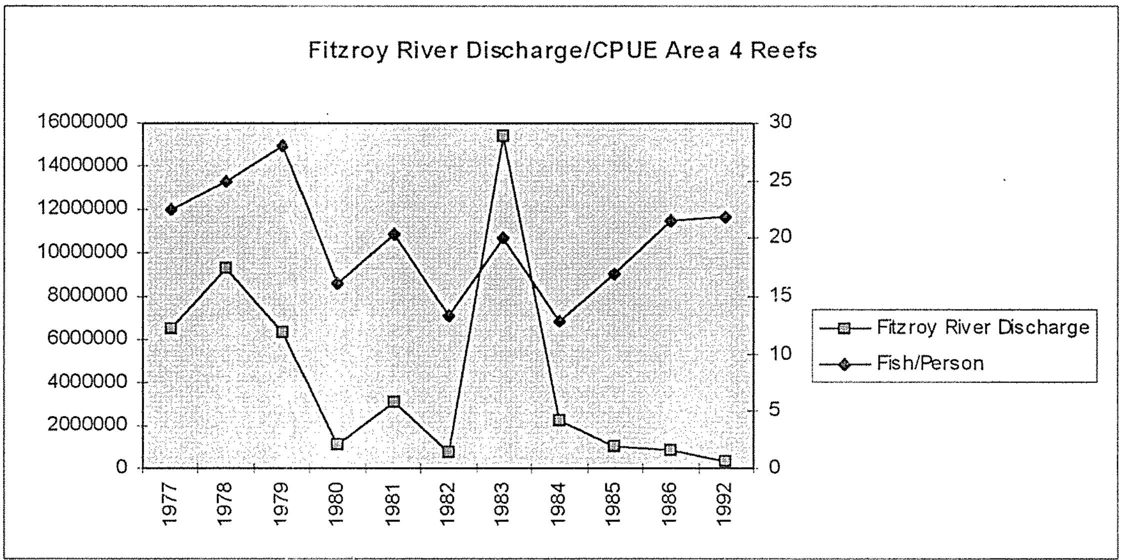



Fig 5 Area 4 Reefs- Fitzroy,Lamont and Llewellyn Reefs- furthest from the Fitzroy

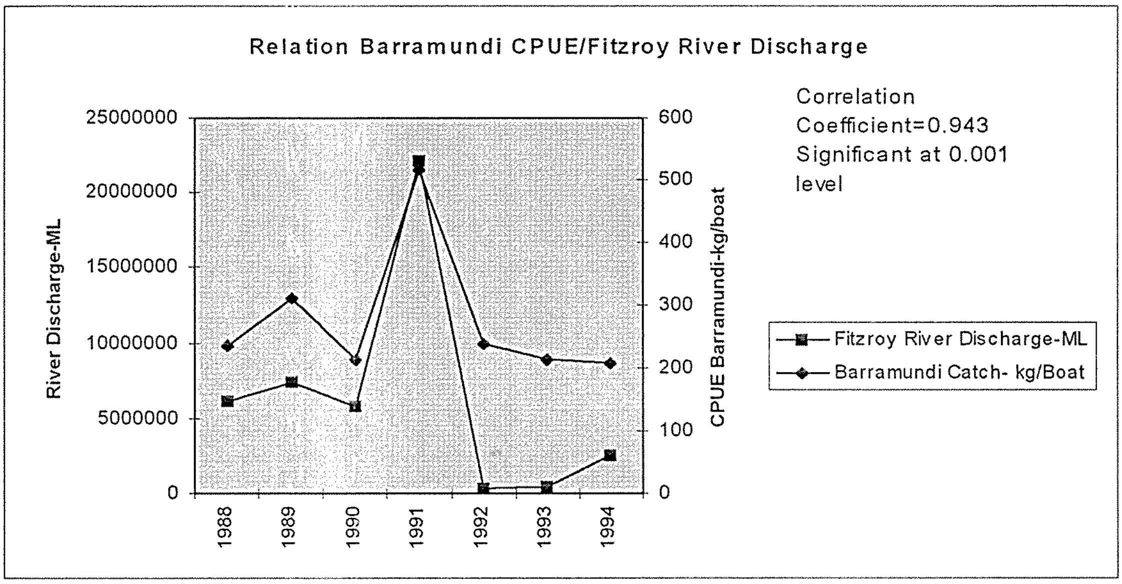



Fig 6 Barramundi CPUE / Fitzroy Discharge

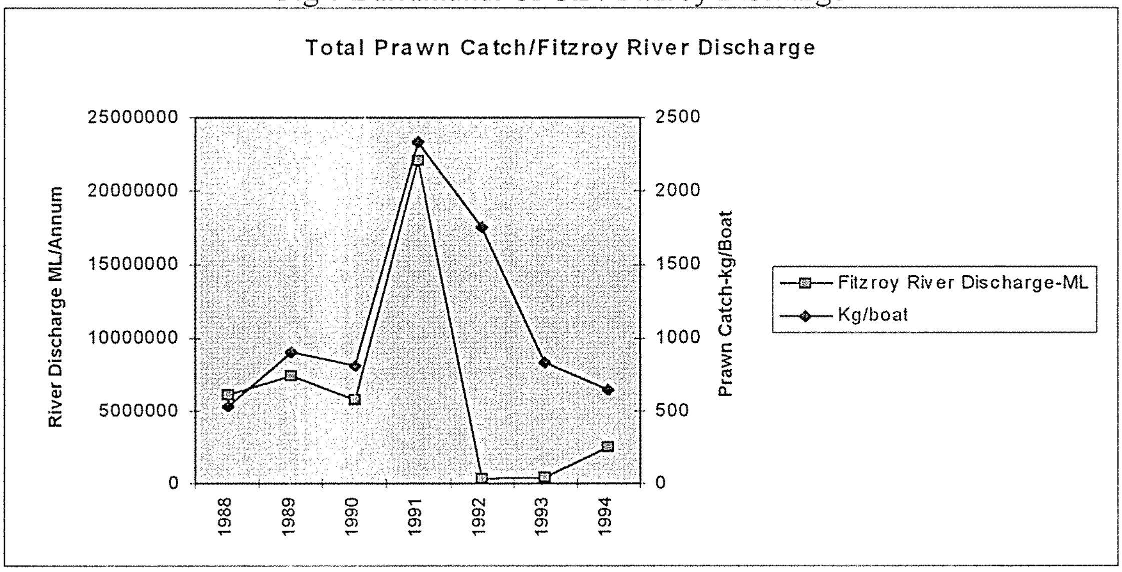



Fig 7 Prawn Catch / Fitzroy Discharge

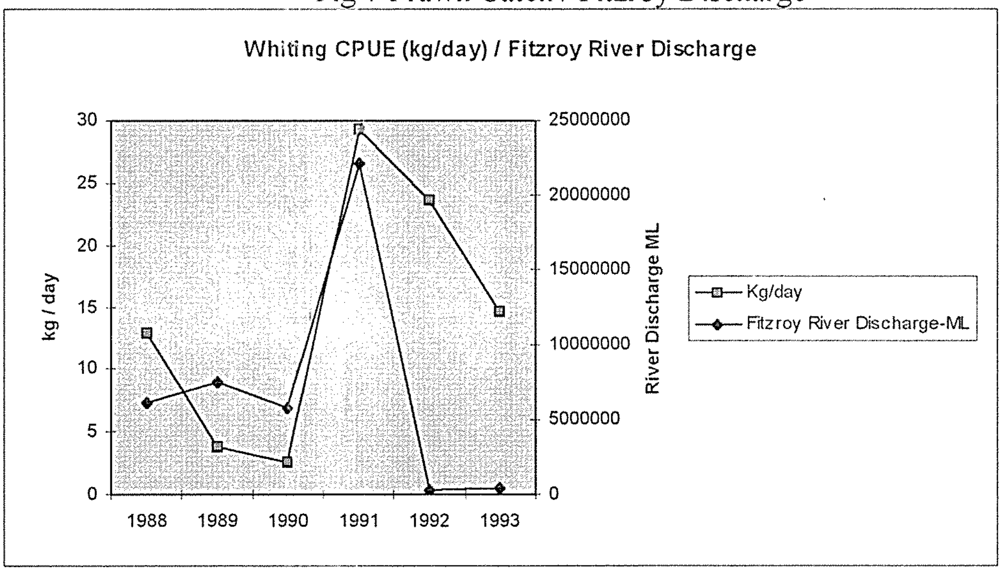



Fig 8 Whitng CPUE / Fitzroy River Discharge

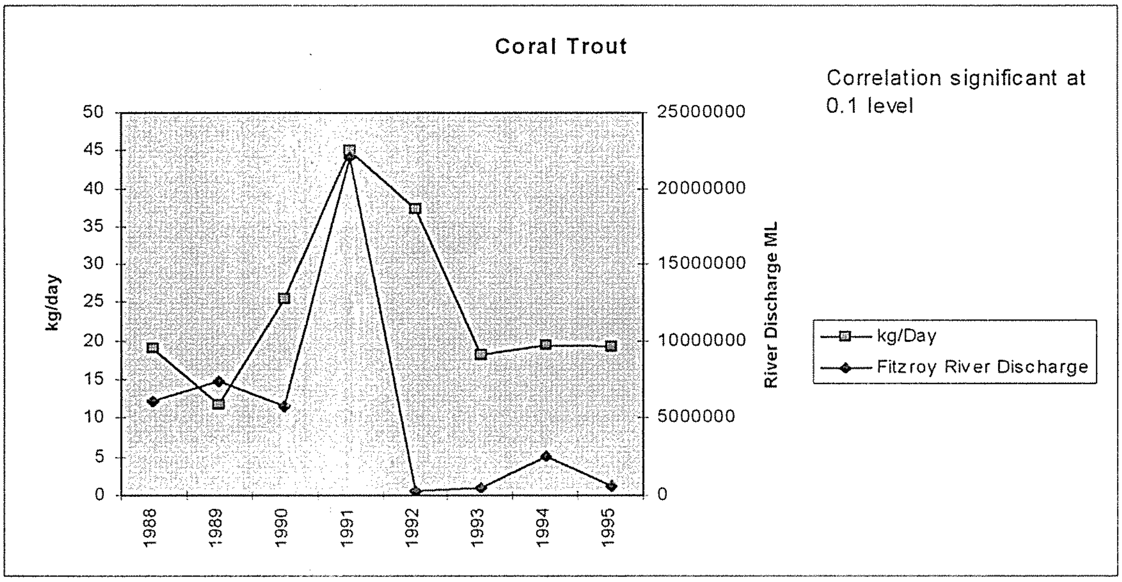

Coral Trout
Correlation significant at 0.1 level
50
45
40
35
30
25
20
15
10
5
0
kg/day
25000000
20000000
15000000
10000000
5000000
0
River Discharge ML
1988
1989
1990
1991
1992
1993
1994
1995
kg/Day
Fitzroy River Discharge

Fig 9

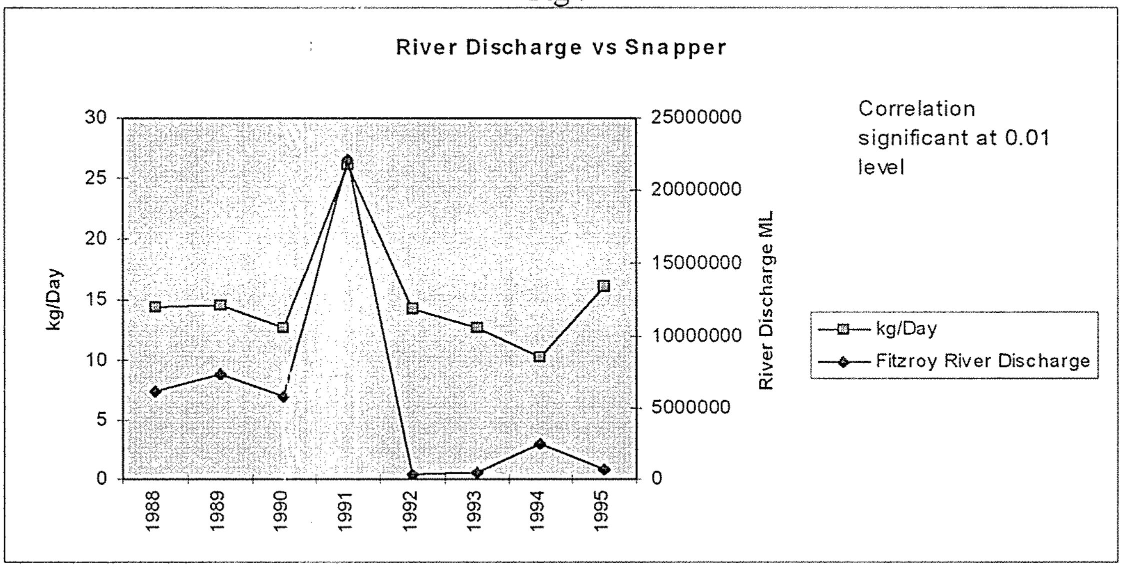

River Discharge vs Snapper
Correlation significant at 0.01 level
30
25
20
15
10
5
0
kg/Day
25000000
20000000
15000000
10000000
5000000
0
River Discharge ML
1988
1989
1990
1991
1992
1993
1994
1995
kg/Day
Fitzroy River Discharge

Fig 10

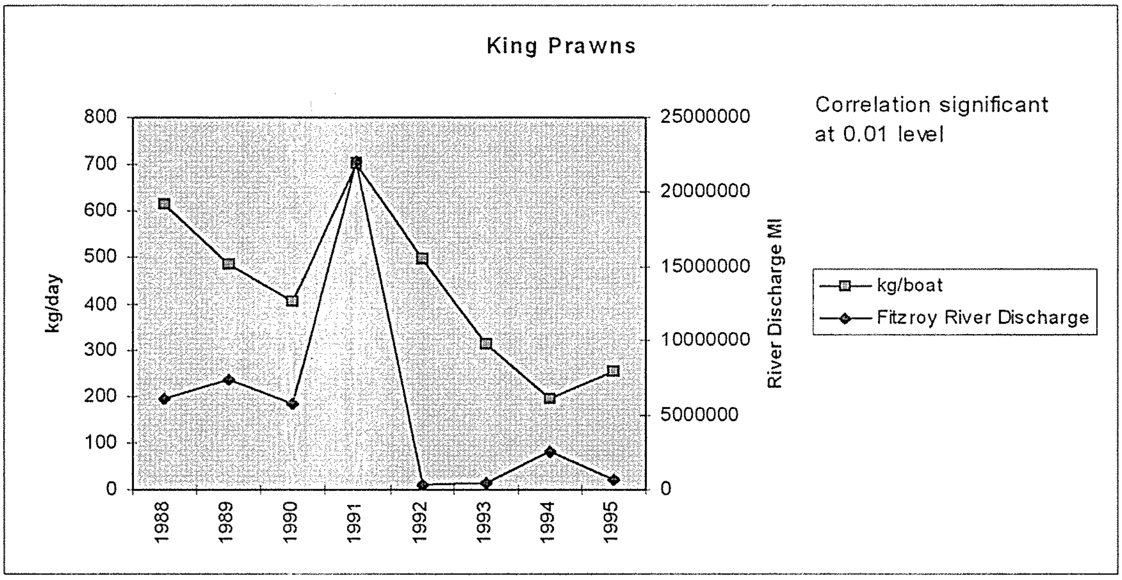
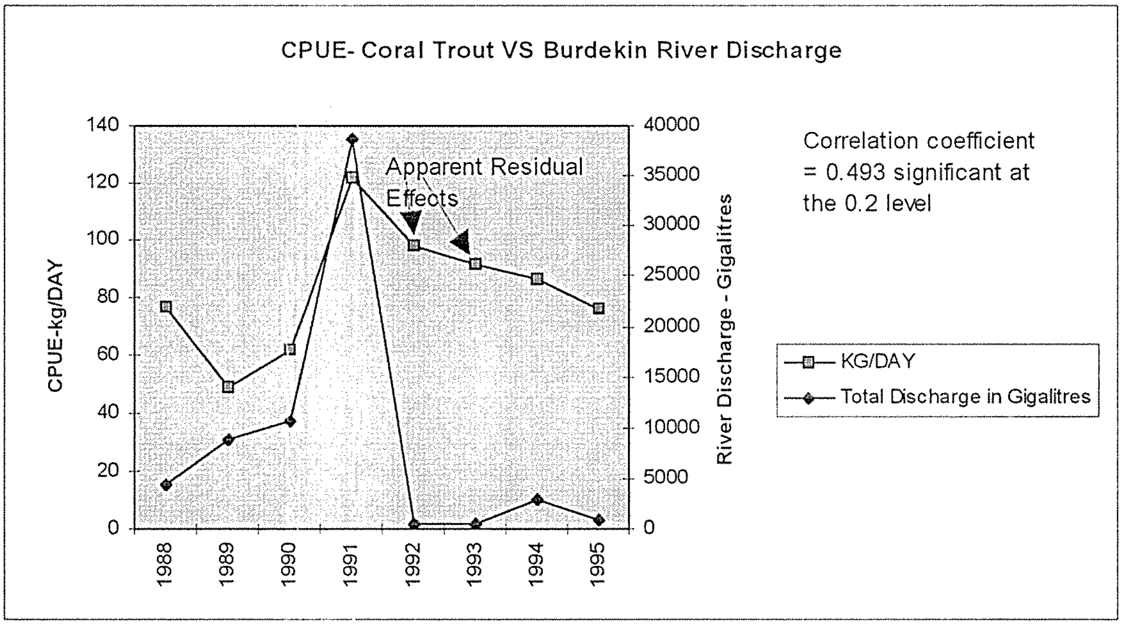
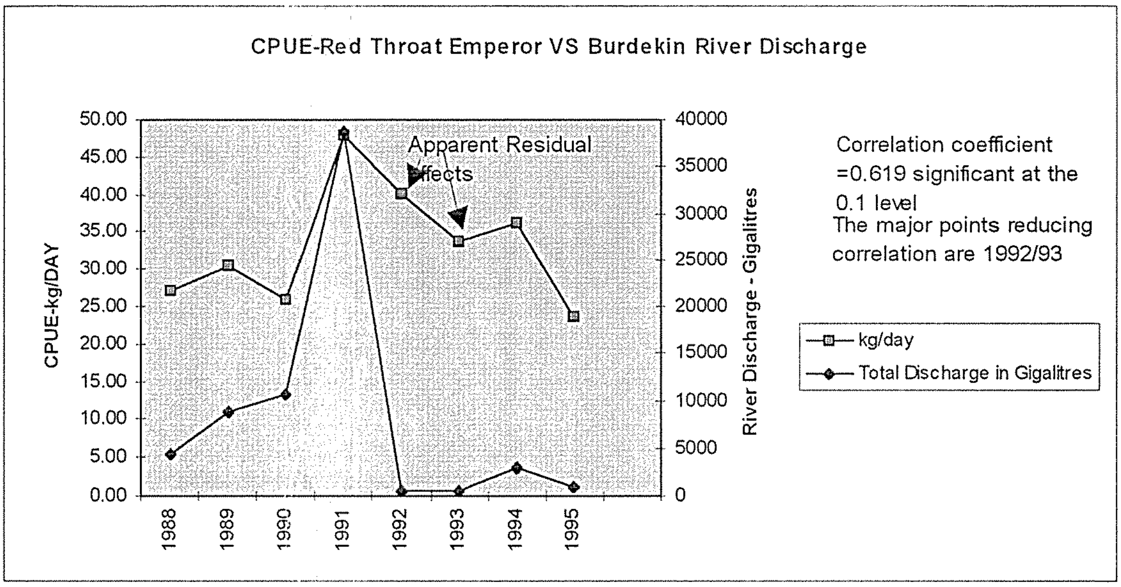

King Prawns
Correlation significant at 0.01 level
kg/day
800
700
600
500
400
300
200
100
0
25000000
20000000
15000000
10000000
5000000
0
River Discharge Ml
kg/boat
Fitzroy River Discharge
1988
1989
1990
1991
1992
1993
1994
1995

Fig 11


CPUE- Coral Trout VS Burdekin River Discharge
Correlation coefficient = 0.493 significant at the 0.2 level
Apparent Residual Effects
CPUE-kg/DAY
140
120
100
80
60
40
20
0
40000
35000
30000
25000
20000
15000
10000
5000
0
River Discharge - Gigalitres
KG/DAY
Total Discharge in Gigalitres
1988
1989
1990
1991
1992
1993
1994
1995


CPUE-Red Throat Emperor VS Burdekin River Discharge
Apparent Residual Effects
Correlation coefficient =0.619 significant at the 0.1 level
The major points reducing correlation are 1992/93
kg/day
Total Discharge in Gigalitres
CPUE-kg/DAY
River Discharge - Gigalitres
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
40000
35000
30000
25000
20000
15000
10000
5000
0
1988
1989
1990
1991
1992
1993
1994
1995