Biology and harvest of tropical fishes in the Queensland Gulf of Carpentaria gillnet fishery

Edited by

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FRDC Project Number 92/145

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Fisheries Research and Development Corporation (1993-95)
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92/145 Biology and harvest of tropical fishes in the Queensland Gulf of Carpentaria gillnet fishery

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OBJECTIVES:

1. To undertake over a two year period an investigation of age, sexuality, reproduction, stock structure, and seasonal abundance of key target species - threadfin salmon (*Polydactylus sheridani* and *Eleutheronema tetradactylum*), grunter (*Pomadasys kaakan*), and jewfish (*Nibea squamosa* and *Protonibea diacanthus*) - from the Queensland inshore gillnet fishery in eastern Gulf of Carpentaria waters.

2. To determine and compare within this timeframe the geographic differences in life cycle details for the species on the major fishing grounds along the Queensland Gulf coast.

3. To develop a protocol for the long-term monitoring of catches and fishing effort for these species on the eastern Gulf coast fishing grounds.

4. To make this information available for consideration in the review of the Queensland Gulf Inshore Fishery Management Plan.

NON TECHNICAL SUMMARY:

The biological and harvest characteristics of the most economically important fish species in Gulf of Carpentaria inshore waters are poorly documented. Along with the barramundi *Lates calcarifer*, these species - the king salmon *Polydactylus sheridani* , the blue salmon *Eleutheronema tetradactylum,* the black jewfish *Protonibea diacanthus*, the jewelfish *Nibea squamosa,* and the golden grunter *Pomadasys kaakan* - have been fished extensively by commercial, recreational and indigenous sectors of the industry.

Evidence from gillnet and line catches in the early 1990s and from commercial logbooks suggested that fishing pressure, especially in southern Gulf fishing grounds, was effecting local stocks of these fish. A review of current fishery management arrangements undertaken for the development of a new Gulf Inshore Fishery Management Plan has highlighted the lack of basic biological information available for the species, the unknown status of the stocks involved, and the urgent need for more detailed catch statistics to define their harvest.

A collaborative research project was developed to address these concerns, involving three agencies from the Queensland Department of Primary Industries Fisheries Group. The primary objectives of the project were to establish a baseline level of knowledge of age, growth and reproduction in the key species from various parts of the Gulf of Carpentaria, and to develop procedures for long-term monitoring of catches and fishing effort for these species

on the fishing grounds. An additional component of the project sought to identify the genetic stock structure of the target species in Queensland Gulf waters.

An improved logbook for collecting an enhanced level of commercial fishery information was developed in association with industry participants, and its introduction to the Gulf Set Net Fishery has been a success. Compliance levels are extremely high (in 1996, circa 90%), with the rate of return greater than that in other Queensland net fisheries. It is likely that a similar logbook scheme will be introduced into the East Coast Set Net Fishery to provide the level of detail on catches and fishing activities required for effective fishery management.

Information on the genetic structure of fish stocks is an important component of successful management strategies to maintain fisheries at sustainable levels. The population structure of key target species in the inshore fishery, as revealed by electrophoretic studies of fish specimens from the various Gulf fishing grounds, suggests that localised stocks exist, with restricted distributions. Additional analyses are required to confirm this biogeography, and to define stock boundaries.

Age and growth determinations of the key Gulf species were undertaken to provide length-at-age information and growth parameters. Golden grunter, black jewfish and jewelfish appear to be long-lived species, while the threadfin salmons, confirmed as protandric hermaphrodites, were represented in net catches by a very few year classes. Complementary assessments of reproduction showed that peak spawning times of the key species occurred during winter or spring months. The Gulf fishing closure period in summer , an intervention that was instituted to protect spawning barramundi stocks, does not provide the same protection for the other highly valued components of the catch. The sizes (and ages) of the Gulf species when they become capable of spawning, as established in this study, gives rise to concern about the biological relevance of present minimum legal size measures in the management of these species.

During the lifetime of the project, results have been drawn upon to assist the Queensland Fisheries Management Authority with the development of a new Fishery Management Plan for the Gulf inshore fishery. The minimum legal size already in place for golden grunter was derived directly from this research. The project's major recommendations include the need for long-term on-going evaluation and monitoring of Gulf fish stock status and condition, and the urgent need for detailed species stock assessments.

KEYWORDS: **Tropical inshore finfish, gillnet fishery, biology, harvest**

TABLE OF CONTENTS

1. GENERAL INTRODUCTION

1.1 BACKGROUND

Queensland's tropical inshore fish stocks support gillnet and line fisheries along the east coast and in the Gulf of Carpentaria. The commercial set net fisheries in the two areas are managed separately by the Queensland Fisheries Management Authority (QFMA), but together involve some 380 licensed operators who produce an annual catch of 1 400 tonnes, worth over $15 million (L Williams pers comm). A growing recreational fishery provides sport and a fresh fish catch each year for an estimated 400,000 participants who come from all around Australia, contributing significantly to local northern economies.

Management interventions in the net fisheries have been oriented towards the barramundi *Lates calcarifer* component of the catch (Healy 1990), and include a cessation of fishing when this species is breeding, various fishing gear restrictions, and limited entry provisions. Management arrangements pertaining to each fishery are detailed in a Fishery Management Plan, and these are reviewed every five years. The QFMA introduced a new East Coast Set Net Fishery Management Plan in 1992; arrangements for the Gulf Fishery are currently under consideration. The reviews have highlighted some fundamental problems in the resource database.

Firstly, little biological information is available for the estuarine finfishes (other than barramundi) that are a major component of catches from tropical Queensland. These include two threadfin species (Polynemidae) several different grunters (genus *Pomadasys*) and a variety of jewfish (Sciaenidae). Formerly discarded, such species have become more economically significant to fishers and are not regarded as bycatch but as significant components of a multi-species fishery (Russell 1988). All of these species are keenly sought by recreational fishers, and are important food items for coastal indigenous communities in Cape York Peninsula.

Despite the high level of fishery interest, life cycle details are almost completely lacking for the non-barramundi catch. Recent research on the king salmon *Polydactylus sheridani* in the Northern Territory (Griffin 1990) has demonstrated that, coincidentally, management measures introduced to sustain barramundi might also be appropriate for this threadfin. For the remaining species, the absence of comparable essential biological information has severely disadvantaged proper consideration for them in the management process.

Secondly, monitoring of commercial barramundi catches in the southern Gulf of Carpentaria revealed that fundamental changes have occurred over a time when overall fishing effort declined markedly (Williams 1992). Other fish families, where sex change is commonly featured in the life cycle, are well represented in the inshore catches (eg. the polynemids *Polydactylus sheridani* and *Eleutheronema tetradactylum*), but their status over time has not been documented.

A number of workers have examined the hermaphroditic reproductive strategy and in particular the impact of exploitation on economically and recreationally important species such as the groupers (Serranidae; Smith 1982). Computer simulation has been used to investigate the potential effect of such reproductive strategies on responses to exploitation of populations (Bannerot 1985). Static and dynamic models predicted maturation at a smaller size (early sex change) as a compensation for exploitation by enhancement of reproductive contact between mates. Likely effects of reproductive strategy and grouper population parameters on predictions used for management advice from standard models (yield-per-recruit and stock production models) were also investigated by comparing these predictions with simulation results. In general, under the conditions examined, predicted equilibrium fishing mortalities exceeded realised optima, and management error from overestimated fishing mortality was non-conservative (type 1) for control of fishing mortality and conservative (type II) for regulation by minimum sizes. This was exacerbated if yield for a given size at first capture was coupled to higher growth rates following sexual transition (sex change). If barramundi and the threadfin salmon populations were to respond in a similar manner to exploitation because of their hermaphroditic reproductive strategy, then these early signals from the southern Gulf might be of vital fishery significance.

Whether similar changes in size, age or sex structure for barramundi or other gillnetted species were occurring elsewhere in Gulf of Carpentaria waters was unknown, as no comparable long-term biological data were available. The introduction of a fishery-wide monitoring program was required to determine trends in resource condition. If the biological evaluations were to be supported by site-specific data on fishing activity, then initial information requirements could be met for establishing sustainable levels of exploitation for key species in the major Gulf fishing grounds.

A clear priority was indicated, then, for prescriptive investigations which would not only react to current fishery concerns, but address future potential problems and provide an informed basis upon which to offer future management advice.

The project team brought together expertise in catch data collection and analysis, age determination and reproductive biology, and population genetics. Communication networks already developed in the Gulf were available to deliver the level of industry involvement required for successful outcomes. While the research study was to be focused on the Gulf fishery, there was a strong expectation that the results would have direct relevance to coastal gillnet fisheries elsewhere in tropical Australia.

1.2 NEED

Achieving responsible and sustainable use of fishery resources requires the integration of several elements: detailed biological information and harvest statistics; an understanding of the dynamics of the resource in relation to fishing pressure and other impacts; and an ongoing evaluation of resource status and condition.

The project detailed in this report responded to the concerns of resource managers and resource users, by providing basic biological information and complementary fishery catch statistics for key Gulf inshore fish species in a time-line set by the Queensland Fisheries Management Authority's Fishery Management Plan review agenda. Existing management measures for the inshore fishery have been predicated only on what was considered appropriate for barramundi (eg. Glaister *et al.* 1988). However, sustainable use of the resource demands that due consideration is given to the other target species as well as the interactions caused through seasonality, changing target catch mix, and gear selectivity. Provision of biological and fishery descriptors for the resource is the essential first step in this more comprehensive and analytical approach to managing the multi-species Gulf inshore fishery.

1.3 OBJECTIVES

The aim of the project was to establish essential biological and harvest information which would facilitate the management of Queensland Gulf of Carpentaria inshore fish stocks. The project concentrated on five tropical fish species which, after barramundi, are the most important components of the Gulf inshore net and line fisheries.

The project proposal submitted to the Fisheries Research and Development Corporation sought funding from the Queensland Trust Account for a five year period. Subsequently, the Corporation approved funds from the General Account for a two year period only (from May 1993 to June 1995). Project objectives were revised to meet this altered timeframe, and emphasised establishing baseline biology of major target species and developing systems for monitoring fishery performance and resource status. After June 1995, longer-term fishery impacts on the target species mix could be assessed in a subsequent exercise, subject to FRDC support.

Revised objectives for the initial phase of project operations as approved by the Corporation in February 1993, were set out in the project documentation as follows:

1. To undertake over a two year period an investigation of age, sexuality, reproduction, stock structure, and seasonal abundance of key target species - threadfin salmon (*Polydactylus sheridani* and *Eleutheronema tetradactylum*), grunter (*Pomadasys kaakan*), and jewfish (*Nibea squamosa* and *Protonibea diacanthus*) - from the Queensland inshore gillnet fishery in eastern Gulf of Carpentaria waters.

2. To determine and compare within this timeframe the geographic differences in life cycle details for the species on the major fishing grounds along the Queensland Gulf coast.

3. To develop a protocol for the long-term monitoring of catches and fishing effort for these species on the eastern Gulf coast fishing grounds.

4. To make this information available for consideration in the review of the current Gulf fishery Management Plan.

Financial support from FRDC for Project 92/145 ceased on 30 June 1995. Funds were allocated by the Queensland Fisheries Management Authority for the twelve month period July 1995-June 1996, to maintain data outputs from the Gulf fishery monitoring programs and to continue technical inputs from core project staff to the Authority's deliberations on Gulf inshore fishery management issues.

1.4 RESEARCH RESPONSIBILITIES

Three laboratories from the Queensland Department of Primary Industries, Fisheries and Forestry (QDPI) were involved in this collaborative project. While all these agencies were geographically remote from the Gulf of Carpentaria, their recent history of involvement in particular aspects of tropical fish research, different skills bases, and logistic considerations determined the responsibilities given to each agency in the project. An outline of the project responsibilities and associated lead investigators is given in Table 1.1.

Table 1.1 Division of project responsibilities between QDPI agencies.

Research Task	Centre	Investigator
Catch statistics	Resource Condition and Trend Unit, Brisbane	Mr L E Williams
Industry liaison	Northern Fisheries Centre, Cairns	Mr R N Garrett
Fish sample collection and processing	Northern Fisheries Centre, Cairns	Mr J M Bibby
Fish age and growth analysis	Northern Fisheries Centre, Cairns	Mr J M Bibby (assisted by Mr G R McPherson)
Fish reproductive analyses	Northern Fisheries Centre, Cairns	Mr G R McPherson
Fish stock genetics	Southern Fisheries Centre, Brisbane	Dr C P Keenan

The various project elements are presented in this document as sectional reports from the relevant task leader. The Principal Investigator, Mr R N Garrett of Northern Fisheries Centre, Cairns undertook the duties of general project co-ordination.

2. GULF SET NET FISHERY - MONITORING AND ASSESSMENT

(Contributed by Mr. L.E. Williams, Resource Condition and Trend Unit, Fisheries Group, GPO Box 2454, Brisbane QLD 4001)

2.1 INTRODUCTION

Operators in the Gulf Set Net Fishery (also known as the Gulf of Carpentaria Barramundi Fishery) have provided information about their fish catches and fishing operations through logbook programs since 1981. Logbooks were introduced to this fishery when the Queensland Government approved the introduction of formal management arrangements in 1980 (Quinn 1984). Until the late 1980's the logbooks were known as production returns, and were used for entitlement retention by individual operators based on satisfying a minimum catch quota and minimum effort applied to this fishery. The suite of logbook records from 1981 to 1996 are the longest continuously running data set for any Queensland commercial fishery. The logbook program has been regularly updated since inception, with each change striving for greater refinement in the data being collected. These updates have stemmed from the need for increasingly detailed analyses for fisheries management.

Perhaps the most significant change to the program has been the method used to register logbook returns. In 1989, with the introduction of the Queensland Commercial Fisheries Information System (CFISH) logbook, registration changed to recording the activities of boats operating in the fishery from the earlier system where operators (master fishers) reported fishing activity. In addition, the method of recording the days fished changed. Under the 1981-1988 logbook system, operators reported monthly fishing activity, for example, as the number of days fished each month. With the CFISH introduction (Anon 1989), boat owners were required to record the days when fishing activity occurred. In practice, fishers recorded the days when fish were caught. From 1992, boat operators were required to record activity for each and every day indicating whether fishing or other activities occurred. This approach was taken by the CFISH manager to ensure greater accuracy in recording fishing effort.

Four large location grids were defined (Quinn 1987) for the Queensland Gulf of Carpentaria coastline in the 1981 logbook (see Figure 2.7). In 1985 the Gulf was classified into 10 smaller grids and from 1989, 30 nautical mile grids were introduced to the Gulf as part of CFISH. Then, in 1992, six nautical mile grids as a subset of the CFISH grids were introduced. Fishers also have the facility to record latitude and longitude of their daily fishing position.

As a condition of licence, Gulf fishers must forward their logsheets each month to the Queensland Fisheries Management Authority (QFMA) in Brisbane, where the data are entered into the CFISH database. Lag between receipt by the QFMA and entry into the database is minimal, with most data entered within one month of receipt. Data entered includes fishing location, catch weight by species and the gear used, all by date. Routine range checks are applied at entry with the data entry operators instructed to advise the logbook coordinator of any "strange" information on the logsheet. The logbook coordinator contacts the fisher for clarification about these queries.

CFISH is the primary source of information about the Gulf Set Net Fishery. As such, considerable emphasis is placed on information being returned to the commercial fishers who operate in the fishery. The feedback has three positive influences on the logbook program:

fishers are kept informed about the state of the Gulf fishery; it encourages timely provision of completed logbook returns; and it reinforces the need to provide accurate information for managing the fishery.

In order to gather additional information about this complex fishery for the harvesters and managers, a "research" logbook was introduced into the fishery in 1994. This logbook allowed fishers to record voluntarily the number of fish caught as well as the usual logbook information about location, catch, gear used, and other effort measures. The format was altered to seek greater precision in the data collected. The logbook features were designed with the assistance of the Gulf fishers, and a draft form was tested by selected volunteers in the latter part of 1993. Following some revision to the draft document, the "research" logbook was formally introduced to the Gulf fishery for the 1994 fishing year.

2.2 SPECIFIC OBJECTIVES

The overall aim of this Section of the project was to develop a monitoring and reporting system that would provide an enhanced level of information for the development of sensible management plans for the Gulf fishery, and that would achieve a high level of compliance amongst the Gulf fishers.

There were three objectives for this initiative:

1. To profile the commercial fishery in terms of total catch, the catch of keynote species, effort, number of participants, gear used and species composition of the catch;
2. To develop and introduce a new fisher-friendly logbook for Gulf operators that was easy to use and maximised detailed catch and effort recording for fishery status assessment;
3. To provide enhanced resource condition and trend information to industry and fishery managers.

Routine commercial fisher data collection in Queensland does not document the number or size of fish being harvested. The implementation of this element within CFISH provides significant additional information for fishery participants in understanding the dynamics of the fishery, and also paves the way for stock assessments of keynote species.

The fish species addressed in this report were put forward in consultation with industry, being those inshore species on which fishers planned to concentrate their effort (in addition to barramundi). It is acknowledged that since the project was undertaken, sharks (Carcharhinidae) and mackerels (Scombridae) have become a commercial focus, especially for a developing fishery in more offshore Gulf waters. Information is lacking about the relative abundance of the inshore and offshore stocks that are being exploited in the Gulf net fishery.

Future fishery monitoring exercises that make use of the baselines established in this project can help ensure that Gulf Fishery Management Plans meet their goals for sustainable resource use and industry viability.

2.3 MATERIALS AND METHODS

2.3.1 Establishing and implementing the "research" logbook

Analysis of the logbook information collected from 1981 to 1992 (Williams 1992) demonstrated the urgent need for improvements in the detail and clarity of the information from the Gulf fishers beyond that provided through CFISH. Development of the "research" logbook specifically for the Gulf allowed for the inclusion of greater detail about the species targeted and where nets were set. Provision was made on the logsheet for recording the number of fish caught so mean daily fish sizes could be estimated using catch weight and catch numbers. As well, keynote species for the Gulf were identified and provision made for fishers to record catch data for each of these species.

A copy of the CFISH "Net and Crab" logsheet that was used in the Gulf Fishery until 1993 appears in the Attachments (see Section 2.6), as well as of copy the new logbook sheet developed in this project.

After preliminary design of the new logsheet, comments and suggestions for improvement were sought from the users of the sheets. Three groups consulted in the matter were:

1. Eight volunteers in the Gulf fishery trialed the logbook during September and October of the 1993 fishing year. These volunteers were fishers who submitted logsheets regularly and were chosen with advice and help from the executive of the Karumba Branch of the Queensland Commercial Fishermen's Organisation (QCFO)
2. CFISH manager, QFMA
3. Data entry operators at QFMA.

Only slight modifications were needed to the draft logsheet design after an extensive review of its performance with the volunteer fishers and the QFMA data entry operators. Concurrently, the CFISH manager organised the programming and testing for a new data entry screen in CFISH so that the full suite of information collected could be entered into the CFISH database.

At the start of the 1994 Gulf of Carpentaria fishing year, each of the Gulf fishery endorsement holders were issued with the "research" logbook, together with supporting letters from QFMA and QDPI. Members of the Karumba QCFO Branch Executive urged their membership to use the new format.

2.3.2 Data extraction and conditioning procedures

Data are extracted from the CFISH database using standardised SQL scripts. Unidentified daily fisher records are extracted.. The file extracted is conditioned with ACCESS scripts so that integration with the Gulf data sets from 1981 to 1988 is easily achieved.

CFISH holds data from 1989 onwards for the Gulf Set Net Fishery. The fishery information from the years prior to 1989 is held on a separate PARADOX database. The results from the two data sets are integrated through packages such as EXCEL. There are several constraints that apply to using the integrated data sets which are an artefact of the changes in details collected since the logbook program commenced.

Firstly, the four Gulf grid arrangement introduced in 1981 is the base used for most of the general analyses undertaken so that the longest time series are possible in any analysis. More detailed analyses are carried out on the data recorded since 1989 using the 30 nautical mile CFISH grids.

Secondly, only vessels that land barramundi are included in analyses. Before 1992, the logbook program clearly identified whether boats operating in the Gulf were Set Net Fishery operators or not. These Set Net Fishery boats primarily targeted barramundi. Other species were caught as incidental catch to barramundi fishing, although some might be targeted at particular times of the year. From 1992, confidentiality provisions applying to the logbook program and the ownership of fishery endorsements prevented clear identification of barramundi fishers. Consequently, in the analysis of logbook returns from the Set Net Fishery, only boats that have reported landing barramundi from 1989 onwards are included. Four boats fished in the Gulf for species other than barramundi, and were excluded from the present analysis of the Gulf Set Net Fishery .

Thirdly, the 1981-1988 data set recorded effort as the number of days in the month when fishing occurred, irrespective of the species caught. From 1989 onwards, the information provided directly by CFISH reports the days fished per boat by species. Consequently, manipulation of the CFISH data must be carried out to make data from the various data sets compatible.

When undertaking specific species analysis using the 1981-1995 data set, the constraints for the 1981-1988 data need to be considered, that is, catch rate by species is monthly data for fishing effort, irrespective of whether that species is caught on every fishing day or not. Because barramundi is the species of major focus in this fishery, it seems reasonable to assume that it would be generally targeted. With species of lower market interest, caution is required with the interpretation of the effort measures and catch rates.

The CFISH information allows computation of species-specific catch rates which reflect the daily catch for the species of interest. If the species of interest is taken as incidental catch to, for example, barramundi, the effort expended in doing so should be calculated from the total days fished by the boat as well as from the number of days on which the species was caught compared to the main target species.

2.3.3 Reporting to fishers and managers

A key feature of the Gulf logbook system is the reporting process in place to convey information to the fishers in the Gulf of Carpentaria. The Karumba Branch of the QCFO holds two key meetings each year, the Mid Year Meeting in July and the Annual General Meeting in November. Generally, both written and verbal reports about performance and status of the Gulf Set Net Fishery are presented at these meetings by QDPI and QFMA officers.

The briefing reports aggregated data on Gulf fishery activity and harvest as well as catch rate trends for major target species on the fishing grounds. Often, vigorous debates occur about the results presented at the meeting and the interpretations placed on the information. A most important concept emphasised at the meetings is that the information being presented is the fishers' data analysed so that they can view what is happening in their fishery. This notion has two important effects. Firstly, fishers are made very aware that their data are being analysed and, secondly, the fishers are encouraged to provide their data on a regular basis and as precisely and accurately as is reasonably possible.

The QFMA fishery manager for the Gulf Set Net Fishery attends these meetings. The manager commissions separate analyses and briefings on specific topics as required.

2.3.4 Accounting for target fishing in fishery logbook analyses

Discussion with operators in the fishery suggests that fishers focus their activities where experience and/or conditions give a high probability of catch. This implies that in a specific location, certain gears are deployed to catch the expected species in that location. It is a mute point whether or not the fishers are targeting a given area or a certain species. There is a need to evaluate critically measures of catch and effort in consideration of stock abundance from logbook data. This issue in the Gulf fishery is currently being addressed by personnel engaged in FRDC Project 95/049: "Tropical Resources Assessment Program".

Defining fishery effort in a mixed species fishery does present problems (and opportunities). Information collected through the Gulf logbook program must be seen as being "census" data, and that appeared to be the most suitable approach for this project. Two methods were employed in defining fishery effort in the Gulf inshore set fishery. Firstly, effort as days fished per boat was used for the complete data collection period from 1981. Then from 1989 onwards it was possible to report on the number of days on which a particular species was landed, as well as the days fished per boat. Future analyses of the Gulf fishery data set will incorporate both approaches.

2.4 RESULTS

2.4.1 Overview of Gulf Set Net Fishery

2.4.1.1 Whole of Gulf Fishery

Total annual catches of all species declined from about 1,600 tonnes (t) whole weight in 1981 to about 900t in 1995, as shown in Figure 2.1. There are two phases to this decline. From 1981 to 1985, annual catch was about 1500t, then it declined to about 900t in 1989 and apart from inter-year variability has remained at about this level ever since. The 1995 total catch was about 42% of the 1981 total catch.

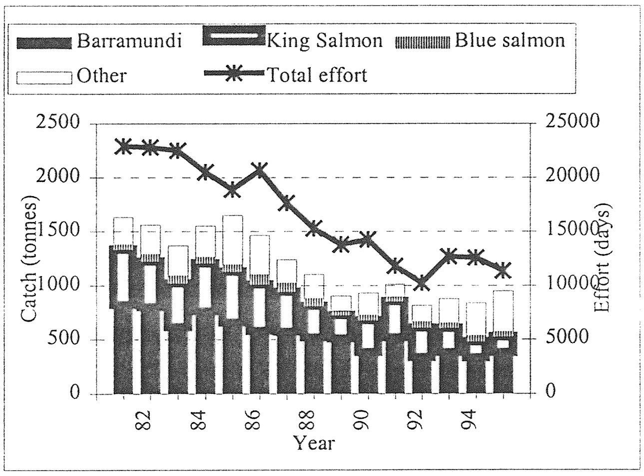


Figure 2.1 **Total catch and effort for the Gulf Set Net Fishery**

The highest barramundi catch recorded was in 1981 at about 820t. The catch then declined to about 500t in 1988, and since then has been about 350t per year. Over the same period, the king salmon catch fell from about 500t in 1981 to about 300t in 1991 and then further declined to about 220t per year. Blue salmon catch was lowest in 1981 with 46t, peaked at about 90t in 1987 and has been maintained thereafter at about 55t per year.

Barramundi typically account for about 46% of the total yearly catch, king salmon 28%, blue salmon 5% and a variety of other species 21%. There is substantial variation in the percentage contribution between years as can be inferred from Figure 2.1.

Figure 2.1 also shows the yearly effort as total days fished. Total effort declined from about 23,000 days in 1981 to about 12,000 days of fishing effort in 1995, a reduction of 45%.

The "other" species referred to in Figure 2.1 include shark, Spanish mackerel, grey mackerel, jewelfish, grunter, jewfish, and mud crabs. Figure 2.2 shows the differences in the catch of the main "other" species for 1989 and 1995.

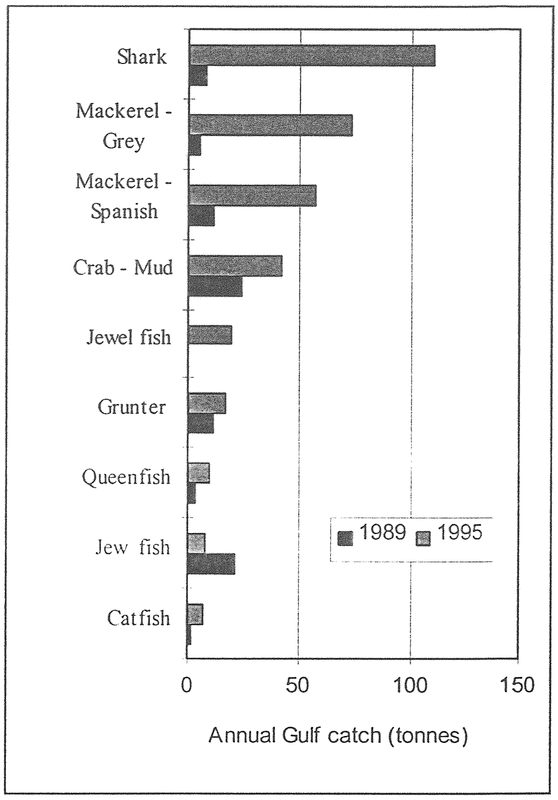


Figure 2.2 Changes in catch of "other" species from 1989 to 1995

Dramatic increases in harvest of shark and grey mackerel of around 1000% have occurred from 1989 to 1995, while Spanish mackerel, queenfish and catfish harvest increased by about 300%. Jewelfish was not reported in harvests in 1989, although it is possible this species was included in the jewfish category. Grunter and mud crab harvest doubled during this period. Only the catch of jewfish appears to have declined between 1989 and 1995.

Mean daily catch rate of all Gulf species caught was about 70 kg per day for the boats that landed barramundi, as is shown in Figure 2.3. The plot of catch per fishing day for all species for the Gulf Set Net Fishery shows no significant upward or downward trend over the 15 year period. However, there is considerable inter-year variation around the trend line.

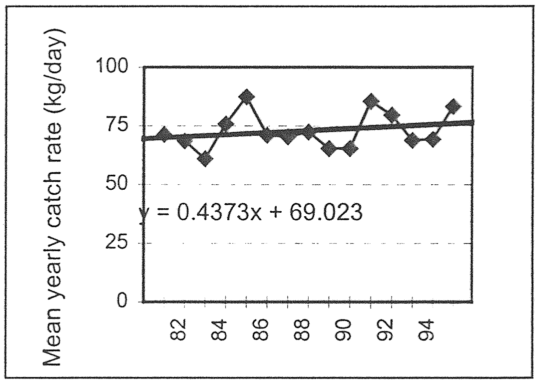


Figure 2.3 Trends in catch rate for all species combined

The number of fishers operating in the fishery has declined since 1981. A maximum of 172 fishers operated in the Gulf in 1982, which fell to 109 operators in 1988. The method of logbook recording then changed emphasis to boats operating in the fishery. In 1989 there were 98 boats sending logbook returns which reduced to 89 boats in 1995.

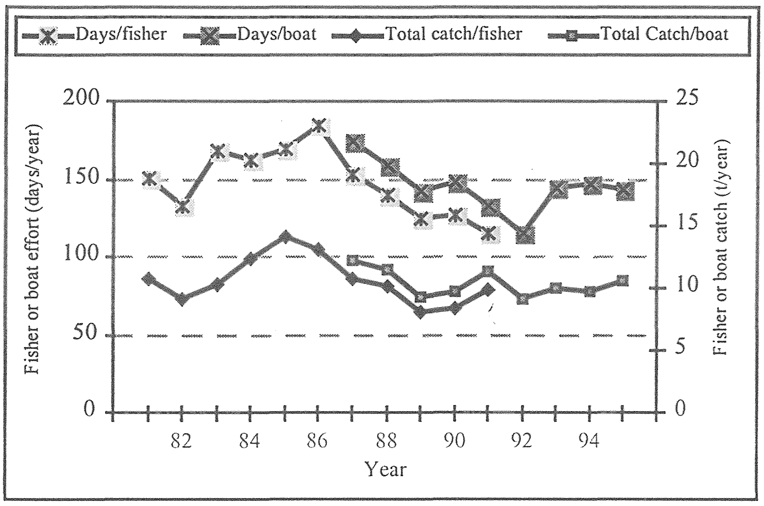


Figure 2.4 Trends in catch and effort per boat

In Figure 2.4, total fishing effort and catch per operator and per boat are shown. These rates illustrate the performance of boats in the fishery. From 1987 to 1991, both catch per operator and catch per boat values are shown because of the differing method of recording the primary fishing unit. Estimates of the number of operators in 1989-1991 were based on the ratio of the number of boats operating and the number of operators in the fishery in 1987 and 1988.

Average yearly total catch (whole weight) per operator or per boat was highest in 1985, at almost 14t. Catch per boat per year has averaged between 9t to 11t in the last few years.

In 1981 an average of about 150 days were fished per year per operator, while in the early 1990's about 120 days were fished per year. The most active year was 1986 with about 180 days fished per operator. The mean number of days fished per boat per year represents on average, about 60% of total fishing time available in each fishing year.

There is a very strong correlation between total catch and total days fished in the Gulf as is shown in the regression equation

*Total catch (kg) = 65.97 * Days Fished + 95564*,

with an r^2 of 0.85. The slope of the regression is highly significant ($P \leq 0.001$). Data used for the regression were the yearly means. This equation allows prediction of likely catch for a given level of effort with a high degree of confidence.

Distribution of total catch by boats operating in the fishery in 1995 is shown in Figure 2.5. This year represents the most recent completed year of fishing information and the distribution is somewhat similar to that for the last four years. Catch categories, apart from the 0.5t group, which has a range from more than zero to less than one tonne, are the weight categories shown plus or minus one tonne.

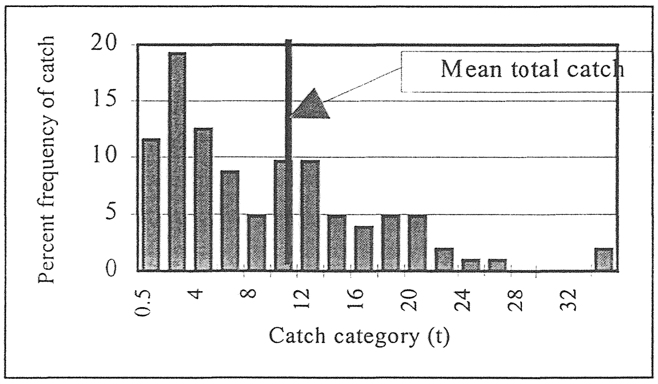


Figure 2.5 Distribution of boat total catch in 1995

In 1995, 89 boats reported operating in the fishery. About 50% of the boats landed 9t or less, compared with the mean catch of about 11t per boat. Modal catch is within the 14t to 16t catch range, with about 13% of the boats in this group.

Distribution of total effort by boat for various categories of boats operating in the fishery in 1995 is shown in Figure 2.6. Effort categories, apart from the 5 days fished group, which has a range from more than zero to less than 10 days, are the days fished categories shown plus or minus 10 days.

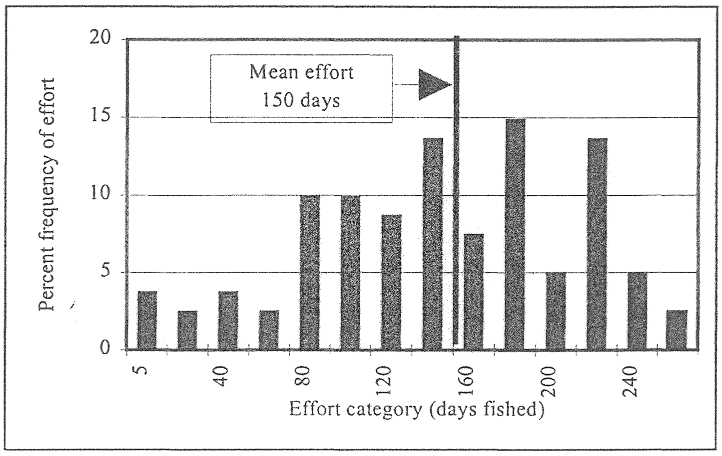


Figure 2.6 Distribution of boat effort in 1995

Three levels of effort dominated fishing in 1995, namely 140, 180 and 220 fishing days, each of which accounted for 14% of the total fleet effort. Most boats fished between 80 to 220 days in the 1995 fishing year, for a mean effort of about 150 days per boat.

2.4.1.2 Gulf regional fisheries

Four grids are used to describe regional performance within the Gulf Set Net Fishery (see Figure 2.7).

Grid A covers the northern part of the Gulf on the western side of Cape York Peninsula. The grid essentially extends from Cape York (10°30'S) south to Pera Head (13°S). It is fished mainly by boats operating out of Weipa. About 20% of the Gulf Set Net fishery fleet use these waters.

Most Grid B boats use Karumba as their home port. The coastline in this grid extends south from Pera Head (13°S) to about the Nassau River (16°S). There are substantial coastal holdings held by Aboriginal communities in this area with some rivers closed to net fishing. About half the Gulf fleet fishes in this area.

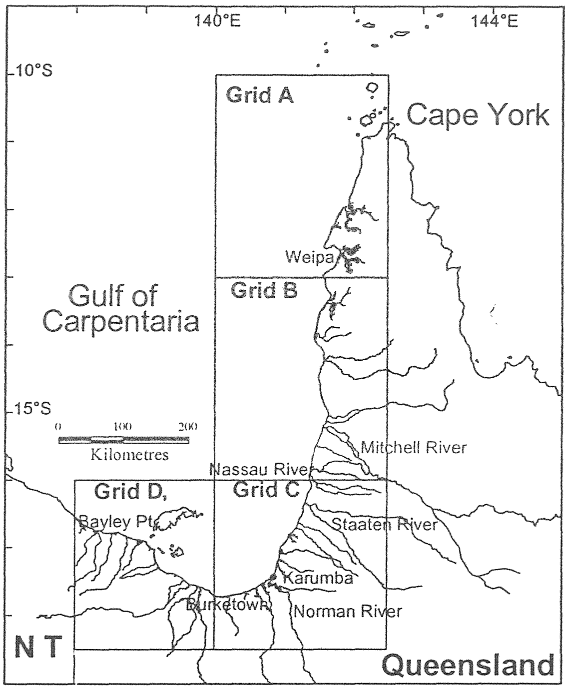


Figure 2.7 Map of Gulf of Carpentaria showing the four fishing grids.

Grid C covers the south-eastern corner of the Gulf, and extends from the Nassau River (16°S) south and west to a point near Burketown (140°E, 17.40°S). Sixty percent of the fleet fish these waters. The main fishing port is Karumba.

Grid D is in the south-western corner of the Gulf and abuts the Queensland-Northern Territory border and is south of Mornington Island. It is arguably the most remote area fishery in the Gulf and about 20% of the fleet fishes these waters.

While Grid B and Grid C are the Gulf areas where most fishing activity occurs, there is considerable movement of vessels between grids throughout the fishing year.

The relative contribution from each grid to the total Gulf catch is shown in Figure 2.8. From 1981 to 1995, Grid C provided about 46% of the total annual catch while Grid B provided about 34%. Grids A and D together produced about 20% of the total catch. Consequently, most of the analyses in this section will concentrate on catches from Grids B and C.

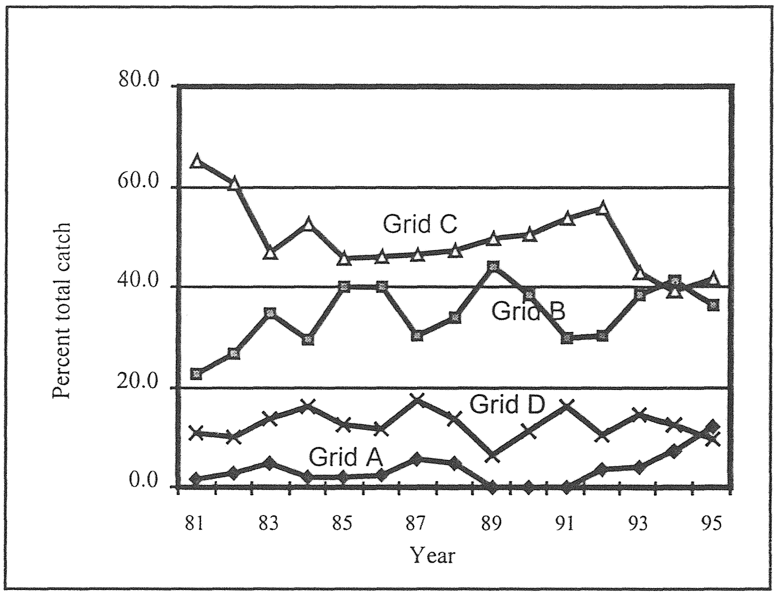


Figure 2.8 Proportion of total catch by Gulf Grid

Grid C's contribution to total Gulf landings has declined from about 60% in the early 1980's to around 40% in the 1990's. At the same time, Grid B as a proportion of total catch increased from about 25% to about 40%.

There is a very strong correlation between fishing effort for a fishing year (expressed as Days Fished (DF)) and total catch for the same year (expressed as kg per grid) for both Grids B and C as shown in Table 2.1. The slope in both regressions (DF) is highly significant. The regression for Grid C has a better predictor of total catch than has Grid B.

Table 2.1 **Grid catch and effort estimators**

Item	Regression	R Square	P value
Grid B	61.96*DF + 70043	0.6	1.10E-03
Grid C	66.32*DF + 19120	0.9	1.77E-07

As shown in Figure 2.9, total catch for Grid B for all species was about 370t in 1981, peaked at about 650t in 1985 then gradually declined to about 330t in 1995 .

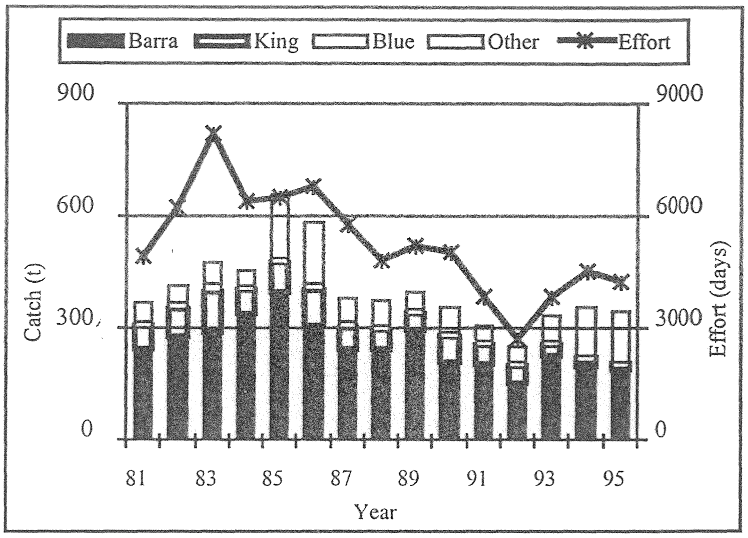


Figure 2.9 Total catch and effort for Grid B

From 1981 to 1991, annual barramundi catch of about 220t averaged almost two thirds (64%) of the total yearly catch in Grid B compared with a mean Gulf value of 47%. King salmon catch from Grid B averaged about 15% of total Grid annual catch (about 68t/year) while blue salmon catch averaged about 3% (about 14t/year).

Grid B effort in 1981 and for each year from 1989-1995 was about 5,000 fishing days per year. Highest effort occurred in 1983 with about 8,000 days of fishing. Mean yearly catch rate for Grid B for the entire period was 77 kg/day with considerable inter-year variation (58 to 101 kg/day/year).

Figure 2.10 shows the results for Grid C. Total annual catch for all species declined by almost half, from about 1,000t in 1981 to 550t in 1995.

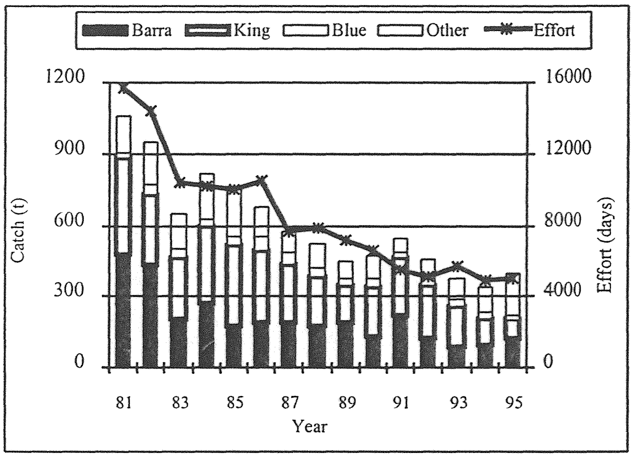


Figure 2.10 Total catch and effort for Grid C

During the 15 years, barramundi comprised about 36% of total yearly landings of all species from Grid C. This is lower than the mean of 47% for the whole Gulf. In Grid C, king salmon averaged almost 40% of the total catch compared to the Gulf average of 28%. Blue salmon provided about 5% of the total catch in Grid C.

During this time, Grid C effort as days fished per year fell from almost 16,000 days in 1981 to 5,000 days in 1995, a drop of almost 66%. The mean catch per day per year for Grid C was 73 kg/day, with considerable inter-year variation (62 to 99 kg/day/year)

2.4.2 Species Harvest Profiles in the Gulf Set Net Fishery

2.4.2.1 Barramundi (Lates calcarifer)

The Gulf Set Net Fishery places great emphasis on the barramundi component of net catches as this species draws highest market price.

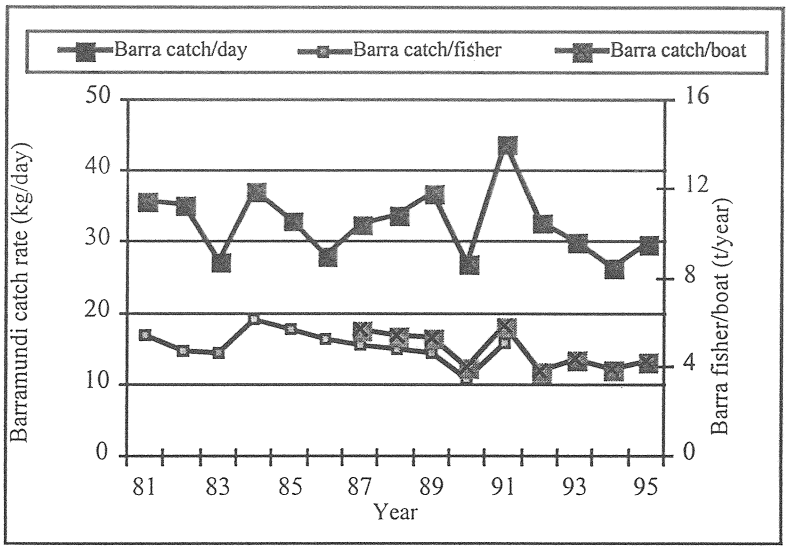


Figure 2.11 Barramundi catch rates for the Gulf

In Figure 2.11, two measures of catch per unit of effort (CPUE) are used to examine barramundi catch throughout the Gulf. Catch per day is the total catch made by all operators for a year divided by the total days fished by these operators in that year. Catch per operator per year or catch per boat per year shows the average barramundi catch as tonnes per year for each operator in the fishery.

The mean catch rate for barramundi caught from 1981 to 1995 was about 33 kg/day, with no significant upward or downward trend over time. Catch of barramundi per operator or boat per year varied between 4.5 and 6 t/year, with a slight downward trend in barramundi landings per boat of about 250 kg per year from 1984 until 1992 when mean boat landings were about four tonne.

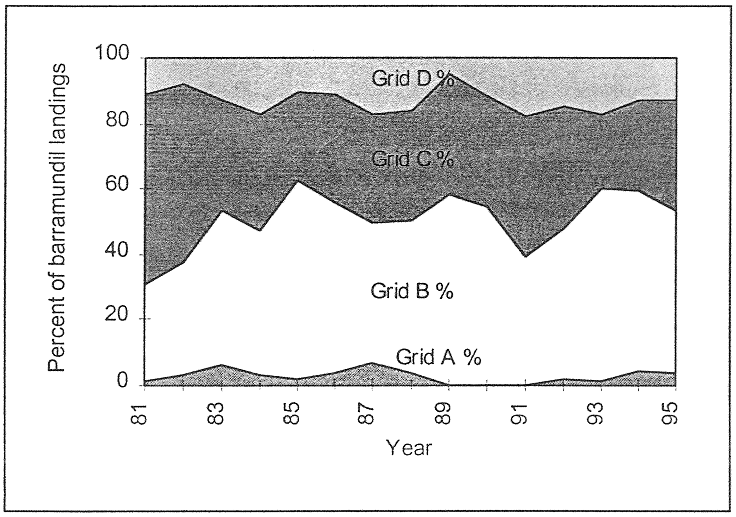


Figure 2.12 Proportion of barramundi landings per Gulf grid

The importance of each grid as a production area for barramundi is not uniform. Figure 2.12 shows the percentage contribution made by each grid to the total barramundi production from the Gulf. The annual mean percentage contribution from Grid A is 3%, Grid B is 46%, Grid C is 38%, and Grid D is 13%.

Grids B and C make the greatest contribution to the Gulf barramundi catch. The lowest contribution was about 28% in any one year and the greatest contribution was almost 60% from one of these grids in any year. From 1983 onwards, Grid C has consistently produced one third (33%) of the Gulf barramundi production, and Grid B has produced about 45%. In 1981 and 1982, Grid C produced more than half of the Gulf barramundi catch.

Figure 2.13 shows the mean daily barramundi catch (kg/day) of operators each year by selected Gulf Grids. Mean catch rate for the whole of the Gulf for the 15 year period was 35 kg/day. The overall annual barramundi catch rate was lowest in 1983 and 1986 at about 28 kg/day, and continues to vary markedly year by year.

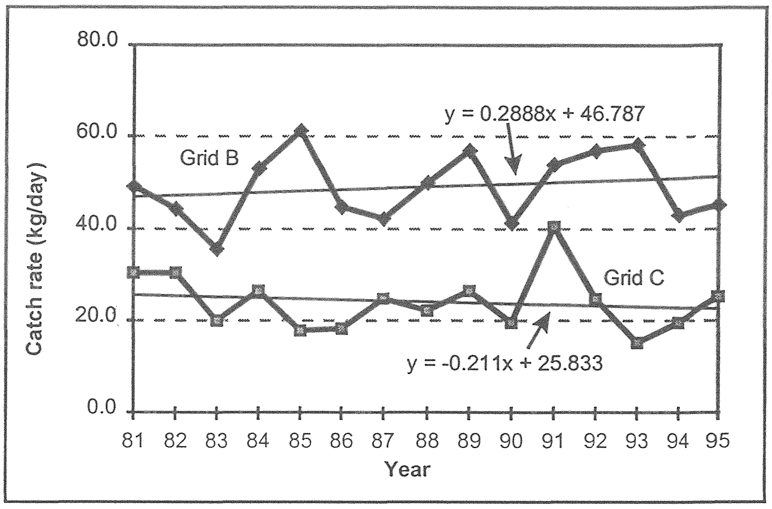


Figure 2.13 Barramundi catch rate trends for some Gulf grids

Grid B daily barramundi catch rate varied from 68 kg/day in 1989 to a low of 36 kg/day in 1983. Grid C highest catch rate was in 1991 at 40 kg/day, and the lowest annual catch rate was 15 kg/day in 1993.

2.4.2.2 King Salmon (Polydactylus sheridani)

The Gulf of Carpentaria king salmon fishery in mainly concentrated in the southern areas of the Gulf. Annual production has declined dramatically, as illustrated in Figure 2.14, from about 500t in 1981 to about 100t in 1995, a drop of 80%.

Grid C dominates king salmon production with about 70% of Gulf landings, while Grid B produces about 18% of the annual catch. The catch in Grid A averages about 1.5% of total Gulf king salmon catch, while Grid D contributes about 9% of Gulf king salmon landings.

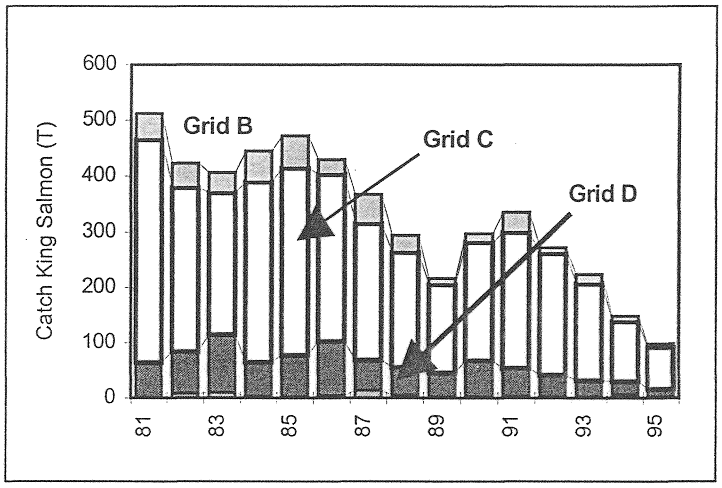


Figure 2.14 Catch of King Salmon by Grid

From 1981 to 1995, total effort as days fished had almost halved in the Gulf, from 22,000 fishing days in 1981 to about 11,000 fishing days in 1995. By 1995, Grid C total fishing effort had halved compared to the 10,000 fishing days in 1981. This effort measure incorporates the total days fished by all boats during the year, whether or not king salmon was landed. The effort in 1995 was 70% of the effort in 1989 using this measure.

When days on which this species were landed is used as an effort measure as derived from CFISH, effort has declined from about 4,500 days in Grid C in 1989 to about 2,700 days in 1995, about 60% of the 1989 value.

King salmon catch rate information for Grid B and Grid C is shown in Figure 2.15. Two catch rates are shown for Grid C: catch rate C_1 is calculated as king salmon catch divided by total days fished whilst catch rate C_2 is the catch rate for the days on which the product was landed.

Year-by-year variation shows a peak catch rate in Grid C in 1991 and 1992 with a return to lower catch rates from 1993. Grid B catch rate is about half of the Grid C catch rate.

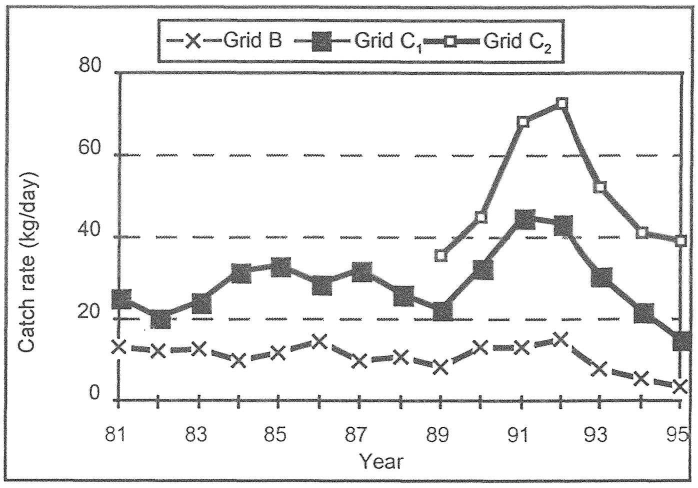


Figure 2.15 King Salmon catch rates in Grids B and C

2.4.2.3 *Blue Salmon (Eleutheronema tetradactylum)*

The blue salmon fishery is also concentrated in the southern part of the Gulf of Carpentaria. Total mean catch over the 15 years has been about 60 tonne each year, and as such is an important but incidental component of the Gulf fishery complex. Since 1989 blue salmon catch has declined to about 50t per year as is shown in Figure 2.16. As with king salmon, the catch in 1995 was low compared with other years in the data set.

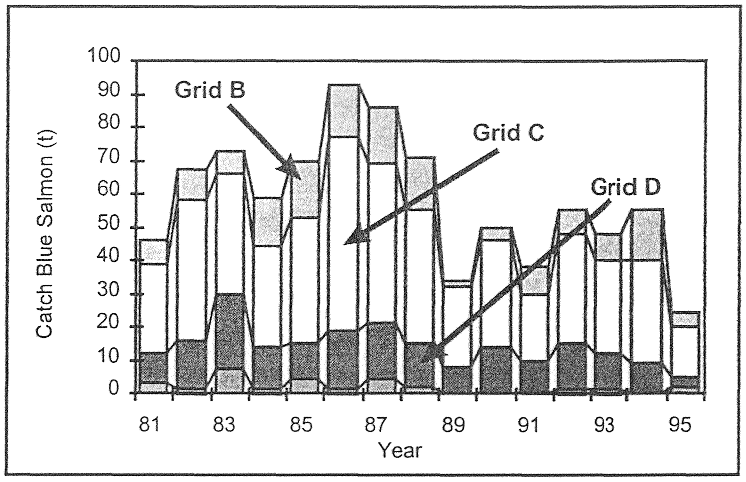


Figure 2.16 Blue salmon catch by grid

Grid A produces only a small proportion (3%) of the Gulf blue salmon catch, Grid C typically produces about 60%, and Grids B and D each produce about 18% of the annual landings.

Catch rates for Grids B, C and D for blue salmon are shown in Figure 2.17. These catch rates are based on when the total days fished is used as the effort measure. Grid B and C catch rates follow a similar pattern for the same years, although Grid C catch rate (4.5 kg/day) is generally about twice that of Grid B (2.5 kg/day). Grid D catch rate is extremely variable between years and exhibits two distinct peaks in 1988 and 1994. These peaks are followed by a dramatic decline in catch rate the next year.

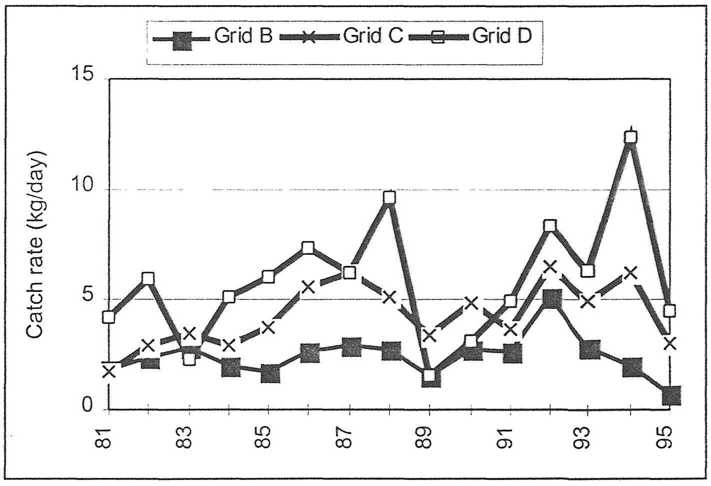


Figure 2.17 Blue Salmon catch rates for Gulf Grids B, C and D

2.4.2.4 Jewelfish (Nibea squamosa)

Reporting of jewelfish catch as a separate entity by CFISH commenced in 1991. The annual catch was about 20t in 1993 and has remained around that level ever since. Fisher reports suggest that this species may have been marketed in the mixed fish or jewfish categories prior to 1992.

Most jewelfish catch is reported from the southern part of the Gulf especially Grid C, as can be seen in Figure 2.18. Grid C, with about 5000 total fishing days for each of the last four years, reported jewelfish landings on about 20% of the days on which fishing occurred.

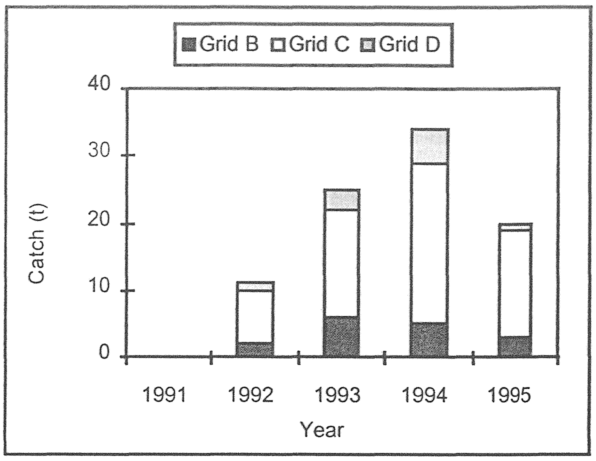


Figure 2.18 Jewel catch for Gulf Grids

Mean yearly catch rate for jewelfish is shown in Figure 2.19 for Grids B, C and D. The catch rates shown are those for when the fish were caught, rather than against the total days fished. Mean annual catch rate for the days on which the fish were landed is about 25 kg.

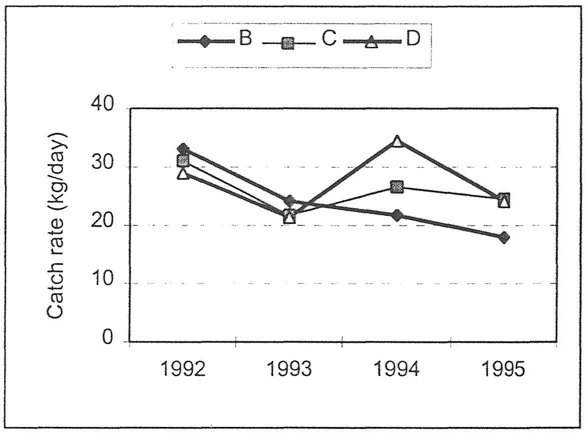


Figure 2.19 Jewel catch rate for Gulf Grids

2.4.2.5 Grunter (Pomadasys kaakan)

The Grunter fishery is mainly concentrated in the southern part of the Gulf as is shown in Figure 2.20. The proportions of total catch from Grids B and C are relatively similar over time, with Grid B catch about two thirds of Grid C catch. Annual catch is quite variable ranging from 7t to 18t and is less than 3% of the total Gulf set net fishery landings.

As with jewelfish and jewfish, grunter tends to be taken as incidental catch

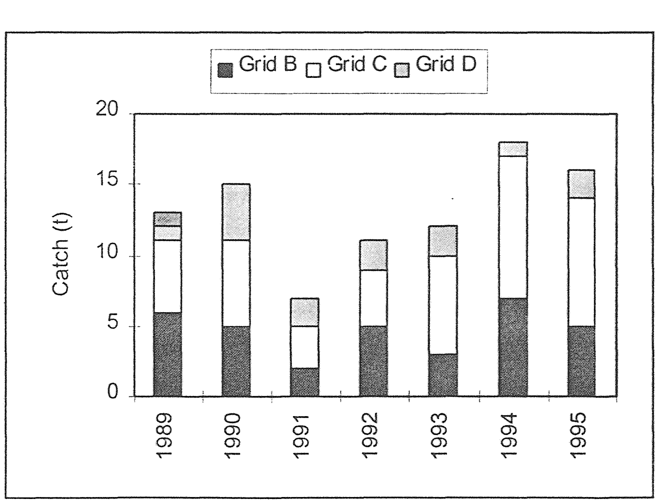


Figure 2.20 Grunter catch for Gulf grids

when other species such as barramundi or king salmon are targeted.

Catch rate for grunter is calculated using the days on which the fish were caught as the effort measure. Catch rate between grids (Figure 2.21) follows a relatively similar pattern apart from Grid D, which showed very low catch rates for 1994. Mean annual catch rate on the days on which the fish were landed is about 15 kg.

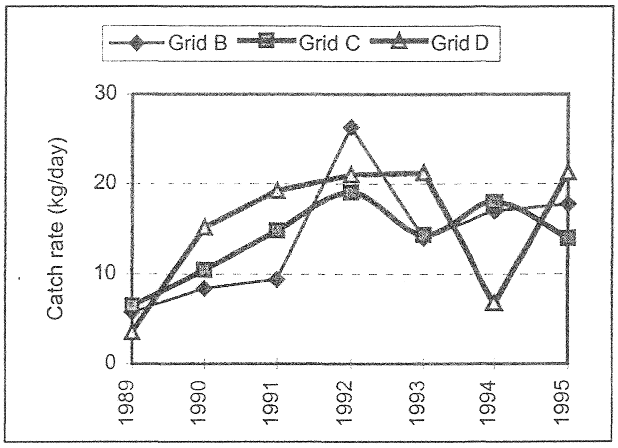


Figure 2.21 Grunter catch rate by Gulf Grid

2.4.2.6 Jewfish (Protonibea diacanthus)

Jewfish are also kept as incidental catch to the major species harvested. Grid C is the major producer of jewfish for the seven year data series derived from CFISH.

There has been a dramatic decline in jewfish catch from 37t in 1990 to about 6t in 1994 (Figure 2.22). The reason for this decline is not clear.

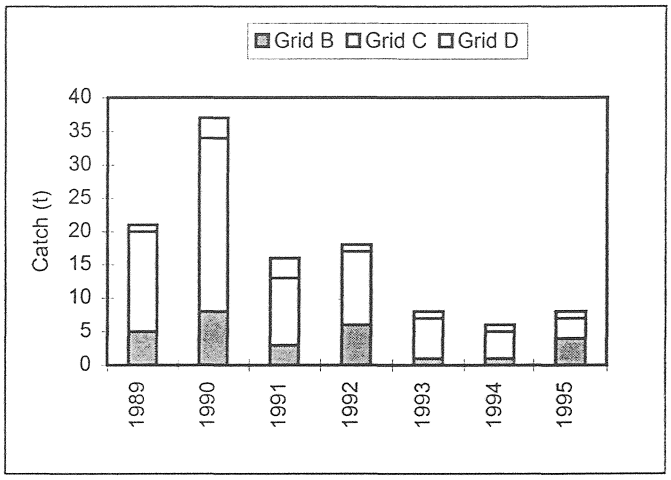


Figure 2.22 Jew catch by Gulf Grids

The catch rate for the days on which jewfish were landed remained about the same (see Figure 2.23) , but the days on which the jewfish were caught declined from about 1700 days per year in 1989 and 1990 to about 250 days in 1994 and 1995.

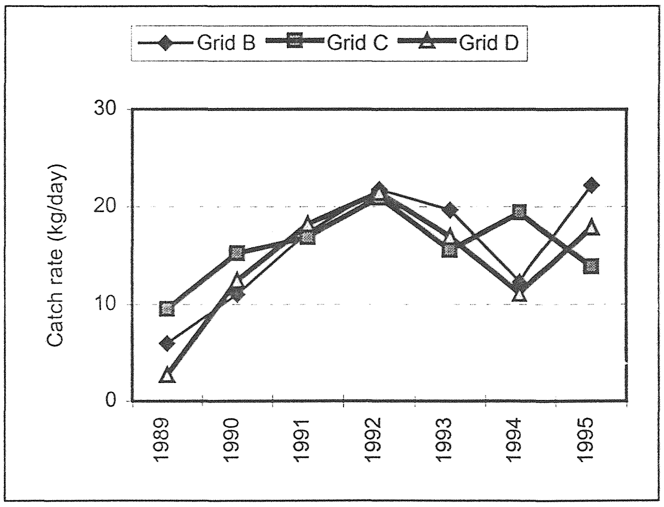


Figure 2.23 Jew catch rates for Gulf Grids

2.4.3 Fish sizes

The new logbook has enabled the collection of more detailed information about the catches of target species in the fishery.

Table 2.2 shows the approximate total Gulf catch by species, mean fish size caught per day, the number of days when numbers of fish were reported, and the number of fish recorded, for each of five different species. The data used in the analysis are the mean fish sizes reported by each fisher for each fishing day. Conditioning of the data was required to exclude records which gave unreasonable size estimates, but less than one percent of the data available needed to be excluded from the analysis. Fish numbers were recorded on about one third of all days when the species were landed.

Table 2.2 Species catch and mean fish size

Species	Annual Catch (t)	Mean fish size (kg)	Days of fishing reported	Number of fish reported
Barramundi	380	3.30	6167	82145
King Salmon	220	2.84	2051	25486
Blue Salmon	55	1.20	824	13650
Jewelfish	12	1.10	166	2944
Grunter	15	1.30	662	7859

Data for 1991 to 1995 were used to estimate the annual total catch for the Gulf, and 1994 and 1995 data were available for fish size calculations. Fish size was calculated from daily records of the number of fish caught and the weight of catch for the species.

Effects of increasing mesh size on mean fish weight is shown in Table 2.3. The mesh size categories are indicative only, because fishers reported the mesh size either from centre of knot to centre of knot or the escapement gap. The mesh sizes used in this analysis define the main mesh sizes used in the Gulf. In spite of the limits that can be placed on the results shown, a clear picture generally is presented with larger fish being taken in larger gill net mesh sizes.

Table 2.3 Mesh size effect on fish size (kg) by species

Species	150 mm mesh	165 mm mesh	180 mm mesh
Barramundi	3.11	3.44	3.79
King Salmon	2.81	2.47	3.95
Blue Salmon	1.03	1.15	1.54
Jewelfish	0.80	1.90	1.20
Grunter	1.50	1.20	1.30

It is recognised that the selectivity of gillnets can influence estimates of parameters of biological processes derived from fishery data. Only an approximation is currently available for the form of the net selectivity curve, and its relationship to the various mesh sizes in use. Further determination of the selectivity curve is an objective proposed for follow-up studies in the Gulf fishery. Tidal influences on net mesh performance would need to be established, and this is likely to be quantitatively difficult.

Mean fish size information about a species caught with particular fishing gear only describes part of the picture about that species. In the following paragraphs, barramundi is used as a case study and similar descriptions can be developed for other species.

Modal weight for barramundi for the three most common mesh sizes, of 150, 165 and 180 mm, are 2.75, 3.25 and 4.25 kg respectively as shown in Figure 2.24.

Seasonal effects on fish size can also be documented using a similar approach of mean, modal and distribution analysis for each of the species reported here.

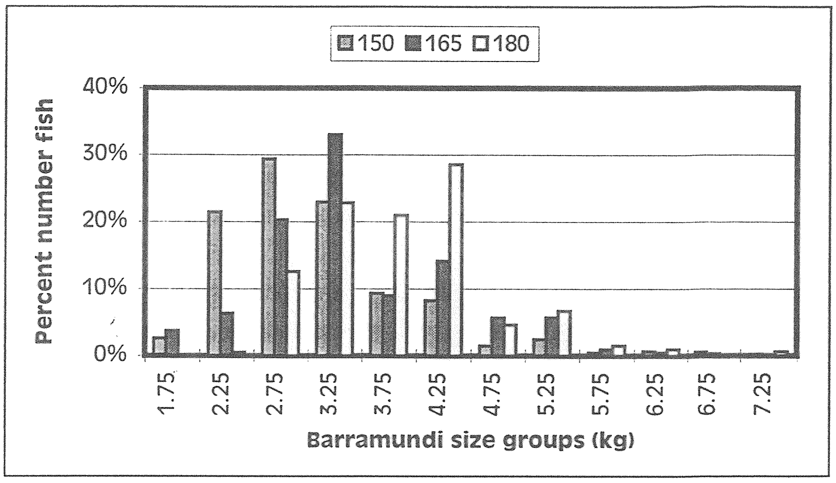


Figure 2.24 Distribution of barramundi fish size affected by net mesh size

2.4.4 Acceptance of the new logbook

A precursor to the "research" logbook was tested by eight volunteers who provided fish number data for 1993 using the standard CFISH logbook. These preliminary results were presented to Gulf fishers at the Karumba QCFO Branch Annual General Meeting in 1993 to illustrate the ease of collecting the additional data and its value for resource management considerations. Support from the volunteers who had trialed the logbook helped ensure its acceptance by Gulf fishers.

In both 1994 and 1995 about 50% of boats voluntarily provided fish numbers data with the catch information in the new logbooks. This group generally operated for 30 more days and caught about two tonne more product than the group who did not provide the additional information. Interestingly, catch rates overall were similar at about 80 kg/total days fished. The same fishing grounds were used by both groups.

In 1994, 45% of fishers did not provide any fish numbers information while 38% of the fleet reported fish numbers caught for 70% or more of the days fished. The 1995 figures were slightly less, with 65% of the fleet not providing any fish number information and 32% of the fleet reporting fish numbers caught for 70% or more of the days fished. In both years the numbers of active participants greatly exceeded the initial expectations which were for about 15% of the fleet to be regularly involved in providing enhanced fishery information.

As one would anticipate, attitudes to logbooks and recording catch varies enormously among individual fishers. There are those that are comfortable completing detailed logbooks and there are those that find it very difficult to complete even the simplest of catch recording systems.

Discussions with the fishers that are comfortable with using the new logbook suggest that they find no difficulty providing the level of detail required, and some volunteer to provide even more information. However, discussions with fishers that are not comfortable with the new logbook requirement for additional information still agree that the data sought is a reasonable request. Some fishers are unable to give accurate records of the numbers of fish because the catch recording system they use on board has not yet been adapted to do so. Increased liaison with these fishers may speed the rate of adoption of new practices.

2.4.5 Future prospects for the new logbook

The introduction of a more detailed logbook, coupled with the long fishery reporting history, has had several positive impacts of the Gulf net fishing community.

The emphasis placed on ensuring feedback is presented to the fishers on a regular basis augers well for the long term acceptance of the expanded data collection. This shows the fishers that the data are used for their benefit in the management process. Furthermore, the fishers are aware that the data are not just disappearing into a "great big black hole" never to reappear, as they have the opportunity to comment on the data analysis, and to question the deductions made.

The QFMA has developed an extensive consultative process for the development of management plans for fisheries throughout Queensland. Arrangements for the Gulf fishery are considered by the Tropical Finfish Management Advisory Committee and the Gulf Zonal Advisory Committee. Through QDPI representation and the Gulf fishers on these committees, other sector representatives on these committees are made aware of the data collected from the commercial sector, the analyses carried out on the data, and how this information is being used in Gulf Set Net Fishery management.

It is highly likely that a similar version of the logbook developed in this project will be introduced into the East Coast Set Net Fishery within the foreseeable future to provide the greater level of detail required to manage this fishery more effectively. Some modifications may be made to the logsheets to meet local requirements but the essence of collecting the additional information about fish numbers as well as more detailed location and effort information will apply.

The data collected in the new system is being used to help assess resource condition and trend in the Gulf Set Net Fishery as part of the Queensland Government's responsibility to ensure that natural resources are managed in an ecologically sustainable way. The additional level of detail available enables analyses to be undertaken which provide higher levels of confidence in the assessments made about the fishery.

Commercial fishery logbook records are one of the sources of information used by managers, scientists, and the participants to describe what is happening in a fishery. The level of detail recorded may vary considerably. In a fishery such as the Gulf Set Net Fishery, where individual fish have quite a high unit value (each barramundi is worth, on average, around $20 to the fisher) recording the numbers of fish caught can be accomplished with little extra effort. This additional data collection complements other fishery-dependent and fishery-independent information used to define the dynamics of the fishery.

In Queensland, commercial fishers have a legal obligation under their fishing authorities to provide logbook information in the form required by the QFMA. The Gulf Set Net Fishery logbook now gives fishers the opportunity to provide an enhanced level of information about their activities not available in the "standard" logbook. About 90% of the Gulf fishers submitting logbook returns have given information on the numbers of barramundi caught in 1996, and about 70% reported the numbers of other species caught.

The CFISH Logbook Coordinator has advised that logbook compliance within this fishery is now very high, with most fishers submitting returns on a regular basis. The coordinator also indicated that the rate of return was higher than in the other net fisheries for Queensland. The QFMA has recently introduced a much more rigorous program for logbook compliance in all fisheries throughout the State. This program will have minimal effect on the Gulf fishers due to their strong compliance history.

2.5 DISCUSSION

The new Gulf Set Net Fishery logbook system collects information that helps managers and participants to understand better the dynamics of the fishery and the demands being placed on Gulf inshore fishery resources. The analyses of the logbook data provided by the commercial fishers, when integrated with other information, has provided significant input into the development of management plans that are directed towards resource sustainability in this remote area fishery.

As a result of the information provided by fishers in the logbook program, changes have already been made to the management practices in the Gulf Set Net Fishery (Anon 1996a). These include changes in the timing of fishing closures, an increase in allowable mesh size of gill nets so that larger fish are harvested reducing the potential for recruitment overfishing, and reducing the quantity of net that can be used in certain fishing areas. These changes are part of the QFMA's new Gulf Fishery Management Plan, and came into force in October 1996.

The "research" logbook introduced in 1994 has, in 1996, become the standard logbook used in the Gulf of Carpentaria Set Net Fishery. Consequently, fishers are now required to document fish numbers from their catches, as well as the other logbook information. The CFISH logbook coordinator advises that almost all fishers are now providing fish numbers information.

The results presented for the Gulf fishery have been noted by industry and managers in other inshore net fisheries on the east coast of Queensland. There is an urgent need to obtain enhanced information for these fisheries that can better assist in the development of management plans appropriate to the needs of the fisheries.

The fifteen year data set available for the Gulf fishery shows that major changes have occurred over this period. There has been a steady decline in the number of operators and in the total effort (measured as days fished) for the fishery. At the same time, neither mean yearly effort per boat nor mean total catch per boat has altered dramatically. Part of the explanation for the fall in numbers of units operating in the fishery is due to the method of recording fishing operations. A change in the method occurred in 1989 when logbook entries were associated with the boat rather than the fisher. As well, discussions with industry participants suggests a decline occurred in the number of effective fishing operations. Various scenarios have been canvassed as to why this decline occurred. Possible alternatives included the change in age structure of fishers operating in the fishery, and the level of profitability of the individual fishing operations causing some operators to minimise their time in the fishery. Determining the causes will require further research.

The issue of latent effort in the Gulf fishery has been raised by fishery managers during the project. Unused fishing time resulting from a failure to fish 365 days in a year is often viewed as latent effort. Discounting for compulsory closed fishing seasons reduces the available fishing time in the fishery and hence the potential effort that can be applied. Fishing activity in Gulf of Carpentaria waters is limited to one or a number of commercial licence endorsements (authorities to use certain apparatus) by the number of days on which that gear can (legally) be worked.

Further limitations on the effort level that can be applied may be deduced from consideration of fisher motivation and behaviour. A fisher will only work an area if there is a high probability of a successful catch; if expectations are not realised then either expectations are lowered or fishing activity is directed elsewhere. It is likely that low profitability will remove commercial effort from a fishery before an exploited stock is likely to collapse. Estimating the potential yield from a fishery (physical or financial) is therefore an important first step in terms of defining fisher incomes and managing the fishery effort required to achieve them. This exercise has yet to be attempted for the Gulf Set Net Fishery.

A high level of inherent variability in catch and catch rate characterises the Gulf fishery. This has led to conservative policies in management for this fishery. The additional information collected with the new logbook system, when considered in conjunction with the other fishery-dependent information, has enabled firm recommendations to be made in fisheries management procedures. The effects of these initiatives will be assessed using information to be collected in the logbook program.

The integration of fishery-dependent information from the various sources has a synergistic effect in achieving an understanding of this complex fishery. Each component only provides part of the picture but together, they provide a strong base on which to build effective fishery management plans.

The new logbook system developed for the Gulf Set Net Fishery has set a challenge to other fisheries in Queensland to match the information that must be provided for sustainable fisheries use.

25

2.6 ATTACHMENTS

The "Example" proforma for the CFISH "Net and Crab" logsheet that was used in the Gulf Fishery until 1993.

QUEENSLAND FISHERIES MANAGEMENT AUTHORITY

NET AND CRAB FISHERY LOGBOOK (NC03)

BOAT NAME	BOAT MARK	SKIPPER'S NAME	SKIPPER'S SIGNATURE	Log Book No	Page No
Sea Swift	FXX	Jack Bowsby	J Bowsby	0	0

BOAT ACTIVITY CODE

- 0 ......Fishing/Searching
- 1 ......Not fishing - Weather
- 2 ......Not fishing - In Port
- 3 ......Not fishing - Broken down
- 4 . . .Not fishing - Steaming
- 5 . . .Not fishing - Other
- 10 . .Not fishing - Refit

If not fishing for an extended period please specify: 1 / 2 / 97 to 20 / 2 / 97 Activity code: 10

When recording Net Fishery catch please record the estimated weights for each species shown. Weights are to be recorded in kilograms and the product form indicated by: F = Fillet, T = Trunk, W = Whole, G = Gutted, L = Live

EXAMPLE

DATE				AREA		NET FISHERY																								CRAB FISHERY				
						EFFORT				CATCH																				EFFORT		CATCH		
DAY	MONTH	YEAR	↓	LATITUDE OR GRID	LONGITUDE OR SITE	Mesh Size (mm)	Total Length of Net (m)	Target Species	Fishing Method: 1 = Drift Gill Netting, 2 = Set Gill Netting, 3 = Ocean Beach Netting, 4 = Tunnell Netting, 5 = Ring Netting ↓	(M) Mullet (kg)	FORM	(B) Barramundi (kg)	FORM	(KS) King Salmon (kg)	FORM	(BS) Blue Salmon (kg)	FORM	.... Mackerel (kg)	FORM	(S) Shark (kg)	FORM	Other .... (kg)	FORM	Other .... (kg)	FORM	Other .... (kg)	FORM	Other .... (kg)	FORM	number of pots or dillies used	total number of all lifts	Mud Crab (number) or (kgs)	Blue Swimmer Crab (number) or (kgs)	Other .... (number) or (kgs)
21	2	97	0	T30	22	50	600	B	2			15	F	10	F															5	10	6		
22	2	97	0	T30	23	50	600	B	2			10	F	5	F																			
23	2	97	0	T31	3	50	600	B	2			20	F	15	F															5	5	2		
24	2	97	0	T31	8	50	600	B	2			50	F	5	F															5	5	11		
25	2	97	0	T31	9	50	600	B	2			40	F	30	F																			
26	2	97	1																															
27	2	97	1																															
28	2	97	1																															

COMMENTS

REMEMBER TO SEND THE COMPLETED GREEN DUPLICATE LOGSHEETS IN AT THE END OF EACH MONTH.

Tag Recoveries:
(see forms at back of book also; please complete details on these)

Tag No	Date

Queensland Department of Primary Industries

RESEARCH LOGBOOK FOR GULF SET NET FISHERY

(RL01)

Log No.		Page No.	
Vessel Name	**Symbol**	**Skipper**	
HOPEFUL	FZZZ	TOM JONES	

If not fishing for an extended period please specify the period

Period ....../....../...... to ....../....../......

Reason for not fishing or searching (please tick) ☐ Weather ☐ In Port ☐ Steaming ☐ Other ☐ Boat or Gear Maintenance ☐ Refit

ACTIVITY Fill in every day: *Fishing/searching ..... 0; *Not fishing/searching 7; OPTIONAL: Weather .... 1; In Port .... 2; Steaming .... 4; Boat or Gear Main. 3; Refitting .... 10; Other 5

FISHING LOCATION (Fill in on days you fish). Please record fishing location as either: Latitude / Longitude or Grid / Site

EFFORT (Fill in on days you are fishing) — Net Details

ESTIMATED CATCH (Fill in on days when you catch fish by net or crab by pot or dilly)

Please record the estimated weights for the species shown. Weights should be recorded in kilograms and the Product Form indicated by: F = Fillet, T = Trunk, W = Whole, G = Gutted.

DATE Day	DATE Month	DATE Year	Activity	Grid	Site	Mesh size (mm)	Total length of net (m) set	Target Species	Place net set F, R, O	Barramundi Number	Barramundi Weight (kg)	Barramundi FORM	King salmon Number	King salmon Weight (kg)	King salmon FORM	Blue salmon Number	Blue salmon Weight (kg)	Blue salmon FORM	Grunter Number	Grunter Weight (kg)	Grunter FORM	Black Jew Number	Black Jew Weight (kg)	Black Jew FORM	Silver Jew Number	Silver Jew Weight (kg)	Silver Jew FORM	Mullet Weight (kg)	Mullet FORM	Spanish Mackerel Weight (kg)	Spanish Mackerel FORM	Shark Weight (kg)	Shark FORM	Jumping Cod Weight (kg)	Jumping Cod FORM	...... Weight (kg)	...... FORM	...... Weight (kg)	...... FORM	Crabbing details No. Pots or Dillies	Crabbing details Total No. Lifts	Mud (Whole) Weight (kg)	Sand (Whole) Weight (kg)
1	10	94	0	AF18	2	150	600	BARRA	F	12	50	F	8	15	F				2	3	F	6	10	F	1	3	F							8	F								
2	10	94	0	AF18	5	150	600	BARRA	F	NO FISH CAUGHT																																	
3	10	94	7																																								
4	10	94	4																																								
5	10	94	0	AD17	10	150	200	BARRA	R	8	18	F	6	9	F	1	8	F				2	4	F								8	F							30	30	12	
						150	400	BARRA	F	NOTE THAT EVEN NETS SET IN TWO PLACES ONLY TOTAL WEIGHT FOR THE																																	
													DAY IS RECORDED I.E. CATCH IS FROM BOTH NET SETS																														
6	10	94	0	AD17	5	200	600	SHARK	O	1	12	F																		18	F	176	F										

And so on.

Comments

Tag Recoveries: (see forms at back of book also; please complete details on these)

Tag No.	Date
....	....
....	....

The "Example" proforma for the new logbook sheet developed in this project.

3. GULF FISH STOCK GENETICS

(contributed by Dr C.P. Keenan, Southern Fisheries Centre, PO Box 76, Deception Bay QLD 4508)

3.1 INTRODUCTION

The collection of information on the genetic structure of fish stocks is an integral component in the implementation of successful management methods to maintain fisheries at sustainable levels. With little knowledge of the stock structure, overfishing can reduce isolated breeding populations to a level where recruitment cannot sustain the harvest and the isolated populations which contribute to the total harvest can collapse, as occurred in the 1970's with the North Atlantic herring *Clupea harengus* (see Utter 1991). The ability of biochemical genetic data to clarify fish population structures and to improve prospects for the success of fishery management regimes is now widely demonstrated (eg. Allendorf *et al.* 1987). Allozyme electrophoresis remains the most appropriate procedure for investigating fish population structure, because of the method's cost-effectiveness, ease of application, and capability to treat large sample sizes (Utter 1991). Other molecular procedures may be applied in complementary fashion when protein electrophoresis cannot adequately resolve or identify differences among groups (Utter and Ryman 1993).

Within this setting, the present allozyme-based study was designed to provide information on the population structure of five species - black jewfish (*Protonibea diacanthus*); blue salmon (*Eleutheronema tetradactylum*); golden grunter (*Pomadasys kaakan*); King salmon (*Polydactylus sheridani*); and jewelfish (*Nibea squamosa*) - harvested in the Queensland Gulf of Carpentaria inshore gillnet fishery. Shaklee *et al* (1993) and Keenan (1994) have demonstrated a structuring of barramundi *Lates calcarifer* populations in the Gulf of Carpentaria region. More recent investigations (Keenan, unpublished) have provided greater definition of the barramundi stock structure in Queensland Gulf waters, and this information is summarised below.

Barramundi stock structure for western Cape York Peninsula region

In the most recent genetic study of barramundi from western Cape York Peninsula, Keenan (unpublished) found that more than half of the total genetic diversity could be attributed to the difference between two extensive populations, one in the south-eastern Gulf and a second along the north-east Gulf coast. From the closely spaced samples available, the boundary between the two stocks was clearly mapped to a 50km wide geographic feature, Pera Head (13° S), just south of the northern Gulf port of Weipa. This prominent stock boundary, where significant differences were found at six of thirteen loci examined, must be attributed to a discontinuity in migration (of larvae, juveniles and/or adults that survive to contribute to the breeding population) around this barrier. Statistical details of these results are given in Table 3.1 and summarised in Figure 3.1.

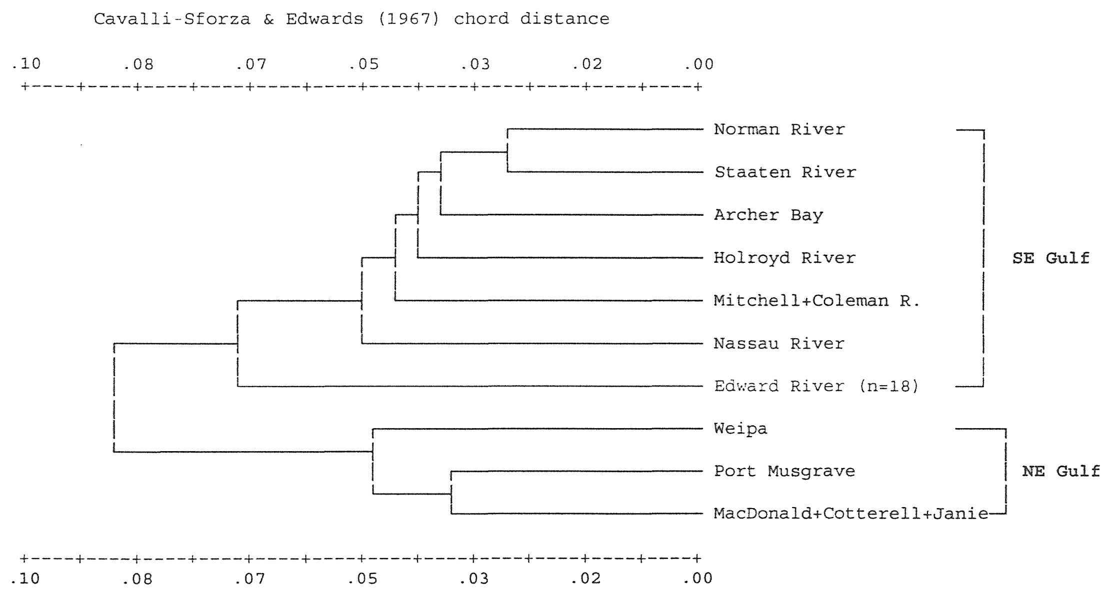
The general fish stock structure in the Gulf of Carpentaria was established during major migrations of estuarine species into the Gulf of Carpentaria which commenced about 12 000 years ago with the flooding of the area after the end of the last ice age (Keenan 1994). Keenan proposed the formation in the Gulf of a zone of hybridisation between barramundi populations derived from both the east and the west coasts of Australia. The present study, which examined the stock structure of five different fish species from the same general area, provides an opportunity to test whether the hypothesis for barramundi holds true for these other species as well, or if different stock structures and derivations might apply.

Table 3.1 Summary of statistical tests for barramundi sample collections from the western Cape York Peninsula region of the Gulf of Carpentaria.

```
Overall                                        Partitioned heterogeneity
heterogeneity
                      N  Location

                  ┌─406 NORMAN               ┐
                  │ 238 STAATEN              │  within population
                  │ 114 NASSAU               │  SOUTH EASTERN GULF
Total G   df      │  84 MITCHELL+COLEMAN     │  G = 138.089, df 150, n.s.
353.365, 234      │  18 EDWARD               │  1 of 13 loci significant
                  │  67 HOLROYD              │
P<0.01            │  90 ARCHER BAY           ┘
                  │between populations: G = 189.097, df 26, P<0.001
3 of 13 loci      │             6 of 13 loci significant
significant       │  58 WEIPA                ┐  NORTH EASTERN GULF
                  │  58 PORT MUSGRAVE        │  G = 26.180, df 36, n.s.
                  └─ 86 MAC+COTT+JANIE       ┘  0 of 13 loci significant
```

Figure 3.1 **Cluster analysis using unweighted pair group method of barramundi sample collections from the western Cape York Peninsula coast of the Gulf of Carpentaria.**



3.2 SPECIFIC OBJECTIVES

1. To determine the level of genetic variation in five key target species from the Queensland inshore gillnet fishery in eastern Gulf of Carpentaria waters.

2. To establish the level of population sub-division in these species along the Queensland Gulf of Carpentaria coastline, and to compare this with the level of differentiation shown on the Queensland north-east coast.

The ultimate aim is the identification of stock structure and stock areas in the commercially significant inshore fish species. The finalisation of this aim will be subject to successful grant applications to research fund providers in the future. Knowledge of the levels of stock delineation in the main target species is critical for future consideration of stock-by-stock management approaches for the Gulf fishery.

3.3 MATERIALS AND METHODS

3.3.1 Sample collection and preparation

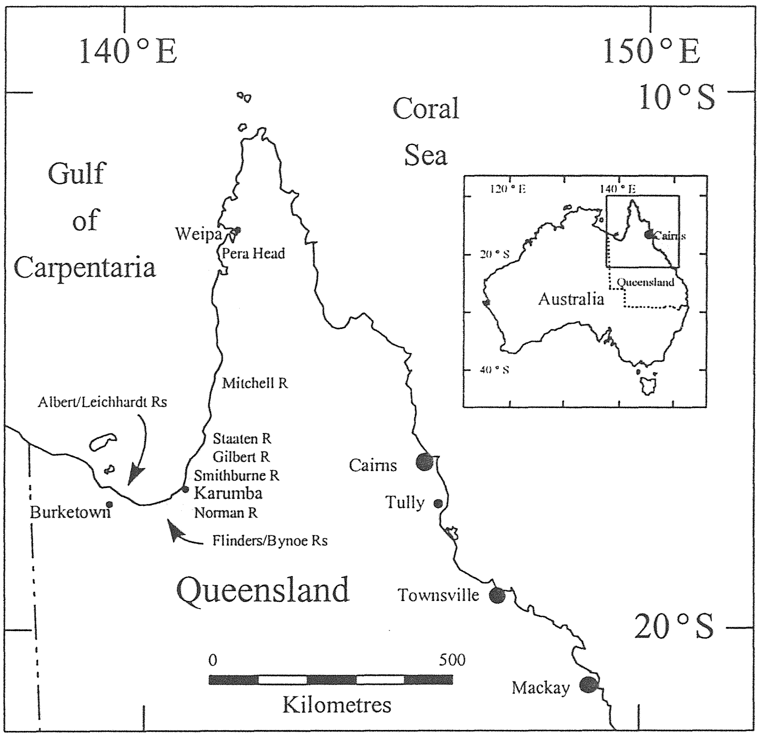


Figure 3.2 North Queensland, showing Gulf of Carpentaria river systems sampled.

Samples of filleted fish were collected by project staff or supplied by volunteer fishers for river systems along the central and south-east Gulf of Carpentaria coastline (Figure 3.2). From these processed carcasses or frames, small (< 5 g) samples of muscle, liver and eye tissue were dissected and packed into individual plastic bags and frozen for transport to the Southern Fisheries Centre. Upon arrival at the laboratory, samples were kept at -30°C until preparation.

The tissue samples were sub-sampled by placing approximately 1 gram of tissue into a labelled vial with a few drops of 0.1M tris-HCl pH 7.0 buffer (Selander *et al.* 1971). The vials were centrifuged at 15,000 rpm for 15 minutes at 4°C in a microfuge to obtain a concentrated tissue extract (Keenan and Shaklee 1985). The labelled vials were then stored in an ultrafreezer at -70°C until electrophoresis.

Horizontal starch gel and polyacrylamide electrophoretic methods followed those of Shaklee and Keenan (1986). Starch gel moulds were modified after Aebersold *et al.* (1987). Starch gels consisted of 10% w/v hydrolysed potato starch. The locations of the enzymes in the gels after electrophoresis were observed using the histochemical staining procedures of Shaklee and Keenan (1986) and Aebersold *et al.* (1987).

Locus nomenclature followed that of Allendorf and Utter (1979) where multiple loci encoding functionally similar proteins were designated numerically, starting from the cathodic end of the gel. Alleles were designated by their electrophoretic mobility relative to the mobility of the most common allele, which was designated as "100". Those in the cathodal region were preceded by a negative sign. Enzyme abbreviations, recommended names and Enzyme Commission numbers were in accordance with guidelines set forth by the IUB Committee on Enzyme Nomenclature (Anon. 1984).

Without precise knowledge of Mendelian inheritance through breeding studies, the genetic nature of protein variants can be assessed following the guidelines of Grant (1985) and Richardson *et al.* (1986): 1) the banding patterns should be consistent with analogous genetic variation in other teleosts; 2) banding patterns should match the predicted quaternary structure of the protein in the heterozygote condition; 3) no unexpected phenotypes should be expressed; 4) when a gene is expressed in more than one tissue, variant phenotypes should be the same among tissues; and 5) samples should conform to Hardy-Weinberg equilibrium in a majority of the samples.

3.3.2 Statistical procedures

Statistical tests were conducted using log-likelihood ratio (G) tests in preference to chi-square tests, because the G statistic and the degrees of freedom for individual loci are completely additive (Sokal and Rohlf 1981). The microcomputer program, "Genes in Populations", designed by B. May and C.C. Krueger and written in C by W. Eng (May and Krueger 1990) was used for these tests.. Each locus was tested for conformance of genotypic counts to Hardy-Weinberg equilibrium for individual collections as well as for pooled samples. In cases where one or more genotypes were uncommon, they were pooled with other uncommon genotypes to yield expected cells of five or more wherever feasible.

Spatial differentiation was analysed by comparing adjacent populations for statistical differences. When not significantly different ($P > 0.05$ over all loci), adjacent collections were pooled and another round of tests conducted, until all tests resulted in significant differences. In cases where sample sizes were inadequate to resolve differences (n<50), adjacent samples were pooled to perform these tests. To account for multiple tests of the same hypothesis, differences between collections were considered significant only if the total G statistic (summed over all loci) was significant at a level $\alpha_{0.05}$, adjusted by the method of Cooper (1968), where $\alpha_{0.05}$ =

(0.05/*n*) and *n* is the number of polymorphic loci (ie. individual tests) contributing to the total G statistic.

Individual locus heterozygosities (*h*) were calculated for polymorphic loci using the formula $h = 1 - x_i^2$, where x_i is the frequency of the *i*th allele. Average sample heterozygosity (*H*) was calculated as the mean of individual locus heterozygosities for variable loci. F_{ST} migration statistics were calculated using unweighted means by the method of Wright (1965) and also by the method of Weir and Cockerham (1984) using BIOSYS (Swofford and Selander 1989). Nei's (1978) unbiased genetic distance (D) corrected for small sample size was calculated and an Unweighted Pair-Grouped Method with Arithmetic Means (UPGMA, Sneath and Sokal 1973) cluster analysis subsequently performed. The goodness-of-fit of the input matrix to the resultant dendrogram was evaluated using the cophenetic correlation coefficient (Sneath and Sokal 1973).

3.4 RESULTS

Table 3.2 Electrophoretic samples pooled by locality.

Locality	Number of samples				
	Black Jewfish	**Jewelfish**	**Golden Grunter**	**Blue Salmon**	**King Salmon**
1. Burketown	27	16	43	24	-
2. Western Gulf	6	-	-	15	-
3. Flinders/Bynoe Rs	58	70	15	63	59
4. Norman R	42	46	105	39	38
5. Smithburne R	7	3	53	22	3
6. Staaten R	30	12	37	2	5
7. Mitchell R	12	4	15	1	5
8. Weipa	-	-	3	-	20
9. Cairns (east coast)	3	-	4	21	1
10. Tully (east coast)	-	-	-	55	14
TOTALS	**185**	**151**	**275**	**242**	**145**

3.4.1 Screening for polymorphic loci

A total of 998 samples of the five species under examination (king salmon, blue salmon, jewelfish, black jewfish and golden grunter) were collected for genetic studies in the period April 1993 to December 1995. The total number of samples for each species from each locality is listed in Table 3.2. These samples represent a unique and useful collection, which has been used to determine the genetic variation in each species and to identify those loci which are polymorphic for use in stock structure analysis. All samples prepared for electrophoresis remain stored in an ultrafreezer at -70°C. Under these conditions it is expected that their enzyme activity will be maintained for well over one year.

In only a few Gulf fishing grounds, such as the Norman River and the Flinders/Bynoe Rivers, were sample sizes adequate (>80 individual fish, preferably closer to 100) for precise stock delineation purposes. In general, low sample numbers from many locations caused an insufficiency of data for determination of detailed stock structure. However, by pooling collections on a locality basis (Table 3.2) to increase sample sizes, stock structure analyses for each species could be attempted. Nevertheless, the results obtained cannot be used immediately to determine detailed stock structure. Rather, some evidence for stock structure at a broader geographic scale has been obtained, and only on this basis can comparisons be made between the different species.

In an initial scan of the collected material, genetic polymorphic loci were determined from a sample of ten fish from each species. These polymorphic loci were then used to determine allele frequencies for all individual fish, which were then summarised by location for stock structure analysis (see Table 3.3).

3.4.2 Blue salmon

Eight polymorphic loci were identified for blue salmon, *Eleutheronema tetradactylum*. Overall sample heterozygosity at these loci was moderate with H = 0.123. Over all populations, there was considerable observed heterogeneity ($P<0.001$) which was primarily based on significance at the tri-peptidase *P-LGG* (leu-gly-gly) locus ($P<0.0001$) but also at the *FDH* ($P<0.005$) and *EST-E* ($P<0.01$) loci. Allele frequencies for *P-LGG* for the Norman River (Gulf) and Tully area (Queensland east coast) populations were almost the inverse of those from adjacent populations. Tests of Hardy-Weinberg equilibrium of this locus for these two populations were significant, with under-reporting of heterozygotes. The actual basis for this result could not be determined by the present study but deserves further inquiry. In genetic terms it is most likely the result of a Wahlund effect (Wahlund 1928) which is the mixing of two distinct populations in the sample collected from the one location. Additional dedicated sampling around the locations concerned might reveal the basis for this apparent discrepancy.

Pairwise tests of adjacent populations of blue salmon (see Appendix for full details) also displayed significant differences. The genetic distance of the two Queensland east coast collections from the Gulf of Carpentaria collections exceeded twice the genetic distance that was observed between Gulf blue salmon populations. The large frequency differences at the *P-LGG* locus in the Norman River and Tully collections means that these populations and those adjacent are significantly different ($P<0.0001$). The Norman River sample was significantly different from both the Flinders/Bynoe Rivers sample and the Smithburne River sample. The Tully sample was significantly different from the Cairns sample at two loci, *P-LGG* and *ADA*.

Table 3.3 Best buffer and tissue combinations for the identification of polymorphic loci for five Gulf species, with identified polymorphic loci from a limited number of samples. [**poly?** = polymorphic yes or no; **YESx2** = more than one polymorphic loci was identified; ? = uncertain if the locus is polymorphic for the small number of animals examined; all buffer symbols are as detailed in Shaklee and Keenan (1986)]

Locus	tissue	King salmon		Black jewfish		Blue salmon		Jewelfish		Golden grunter	
		buffer	poly?	buffer	poly?	buffer	poly?	buffer	poly?	buffer	poly?
AAT-1	L	TM	No	TM	No	TM	No	TM	No	TM	No
AAT-2	M	TM	No	TM	No	TM	No	TM	No	TM	No
AAT-3	M	TM	No	TM	No	TM	No	TM	No	TM	No
ACP	L	CAME	No	CAME	No	CAME	No	CAME	No	CAME	No
ADA	L	TC-1	**YESx2**	TC-1	**YES**	TM	**YES**	TM	**YES**	TM	No
ADH	L	CAME	**YES**	EBT	**YES**	TM	**YES**	TM	**YES**	TM	**YES**
AH-1	L	TC-1	No	TC-1	No	TC-1	No	TC-1	No	TC-1	No
AH-2	M	TC-1	No	TC-1	No	TC-1	No	TC-1	No	TC-1	No
AK	L/M	CAME	No	CAME	No	CAME	No	CAME	No	CAME	maybe
ALAT-1	L	TM	**YES**	TM	No	TM	No	TM	No	TM	No
ALAT-2	M	TM	No	TM	No	TM	No	TM	No	Poulik	**YES**
ALAT-3	L	TM	No	TC-1	No	TM	No	TM	No	TM	No
CK	M	CAME	No	CAME	No	CAME	No	CAME	No	CAME	No
CK-C	E	CAME	?	CAME	?	CAME	?	CAME	?	CAME	?
ENO-2	M	EBT	No	TC1	**YES**	EBT	No	EBT	No	Poulik	**YES**
EST	E	PAGE	**YES**	PAGE	No	PAGE	**YES**	PAGE	No	PAGE	No
EST-D	L	EBT	No	EBT	No	EBT	**YES**	EBT	**YES**	TM	**YESx2**
FBALD	M	CAME	No	CAME	No	CAME	No	CAME	No	CAME	No
FDH	L	TM	**YES**	EBT	No	TM	**YES**	EBT	**YESx2**	EBT	No
FH	L	TM	No	TM	No	TM	No	TM	No	TM	No
GAPDH-1	M/L	CAME	No	CAME	No	CAME	No	CAME	**YES**	CAME	No
GAPDH-2	L/M	CAME	No	CAME	No	CAME	No	CAME	**YES**	CAME	No
G3PDH	M	CAME	No	CAME	No	CAME	No	CAME	**YES**	CAME	No
GPI-1	M	CAME	**YES**	TC-1	**YES**	TM	No	TC-1	**YES**	Poulik	**YES**
GPI-2	M	CAME	**YES**	TC-1	**YES**	TC-1	No	CAME	**YES**	CAME	**YES**
HK	L/M	TM	No	TM	No	TM	No	TM	No	TM	No
IDDH	L	EBT	No	EBT	No	EBT	No	EBT	No	EBT	No
IDH	M	CAME	No	CAME	No	CAME	No	CAME	No	CAME	**YES**
LDH-A	M/E	PAGE	No	PAGE	No	PAGE	**YES**	PAGE	No	Poulik	**YES**
LDH-C	E	PAGE	No	PAGE	No	PAGE	?	PAGE	No	PAGE	No
MDH	M	CAME	No	CAME	No	CAME	No	CAME	No	CAME	**YESx2**
MDHp	M	CAME	**YES**	TM	No	CAME	No	CAME	**YES**	CAME	No
MPI	M	TM	No	TM	No	TM	No	TC-1	**YES**	TM	No
PEP-LG	L	TM	**YES**	TM/Poul	No	TM/Poul	No	TM	**YES**	TM	No
PEP-LGG	L	CAME	**YES**	?	?	CAME	**YES**	TC-1	No	TC-1	No
PGDH	M	TM	No	TM	No	TM	No	TM	No	TM	No
PGK	M/L	CAME	No	CAME	No	CAME	No	CAME	No	CAME	No
PGM	M	CAME	No	TC-1	**(YES)**	CAME	No	TC-1	**YES**	CAME	No
SOD-1	L	TC-1	No	TC-1	No	TM	**YES**	TC-1	No	TC-1	No
SOD-2	E	PAGE	No	PAGE	No	PAGE	No	PAGE	No	PAGE	No
TPI	L	CAME	No	CAME?	No	CAME	No	CAME?	No	CAME	No
XDH	L	CAME	No	CAME	No	CAME	No	CAME	No	CAME	No
TOTAL	42		12		5 (+1)		8		14		12

3.4.3 King salmon

Eleven polymorphic loci were identified in the king salmon, *Polydactylus sheridani*, which displayed the highest sample heterozygosity (*H*=0.313) of the five species examined. Average sample size of each population for this species was only *n*=28.8. Despite this low sample size, a contingency test of all data was significant (P<0.01) with four loci showing significant differences, *ADA-2* (P<0.0001), *MDHp* (P<0.0001), *PEPLG* (P<0.025) and *P-LGG* (P<0.0005). These large differences were mainly attributed to differences between the Weipa and the Tully collections (P<0.001) at two loci *MDHp* (P<0.0001) and *P-LGG* (P<0.005). In pairwise tests of adjacent populations, the *ADA* locus was significantly different between the Flinders/Bynoe Rivers and the Norman River collections (P<0.0005) and between the Norman River and the Weipa collections (P<0.001). However, over all loci these locations were not significantly different. Four loci varied from Hardy-Weinberg equilibrium but in only one case, *FDH* in the Norman River sample, was the test valid.

3.4.4 Black jewfish

Only five polymorphic loci were found in the black jewfish *Protonibea diacanthus*. Overall sample heterozygosity at these loci was also quite low (*H* = 0.076) and therefore the statistical tests had little power. This was compounded by generally low sample sizes. Further, comparisons with the east coast populations could not be considered valid because of the small number of samples in the Cairns collection. All loci were in Hardy-Weinberg equilibrium. A contingency test of all loci over all populations was not significant suggesting homogeneity. Comparisons of adjacent collections revealed only one significant test at a single locus; for the test between the Flinders/Bynoe Rivers and the Norman River populations at the *ADA* locus. When all loci were considered, no significant difference was observed between these two populations. No other statistical test of the data collected for this species yielded a result of significance. Increasing the sample sizes (and perhaps identifying additional polymorphic loci) would increase the power of the tests and likely determine if this apparent uniformity of population structure is biologically accurate or merely a statistical artefact from a restricted database.

3.4.5 Jewelfish

The jewelfish or purple jewfish, *Nibea squamosa*, displayed the second highest sample heterozygosity (*H*=0.187) and the highest number of polymorphic loci (14) of the five species examined. However, only the Flinders River/Bynoe River collection was sufficiently large (70 samples) to provide accurate gene frequency data. Three tests of Hardy-Weinberg equilibrium were significant but these tests were not valid because expected values were less than five in all cases. A contingency test of all data was not significant despite three loci showing significant differences, *ADA* (P<0.025), *EST-D* (P<0.05) and *PEPLG* (P<0.005). Where adequate sample sizes were available significant differences were observed in pairwise tests. Significant differences were observed between collections taken from three adjacent fishing grounds - the Flinders River/Bynoe River, the Norman River, and a pooled population from the Smithburne/Staaten and Mitchell Rivers. The Flinders/Bynoe and Norman samples were different at three loci (*ADA*, P<0.05, *FDH-2*, P<0.05 and *PEPLG*, P<0.05) and overall loci tested (P<0.05). The Norman River sample and the pooled sample from the Smithburne/Staaten and Mitchell Rivers were also different at two of these three loci (*ADA*, P<0.025 and *FDH*-2, P<0.05) as well as EST-*D* (P<0.025) but not overall. Increased sample sizes from each of these locations would be necessary to confirm the evidence for jewelfish stock structuring between these rivers. Jewelfish appear absent from the tropical Queensland east coast (Sasaki 1992), so for this species no comparisons are possible on genetic differentiation between the east and west coasts of the Cape.

One result produced in the electrophoretic study of jewelfish was quite unexpected. The analysis identified a group of samples that most likely belonged to another distinct (and previously unrecognised) species. This group of samples showed fixed differences from the other jewelfish material at five (*ADA*, *ADH*, *GAPDH*, *GPI*, *PEP-LGG*) of the fourteen (35%) allozyme loci examined. Fixed differences at about 20% of all allozyme loci are usually considered to be indicative of species level differences (Musyl and Keenan 1992; 1996), particularly if the samples are from the same location. Investigations conducted elsewhere in this project (Sections 4 and 5) have confirmed that several sciaenid species are labelled 'jewelfish'. The samples likely to have come from another species were deleted from analyses of *N. squamosa*.

3.4.6 Golden grunter

For golden grunter, *Pomadasys kaakan*, eleven polymorphic loci were identified with an average H=0.074 across these eleven loci. Three tests of Hardy-Weinberg equilibrium were significant but the tests were not valid because expected values were less than five in all cases. A contingency test of all data was not significant despite two loci showing significant differences, *ADH* ($P<0.0005$) and *GPI-2* ($P<0.025$). Where adequate sample sizes were available significant differences were observed in pairwise tests. The east coast Cairns sample was significantly different ($P<0.01$) from the Staaten River sample primarily because of very large frequency differences at the *ADH* locus ($P<0.0001$). As with jewelfish (see above) significant differences were observed between all three adjacent collections from the Norman, Smithburne and Staaten Rivers. The Norman and Smithburne River samples were different at two loci (*ESTD2*, $P<0.025$ and *GPI-2*, $P<0.001$) and overall ($P<0.05$). The Smithburne and Staaten River samples were also different at these two loci (*ESTD2*, $P<0.01$ and *GPI-2*, $P<0.025$) but not overall. Increasing the sample sizes for these two populations may help clarify this situation.

3.5 DISCUSSION

A summary of sample collection and genetic statistics for each species is provided in Table 3.4. It is clear that the mean sample size for each population, which varies from about 30 to 40, is inadequate to define closely related populations. However, even with these relatively small collections, there is indication of significant population differentiation at both the macro-scale (east versus western Cape York Peninsula) and also at the micro-scale between adjacent river systems. At the macro-scale, the observed differences in three of the four species (blue salmon, golden grunter and king salmon) with a genetic distance of more than 0.09, are far greater than that observed for Gulf barramundi populations (genetic distance of 0.05, Keenan unpublished). This result suggests that these species are likely to have a much more distinct population structure than that found in the barramundi populations from the region.

This study presents further evidence that the population structure of other key target species in the inshore fishery may be more distinctive than that of the Gulf barramundi. Keenan (1994) and unpublished (see above) concluded that there was a single barramundi stock in the south-east Gulf of Carpentaria, with boundaries to the west of the Leichhardt River near Burketown and north-east to Pera Head, just south of Weipa. Rather unexpectedly, tests in the current study showed significant genetic differences within species from the Flinders/Bynoe Rivers and from Norman River, which geographically are separated by less than 30km at their river mouths. This was observed at one locus in the black jewfish (but not significant over all loci), in blue salmon overall loci, in jewelfish over all loci and in King salmon at a single locus (but not over all). Similar genetic differences were evident in collections of blue salmon, golden grunter and jewelfish from the Norman and Smithburne Rivers, which are 50km apart at their mouths. For the golden grunter, the Staaten River population about 80km to the north of the Smithburne River showed significant differences at two loci, but not over all loci.

This level of population differentiation in a wide range of inshore fish species is surprising in an area as apparently homogeneous as the south-east Gulf of Carpentaria. Unfortunately, few species life history details are available to corroborate the distinctive nature of the river systems and the fish stocks they support. Movement and migration information, as revealed by intensive tagging studies, is absent for all Gulf inshore fish species other than barramundi. The findings of barramundi tagging programs by CSIRO (Davis 1984) and QDPI (Garrett 1992) broadly support the stock structure identified by Keenan (1994) and Keenan (unpublished). It is possible that increasing the sample size of the non-barramundi species might diminish the level of population differentiation established above. Precise knowledge of the spawning localities for these species could help to explain the differences observed in this study, but again such information is not yet available.

Table 3.4 Summary statistics of genetic variation in five species from the Gulf of Carpentaria inshore gillnet fishery. [ns - not significant, **P<0.01, ***P<0.001].

Species	mean number	poly loci	H_t	F_{st}	total G, df, significance	Rogers' (1972) genetic distance E-W
Black jewfish	37	5	0.076	0.023	28.6, 32, ns	0.049
Blue salmon	39	8	0.123	0.171	257.2, 60, ***	0.096
Golden grunter	39	11	0.074	0.178	151.9, 120, ns	0.091
Jewelfish	37	14	0.187	0.034	89.2, 60, ns	na
King salmon	28	11	0.313	0.062	139.6, 52, **	0.164

Two other currently operational research investigations should provide a contextual assessment of the species stock structure established for eastern Gulf waters. Griffith University (Brisbane Qld) PhD student Stephen Chenoweth is examining mitochondrial (mt) DNA variation in barramundi, blue salmon and King salmon from both Queensland and the Northern Territory, and will access material from the FRDC project. Chenoweth's program should provide significant comparative data to the electrophoretic study, and will therefore be useful in defining clearly the stock structure of the species involved. As well, the Northern Territory Department of Primary Industry and Fisheries has commenced an investigation of inshore fish stock structure in the western area of the Gulf of Carpentaria as part of its Coastal

Fisheries Program initiative. Once these two projects are completed, information on stock structure and genetic differentiation should be available for the major fishery target species throughout tropical northern Australia.

3.6 SUMMARY

3.6.1 Genetic variation in Gulf inshore fish

The project has achieved significant progress towards the objectives of defining population structure of the five Gulf fish species under study. As outlined in the original project proposal to FRDC in December 1992, this stock structure information was to be gathered over a five year period, and would investigate the temporal nature of observed genetic variability. With the telescoping of the project down to two years, the collection of sufficient data for all five species has been difficult to achieve for two reasons. Firstly the funding was based on known costs at the time spread over the original length of the project and was not increased to cater for the much more intensive workload; and secondly, the program of dedicated sampling that is required for each species, of at least 100 fish from each major location with tissues in condition suitable for electrophoresis, has not been completed within the truncated two year project period.

Table 3.2 shows where additional collection efforts are required to establish sample sizes for precise stock delineation in the five species under consideration. Because the outcomes are important for fishery resource management, undertaking the exercise should be accorded a high priority. Complementary sampling in adjacent Northern Territory Gulf waters should be conducted to broaden the picture and especially to provide definition of stock structure around the border coastline. It should be noted that the time-consuming and complex screening of each species for genetic variation has been completed in the present study, and polymorphic genetic loci and the conditions for electrophoresis have been identified. From this point on, the treatment and consideration of additional material to the database will be straightforward. A complete analysis of electrophoretic data will be attainable when fish sample sizes from each targeted location are increased. Only then will the genetic stock structure of these Gulf of Carpentaria species be revealed with confidence.

3.6.2 Priorities for the collection of additional material for genetic analysis

All species: collection of material from the Smithburne River to Weipa and further north. These areas are from either side of the identified barramundi stock boundary at Pera Head.
All species except blue salmon: a representative sample from the east coast in the Cairns/Tully region for comparative purposes.
All species: additional samples from the western Gulf area, needed to define the western extremity of populations.

Generally, sufficiently large and statistically adequate sample sizes are now available for the fish species from the Flinders River/Bynoe River and Norman River regions in the central section of the eastern Gulf coast. If the sampling strategy indicated above was employed, subsequent analysis could compare the western, central and northern (Weipa) Gulf regions with each other and also with the east coast.

3.7 APPENDIX

Summarised results for each species

BLACK JEWFISH

POP	#	N		NAME
Pop	1	33	-	BURKETOWN;WESTERN GULF;
Pop	2	49	-	NORMAN RIVER;SMITHBURNE R;
Pop	3	42	-	STAATEN RIVER;MITCHELL RIVER;
Pop	4	58	-	FLINDERS/BYNOE;
Pop	5	3	-	CAIRNS-EAST COAST;

Allele Frequency

		Pop 1	Pop 2	Pop 3	Pop 4	Pop 5
ADA						
	1	0.967	0.867	0.957	0.966	1.000
	2	0	0.011	0	0	0
	3	0.033	0.122	0.043	0.034	0
N		*30*	*45*	*35*	*58*	*3*
ADH						
	1	0.970	0.969	0.949	0.966	1.000
	2	0.030	0.031	0.051	0.034	0
N		*33*	*49*	*39*	*58*	*3*
ENO-2						
	1	0.939	0.929	0.952	0.974	1.000
	2	0.061	0.071	0.048	0.026	0
N		*33*	*49*	*42*	*58*	*3*
GPI-1						
	1	0.922	0.904	0.917	0.891	1.000
	2	0.063	0.096	0.083	0.091	0
	3	0.016	0	0	0.018	0
N		*32*	*47*	*42*	*55*	*3*
GPI-2						
	1	0.970	1.000	1.000	1.000	1.000
	2	0	0	0	0	0
	3	0.030	0	0	0	0
N		*33*	*49*	*42*	*58*	*3*
Avg Hs		0.088	0.120	0.085	0.076	0
std err		0.018	0.041	0.025	0.033	0
Avg Ho		0.093	0.090	0.090	0.060	0
std err		0.019	0.039	0.027	0.025	0

Genetic Diversity

Locus	Ht	Hs	Ho
ADA	0.093	0.089	0.089
ADH	0.057	0.056	0.051
ENO-2	0.079	0.078	0.067
GPI-1	0.137	0.134	0.115
GPI-2	0.012	0.012	0.012

	Ht	Hs	Ho
Average	0.076	0.074	0.067
Variance	0	0	0
Std. Err	0.021	0.020	0.017

Locus	Fis	Fit	Fst	G	df	
ADA	0.007	0.047	0.039	11.246	8	ns
ADH	0.104	0.113	0.010	1.064	4	ns
ENO-2	0.134	0.148	0.017	3.314	4	ns
GPI-1	0.142	0.159	0.020	6.060	8	ns
GPI-2	-0.031	-0.006	0.024	6.946	8	ns
Average	**Fis**	**Fit**	**Fst**			
	0.096	0.117	0.023			
Total				**G**	**df**	
				28.629	32	ns

UPGMA using ROGERS (1972)

```
Pop  1    33  - BURKETOWN;WESTERN GULF;
Pop  2    49  - NORMAN RIVER;SMITHBURNE R;
Pop  3    42  - STAATEN RIVER;MITCHELL RIVER;
Pop  4    58  - FLINDERS/BYNOE;
Pop  5     3  - CAIRNS-EAST COAST;
```

```
                0.012          0.024          0.036          0.049
  ................|..............|..............|..............|

5 -------------------------------------------------------------
                                                               |
2 ---------------------------------------                      |
                                         |---------------------
1 ------------------------               |
                          |--------------
3 ------------------      |
                    |-----
4 ------------------

  ................|..............|..............|..............|
                0.012          0.024          0.036          0.049
```

Significant Pairwise Tests

N	Population
58	- FLINDERS/BYNOE;
42	- NORMAN RIVER;

Locus	Fis	Fit	Fst	G	df	
ADA	0.030	0.064	0.035	7.340	2	P<0.05
ADH	0.315	0.315	0.000	0.002	1	
ENO-2	0.385	0.392	0.011	2.327	1	
GPI-1	0.383	0.384	0.001	2.216	2	
GPI-2	0.000	0.000	0.000	0.000	0	
Average	Fis	Fit	Fst			
	0.263	0.274	0.014			
Total				G	df	
				11.886	6	ns

Sidak's Multiplicative Inequality at 0.05 = 0.013
Sidak's Multiplicative Inequality at 0.01 = 0.003
Poly across pop is 4

BLUE SALMON

POP #	N	NAME
Pop 1	39	- BURKETOWN;WESTERN GULF;
Pop 2	63	- FLINDERS/BYNOE;
Pop 3	39	- NORMAN RIVER;
Pop 4	22	- SMITHBURNE;
Pop 5	21	- CAIRNS-EAST COAST
Pop 6	54	- TULLY-EAST COAST;

Allele Frequency

		Pop 1	Pop 2	Pop 3	Pop 4	Pop 5	Pop 6
ADA							
	1	0.974	0.960	0.962	0.977	0.905	0.991
	2	0.026	0.040	0.038	0.023	0.095	0.009
N		*38*	*62*	*39*	*22*	*21*	*54*
ADH							
	1	1.000	0.983	1.000	1.000	1.000	1.000
	2	0	0.017	0	0	0	0
N		*38*	*60*	*38*	*22*	*16*	*54*
EST-D							
	1	1.000	0.976	0.987	1.000	0.976	0.981
	2	0	0.024	0.013	0	0.024	0.019
N		*39*	*63*	*39*	*22*	*21*	*54*
EST-E							
	1	0.846	0.774	0.803	0.682	0.905	0.913
	2	0.154	0.226	0.197	0.318	0.095	0.087
N		*39*	*62*	*38*	*22*	*21*	*52*

FDH							
	1	0.949	0.913	0.910	0.909	0.971	1.000
	2	0.051	0.087	0.090	0.091	0.029	0
N		*39*	*63*	*39*	*22*	*17*	*53*
LDH							
	1	1.000	1.000	0.987	0.977	1.000	1.000
	2	0	0	0	0	0	0
	3	0	0	0.013	0	0	0
	4	0	0	0	0.023	0	0
N		*39*	*63*	*39*	*22*	*21*	*54*
P-LGG							
	1	0.145	0.127	0.577	0.114	0.175	0.824
	2	0.855	0.873	0.423	0.886	0.825	0.176
N		*38*	*63*	*39*	*22*	*20*	*54*
SOD							
	1	0.983	0.991	0.985	0.975	1.000	1.000
	2	0	0.009	0	0	0	0
	3	0	0	0.015	0	0	0
	4	0.017	0	0	0.025	0	0
N		*29*	*58*	*34*	*20*	*14*	*52*
Avg Hs		0.086	0.113	0.140	0.117	0.092	0.063
std err		0.038	0.043	0.062	0.052	0.038	0.038
Avg Ho		0.072	0.100	0.127	0.114	0.080	0.040
std err		0.029	0.036	0.050	0.046	0.030	0.022

Genetic Diversity

Locus	**Ht**	**Hs**	**Ho**
ADA	0.074	0.073	0.077
ADH	0.006	0.005	0.006
EST-D	0.026	0.026	0.026
EST-E	0.295	0.282	0.261
FDH	0.109	0.107	0.111
LDH	0.012	0.012	0.012
P-LGG	0.440	0.290	0.196
SOD	0.022	0.021	0.022

	Ht	**Hs**	**Ho**
Average	0.123	0.102	0.089
Variance	0.003	0.002	0.001
Std. Err	0.056	0.042	0.034

Locus	**Fis**	**Fit**	**Fst**	**G**	**df**		
ADA	-0.062	-0.040	0.020	6.601	5	ns	
ADH	-0.017	-0.003	0.014	5.365	5	ns	
EST-D	-0.021	-0.013	0.008	4.545	5	ns	
EST-E	0.075	0.115	0.043	16.701	5	P<0.01	**
FDH	-0.036	-0.013	0.022	17.072	5	P<0.005	**
LDH	-0.020	-0.005	0.015	8.407	15	ns	
P-LGG	0.322	0.554	0.342	186.516	5	P<0.0001	****
SOD	-0.019	-0.008	0.010	12.017	15	ns	

Average	**Fis**	**Fit**	**Fst**
	0.128	0.277	0.171

Total	**G**	**df**		
	257.223	60	P<0.001	***

Hardy-Weinberg

pop 3 locus P-LGG ** Deviation **				
chi	-	3.923	df	- 1
G	-	3.961	crVal	- 3.84
genotype	-	11	12	22
observed	-	16	13	10
expected	-	12.98	19.04	6.98

pop 6 locus P-LGG ** Deviation **				
chi	-	25.018	df	- 1
G	-	20.034	crVal	- 3.84
genotype	-	11	12	22
observed	-	42	5	7
expected	-	36.67	15.66	1.67

For P-LGG there is under-reporting of heterozygotes in two populations, both these populations are the ones with significant gene frequency changes from adjacent populations.

Significant Pairwise Tests

N **Population**
63 - FLINDERS/BYNOE;
39 - NORMAN RIVER;

Locus	**Fis**	**Fit**	**Fst**	G	df	
ADA	-0.041	-0.041	0.000	0.004	1	
ADH	-0.017	-0.008	0.008	1.976	1	
EST-D	-0.020	-0.019	0.002	0.321	1	
EST-E	0.051	0.052	0.001	0.228	1	
FDH	0.001	0.001	0.000	0.004	1	
LDH	-0.013	-0.006	0.006	1.931	2	
P-LGG	0.262	0.426	0.222	46.701	1	P<0.0001
SOD	-0.013	-0.009	0.004	2.915	2	
Average	**Fis**	**Fit**	**Fst**			
	0.104	0.186	0.091			
Total				G	df	
				54.079	10	P<0.001

Sidak's Multiplicative Inequality at 0.05 = 0.006
Sidak's Multiplicative Inequality at 0.01 = 0.001
Poly across pop is 8

N	Population
39	- NORMAN RIVER;
22	- SMITHBURNE;

Locus	Fis	Fit	Fst	G	df	
ADA	-0.034	-0.032	0.002	0.232	1	
ADH	0.000	0.000	0.000	0.000	0	
EST-D	-0.013	-0.006	0.006	0.899	1	
EST-E	0.060	0.078	0.019	2.172	1	
FDH	-0.099	-0.099	0.000	0.000	1	
LDH	-0.020	-0.014	0.006	2.937	3	
P-LGG	0.187	0.380	0.237	27.705	1	P<0.0001
SOD	-0.022	-0.015	0.006	2.914	3	
Average	Fis	Fit	Fst			
	0.065	0.159	0.101			
Total				G	df	
				36.860	11	P<0.01

N	Population
21	- CAIRNS-EAST COAST
54	- TULLY-EAST COAST;

Locus	Fis	Fit	Fst	G	df	
ADA	-0.096	-0.055	0.037	6.071	1	P<0.025
ADH	0.000	0.000	0.000	0.000	0	
EST-D	-0.022	-0.022	0.000	0.042	1	
EST-E	-0.100	-0.100	0.000	0.028	1	
FDH	-0.030	-0.015	0.015	2.853	1	
LDH	0.000	0.000	0.000	0.000	0	
P-LGG	0.581	0.757	0.421	54.318	1	P<0.0001
SOD	0.000	0.000	0.000	0.000	0	
Average	Fis	Fit	Fst			
	0.227	0.426	0.257			
Total				G	df	
				63.312	5	P<0.001

UPGMA using ROGERS (1972)

```
Pop  1     39  - BURKETOWN;WESTERN GULF;
Pop  2     63  - FLINDERS/BYNOE;
Pop  3     39  - NORMAN RIVER;
Pop  4     22  - SMITHBURNE;
Pop  5     21  - CAIRNS-EAST COAST
Pop  6     54  - TULLY-EAST COAST;
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                     0.024          0.048          0.072          0.096
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    5 --------------------------
                                 |-------------------------------
    4 -------------------        |                               |
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    1 ----------------   |                                       |
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    3 ---------------------------------------                    |
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    6 ---------------------------------------

       ...............|..............|..............|..............|
                     0.024          0.048          0.072          0.096
```

GOLDEN GRUNTER

POP	#	N	NAME
Pop	1	43	- BURKETOWN;
Pop	2	15	- FLINDERS/BYNOE;
Pop	3	105	- NORMAN RIVER
Pop	4	53	- SMITHBURNE;
Pop	5	37	- STAATEN RIVER;
Pop	6	15	- MITCHELL RIVER;
Pop	7	7	- CAIRNS-EAST COAST;

Allele Frequency

		Pop 1	Pop 2	Pop 3	Pop 4	Pop 5	Pop 6	Pop 7
ADH-1								
	1	0.919	0.933	0.873	0.826	0.878	1.000	0.143
	2	0	0	0	0	0	0	0.071
	3	0.070	0.067	0.113	0.141	0.108	0	0.786
	4	0.012	0	0.015	0.011	0.014	0	0
	5	0	0	0	0.011	0	0	0
	6	0	0	0	0.011	0	0	0
N		*43*	*15*	*102*	*46*	*37*	*14*	*7*
ALAT								
	1	1.000	1.000	0.990	0.991	0.986	0.967	1.000
	2	0	0	0.010	0.009	0.014	0.033	0
N		*43*	*15*	*105*	*53*	*37*	*15*	*7*
ENO-2								
	1	0.965	1.000	0.976	0.990	0.986	1.000	1.000
	2	0.035	0	0.024	0.010	0.014	0	0
N		*43*	*15*	*105*	*52*	*37*	*15*	*7*

ESTD1								
	1	0.988	1.000	0.993	1.000	0.972	1.000	0.929
	2	0.012	0	0	0	0.014	0	0.071
	3	0	0	0.007	0	0.014	0	0
N		*43*	*15*	*74*	*50*	*36*	*14*	*7*
ESTD2								
	1	0.881	0.893	0.939	0.990	0.894	0.923	1.000
	2	0	0	0.010	0	0.015	0	0
	3	0.095	0.071	0.046	0	0.076	0.077	0
	4	0.024	0.036	0.005	0.010	0.015	0	0
N		*42*	*14*	*98*	*52*	*33*	*13*	*7*
GPI-1								
	1	0.860	0.867	0.857	0.800	0.878	0.857	0.929
	2	0.140	0.133	0.143	0.200	0.122	0.143	0.071
N		*43*	*15*	*105*	*50*	*37*	*14*	*7*
GPI-2								
	1	1.000	1.000	1.000	0.953	1.000	1.000	1.000
	2	0	0	0	0.047	0	0	0
N		*43*	*15*	*105*	*53*	*36*	*14*	*7*
IDH								
	1	0.988	1.000	0.990	0.991	1.000	1.000	1.000
	2	0	0	0.010	0	0	0	0
	3	0.012	0	0	0.009	0	0	0
N		*43*	*15*	*105*	*53*	*37*	*15*	*7*
LDH								
	1	1.000	1.000	1.000	1.000	0.973	1.000	1.000
	2	0	0	0	0	0.027	0	0
N		*43*	*15*	*105*	*53*	*37*	*15*	*7*
MDH-1								
	1	1.000	1.000	0.995	0.991	1.000	1.000	1.000
	2	0	0	0	0.009	0	0	0
	3	0	0	0.005	0	0	0	0
N		*43*	*15*	*105*	*53*	*37*	*15*	*7*
MDH-2								
	1	0.988	1.000	0.990	1.000	0.986	1.000	1.000
	2	0.012	0	0.010	0	0.014	0	0
N		*43*	*15*	*105*	*53*	*37*	*15*	*7*
		Pop 1	Pop 2	Pop 3	Pop 4	Pop 5	Pop 6	Pop 7
Avg Hs		0.067	0.050	0.065	0.073	0.074	0.041	0.057
std err		0.027	0.027	0.027	0.036	0.027	0.024	0.034
Avg Ho		0.062	0.043	0.065	0.067	0.070	0.032	0.039
std err		0.027	0.026	0.028	0.037	0.026	0.026	0.020

Genetic Diversity

Locus	Ht	Hs	Ho
ADH-1	0.333	0.196	0.177
ALAT	0.019	0.018	0.019
ENO-2	0.023	0.023	0.023
ESTD1	0.033	0.032	0.034
ESTD2	0.130	0.126	0.063
GPI-1	0.235	0.232	0.245
GPI-2	0.013	0.013	0.003
IDH	0.009	0.009	0.009
LDH	0.008	0.008	0.008
MDH-1	0.004	0.004	0.004
MDH-2	0.010	0.010	0.010

	Ht	Hs	Ho
Average	0.074	0.061	0.054
Variance	0.001	0.001	0.001
Std. Err	0.034	0.025	0.024

Locus	Fis	Fit	Fst	G	df		
ADH-1	0.095	0.467	0.411	63.216	30	P<0.0005	***
ALAT	-0.023	-0.009	0.013	3.682	6	ns	
ENO-2	-0.026	-0.012	0.014	4.731	6	ns	
ESTD1	-0.052	-0.015	0.036	11.139	12	ns	
ESTD2	0.502	0.515	0.026	24.572	18	ns	
GPI-1	-0.052	-0.041	0.010	3.331	6	ns	
GPI-2	0.790	0.799	0.041	16.586	6	P<0.025	*
IDH	-0.010	-0.003	0.007	8.094	12	ns	
LDH	-0.028	-0.004	0.023	8.071	6	ns	
MDH-1	-0.008	-0.002	0.006	5.226	12	ns	
MDH-2	-0.012	-0.005	0.007	3.272	6	ns	

Average	Fis	Fit	Fst			
	0.115	0.272	0.178			
Total				G	df	
				151.919	120	ns

Significant Pairwise Tests

N	Population
105	- NORMAN RIVER;
53	- SMITHBURNE;

Locus	Fis	Fit	Fst	G	df	
ADH-1	-0.070	-0.066	0.003	5.321	4	
ALAT	-0.010	-0.010	0.000	0.000	1	
ENO-2	-0.020	-0.017	0.003	0.840	1	
ESTD1	-0.007	-0.003	0.003	1.035	2	
ESTD2	0.105	0.121	0.018	9.750	3	P<0.025
GPI-1	0.029	0.034	0.006	1.589	1	
GPI-2	0.790	0.795	0.024	11.083	1	P<0.001
IDH	-0.010	-0.007	0.002	3.819	2	
LDH	0.000	0.000	0.000	0.000	0	
MDH-1	-0.008	-0.006	0.002	3.003	2	
MDH-2	-0.010	-0.005	0.005	1.641	1	

Average	Fis	Fit	Fst			
	0.041	0.048	0.007			
Total				G	df	
				38.082	18	P<0.05

N	Population
53	- SMITHBURNE;
37	- STAATEN RIVER;

Locus	Fis	Fit	Fst	G	df	
ADH-1	-0.066	-0.062	0.004	2.878	4	
ALAT	-0.012	-0.012	0.000	0.065	1	
ENO-2	-0.012	-0.012	0.000	0.058	1	
ESTD1	-0.021	-0.011	0.011	3.516	2	
ESTD2	0.201	0.229	0.035	11.854	3	P<0.01
GPI-1	0.046	0.057	0.011	1.934	1	
GPI-2	0.790	0.795	0.024	5.281	1	P<0.025
IDH	-0.010	-0.005	0.005	1.063	2	
LDH	-0.028	-0.014	0.014	3.588	1	
MDH-1	-0.010	-0.005	0.005	1.063	1	
MDH-2	-0.014	-0.007	0.007	1.786	1	
Average	**Fis**	**Fit**	**Fst**			
	0.062	0.073	0.012			
Total				G	df	
				33.085	18	ns

N	Population
37	- STAATEN RIVER;
6	- CAIRNS-EAST COAST;

Locus	Fis	Fit	Fst	G	df	
ADH-1	-0.110	0.622	0.660	43.644	3	P<0.0001
ALAT	-0.014	-0.007	0.007	0.302	1	
ENO-2	-0.014	-0.007	0.007	0.302	1	
ESTD1	-0.073	-0.052	0.019	1.769	2	
ESTD2	0.222	0.255	0.043	2.461	3	
GPI-1	0.029	0.033	0.004	0.159	1	
GPI-2	0.000	0.000	0.000	0.000	0	
IDH	0.000	0.000	0.000	0.000	0	
LDH	-0.028	-0.014	0.014	0.609	1	
MDH-1	0.000	0.000	0.000	0.000	0	
MDH-2	-0.014	-0.007	0.007	0.302	1	
Average	**Fis**	**Fit**	**Fst**			
	-0.003	0.363	0.366			
Total				G	df	
				49.550	13	P<0.01

Hardy-Weinberg

pop 1 locus ESTD2 ** Deviation **
Expected value for smallest class was made equal to one
chi - 7.257 df - 1
G - 7.043 crVal - 3.84

genotype -	11	12	13	14	22	23	24	33	34	44	(33,34,44)
observed -	35	-	4	0	-	-	-	2	0	1	3
expected -	32.60	-	7.05	1.76	-	-	-	0.38	0.19	0.02	1.00

pop 2 locus ESTD2 ** Deviation **
chi - 2.699 df - 1
G - 4.304 crVal - 3.84

genotype -	11	12	13	14	22	23	24	33	34	44	(14,33,34,44)
observed -	12	-	0	1	-	-	-	1	0	0	2
expected -	11.16	-	1.79	0.89	-	-	-	0.07	0.07	0.02	1.05

```
pop 4 locus GPI-2 ** Deviation **
Expected value for smallest class was made equal to one
chi        -  4.048   df     -   1
G          -  3.487   crVal  - 3.84
genotype   -      11      12     22    (22)
observed   -      50       1      2      2
expected   -   48.12    4.76   0.12   1.00
```

UPGMA using ROGERS (1972)

```
Pop  1     43   - BURKETOWN;
Pop  2     15   - FLINDERS/BYNOE;
Pop  3    105   - NORMAN RIVER
Pop  4     53   - SMITHBURNE;
Pop  5     37   - STAATEN RIVER;
Pop  6     15   - MITCHELL RIVER;
Pop  7      7   - CAIRNS-EAST COAST;
```

```
                     0.023          0.045         0.068           0.091
        ................|..............|.............|...............|

     7 -------------------------------------------------------------
                                                                     |
     4 ---------------------                                         |
                            |                                        |
     6 -------------        |-----------------------------------------
                    |       |
     1 -------      |-------
              |--   |
     2 -------   |  |
                 |--
     3 --------- |
                |
     5 ---------

        ................|..............|.............|...............|
                     0.023          0.045         0.068           0.091
```

JEWELFISH

POP	#	N	NAME
Pop	1	19	- SMITHBURNE R;STAATEN RIVER;MITCHELL R;
Pop	2	15	- BURKETOWN;
Pop	3	70	- FLINDERS/BYNOE;
Pop	4	46	- NORMAN RIVER;

Allele Frequency

		Pop 1	Pop 2	Pop 3	Pop 4
ADA					
	1	0.542	0.438	0.500	0.329
	2	0.375	0.563	0.457	0.645
	3	0	0	0.043	0.026
	4	0.083	0	0	0
N		*12*	*8*	*47*	*38*

ADH					
	1	0.808	0.750	0.850	0.770
	2	0	0	0.020	0
	3	0.192	0.250	0.130	0.230
N		*13*	*8*	*50*	*37*
EST-D					
	1	0.912	1.000	0.978	1.000
	2	0.088	0	0.022	0
N		*17*	*15*	*69*	*40*
FDH-1					
	1	1.000	0.929	0.953	0.985
	2	0	0.071	0.047	0.015
N		*7*	*14*	*64*	*34*
FDH-2					
	1	0.955	0.808	0.910	0.786
	2	0.045	0.192	0.090	0.214
N		*11*	*13*	*39*	*35*
GAPD1					
	1	1.000	1.000	0.991	1.000
	2	0	0	0.009	0
N		*18*	*9*	*53*	*40*
GAPD2					
	1	0.889	0.722	0.900	0.808
	2	0.111	0.278	0.100	0.192
N		*18*	*9*	*50*	*39*
G3PDH					
	1	0.974	1.000	0.981	1.000
	2	0.026	0	0.019	0
N		*19*	*9*	*53*	*41*
GPI-1					
	1	0.974	1.000	1.000	0.988
	2	0.026	0	0	0.013
N		*19*	*15*	*70*	*40*
GPI-2					
	1	0.861	0.833	0.809	0.813
	2	0.139	0.167	0.191	0.188
N		*18*	*9*	*47*	*40*
MDHp					
	1	0.944	0.889	0.942	0.947
	2	0	0	0	0
	3	0	0	0.029	0
	4	0.056	0.111	0.029	0.053
N		*18*	*9*	*52*	*38*
MPI					
	1	0.882	0.875	0.900	0.885
	2	0.118	0.125	0.100	0.090
	3	0	0	0	0.026
N		*17*	*8*	*50*	*39*
PEPLG					
	1	0.472	0.833	0.754	0.615
	2	0.528	0.167	0.246	0.385
N		*18*	*15*	*67*	*39*

PGM

	1	1.000	1.000	1.000	0.988
	2	0	0	0	0.012
N		*19*	*15*	*70*	*41*

Avg Hs	0.176	0.192	0.164	0.189
std err	0.048	0.046	0.042	0.049
Avg Ho	0.207	0.246	0.167	0.193
std err	0.066	0.070	0.047	0.056

Genetic Diversity

Locus	**Ht**	**Hs**	**Ho**
ADA	0.535	0.516	0.657
ADH	0.329	0.325	0.364
EST-D	0.053	0.051	0.026
FDH-1	0.064	0.063	0.067
FDH-2	0.234	0.224	0.191
GAPD1	0.005	0.005	0.005
GAPD2	0.283	0.272	0.292
G3PDH	0.022	0.022	0.023
GPI-1	0.019	0.019	0.019
GPI-2	0.284	0.283	0.319
MDHp	0.130	0.128	0.138
MPI	0.204	0.204	0.193
PEPLG	0.443	0.405	0.546
PGM	0.006	0.006	0.006

	Ht	Hs	Ho
Average	0.187	0.180	0.203
Variance	0.002	0.002	0.003
Std. Err	0.046	0.044	0.056

Locus	**Fis**	**Fit**	**Fst**	**G**	**df**	
ADA	-0.272	-0.228	0.035	19.103	9	P<0.025
ADH	-0.120	-0.108	0.011	6.377	6	ns
EST-D	0.497	0.522	0.049	8.873	3	P<0.05
FDH-1	-0.060	-0.034	0.024	3.335	3	ns
FDH-2	0.149	0.184	0.042	7.329	3	ns
GAPD1	-0.010	-0.002	0.007	1.640	3	ns
GAPD2	-0.073	-0.034	0.036	5.567	3	ns
G3PDH	-0.024	-0.011	0.012	3.262	3	ns
GPI-1	-0.022	-0.010	0.012	3.865	3	ns
GPI-2	-0.128	-0.125	0.003	0.575	3	ns
MDHp	-0.081	-0.067	0.013	7.005	9	ns
MPI	0.051	0.053	0.002	4.587	6	ns
PEPLG	-0.348	-0.233	0.086	15.155	3	P<0.005
PGM	-0.012	-0.003	0.009	2.535	3	ns

Average	**Fis**	**Fit**	**Fst**
	-0.128	-0.090	0.034

Total	**G**	**df**	
	89.207	60	ns

Sidak's Multiplicative Inequality at 0.05 = 0.004
Sidak's Multiplicative Inequality at 0.01 = 0.001
Poly across pop is 14

Significant Pairwise Tests

N Population
70 - FLINDERS/BYNOE;
41 - NORMAN RIVER;

Locus	Fis	Fit	Fst	G	df	
ADA	-0.153	-0.118	0.031	5.993	2	P<0.05
ADH	0.070	0.082	0.013	4.965	2	
EST-D	-0.022	-0.011	0.011	2.768	1	
FDH-1	-0.041	-0.032	0.009	1.536	1	
FDH-2	0.115	0.142	0.030	4.581	1	P<0.05
GAPD1	-0.010	-0.005	0.005	1.129	1	
GAPD2	0.204	0.217	0.017	3.070	1	
G3PDH	-0.019	-0.010	0.010	2.309	1	
GPI-1	-0.013	-0.006	0.006	2.031	1	
GPI-2	-0.083	-0.083	0.000	0.004	1	
MDHp	-0.050	-0.047	0.003	3.921	3	
MPI	0.259	0.260	0.001	3.360	2	
PEPLG	-0.206	-0.179	0.022	4.445	1	P<0.05
PGM	-0.012	-0.006	0.006	2.000	1	
Average	**Fis**	**Fit**	**Fst**			
	-0.020	-0.002	0.017			
Total				G	df	
				42.113	19	P<0.05

N Population
19 - SMITHBURNE R;STAATEN RIVER;MITCHELL R;
41 - NORMAN RIVER;

Locus	Fis	Fit	Fst	G	df	
ADA	-0.098	-0.035	0.057	11.329	3	P<0.025
ADH	-0.107	-0.105	0.002	0.160	2	
EST-D	0.634	0.651	0.046	7.452	1	P<0.01
FDH-1	-0.015	-0.007	0.007	0.377	1	
FDH-2	0.043	0.104	0.063	4.138	1	P<0.05
GAPD1	0.000	0.000	0.000	0.000	0	
GAPD2	0.109	0.120	0.013	1.242	1	
G3PDH	-0.027	-0.013	0.013	2.318	1	
GPI-1	-0.022	-0.020	0.003	0.276	1	
GPI-2	-0.108	-0.103	0.004	0.425	1	
MDHp	-0.057	-0.057	0.000	0.004	3	
MPI	0.127	0.128	0.002	1.629	2	
PEPLG	-0.491	-0.460	0.021	2.050	1	
PGM	-0.012	-0.006	0.006	0.765	1	
Average	**Fis**	**Fit**	**Fst**			
	-0.097	-0.069	0.025			
Total				G	df	
				32.165	19	

Hardy-Weinberg

pop 1 locus PEPLG ** Deviation **

chi	-	8.124	df -	1
G	-	8.962	crVal -	3.84
genotype	-	11	12	22
observed	-	1	15	2
expected	-	4.01	8.97	5.01

```
pop 2 locus ADA ** Deviation **
chi        -  4.840   df    -    1
G          -  6.198   crVal - 3.84
genotype   -      11      12      22
observed   -       0       7       1
expected   -    1.53    3.94    2.53

pop 3 locus ADH ** Deviation **
chi        -  2.402   df    -    1
G          -  3.973   crVal - 3.84
genotype   -      11      12      13      22      23      33 (22,23,33)
observed   -      37       0      11       1       0       1       2
expected   -   36.13    1.70   11.05    0.02    0.26    0.85    1.13
```

UPGMA using ROGERS (1972)

```
Pop  1     19  - SMITHBURNE R;STAATEN RIVER;MITCHELL R;
Pop  2     15  - BURKETOWN;
Pop  3     70  - FLINDERS/BYNOE;
Pop  4     46  - NORMAN RIVER;
```

```
                 0.016          0.033          0.049          0.065
       ...............|..............|..............|..............|

     2 -----------------------------------------
                                                |-----------------
     4 -----------------------------------------                 |
                                                                 |
     1 -----------------------------------------------           |
                                                      |----------
     3 -----------------------------------------------

       ...............|..............|..............|..............|
                   0.016          0.033          0.049          0.065
```

KING SALMON

POP	#	N		NAME
Pop	1	59	-	FLINDERS/BYNOE;
Pop	2	38	-	NORMAN RIVER;
Pop	3	12	-	SMITH-STAAT-MITCH;
Pop	4	20	-	WEIPA;
Pop	5	15	-	TULLY-EAST COAST;

Allele Frequency

		Pop 1	Pop 2	Pop 3	Pop 4	Pop 5
ADA-1						
	1	0.839	0.855	0.917	0.950	0.833
	2	0	0	0	0	0
	3	0.161	0.145	0.083	0.050	0.167
N		*59*	*38*	*12*	*20*	*15*
ADA-2						
	1	0.897	0.684	0.600	0.947	1.000
	2	0.103	0.316	0.400	0.053	0
N		*58*	*38*	*5*	*19*	*14*

ADH						
	1	0.686	0.763	0.917	0.842	0.700
	2	0.314	0.237	0.083	0.158	0.300
N		*59*	*38*	*12*	*19*	*15*
ALAT						
	1	0.728	0.789	0.917	0.842	0.700
	2	0.272	0.211	0.083	0.158	0.300
N		*57*	*38*	*12*	*19*	*15*
EST-E						
	1	0.628	0.608	0.500	0.528	0.667
	2	0.372	0.392	0.500	0.472	0.333
N		*43*	*37*	*12*	*18*	*12*
FDH						
	1	0.568	0.592	0.667	0.632	0.433
	2	0.432	0.408	0.333	0.368	0.567
N		*59*	*38*	*12*	*19*	*15*
GPI-1						
	1	0.983	0.987	1.000	0.925	0.967
	2	0.017	0.013	0	0.075	0.033
N		*59*	*38*	*12*	*20*	*15*
GPI-2						
	1	0.966	0.908	0.917	0.975	0.967
	2	0.034	0.092	0.083	0.025	0.033
N		*59*	*38*	*12*	*20*	*15*
MDHp						
	1	0.983	0.947	0.958	1.000	0.667
	2	0.017	0.053	0.042	0	0.333
N		*59*	*38*	*12*	*17*	*15*
PEPLG						
	1	0.695	0.632	0.542	0.600	0.367
	2	0.305	0.368	0.458	0.400	0.633
N		*59*	*38*	*12*	*20*	*15*
P-LGG						
	1	0.491	0.500	0.500	0.579	0.929
	2	0.509	0.474	0.500	0.368	0.071
	3	0	0.026	0	0.053	0
N		*58*	*38*	*6*	*19*	*14*
Avg Hs		0.300	0.329	0.283	0.262	0.293
std err		0.057	0.051	0.060	0.060	0.057
Avg Ho		0.306	0.367	0.315	0.292	0.316
std err		0.060	0.067	0.077	0.075	0.070

Genetic Diversity

Locus	Ht	Hs	Ho
ADA-1	0.213	0.209	0.165
ADA-2	0.288	0.239	0.328
ADH	0.341	0.326	0.368
ALAT	0.326	0.313	0.388
EST-E	0.485	0.477	0.516
FDH	0.488	0.475	0.502
GPI-1	0.054	0.052	0.055
GPI-2	0.101	0.100	0.086
MDHp	0.162	0.131	0.124
PEPLG	0.491	0.466	0.486
P-LGG	0.492	0.437	0.493

	Ht	Hs	Ho
Average	0.313	0.293	0.319
Variance	0.002	0.002	0.003
Std. Err	0.050	0.048	0.054

Locus	Fis	Fit	Fst	G	df		
ADA-1	0.210	0.226	0.020	4.726	8	ns	
ADA-2	-0.368	-0.138	0.168	31.635	4	P<0.0001	****
ADH	-0.129	-0.079	0.044	9.202	4	ns	
ALAT	-0.239	-0.193	0.038	6.845	4	ns	
EST-E	-0.081	-0.064	0.016	2.503	4	ns	
FDH	-0.057	-0.029	0.026	3.890	4	ns	
GPI-1	-0.055	-0.028	0.025	4.863	4	ns	
GPI-2	0.138	0.151	0.016	4.303	4	ns	
MDHp	0.053	0.232	0.189	30.328	4	P<0.0001	****
PEPLG	-0.043	0.010	0.051	11.471	4	P<0.025	*
P-LGG	-0.130	-0.003	0.113	29.898	8	P<0.0005	***
Average	**Fis**	**Fit**	**Fst**				
	-0.089	-0.021	0.062				
Total				G	df		
				139.663	52	P<0.01	**

Sidak's Multiplicative Inequality at 0.05 = 0.005
Sidak's Multiplicative Inequality at 0.01 = 0.001
Poly across pop is 11

Significant Pairwise Tests

N	Population
59	- FLINDERS/BYNOE;
38	- NORMAN RIVER;

Locus	Fis	Fit	Fst	G	df	
ADA-1	0.117	0.117	0.001	0.094	2	
ADA-2	-0.187	-0.106	0.068	13.352	1	P<0.0005
ADH	0.043	0.050	0.007	1.359	1	
ALAT	-0.180	-0.174	0.005	0.936	1	
EST-E	-0.086	-0.086	0.000	0.066	1	
FDH	-0.215	-0.214	0.001	0.112	1	
GPI-1	-0.016	-0.015	0.000	0.045	1	
GPI-2	0.369	0.379	0.014	2.843	1	
MDHp	-0.046	-0.036	0.009	1.908	1	
PEPLG	-0.028	-0.023	0.004	0.834	1	
P-LGG	-0.104	-0.103	0.001	3.828	2	

Average	Fis	Fit	Fst	G	df
	-0.072	-0.062	0.009		
Total				G	df
				25.378	13

N	Population
38	- NORMAN RIVER;
20	- WEIPA;

Locus	Fis	Fit	Fst	G	df	
ADA-1	0.309	0.326	0.026	2.661	2	
ADA-2	-0.188	-0.051	0.115	11.955	1	P<0.001
ADH	-0.091	-0.080	0.010	0.986	1	
ALAT	-0.231	-0.226	0.005	0.463	1	
EST-E	-0.267	-0.259	0.007	0.639	1	
FDH	-0.249	-0.247	0.002	0.166	1	
GPI-1	-0.070	-0.046	0.023	2.840	1	
GPI-2	0.403	0.415	0.020	2.147	1	
MDHp	-0.056	-0.027	0.027	3.025	1	
PEPLG	-0.030	-0.029	0.001	0.111	1	
P-LGG	-0.101	-0.092	0.008	1.426	2	

Average	Fis	Fit	Fst	G	df
	-0.115	-0.096	0.018		
Total				G	df
				26.418	13

N	Population
20	- WEIPA;
15	- TULLY-EAST COAST;

Locus	**Fis**	**Fit**	**Fst**	**G**	**df**	
ADA-1	0.463	0.482	0.035	2.597	2	
ADA-2	-0.056	-0.027	0.027	2.254	1	
ADH	-0.335	-0.297	0.029	1.960	1	
ALAT	-0.335	-0.297	0.029	1.960	1	
EST-E	-0.119	-0.097	0.020	1.155	1	
FDH	-0.038	0.003	0.039	2.668	1	
GPI-1	-0.066	-0.057	0.008	0.585	1	
GPI-2	-0.031	-0.030	0.001	0.042	1	
MDHp	0.100	0.280	0.200	17.284	1	P<0.0001
PEPLG	-0.165	-0.101	0.055	3.770	1	
P-LGG	-0.015	0.126	0.139	11.709	2	P<0.005
Average	**Fis**	**Fit**	**Fst**			
	-0.095	-0.029	0.060			
Total				**G**	**df**	
				45.986	13	P<0.001

Hardy-Weinberg

pop 2 locus ALAT ** Deviation **

chi	-	2.702	df	- 1
G	-	4.319	crVal	- 3.84
genotype	-	11	12	22
observed	-	22	16	0
expected	-	23.68	12.63	1.68

pop 2 locus FDH ** Deviation **

chi	-	4.980	df	- 1
G	-	5.238	crVal	- 3.84
genotype	-	11	12	22
observed	-	10	25	3
expected	-	13.32	18.36	6.32

pop 5 locus ADH ** Deviation **

chi	-	2.755	df	- 1
G	-	3.985	crVal	- 3.84
genotype	-	11	12	22
observed	-	6	9	0
expected	-	7.35	6.30	1.35

pop 5 locus ALAT ** Deviation **

chi	-	2.755	df	- 1
G	-	3.985	crVal	- 3.84
genotype	-	11	12	22
observed	-	6	9	0
expected	-	7.35	6.30	1.35

UPGMA using ROGERS (1972)

```
Pop  1      59  - FLINDERS/BYNOE;
Pop  2      38  - NORMAN RIVER;
Pop  3      12  - SMITH-STAAT-MITCH;
Pop  4      20  - WEIPA;
Pop  5      15  - TULLY-EAST COAST;

                  0.041          0.082          0.123          0.164
    ................|..............|..............|..............|


  5 -------------------------------------------------------------
                                                                 |
  3 ----------------------------------                           |
                                      |--------------------------
  4 -------------------------------   |
                                   |--
  1 ---------------------          |
                         |---------
  2 ---------------------

    ................|..............|..............|..............|
                  0.041          0.082          0.123          0.164
```

4. AGE AND GROWTH OF FIVE TARGET FISH SPECIES IN THE GULF OF CARPENTARIA INSHORE GILLNET FISHERY

(contributed by Messrs J.M. Bibby and G.R. McPherson, Northern Fisheries Centre, PO Box 5396, Cairns Qld 4870)

4.1 INTRODUCTION

Barramundi (*Lates calcarifer*) is the most highly prized member of a suite of fish species taken by the Queensland inshore gill net fishery in the Gulf of Carpentaria. Other valued components of the net catch are banded grunter (*Pomadasys kaakan*), king salmon (*Polydactylus sheridani*), blue salmon (*Eleutheronema tetradactylum*), black jewfish (*Protonibea diacanthus*), and the jewelfish (*Nibea squamosa*).

Age and growth studies are fundamental for population biology studies and to establish sound management policies (Morales-Nin 1995). Until now, few growth studies on Gulf of Carpentaria inshore fish, other than barramundi, were available. The growth of grunter and blue salmon elsewhere in Queensland has been studied by scale and otolith interpretation (Bade 1989; Stanger 1974). For the other species, some age and growth data has been published for populations in waters off Pakistan and north-west India that may be used for comparative purposes.

Growth rings in fish otoliths have proved a useful tool for age determination in tropical marine species where seasonal markings may not be present on other body parts such as scales. Age and growth in the five important Gulf of Carpentaria fish species listed above, were assessed using whole and sectioned otoliths once their suitability for age determination was established.

The length-at-age keys and population parameters derived in this program have been made available to the Queensland Fisheries Management Authority for use in developing a new Gulf of Carpentaria Inshore Fishery Management Plan.

4.2 SPECIFIC OBJECTIVES

1. To examine the age and growth of the key non-barramundi target species of the Queensland inshore gill net fishery in the Gulf of Carpentaria. The target species were grunter (*Pomadasys kaakan*), threadfin salmon (*Polydactylus sheridani* and *Eleutheronema tetradactylum*), and jewfishes (*Protonibea diacanthus* and *Nibea squamosa*).

2. To provide length-at-age information and growth parameters for use in the fishery management of the target species in Gulf of Carpentaria waters.

The initiatives described in this contribution address age and growth characteristics for the species throughout their Queensland Gulf of Carpentaria distribution. Pending successful genetic stock delineation for the target species, more research may be necessary to identify stock-specific attributes of age and growth. This work, for the moment, remains an undertaking for the future.

4.3 MATERIALS AND METHODS

4.3.1 Collection of samples

In this study the fishing grounds associated with several river systems were targeted throughout the central and south-east region of the Gulf of Carpentaria (Figure 4.1). River systems included the Mitchell, Staaten, Gilbert, Smithburne, Norman, Flinders, Bynoe, Albert and the Leichhardt.

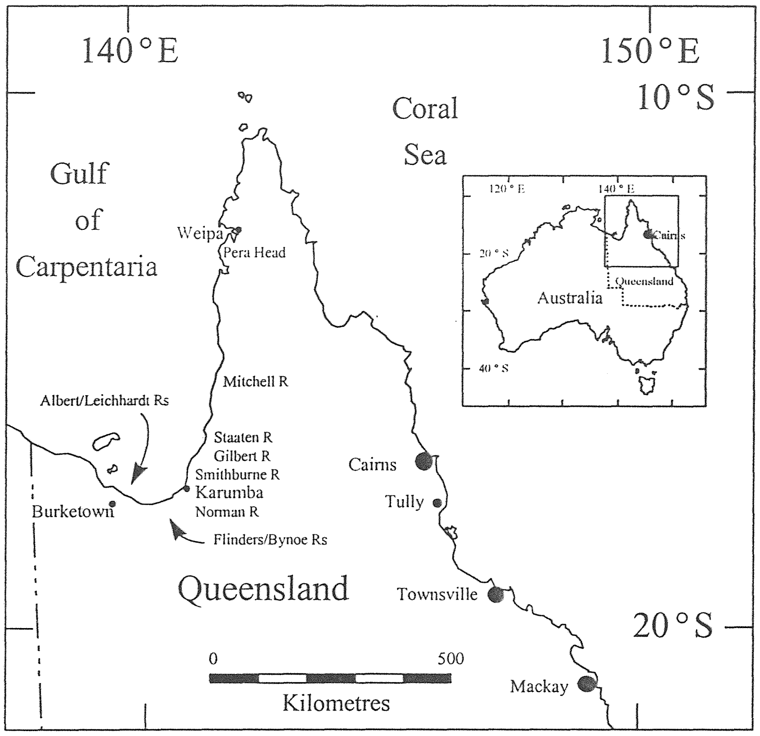

Figure 4.1 North Queensland, showing Gulf of Carpentaria river systems sampled.

Sample collections commenced in January 1993 in anticipation of project commencement, and were completed by November 1995. The research program outlined in the December 1992 application to FRDC indicated that samples for age and growth determination would be collected primarily during the first years of the project, and detailed analyses would be completed during a later phase. A lack of funding support for this later initiative has forced a rescheduling of this timetable to deliver more comprehensive baseline age and growth information for the species studied. Material collected in earlier QDPI surveys of Gulf fish stocks was incorporated into the database to expand the available time series of data for the biology of the species.

Fish specimens for the study of age and growth were primarily obtained from professional fisher net catches (91% of aged samples and 88% of all samples, see also Appendix 4.1). Filleted frames and skins were packaged on-site by volunteer fishers and forwarded in a frozen condition to the QDPI Northern Fisheries Centre Cairns, and purchased at $2/frame. Samples were also collected from research angling and recreational fishery hook-and-line catches (9% of aged samples and 12% of all samples, see also Appendix 4.1) to help account for out-sized animals due to net selectivity. Line-caught samples were usually collected in association with tag and release fishing operations. Samples were collected during the commercial fishery closed fishing season in November, December and January, although accessibility to most areas during this time, the wet season, was restricted.

Tagging operations were conducted by project staff and locally based recreational and professional fishers between 1st March 1993 and the 30th June 1994, at Karumba on the mouth of the Norman River. Due to the limited time and program resources, only one species, the golden grunter, was selected for the trial. Six hundred and fifty-three animals were tagged with dart tags (Hallprint Pty Ltd) with 501 fish injected with the oxytetracycline (OTC) based Terramycin/LA (Pfizer Inc) into the interperitoneal cavity at 75mg/kg of body weight. Terramycin/LA is a fluorochromatic, long acting, broad spectrum veterinary antibiotic and was used in this study to chemically mark hard body structures, such as otoliths and scales, for age validation (Wilson 1995).

Due to unexpectedly low return rates of tagged fish in 1993 and 1994 an *ad hoc* survival experiment was implemented in June 1995 and run for 12 months to gauge the effects of capture, tagging and injection stresses on golden grunter. Seventy-six wild caught animals were tagged with dart tags and separated into four groups:

1. Control group - no injection, dart tag only
2. Water blank injection
3. Terramycin/LA solution group - this Terramycin was used in the tagging study, and
4. Oxytetracycline (BP) hydrochloride (Rhone-Poulenc) powder - this is a dry product that requires hydration prior to injection.

The two forms of OTC were injected at the same rate as per the field mark-recapture program. Tag loss was also recorded during the survival experiment.

Fish specimens were measured to the nearest 0.5 cm Length at Caudal Fork (LCF) and/or Total Length (TL) depending on caudal fin shape, and, where possible, weighed to the nearest 1.0 g Total Weight (TWT). Because most samples obtained from professional and recreational catches had been filleted, they were not weighed.

Specimen sex and reproductive maturity stage were macroscopically determined after the scheme of Nikolsky (1963). Gonads were weighed to the nearest 0.1 g, then preserved in a 10% neutral buffered formaldehyde solution (Hunter 1985). Reproductive data used in association with age and growth analyses were based on macroscopic assessment when histological assessment was not available.

Body scales for age assessment were removed from the lateral surface, usually behind the pectoral fin area. One or two scales that were not obviously replacement scales were washed, air dried for up to 24 hours, then mounted on Quickpoint® glass 35mm slide mounts to keep the scale flat for later examination.

Otoliths were removed, cleaned in water, allowed to air dry for 24-72 hours, and then stored in individually numbered polyethylene containers before assessment.

4.3.2 Age determination procedures

Mounted scales were examined under a stereo-macroscope, or projected onto a white board with a 35mm slide projector. The body scales of the species studied generally appeared inappropriate for ageing as they were often opaque, had extensive surface pitting, and/or tended to have a crowding of 'annuli' on the scale margins in 'older' animals which made reading difficult. However, the scales of black jewfish and jewelfish were retained for comparison with otolith section assessments.

Whole otoliths (sagittae) were immersed in aniseed oil and viewed using a stereo-macroscope. If an age could be readily assigned to an otolith on the first reading, two further readings were made separated by a minimum of two days. Otoliths that were difficult to interpret on the first reading were subjected to a heating treatment (Christensen 1964), then read three times as for whole untreated otoliths.

Each otolith was read without knowledge of collection details. After each reading, the aniseed oil was rinsed off in absolute alcohol and the otolith allowed to air dry for five minutes before its return to storage.

While otolith markings could easily be interpreted for whole otoliths of golden grunter and king salmon, longitudinal sections were made of golden grunter otoliths, and transverse sections made of king salmon otoliths, for comparison with ages derived from entire bones. Blue salmon could also be aged quite readily from otoliths, but only through the older age groups. In this species the laterally compressed otolith appeared opaque around the focal area, obscuring the earliest annuli. As a result, blue salmon otoliths were transversely sectioned prior to assessment. The chunky three-dimensional character of black jewfish and jewelfish otoliths, especially above the focus, required all otoliths to be sectioned in a transverse plane before reading was attempted.

Otoliths requiring sectioning were embedded in Buehler Castolite epoxy resin and sectioned using a Buehler Isomet low speed saw with a 0.3mm diamond wafering blade. Sections were viewed under a stereo-macroscope using a combination of transmitted (tungsten) and reflected (halogen) lighting. Magnification differed between the species and the methods, depending on the general size of the whole or sectioned otoliths. Sectioned otoliths were read three times in the manner already described for whole otoliths.

In the reading or assessing of the marks on an otolith, each completed 'opaque' band was counted, and each annulus was measured as the distance from the focus to the commencement of the following translucent area, with an ocular micrometer. The distance from the focus to the otolith margin was also measured. Measurements on whole otoliths of golden grunter and king salmon were made from the focus to the posterior margin along the longitudinal axis. Measurements on transverse sections of the otoliths of blue salmon, black jewfish and jewelfish were made from the focus towards the proximal surface (interior face with the sulcus). Measurements on longitudinal sections of the otoliths of golden grunter were made along the longitudinal axis to the posterior margin.

4.3.3 Data analyses

All statistical tests were conducted on an IBM-compatible PC, using the STATISTX program.

Kolmogorov-Smirnov tests for goodness of fit were used to compare the distribution of fish lengths of the sub-sample taken and aged in different years of the project.

Annulus formation was partially validated with two different procedures. Partial validation of age determinations was achieved for some year classes in all five species by determining the time of check formation (Brothers 1982) using the Edge Growth Ratio (EGR; Harris 1985; Gooley 1992) which is the ratio of the width of the current season's growth zone (ie, annulus to radius) to the width of the preceding year's growth zone (ie, annulus to annulus). ANOVA was used to compare the monthly EGR's of combined age classes due to low sample numbers. Only those animals of age > 1 were used for this analysis as the distance from the focus to the first annulus is usually much greater than that from the first to the second annuli.

Further partial validation of annuli was examined by ANOVA (in conjunction with Tukey pair-wise comparison of means, and two-sampled *t*-tests) of focus to last annulus distances and length-at-age data (Manooch 1982). Lengths-at-age were back-calculated to the last annulus formed to reduce the effects of sampling from a highly seasonal fishery (Davis and Kirkwood 1984; McPherson 1992). In conjunction with the EGR results of a single annulus formation per year, the significant differentiation of length-at-age based on annulus distances was assumed to be a further indication of annual classes.
ANOVA was used to compare estimates from the primary and secondary age determination methods used for each species. A single reading for the primary age method was compared to a single reading for the secondary age method. Fish ages determined from whole otoliths were compared with ages from sectioned otoliths in golden grunter, king salmon and blue salmon. Sectioned ages were compared to scale ages for black jewfish and jewelfish.

Precision of within-reader bias was calculated using the Index of Average Percent Error (Beamish and Fournier 1981).

Sub-models of the Schnute (1981) age-length growth model listed by Baker *et al.* (1991) and Quinn and Deriso (in press) were fitted to the back-calculated length-at-age data using a FORTRAN package written by Terry Quinn (Baker *et al.* 1991). Different growth models were compared on the basis of their Residual Sums of Squares (*RSS*), and the most parsimonious model selected according to the methodology described by Quinn and Deriso (in press) after Schnute (1981).

4.4 RESULTS

4.4.1 Sample collection database

The total number of fish samples obtained over the lifetime of the project is given in Table 4.1. The number (and method) aged by the primary and secondary methods is also given, as are the numbers of otoliths that have yet to be assessed. Considerable material remains to be aged as a consequence of the reduced project duration.

Table 4.1 Summary information for primary and secondary ageing material collected for each species, showing totals for primary aged material, totals for secondary aged material with a corresponding primary method age, and numbers still to be aged.

	Total Samples	AGED , primary method	AGED, both primary and secondary method	TO BE AGED primary method
Golden grunter	1107	276 whole	145 section	831
King salmon	1185	740 whole	20 section	445
Blue salmon	664	200 section	177 whole	464
Black jewfish	406	194 section	15 scale	208
Jewelfish	726	262 section	233 scale	464

Fish length expressed as LCF was used throughout this study in preference to total length for fish with emarginate caudal fins. Highly fimbriate caudal fin lobes that occur in king and blue salmon can cause measurement error through damage to frozen fins during handling and transport. However, calculation of total length was essential for comparison of results with published studies and to provide the Queensland Fisheries Management Authority with total length information for consideration of minimum legal sizes. Parameters of the linear regression relationships between total length and fork length for the species with emarginate caudal fin profiles (golden grunter, king salmon and blue salmon) are given in Table 4.2.

Table 4.2 Relationship between total length and fork length in three Gulf species.

Species	TL : LCF relationship	n	R^2	Range (cm) LCF
Golden grunter	TL = 0.12 + 1.04 * LCF	754	0.99	3.9 - 61.0
King salmon	TL = 1.42 + 1.19 * LCF	432	0.99	15.5 - 106.5
Blue salmon	TL = 1.05 + 1.18 * LCF	592	0.99	9.6 - 88.0

4.4.2 Mark-recapture exercises

Six hundred and fifty three golden grunter between 15.7cm and 60.0cm LCF (Figure 4.2) were tagged and released, and of these 501 were injected with Terramycin. To November 1996, only nine recaptures had been reported (1.4%), with seven having been chemically marked. Only one recaptured grunter had been at large for more than one month (64 days at liberty) and the furthest known distance travelled from the point of release was only 3nm.

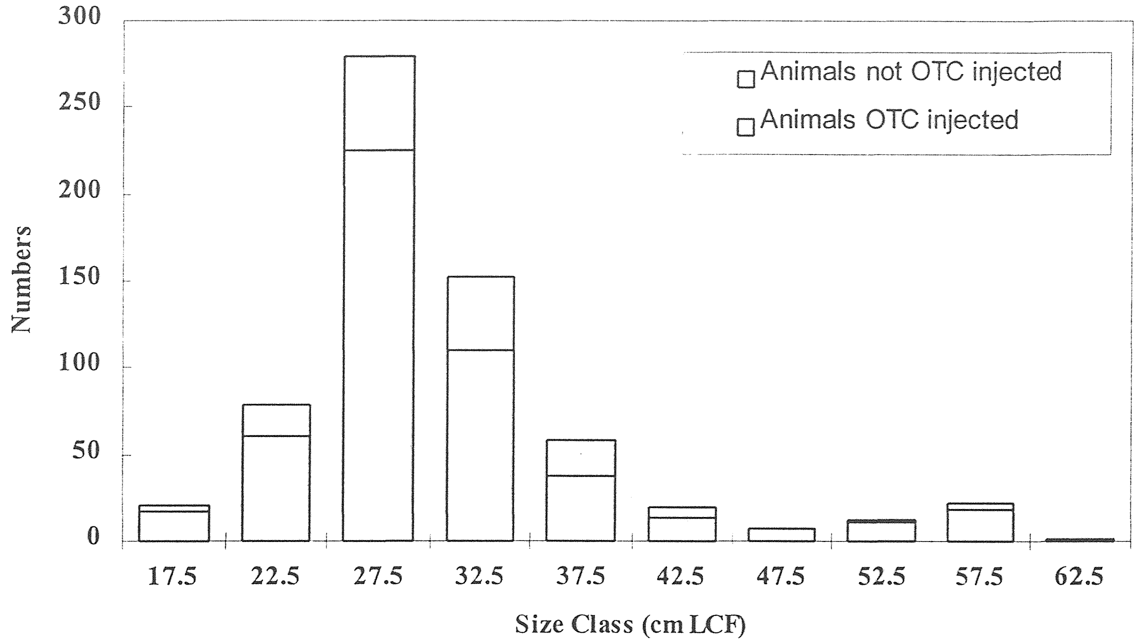

Figure 4.2: Size frequencies of tagged golden grunter displaying numbers of animals injected with Terramycin (OTC) and those not injected.

Such a poor recapture rate over time was unexpected. The authors reasoned that factor besides a lack of fisher response were likely to be involved; alternative explanations such as

a) tagging/injection induced mortality, or

b) tag loss

might be responsible (Beamish *et al.* 1983; Mace and Johnston 1983; Whitelaw and Sainsbury 1986; McFarlane and Beamish 1987; Monaghan 1993; Sprankle *et al.* 1996) and should be investigated.

A pilot exercise was, therefore, implemented in June 1995, to gauge the likely consequences of capture, tagging and injection stresses on golden grunter. Four groups involving 76 tagged animals (Table 4.3) of a broad range of fish lengths were mixed together after tagging and OTC injection, and kept in two 2000L fibreglass tanks at Northern Fisheries Centre Cairns for 12 months. Five of 36 fish (14%) injected with the Terramycin solution died within 2 days of injection, with a further 18 (50%) dying within 10 days of injection (see Table 4.3). No additional mortalities were observed after this time.

Table 4.3: Terramycin injection experiment results summary displaying numbers of animals for the different treatments and number of deaths associated with each treatment group.

Treatment	Number of fish	Number of deaths	% mortality
Control	10	0	0
Water	20	0	0
Terramycin solution	36	23	63.9
Terramycin hydrochloride	10	0	0

During the experiment the fish were also monitored daily for tag loss. Six fish had shed their tags between June and October 1995, with 13 further animals shedding their tags between November 1995 and June 1996. This represents an overall tag shedding rate of 35% in the surviving 53 fish.

4.4.3 Golden grunter

In golden grunter, Kolmogorov-Smirnov tests of goodness of fit for the primary aged (age>0) sample versus all samples were not significantly different ($P = 0.288$, $n_{aged} = 276$, $n_{all} = 1100$). The fish whose otoliths were selected for primary ageing had the same length distribution as those included in the total sample.

The monthly variation in the Edge Growth Ratio (EGR) was highly significant ($n = 223$, $P < 0.005$), confirming that annuli were formed annually (Gooley 1992). The Tukey tests on the monthly means demonstrated a decrease from July to a minimum in October (see Figure 4.3). The exact month of minimal EGR could not be determined due to the seasonal closure in November, December and January when relatively few data were obtained, although a spring (September-November) timing of annulus formation appears likely. Data from August may indicate that annulus formation is earlier; however, caution should be exercised due to low numbers of samples from this month ($n = 5$).

Further validation of the annual nature of the growth stanzas came from the consistent increase of the mean focus-to-last-annulus distance up to 8 years, with significant differences ($P < 0.05$) from 1 to 5 years. While the mean back-calculated length-at-age increased consistently up to 13 years, Tukey pair-wise comparisons of means showed significant ($P < 0.05$) differences between year classes 2 to 5. Age class 1 and age class 2 could not be differentiated using Tukey tests, but were significant ($P < 0.05$, $n_{age=1} = 8$, $n_{age=2} = 13$) using a t-test for unequal variances.

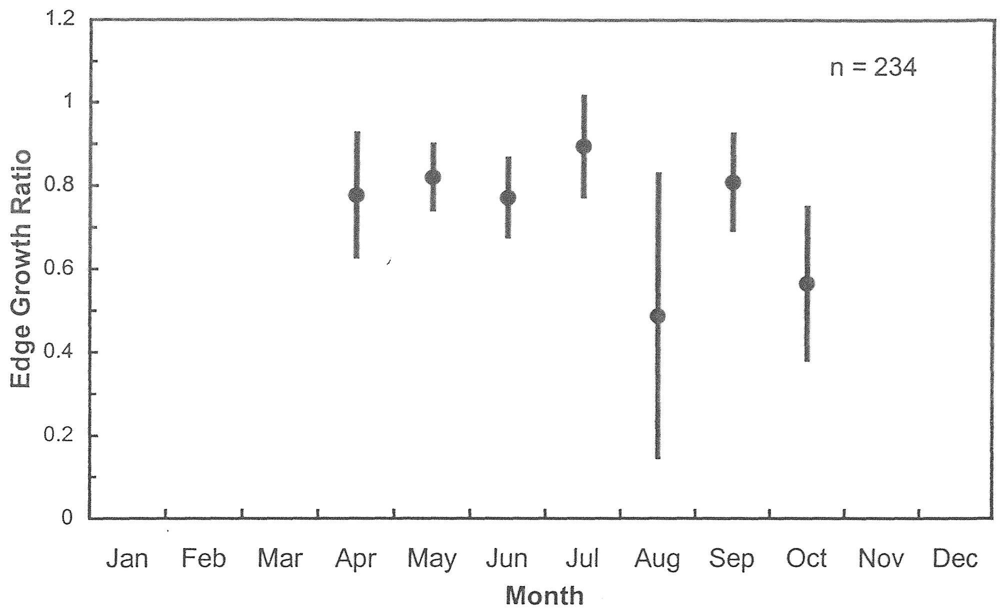

Figure 4.3: Mean monthly Edge Growth Ratios (and 95% confidence intervals) for banded grunter, where $n_{month} > 1$ and estimated age > 1

Comparison of primary whole otolith age with secondary section otolith age (for ages>0) did not detect any differences between the techniques. The ages did not significantly differ (paired *t*-test ; d.f.=144, P=0.218) and there were no systematic differences between the age estimates over the 13 age classes examined (sign test P=0.148). Only 12.4% of the fish compared differed between whole or sectioned ages by ±1 age class, and there were no differences >1 year. Due to the comparative ease of preparation of the whole otolith ageing technique (including heat treatment if necessary) over the sectioning technique, whole otoliths were selected as the primary ageing method for golden grunter. The Index of Average Percent Error was 6.67, which appears reasonable for this exercise (Beamish and Fournier 1981).

The Schnute Case 5 growth model, reparameterised as the von Bertalanffy growth curve (LVB), provided the most parsimonious fit to the assigned age data for golden grunter.

Table 4.4 Parameters (and standard errors) of the von Bertalanffy growth function for golden grunter.

L_∞ (LCF)	K	t_0	R^2	n
57.9 (0.06)	0.35 (0.02)	-0.66 (0.10)	0.88	250

The parameters (and standard errors) of the LVB curve fitted to the back-calculated data are given in Table 4.4. The back-calculated data and the LVB curve are given in Figure 4.4.

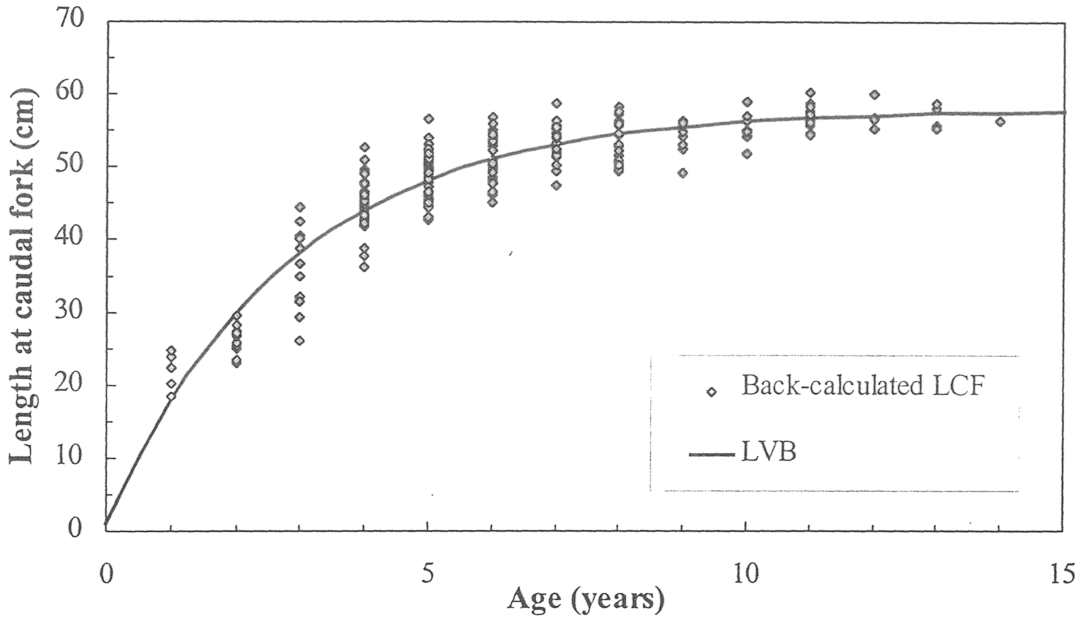

Figure 4.4 Back-calculated length-at-age data and von Bertalanffy growth function for golden grunter.

4.4.4 King salmon

Scales were not considered for ageing this species, or for blue salmon either, due to the softness of the skin, and the readiness of scales to be lost during the field collection and laboratory handling process.

Fish sampled in Gulf fishing grounds prior to the commencement of the project included the 740 specimens for which ages have been assigned. Approximately 62% of the total sample of 1185 fish specimens has been aged during this study.

For king salmon, the monthly variation in the edge growth ratio (EGR) was highly significant (ANOVA, n=796, $P<0.001$) and Tukey tests on the monthly means demonstrated lowest EGR's during October and February (see Figure 4.5). As this period coincided with the seasonal fishing closure from November-January, sample numbers were low and the exact period of annulus formation could not be clearly defined.

Additional validation of the annual nature of the growth markings came from the consistent increase of the mean focus-to-last-annulus distance up to 9 years, with significant differences ($P < 0.05$) from 1 to 8 years. While the mean back-calculated length-at-age increased consistently up to 7 years, Tukey pair-wise comparisons of means showed significant ($P < 0.05$) differences between year classes 1 to 5.

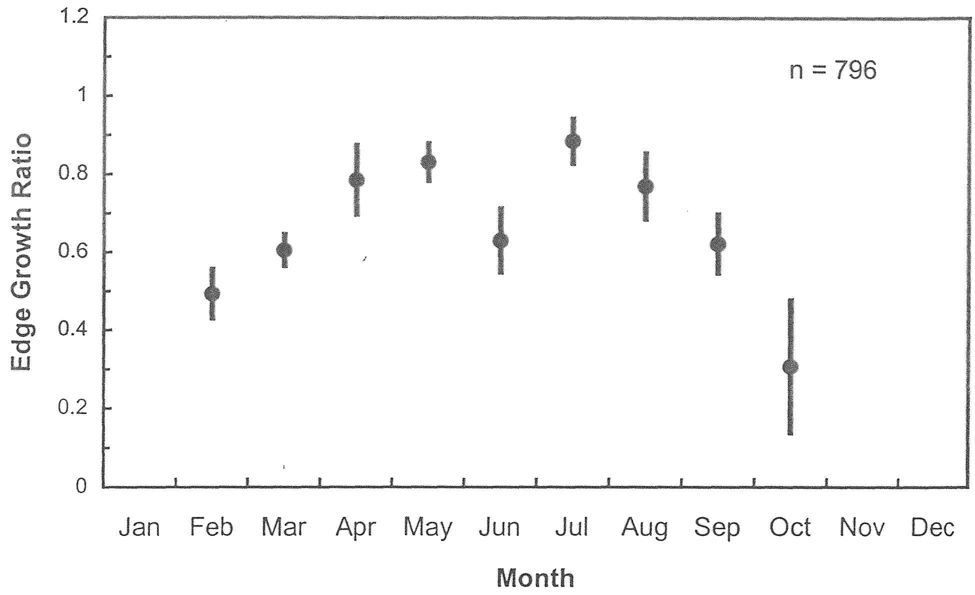

Figure 4.5 Mean monthly Edge Growth Ratios (and 95% confidence intervals) for king salmon, where $n_{month} > 1$ and estimated age > 1

Comparison of primary whole otolith age with secondary section otolith age (for ages>0) did not detect any significant differences between the techniques. Of 20 king salmon whose otoliths were sectioned, sectioned ages for 19 fish agreed with ages from whole otoliths when assessed by two different readers. The remaining otolith was rejected for whole ageing by both readers. As with golden grunter, the ease of the whole otolith ageing method compared to the sectioning technique, resulted in whole otoliths being selected as the primary ageing method for king salmon. No detailed comparison between primary and secondary ageing techniques was considered necessary because of the extreme clarity of the annuli. The Index of Average Percent Error for whole otoliths was low at 1.18 (n = 740).

The Schnute Case 3 growth model, a non-asymptotic power curve, provided the most parsimonious fit to the length-at-age data for king salmon. This model provided only a marginally lower *RSS* value (27979) than the Case 5 (LVB; *RSS* = 28122, $R^2 = 0.755$), but was preferred in accordance with Quinn and Deriso (in press). The parameters (and standard errors) of the Case 3 curve (ie, length to caudal fork l_1 at age τ_1, length to caudal fork l_2 at age τ_2, and the curve shape parameter γ) fitted to back-calculated data are given in Table 4.5. The back-calculated length-at-ages and the Case 3 curve are given in Figure 4.6.

Table 4.5 Parameters (and standard errors) of the Schnute Case 3 growth model for king salmon.

l_1(LCF) at τ_1	l_2 (LCF) at τ_2	γ	R^2	n
28.9 at 1 (1.40)	120.5 at 14 (2.23)	1.7 (0.10)	0.756	714

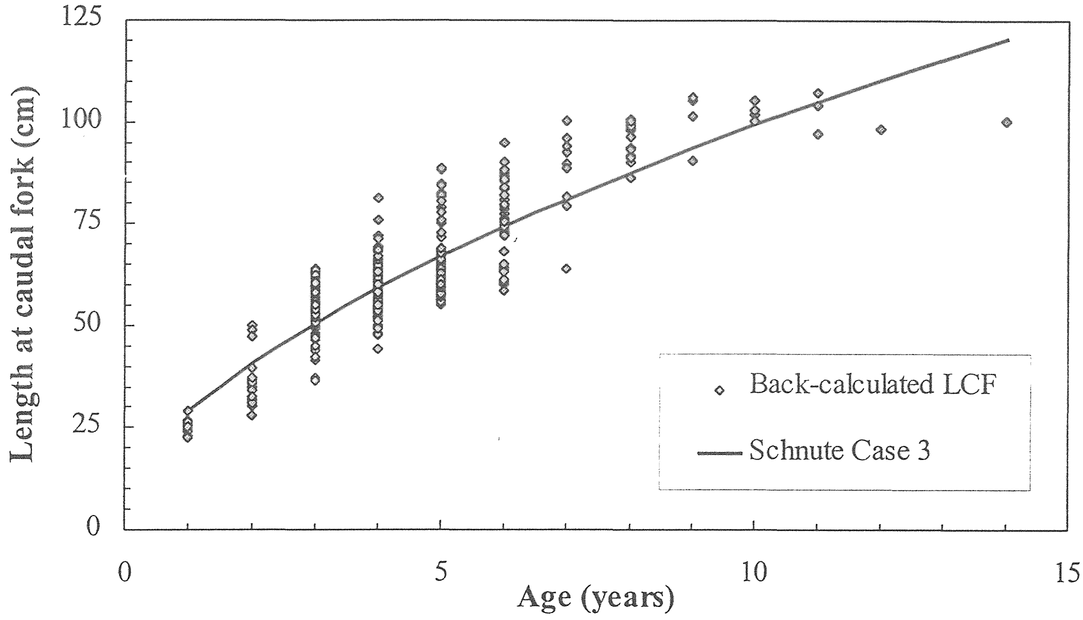

Figure 4.6 Back-calculated length-at-age data and Schnute Case 3 growth model for king salmon.

4.4.5 Blue salmon

The Kolmogorov-Smirnov test between the total collection of blue salmon and the sample of aged fish was highly significant ($P < 0.0001$, $n_{all} = 652$, $n_{aged} = 200$). The length distributions are somewhat different and may have arisen in the selection of fish for ageing. Assigning ages to the remaining 452 fish in the collection should resolve the matter.

Comparison of whole otolith age with section otolith age (for ages>0) detected differences between the techniques (paired *t*-test ; d.f.=199, $P<0.001$). There were systematic differences between the age estimates so derived, primarily at ages 4 and 5 where section ages were higher (sign test $P<0.0001$). Age estimates differed by ±1 years for 26% of observations (ie, 51 out of 195) although only 1.5% (ie, 3 out of 195) differed by 2 years. Sectioned otoliths were utilised for primary ageing of this species. The need to prevent damage to each fragile otolith during repeated age estimates also favoured blocking and sectioning of otoliths.

The ANOVA of the monthly variation in the edge growth ratio (EGR) was highly significant ($P<0.001$, n=188) confirming that annuli were formed annually. Tukey tests on the monthly means demonstrated significantly lower EGR's (and hence annulus formation) between October and March (see Figure 4.7).

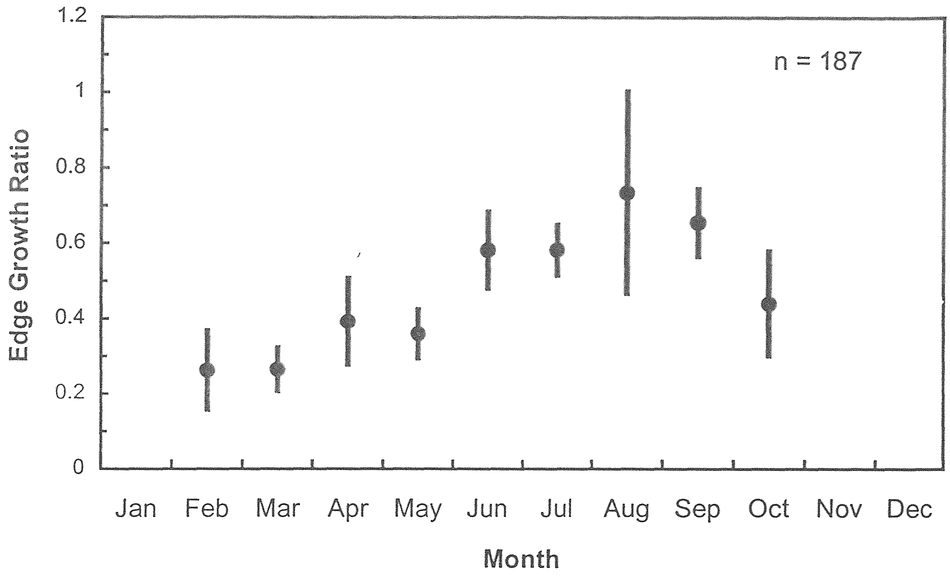

Figure 4.7 Mean monthly Edge Growth Ratios (and 95% confidence intervals) for blue salmon, where $n_{month} > 1$ and estimated age > 1

Additional validation of the annual nature of the blue salmon otolith annuli was presented by the consistent increase of the mean focus-to-last-annulus distance up to 7 years, with significant differences ($P < 0.05$) from 1 to 4 years. While the mean back-calculated length-at-age increased consistently up to 7 years, Tukey pair-wise comparisons of means showed significant ($P < 0.05$) differences between year classes 1 to 5. The Index of Average Percent Error was 5.54.

As was the case found with king salmon, the Schnute Case 3 growth model provided the most parsimonious fit to the data for blue salmon. As was the case for the king salmon, this model gave a marginally lower *RSS* value (5667) compared with that of the Case 5 (LVB; RSS = 5737, R2 = 0.739), and as such was favoured after Quinn and Deriso (in press). The parameters (and standard errors) of the Case 3 curve (ie, length to caudal fork l_1 at age τ_1, length to caudal fork l_2 at age τ_2, and the curve shape parameter γ) fitted to back-calculated data are given in Table 4.6. The back-calculated length-at-ages and the Case 3 curve are given in Figure 4.8.

Table 4.6 Parameters (and standard errors) of the Schnute Case 3 growth model for blue salmon.

l_1 at τ_1 (LCF)	l_2 at τ_2 (LCF)	γ	R^2	n
24.6 at 1 (1.94)	69.4 at 7 (3.32)	2.32 (0.28)	0.742	195

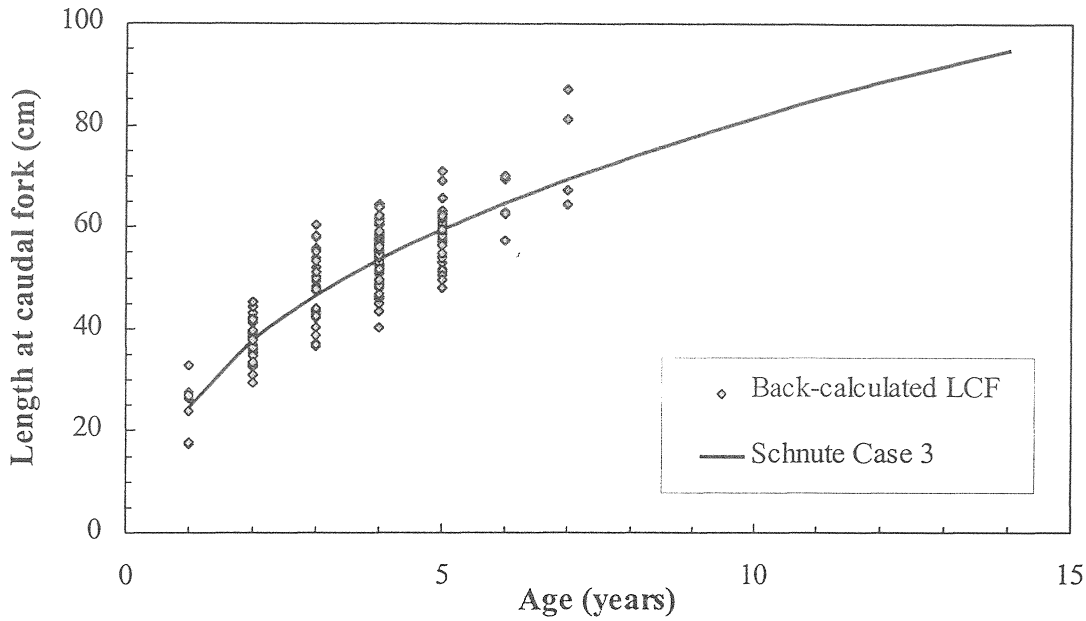

Figure 4.8 Back-calculated length-at-age data and Schnute Case 3 growth model for blue salmon.

4.4.6 Black jewfish

There was no significant difference between the distribution of fish in the sub-sample of specimens chosen for age determination and that of the total collection, using the Kolmogorov-Smirnov test (P = 0.166, $n_{aged} = 194$, $n_{all} = 530$).

Otoliths of black jewfish were quite large (up to 4cm×1cm×2cm in size and 9-10g in weight for a 150 cm TL fish), with dense thickening at the sulcus precluding age estimation from whole otoliths. These large otoliths, when set in resin for sectioning, could take up to 20 minutes to cut with the Isomet low speed saw. Sectioned otoliths were used as the prime age determination technique, with preliminary trials using scales readings being conducted for comparison.

Comparison of sectioned age with scale age (for ages>0) detected differences between the techniques (paired *t*-test ; d.f.=15, P=0.034). There appeared to be systematic differences between the age estimates where section ages were higher (sign test P=0.006). Age estimates differed by up to 3 age classes, with the variation observed over all age classes. Subsequently, sectioned otoliths were utilised for age determination in this species.

Black jewfish occur in the commercial and recreational catches throughout the year but the species is most abundant during the winter months. Although a significant result was obtained when seasonal variation in EGR's was considered (ANOVA, n = 182, P < 0.001), there was no clear result using the Tukey test. A differentiation of EGR results from the months April, June and July and those of October and December implies that annuli are formed in late spring to early summer (see Figure 4.9). However, examination of additional material from the collection database, especially for the months from April to November, could better resolve this issue.

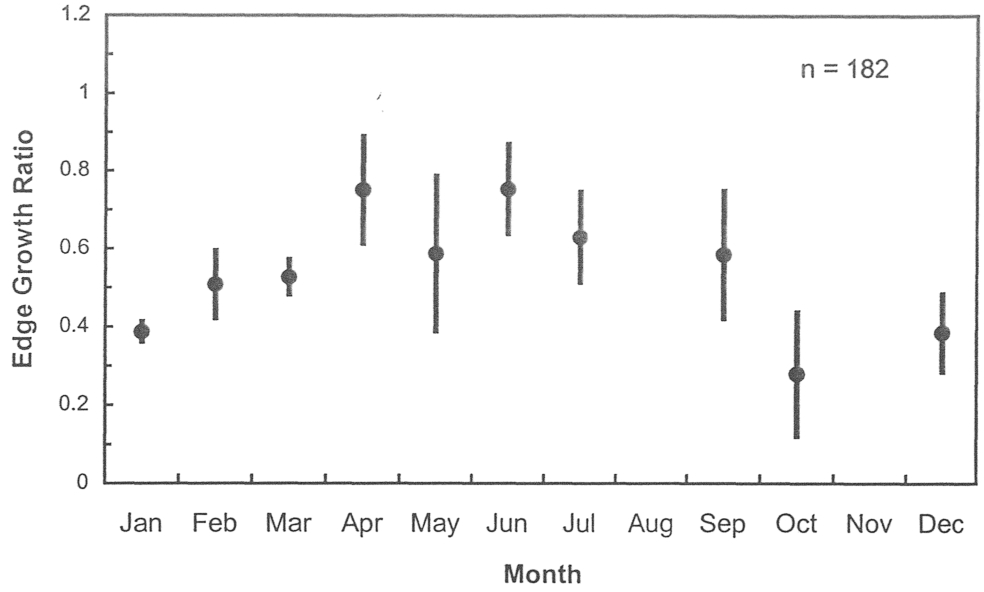

Figure 4.9 Mean monthly Edge Growth Ratios (and 95% confidence intervals) for black jewfish, where $n_{month} > 1$ and estimated age > 1

Evidence for the annual nature of the otolith annuli came from the consistent increase of the mean focus-to-last-annulus distance up to 10 years, with significant differences ($P < 0.05$) up to 4 years. While the mean back-calculated length-at-age increased consistently up to 5 years, (and then from 7 to 10 years), Tukey pair-wise comparisons of means showed significant ($P < 0.05$) differences only up to age class 3. The Index of Average Percent Error was relatively low at 3.21 (n = 194).

The Schnute Case 5 growth model provided the most parsimonious fit to the aged data for black jewfish. The parameters (and standard errors) of the LVB curve fitted to the back-calculated data are given in Table 4.7. The back-calculated fish lengths-at-age and the LVB curve are given in Figure 4.10.

Table 4.7 Parameters (and standard errors) of the von Bertalanffy growth function for black jewfish.

L_∞ (TL)	K	t_0	R^2	n
136.6 (0.95)	0.32 (0.03)	0.18 (0.13)	0.86	194

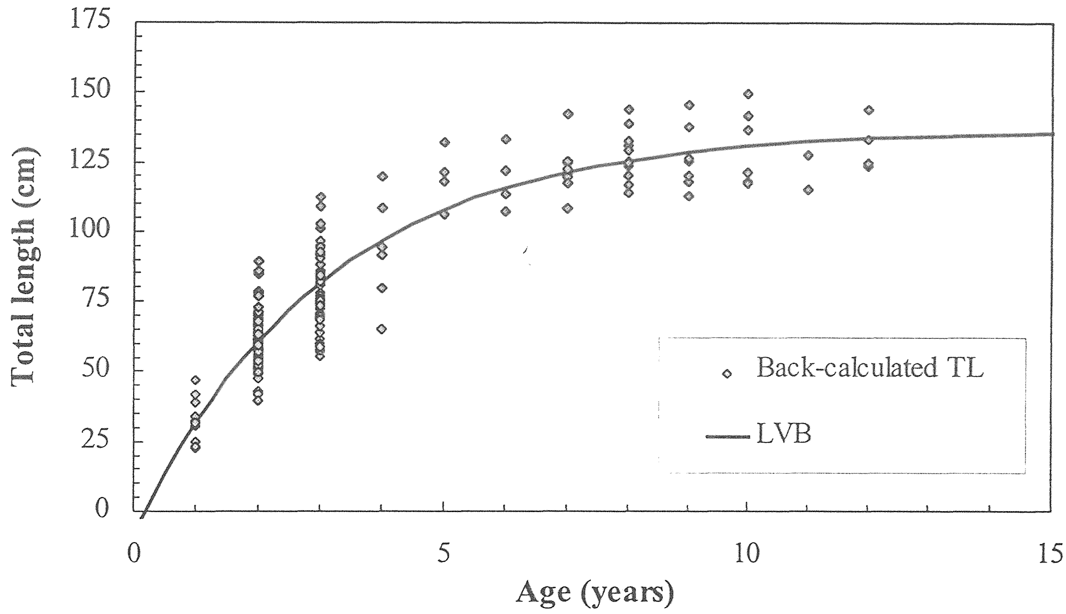

Figure 4.10 Back-calculated length-at-age data and von Bertalanffy growth function for black jewfish.

4.4.7 Jewelfish

The Kolmogorov-Smirnov test for similarity of length distribution of aged versus total samples was significant ($P = 0.021$, $n_{aged} = 262$, $n_{all} = 789$). Age determination of the remaining material is required to resolve this matter.

As sampling progressed, it became apparent that the specimens being provided by volunteer Gulf fishers as 'jewelfish' represented more than one species. Mr Jeff Johnson at the Queensland Museum examined this 'jewelfish' material, and it appeared that fish over approximately 55 cm TL were *Nibea squamosa*, those between 30 and 55 cm were a mixture of *Nibea squamosa* and another *Nibea* species (probably *N. microgenys*), and those few specimens in the collection less than 30 cm long comprised the above two species as well as *Austronibea oedogenys*, *Johnius amblycephalus* and *J. novaehollandiae* (J. Johnston, pers comm 1996).

The taxonomic complexity of the 'jewelfish' appellation was not demonstrated until late in the sampling program. Otoliths of the two *Johnius* species could easily be differentiated from other species in the complex, and their otoliths were excluded from further assessment. Sasaki's (1992) description of otolith morphology for *N. squamosa* and *N. microgenys* proved to be of dubious value in distinguishing between these two species. Species differences were apparent, however, when assigned otolith age and fish length were considered.

As with black jewfish, preliminary trials indicated some potential for age determination with scales, but only as the secondary method. The otoliths of jewelfish, like those of the black jewfish, were distinctly three dimensional, and required sectioning before age assessment. Comparison of sectioned age with scale age (for ages>0) detected highly significant differences between the two techniques (paired *t*-test ; d.f.=227, $P<0.001$). There were systematic differences between the age estimates, where section ages were higher (sign test $P<0.0001$), particularly for the older age groups. The scale ages grossly underestimated the sectioned ages, especially in fish >4 years old. Sectioned otoliths were utilised for primary ageing of this species.

The ANOVA of the EGR's for the combined species complex was highly significant (n = 249, $P \leq 0.001$), with Tukey tests indicating minimal EGR's during the late spring and summer months (see Figure 4.11). Peak annulus formation for both *N. squamosa* and *N. microgenys* appears to be in November.

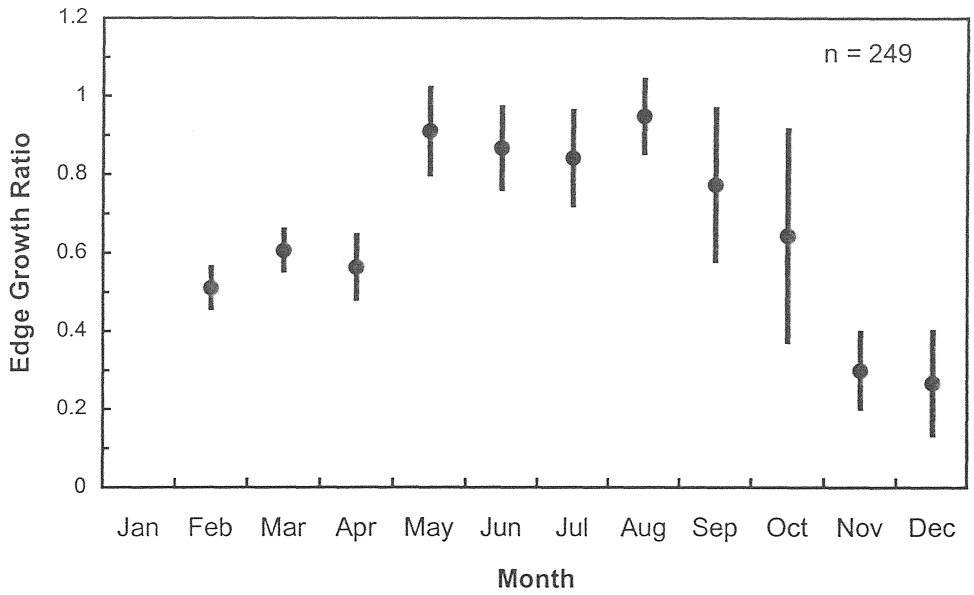

Figure 4.11 Mean monthly Edge Growth Ratios (and 95% confidence intervals) for jewelfish complex, where $n_{month} > 1$ and estimated age > 1

Further evidence for the annual nature of the otolith growth came from the consistent increase of the mean focus-to-last-annulus distance up to 12 years, with significant differences ($P < 0.05$) up to 4 years. While the mean back-calculated length-at-age increased consistently up to 5 years, Tukey pair-wise comparisons of means also demonstrated significant ($P < 0.05$) differences up to age class 5. The Index of Average Percent Error was 2.89 (n = 262).

The Schnute Case 5 growth model provided the most parsimonious fit to the data for the jewelfish complex, as well as for the isolated samples of *N. squamosa and N. microgenys.* The parameters (and standard errors) of the LVB curve fitted to the back-calculated data are given in Table 4.8. The total back-calculated fish lengths-at-age and the species-isolated LVB curves are given in Figure 4.12.

Table 4.8 Parameters (and standard errors) of the von Bertalanffy growth function for the jewelfish species complex, *N. squamosa* and *N. microgenys*.

	L_∞ (TL)	K	t_0	R^2	n
Jewelfish complex	65.8 (0.95)	0.35 (0.03)	0.19 (0.13)	0.82	261
N. squamosa	68.4 (0.88)	0.33 (0.02)	0.07 (0.15)	0.88	212
N. microgenys	70.3 (4.62)	0.15 (0.03)	-0.58 (0.03)	0.95	49

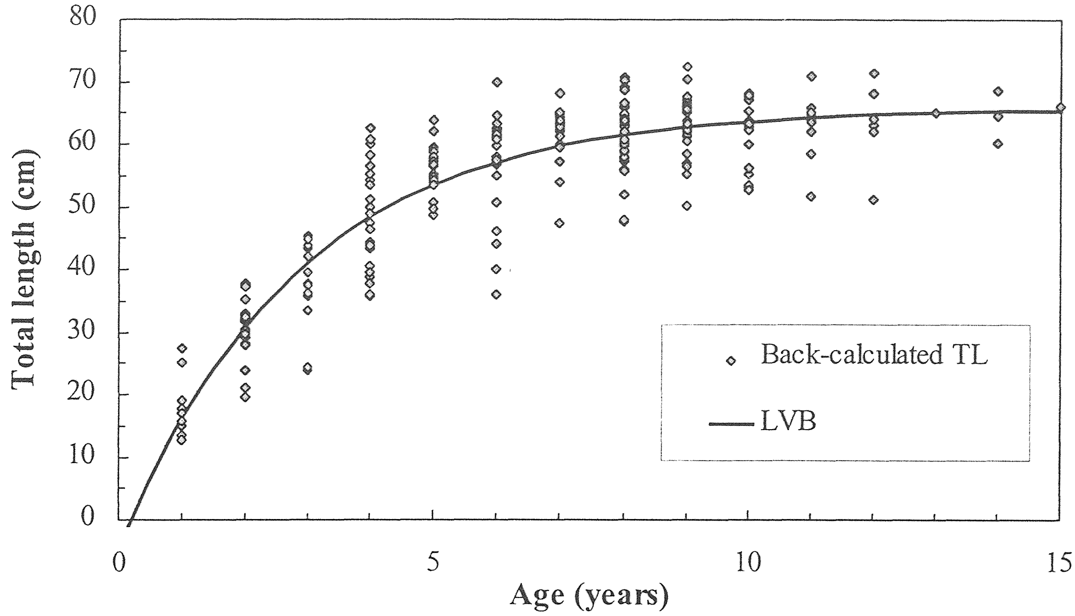

Figure 4.12 Back-calculated length-at-age data and von Bertalanffy growth function for the jewelfish species complex.

4.5 DISCUSSION

This study has examined the age and growth of five finfish species associated with the Gulf of Carpentaria commercial gillnet and recreational line fisheries, viz, the golden grunter (*Pomadasys kaakan*), king salmon (*Polydactylus sheridani*), blue salmon (*Eleutheronema tetradactylum*), black jewfish (*Protonibea diacanthus*), and a jewelfish species complex (nominally referred to as *Nibea squamosa*). The common names used throughout this report reflect the most common usage within the commercial and recreational fisheries throughout the Gulf of Carpentaria.

The collection of adequate numbers of samples for age and growth analysis, each month throughout the year, proved difficult. The difficulties arose from the highly seasonal nature of the commercial gillnet fishery caused by the November to January closure, and the seasonality of the recreational line fishery caused by a greater tourist influx into the area during the cooler winter months. The result has been reduced definition of the estimation of time of formation of annuli on otoliths for all species being considered. Additional dedicated research sampling during the closure time would be necessary to achieve greater definition of these life cycle events.

Validation of age information using mark-recapture and chemical marking of golden grunter was not possible due to the disappointingly low number of recaptures. The result was unexpected, especially when considering the wide use of, and support for, OTC application (eg Wilson 1995) and dart tags in mark-recapture programs. It became apparent in the initial stages of the OTC survival tank exercise that an OTC related mortality and/or dart tag loss may have contributed to the observed low recapture rates in the golden grunter mark-recapture field study.

Further and more structured trials involving different chemical markers (such as Calcein and Alizarin complexone; Thomas *et al* 1995), at various application rates, appear necessary to minimise induced mortalities and to interpret published results for other species. As well, the influence of tag type and fish size on mortalities and tag loss needs to be established as part of mark-recapture assessments involving a previously unstudied species. The assumptions implied in the published literature that

i) in mark-recapture studies, dart tags are appropriate, and
ii) in age validation that OTC is a suitable marker,

may not always be valid for the species of interest.

4.5.1 Golden grunter

The whole otolith ageing method was used as minimal laboratory preparation time was required prior to reading, and it provided results that were not significantly different from those obtained using the sectioned otolith method. There was no evidence for the systematic over-estimation of fish ages by the sectioned otolith method in older year classes (compared with the whole otolith method) that has been observed for *Lutjanus* species in the Gulf of Carpentaria (Milton *et al.* 1995), nor systematic under-ageing for untreated whole otoliths relative to sectioned otoliths as occurred in Great Barrier Reef coral trout *Plectropomus leopardus* (G McPherson 1996).

The monthly EGR's for golden grunter demonstrate that annulus formation commences in the spring and continues throughout the early part of summer. This is approximately the same time of year of the 'A1' check noted for golden grunter on the Queensland east coast around Townsville (Bade 1989). Bade also observed a secondary annual check during the spring/summer period which appeared to coincide with spawning peaks. Deshmukh (1973) reported hyaline outer zones on otoliths during the months of November to January in north-western coastal waters of India, although these were northern hemisphere autumn/winter months when water temperatures were at their lowest and were not associated with spawning.

The back-calculated total lengths-at-age (both measured or derived from a TL:LCF relationship) for the first five year classes of Gulf golden grunter were similar to the mean observed total lengths-at-age for scale-aged fish from the east coast (Bade 1989) and are shown in Figure 4.13. The Queensland estimates for these early year classes are comparable with data from *P kaakan* in Pakistan (Majid and Imad 1991), but are lower than those for the species in north-west India (Deshmukh 1973).

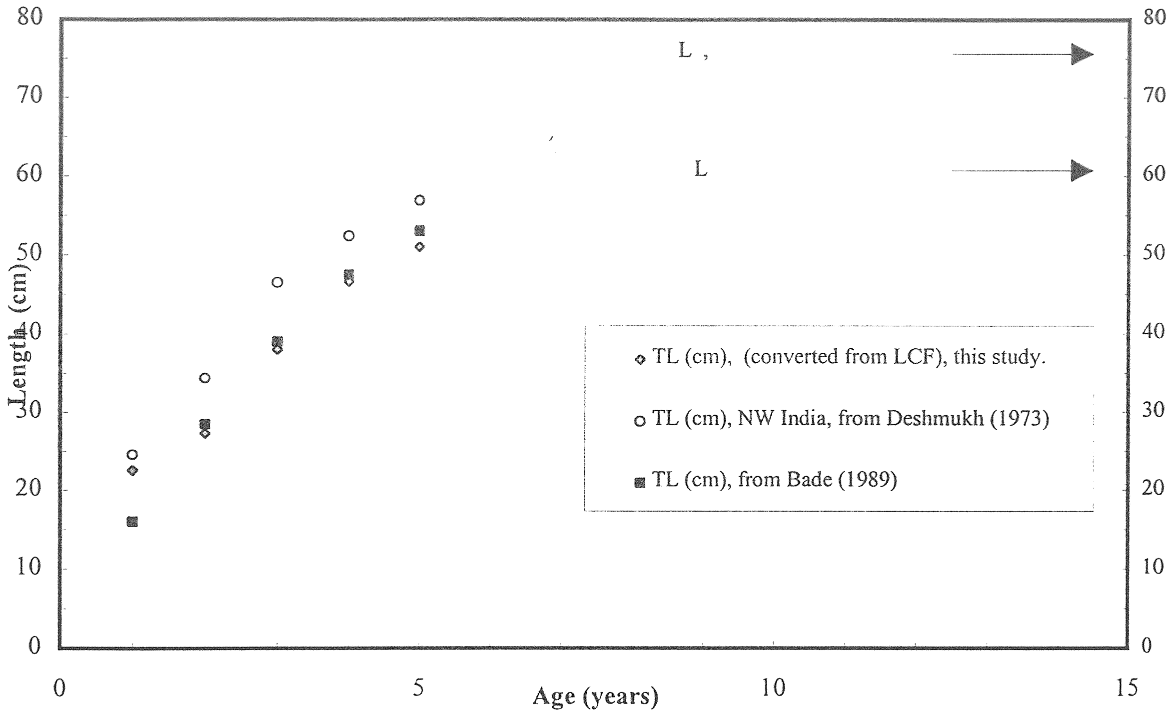

Figure 4.13 Mean lengths-at-age for golden grunter at three different Indo-Pacific localities.

Available growth parameter estimates for *P. kaakan* from the Queensland Gulf (this study) and from the east coast (Bade 1989) appear to differ substantially (Table 4.9), despite the close similarity of the lengths-at-age in early year classes (Figure 4.13) and the similarity of maximum sizes reported for the Gulf and east coast, namely 67.5 and 63.6 cm TL respectively. These differences may be due to the differences in curve fitting procedures utilised for both studies, although the overall 'growth performance index (ie ϕ')' of Pauly and Munro (1984) indicated greater similarity between the Queensland populations than with the other Indo-Pacific populations. Gulf fish and those in Pakistan have comparable von Bertalanffy growth curve parameters, indicating that stock differences might be only marginal.

Table 4.9 Parameters of the von Bertalanffy growth function for *P. kaakan* from four Indo-Pacific locations.

Parameter	Gulf of Carpentaria[1]	Queensland east coast[2]	Pakistan[3]	NW India[4]
L_∞ (TL)	60.3	75.6	62.5	68.2
K	0.35	0.24	0.25	0.35
t_0	-0.06	0.04	N/A	-0.01
n	250	593	414	446
ϕ'[5]	3.10	3.14	2.99	3.22

[1] - this study [2] - Bade (1989) [3] - Majid and Imad (1991)
[4] - Deshmukh (1993) [5] - $\phi' = Log_{10}K + 2Log_{10}L_\infty$ (Pauly and Munro 1984)

Additional examination of the most appropriate growth model for golden grunter is required. There is evidence to suggest that a 'bent stick' model involving two different linear growth phases may be more appropriate than the LVB curve depicted in Figure 4.4. As the location of the transition point of the conjoint lines is most likely to be related to fish size or age at maturity, final analyses cannot be completed until all relevant reproductive information is available for the species.

4.5.2 King salmon

There are no comparative growth data available for king salmon populations elsewhere in its range. While the species is reported to attain 30 kg (Grant 1972), or approximately 150 cm TL in Queensland, the largest fish observed in this study was 125 cm. Kailola *et al* (1993) reported a maximum size of 170 cm for Australian waters at a validated age of approximately 20 years; however the source of these data could not be located.

Kagwade (1971) estimated length-at-age for *Polydactylus indicus,* an ecologically very similar species that attained a maximum size of 142 cm in Indian waters. Comparison of the calculated ages from scales, and ages from whole otoliths, for *P. indicus* and king salmon *P. sheridani* respectively, are shown in Figure 4.14.

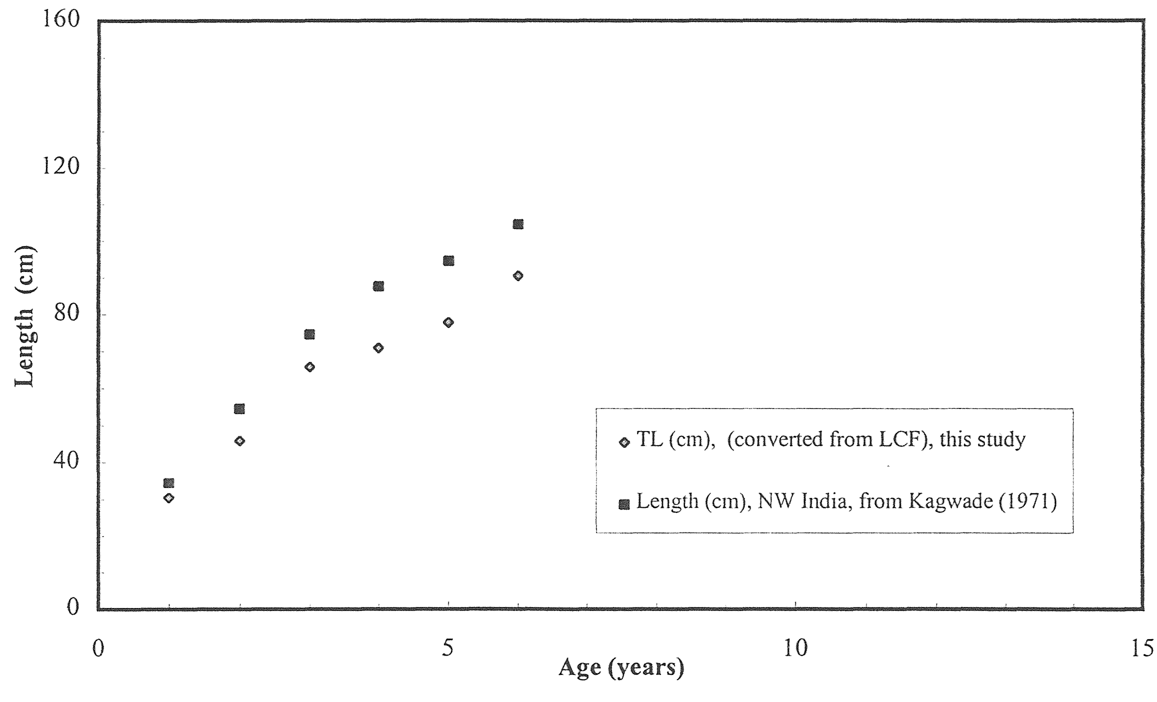

Figure 4.14 Mean lengths-at-age for two similar polynemid salmon, *Polydactylus sheridani* and *P indicus,* from the Indo-Pacific region

4.5.3 Blue salmon

Comparative growth data are available from elsewhere in Queensland for this species. Mean length-at-age data for Townsville fish (Stanger 1974) and for the first six age classes of Gulf fish (using back-calculated LCF) are given in Figure 4.15. Stanger (1974) obtained a L_∞ of 66 cm LCF from his LVB growth model, which is similar to the Schnute Case 3 length-at-age value of 69.4 cm LCF calculated for the oldest age class observed in this study. However, this estimate of largest mean size is well below the maximum length observed of 88.0 cm LCF. Grant (1982) and Menon and Babun Rao (1984) reported 145 kg (approximately 200 cm) and 200 cm fish respectively from the Indo-Pacific region. These extreme records do not appear to be comparable with fish currently taken in the Queensland fishery.

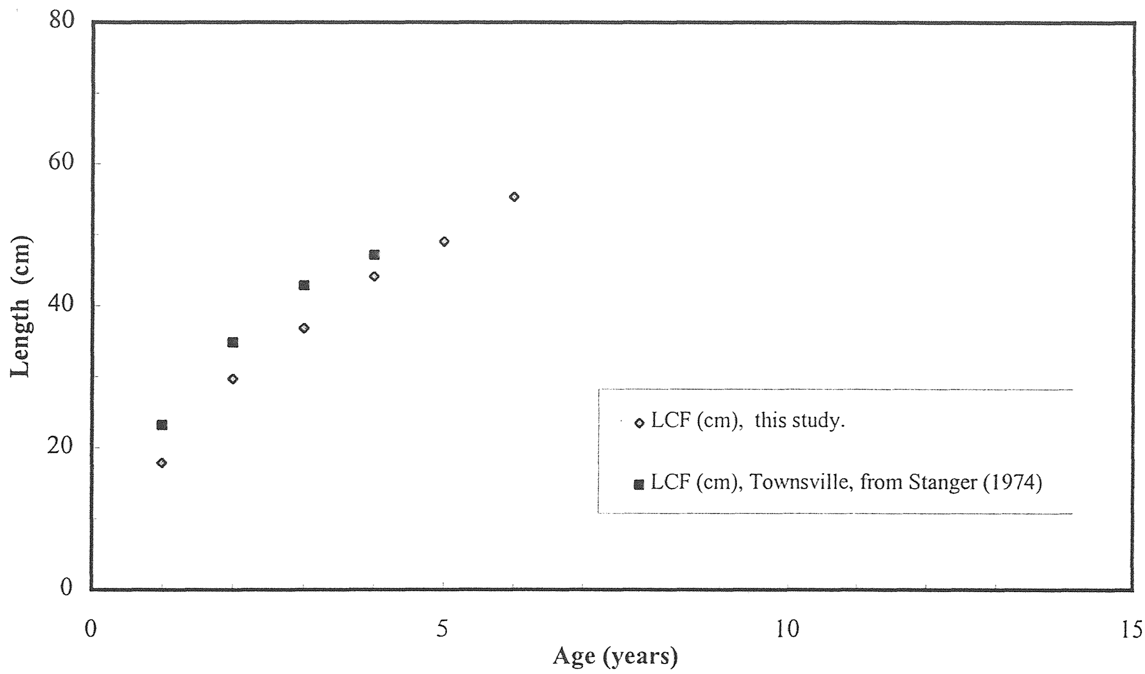

Figure 4.15 Mean lengths-at-age for blue salmon in Queensland waters.

4.5.4 Black jewfish

The largest black jewfish observed in the Gulf study measured 154cm TL. The species is reported by Grant (1982) to grow to at least 45 kg (approximately 176 cm long). These fish are substantially larger than the maximum size of 107.5 cm reported from India by Rao (1966). Isaac (1990) used the length-frequency data of Rao (1966) to calculate growth parameters for *Pseudosciaena diacanthus* (=*Protonibea diacanthus*), using a range of length-based methods. Despite the restricted size range (22.5-107.5 cm) and the high variability between the estimates of L_∞ and K, the growth performance index (ϕ') demonstrated little variability with a mean between the methods of 3.65, with only a 3% difference to the present

ϕ' estimate of 3.77. Despite the biological interest in *P. diacanthus* overseas, no length-at-age data are available for comparison with the Gulf fish results.

4.5.5 Jewelfish

Although 'jewelfish' has been a component of commercial and recreational catches in the Gulf for many years (Bill Kehoe, Karumba Branch Queensland Commercial Fishermen's Organisation pers. comm), *Nibea squamosa* has only been described very recently (Sasaki 1992). Our results suggest that 'jewelfish' may be a complex of species, and further work on the various morphs is necessary to establish the catch contributions made by the different species.

Despite the multi-species nature of the jewelfish complex, 81% of the aged samples were identified as being *N squamosa*. This material has provided an initial estimate of length-at-age and growth for the species. No comparative data are available from elsewhere in the species range.

4.6 RECOMMENDATIONS FOR FURTHER INVESTIGATION

The models developed in this study give at best preliminary or provisional estimates of growth function. Their veracity must be substantially improved before age and growth information for the different species can be used with confidence in fishery management planning exercises.

Only 24.9% of the golden grunter specimens collected for age and growth determination in this study have been assessed to date. This aged sub-sample exhibited a length distribution similar to that of the total collection. The general lack of validation, and evidence for an alternative expression to the von Bertalanffy model of growth, warrants that additional age analyses should be conducted for this species. These new assessments should examine all material at hand, perhaps supplemented by infusion of further specimens as required.

Age determinations were completed for more than half (62%) of the king salmon collected. The most parsimonious model for growth that could be applied to these data (Schnute Case 3) gave the poorest fit to the available information, as compared with the LVB model used for the non-polynemid species examined in this study. The remaining king salmon otoliths, originally intended to be assessed in the later years of the original project proposal, should be examined as a matter of priority to determine if the additional data can improve the goodness of fit.

The material used to generate the pattern of growth in blue salmon represented only a fraction (30%) of the specimens available for examination. This sub-set demonstrated a length distribution markedly different from that of the total collection. As with king salmon, the most parsimonious growth model fitted to the age information (Schnute Case 3) rated very poorly by comparison with the growth models developed for the other species examined. Age determinations should, therefore, be completed for the remaining material and a model constructed that fits better with the available data.

Black jewfish proved to be one of the most long-lived species examined in the study, and the growth model appears to fit the data quite well. However, no evidence could be found to support validation of the growth estimates obtained from the 194 fish scrutinised. Just as many fish remain to be assessed; by doing so, substantive confirmation for the preliminary growth function may be established.

The overall paucity of data for jewelfish, and specifically for *Nibea squamosa*, suggests that all available material should be assessed for age and growth information. While there are potentially several different *Nibea* species in the jewelfish complex, approximately 81% of the 263 specimens aged were identified as *N. squamosa,* with the remainder being of unclear taxonomy (either *N. squamosa* or *N. microgenys).* As of November 1996, only about one third of the available material (36%) contributed to the growth curve presented in this report. For biological accuracy, growth curves should be developed for each of the individual species components in the jewelfish complex.

The mark-recapture and age validation exercise for *Pomadasys kaakan* assumed the direct application of methodology used successfully with other species. Instead, the result obtained highlights that fishery research projects incorporating such activities should undertake prior assessments of marking induced mortalities and tag loss as necessary preliminaries. Such data are essential components of the risk assessment that must be conducted before initiating extensive field programs with hitherto unstudied species.

4.7 APPENDICES

Appendix 4.1: Numbers of samples collected for the five key species showing the method of capture and including minimum and maximum lengths (LCF or TL)

(a) samples from which age/growth results were obtained

	Net			Hook-and-line			other methods			unknown method		
Species	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n
Banded grunter (LCF)	23	61	203	7.5	59	68	8	33	5	n/a	n/a	0
King salmon (LCF)	13.5	109.5	740	n/a	n/a	0	n/a	n/a	0	n/a	n/a	0
Blue salmon (LCF)	20	88	182	29	61.5	14	7.8	13.3	4	n/a	n/a	0
Black jewfish (TL)	43.5	154	145	40	147	48	n/a	n/a	0	137	137	1
Jewelfish (TL)	25	74	232	21.5	61.5	25	9.5	20	5	n/a	n/a	0
Totals			1674			155			14			1

(b) samples for which age material was collected

	Net			Hook-and-line			other methods			unknown method		
Species	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n
Banded grunter (LCF)	23	62.5	801	7.5	61	265	3.9	59.5	19	35	67	22
King salmon (LCF)	21	108.5	1185	29	58.5	15	13.5	46	8	n/a	n/a	0
Blue salmon (LCF)	20	88	602	19.5	61.5	46	7.3	36	16	n/a	n/a	0
Black jewfish (TL)	43.5	154	348	40	147	53	n/a	n/a	0	137	137	1
Jewelfish (TL)	22	77	641	15	69	76	9.5	20	7	33.5	35.5	2
Totals			3723			455			50			25

5. REPRODUCTIVE BIOLOGY OF FIVE TARGET FISH SPECIES IN THE GULF OF CARPENTARIA INSHORE GILLNET FISHERY

(Contributed by Mr G R McPherson, Northern Fisheries Centre, PO Box 5396, Cairns QLD 4870)

5.1 INTRODUCTION

The dominant finfish species in the Queensland Gulf of Carpentaria inshore gillnet fishery are the barramundi, king salmon and blue salmon, golden grunter, black jewfish and the jewelfish. The biology of Gulf barramundi has been a focus of research investigation in recent years (eg. Davis 1982 and 1984; Garrett 1987 and 1992; Russell and Garrett 1983) because of its market attractiveness and aquaculture potential. By comparison, surprisingly little biological information is available for the other species which contribute significantly to Gulf fishery landings. The few published accounts that are available relate almost entirely to the species elsewhere in their Australian or Asian range.

A lack of biological data, especially of information associated with reproduction, diminishes the certainty that informed decisions will be made regarding the status of fished resources and the sustainability of the harvest. A sound knowledge of the reproductive strategies employed by Gulf fish species is required to determine appropriate legal fish taking sizes, to provide protection for breeding aggregations that are vulnerable to fishing pressure, and to aid in understanding of recruitment processes in the maintenance of local populations. Because such information is currently not available for key species taken in the Gulf inshore gillnet fishery, the effectiveness of management initiatives for these resources may well be less than desired.

5.2 SPECIFIC OBJECTIVES

The uncertainties surrounding some of the most fundamental biological and population processes in the most important target species in the Gulf gillnet fishery have identified a clear research need.

To address this need, a program of research was initiated with the following objectives:

1. To undertake over a two year period an investigation of the reproductive biology of key target species from the Queensland inshore gillnet fishery in the eastern Gulf of Carpentaria waters.

2. To include this information in biological baseline fishery assessments for the major catch species.

3. To make these assessments available for consideration by management authorities in the development of Gulf Fishery Management Plans.

5.3 MATERIALS AND METHODS

5.3.1 Collection of material

Material assessed for the reproductive study was derived from specimens provided by volunteer fishers. These fish were also used for age and growth analyses, and the full details of the sampling program are given in Section 4.

Truncation of the originally planned program for sample collection, examination and analysis down to a two year exercise was forced by funding limitations. Material was collected throughout the life of the project in an attempt to gather adequate sample sizes for examination and analysis. Only preliminary assessments of the collections have been completed, and their results form the basis for this report. The remaining material will be worked up as opportunity and need arises. The collections represent a valuable baseline of information that will serve as reference points for future fishery assessments of key Gulf fish species.

Fish lengths in golden grunter, king and blue salmon, black jewfish and jewelfish were measured to the nearest 0.5 cm in Length at Caudal Fork (LCF) and/or Total Length (TL) depending on caudal fin shape. Whenever possible, fish were weighed to the nearest 1.0 g Total Weight (TWT); however most samples from commercial net and recreational line catches had already been filleted and so were not weighed.

Specimen gender and reproductive maturity stage were macroscopically determined from examination of the sex organs *in situ* (Nikolsky 1963). Gonads were weighed to the nearest 0.1 g, then preserved in a 10% neutral buffered formaldehyde solution (Hunter 1985). Reproductive data used in association with age and growth analyses were based on macroscopic assessment when histological assessment was not available.

5.3.2 Laboratory analyses

Preserved gonad tissue samples from Gulf fish were embedded in paraffin and sectioned at 6 μm (testicular and non-mature ovarian tissue) or at 6-10 μm (mature ovarian tissue), then stained with Harris's haematoxylin and eosin. Slides were prepared from proximal, medial, and distal regions of one gonad lobe.

Calculated length at 50% maturity was estimated from a logistic model after Saila *et al.* (1988), using the proportion of mature gonads in fish grouped by 2.5 or 5 cm length classes.

Gonadosomatic indices (GSI's) were calculated as the ratio of gonad weight to total body weight for both males and females. Where total weight information was not available, an estimate was calculated from length-weight relationships that were derived for each species.

Preliminary yield-per-recruit modelling exercises were conducted to help determine appropriate minimum legal sizes for the Gulf fish species of interest. The yield-per-recruit (YPR) analyses used an integrated model (Quinn and Deriso, in press; Schnute 1981) which incorporates a survival probability function for undersized fish which are returned to the water, selection and maturity probabilities, and various growth models.

Species length-weight relationships were established by linear regression of log-log transformed data to fit the model $ln(\text{TWT}) = a' + b \cdot ln(\text{L})$ which was then extrapolated to $\text{TWT} = a \cdot L^b$ (where TWT = Total weight in kg, L = LCF or TL in cm, and $a = e^{a'}$). For those species with fish length measured as LCF, linear regressions of LCF:TL were calculated such that $\text{TL} = a + b \cdot \text{LCF}$ (see Section 4, Table 4.2).

5.4 RESULTS

5.4.1 Sample collection database

Macroscopic determination of maturity was made of the gonads from a total of 1456 specimens from the five Gulf fish species under consideration. Histological preparations of preserved material were used to test the reliability of macroscopic assessment of maturity. As Table 5.1 demonstrates, to date only a small number of comparisons have been undertaken (average of 12.1% for each species).

The reliability of macroscopic staging used in this study is uncertain as the gonads examined were usually from whole specimens or frames stored in refrigerated seawater on board the processing vessel for some time before freezing and forwarding for laboratory analysis. While this sampling protocol was sufficient to retain samples for age and growth analysis, it proved inadequate for reliable identification of fish in a spent reproductive condition from those whose gonads were simply in a poorly preserved condition. Histological assessments subsequently confirmed many of the difficult field macroscopic assessments. Routine examination of the histological preparations from the remaining material detailed in Table 5.1 will be conducted and reported on outside of this project.

Table 5.1 Summary data for reproductive material collected for each species, showing length ranges of macroscopically observed mature fish, number of histological samples taken, and the number of histological samples used in reliability assessments of gonad maturity.

Species (Length type)	Sex	Observed range - length at maturity	Histo. Taken	Samples Exam.
Golden grunter	M	24- 61	161	14
(LCF)	F	18- 63	286	45
King salmon	M	28-101	108	0
(LCF)	F	87-109	35	10
Blue salmon	M	24- 44	42	6
(LCF)	F	33- 88	240	49
Black jewfish	M	65-139	153	0
(TL)	F	92-150	157	1
Jewelfish	M	42- 77	124	31
(TL)	F	34- 55	150	27

5.4.2 Length-weight relationships used in reproductive assessments

The length-weight relationships for each of the Gulf species was determined by the regression of natural log fish length (LCF or TL) to natural log total weight. The simple regression coefficients are given in Table 5.2.

Table 5.2 Regression coefficients of fish length : total weight relationships in the form $TWT = a \bullet L^b$.

Species	Length type	a	b	r^2	n	Length range
Golden grunter	LCF	2.64E-05	2.85	0.99	156	3.9 - 57.5
King salmon	LCF	2.37E-05	2.81	0.99	169	20.5 - 101
Blue salmon	LCF	1.34E-05	3.02	0.98	115	9.6 - 64
Black jewfish	TL	1.50E-05	2.88	0.99	25	59 - 143
Jewelfish	TL	3.97E-05	2.61	0.98	119	15 - 69

These length data were combined with size-at-age information (Section 4, this study) in consideration of fish length and age at sexual maturity.

5.4.3 Golden grunter

The GSI's of both male and female *Pomadasys kaakan* exhibited a noticeable increase during the winter months (see Figure 5.1 and Figure 5.2), reaching a peak for both sexes in August. GSI values fell off slowly during the spring. Although data from the summer months is limited to a few male fish taken in December, it appears that most reproductive activity is completed by that time of the year. Following a period of reproductive inactivity through autumn, a small number of mature fish were first detected in June. Greater definition of the seasonality of reproduction in golden grunter must await the examination of the remaining prepared histological material.

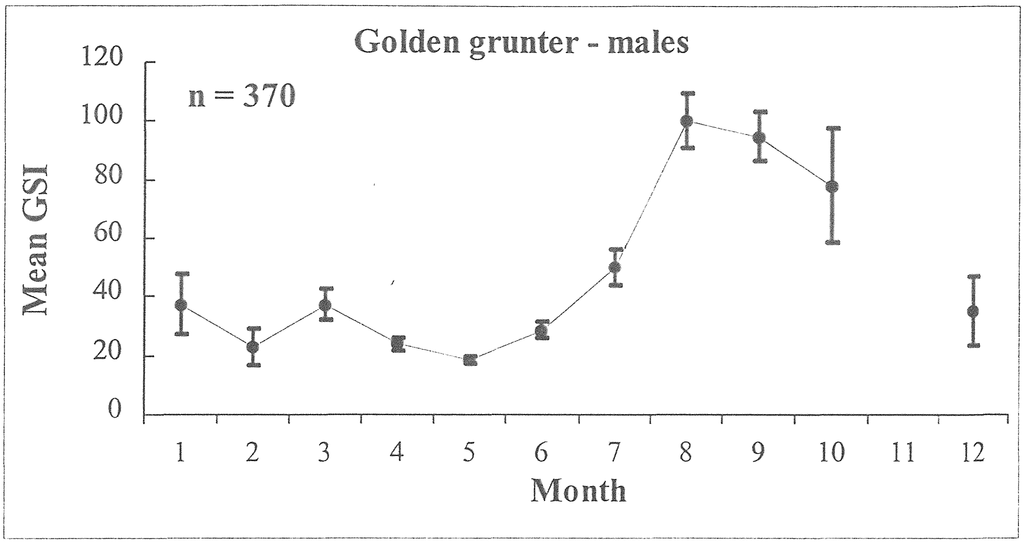

Figure 5.1 Gonadosomatic index for male golden grunter.

Only very preliminary estimates of length at maturity for golden grunter are presented in this document. Macroscopic examination of samples suggested minimum observed lengths at maturity for male and female golden grunter were 24 and 18 cm LCF respectively (Table 5.1). Histological confirmation for these estimates is required because of the uncertainties associated with macroscopic staging of gonads from the commercial fishery (8 and 15% of male and female fish samples respectively have been histologically assessed). The available data indicate that golden grunter may mature as early as years 1 and 2, but most fish mature during their third year of life (Section 4, this study).

Using the logistic method of Saila *et al* (1988) to calculate ℓ_{50}, the length at 50% maturity, the most parsimonious fit of the model to the data gave estimates of 36.6 and 46.3 cm LCF for male and female golden grunter respectively (Figure 5.3 and Figure 5.4). These findings suggested that maturity occurs primarily during year 3 for males, and during years 3 or 4 for female fish (Section 4, this study).

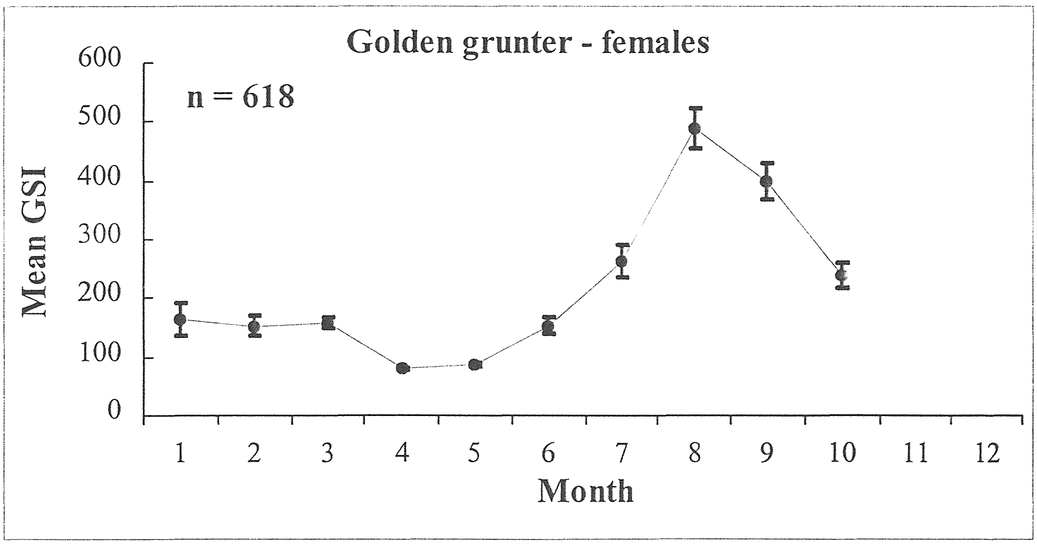

Figure 5.2 Gonadosomatic index for female golden grunter.

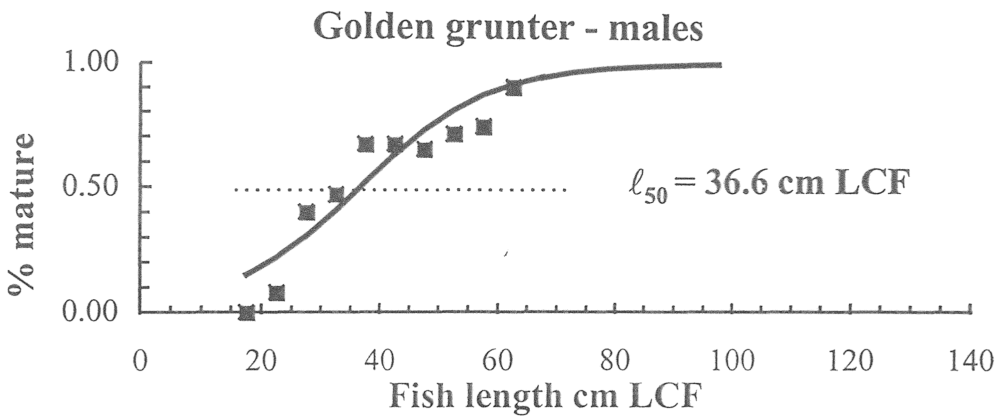

Figure 5.3 **Logistic model estimation of the ℓ_{50} for male golden grunter.**

Using an integrated model approach (Schnute 1981), preliminary yield-per-recruit analyses of golden grunter caught in gillnets indicated that the full selection to any of the net mesh sizes currently allowed for use in the fishery, occurred at a fish length greater than 40 cm. A new minimum legal size (MLS) for the species of 40 cm is to be introduced to the Gulf of Carpentaria inshore fishery in February 1997. A fishing mortality (F) value of 0.4 was estimated from recreational line fishery data, plus the limited net catch data available. The predictions for the percentage (or relative) virgin spawning stock biomass (% SSB/R) indicated that spawning stock biomass levels would remain quite high, at least as far as the gillnet component of the fishery was concerned, at the present level of fishing mortality (see Figure 5.5).

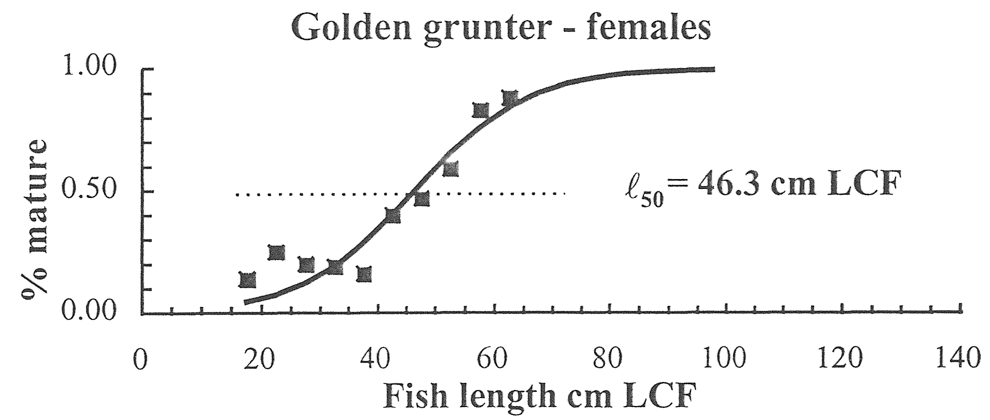

Figure 5.4 **Logistic model estimation of the ℓ_{50} for female golden grunter.**

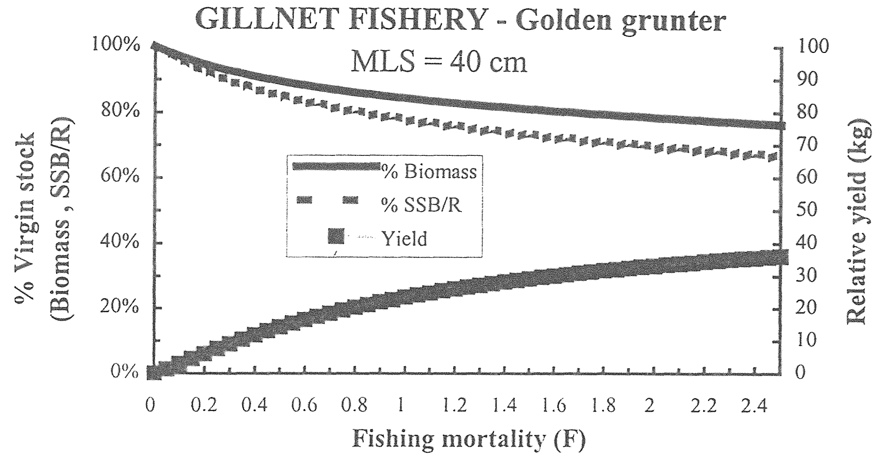

Figure 5.5 **YPR model (% biomass and SSB/R of virgin stocks and relative yield) for golden grunter (combined sexes) from the gillnet fishery.**

By comparison, YPR analysis of golden grunter from the mainly recreational line fishery clearly showed that relative yield was higher with the MLS set at 30 cm TL than with the new 40cm TL limit to become effective in 1997. However the available biomass and particularly SSB/R were substantially lower (Figure 5.6) at the 30cm TL MSL value. The SSB/R did not reach a predicted level of 40% (which is presently considered as a critical level for demersal fish stocks; see Clarke (1991)) until F levels rose above 0.4. The model assumed that there was a 5% mortality of fish released below legal size.

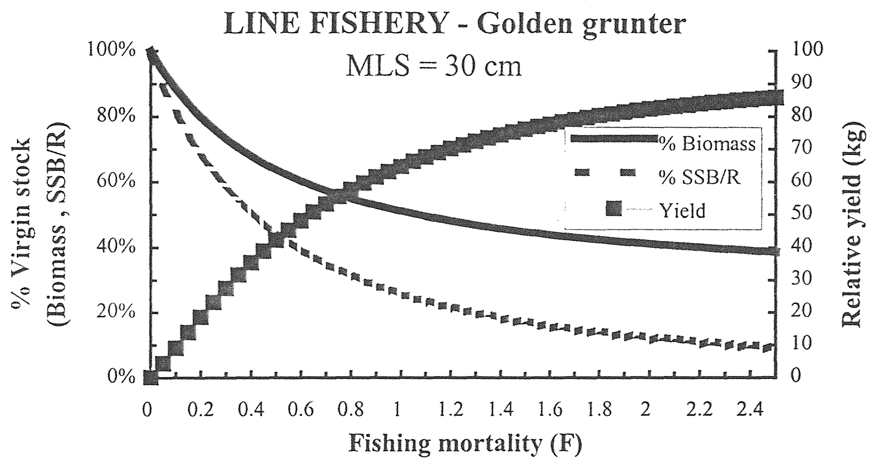

Figure 5.6 **YPR model (% biomass and SSB/R of virgin stocks and relative yield) for golden grunter (combined sexes) from the line fishery, with an MLS of 30 cm TL.**

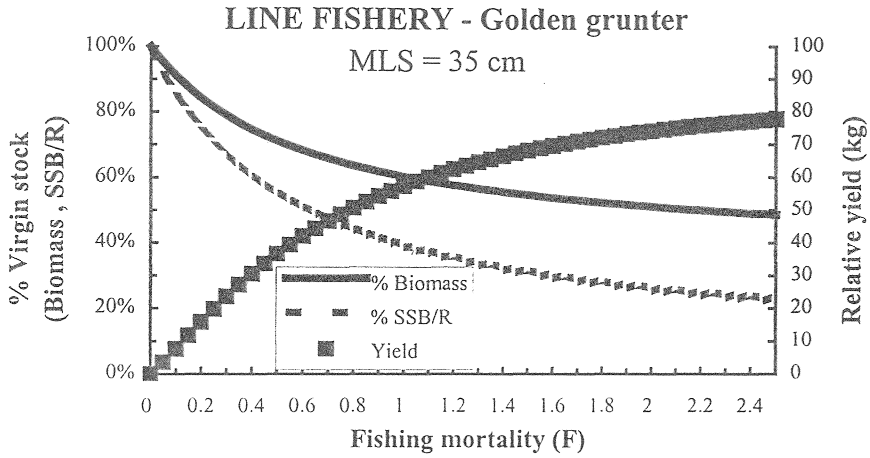

Figure 5.7 **YPR model (% biomass and SSB/R of virgin stocks and relative yield) for golden grunter (combined sexes) from the line fishery with a MLS of 35 cm TL.**

The model predicted that a tentative increase in MLS to 35 cm would not substantially alter the relative weight yield to the line fishery from that available with a 30cm MSL. Yield in weight is not always considered essential for recreational fisheries (Die *et al.* 1988). The increase to 35 cm did substantially raise the SSB/R for any predicted level of F (Figure 5.7), with the virgin stock biomass rising to about 60% for the current estimated F level in the line fishery. The increase in SSB/R for the minimum legal size value of 40 cm, to be introduced in 1997, is even more favourable (Figure 5.8).

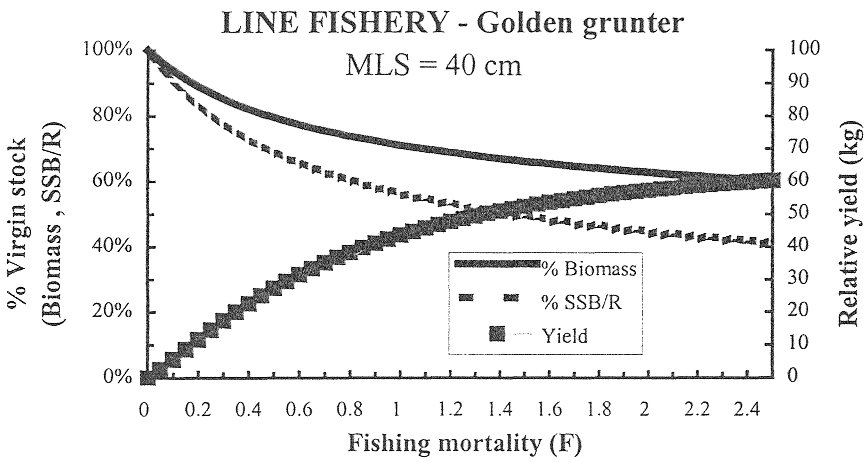

Figure 5.8 **YPR model (% biomass and SSB/R of virgin stocks and relative yield) for golden grunter (combined sexes) from the line fishery with a MLS of 40 cm TL.**

5.4.4 King salmon

Preliminary histological examination of Gulf of Carpentaria king salmon gonads indicated that the species is a protandrous hermaphrodite, with initial maturation as a male and subsequent change of sex to a female during the life cycle of an individual fish. This finding is consistent with the results of earlier studies in Gulf waters (Garrett 1992b) and elsewhere in Australia (Griffin 1990; Russell 1988). Macroscopic assessment of gonad maturity status indicates that length at first maturity in the male phase occurs from 28 cm LCF (Table 5.1), during the second year of growth (see Section 4, this study).

The observed length range of 28-101 and 87-109 cm for mature male and female king salmon respectively (Table 5.1) suggests that sex change is not restricted to within a narrow length range. At the present preliminary state of data analysis, the best estimate of length at 50% maturity in the female phase is 95.4 cm LCF (Figure 5.9), at which size king salmon are between 6 and 10 years old (Section 4, this study). Insufficient data are currently available from histological assessments to confirm the age of maturity of the male and female phases of this species as the majority of fish aged in this study did not have matching reproductive data recorded. The task of confirmation will be completed and reported elsewhere.

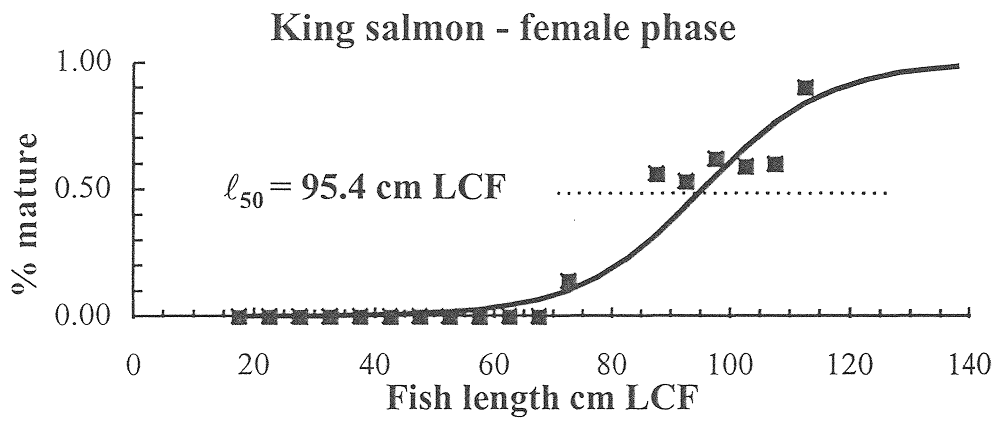

Figure 5.9 Logistic model estimation of the ℓ_{50} for female phase king salmon.

Based on GSI data, maturation of the testes in king salmon males occurs quite rapidly in late winter (August), then slowly tails away during early spring months (Figure 5.10). The commercial netting closure during summer eliminated the major source of samples for this species. However from the appearance of the graph in Figure 5.10, it seems likely that any reproductive activity during these months would be at a low level in comparison with that in late winter/early spring, at least in those Gulf riverine and coastal habitats where the inshore gillnet fishery operates. The circumstances surrounding the maturation status and cycles of more offshore salmon stocks remain unknown.

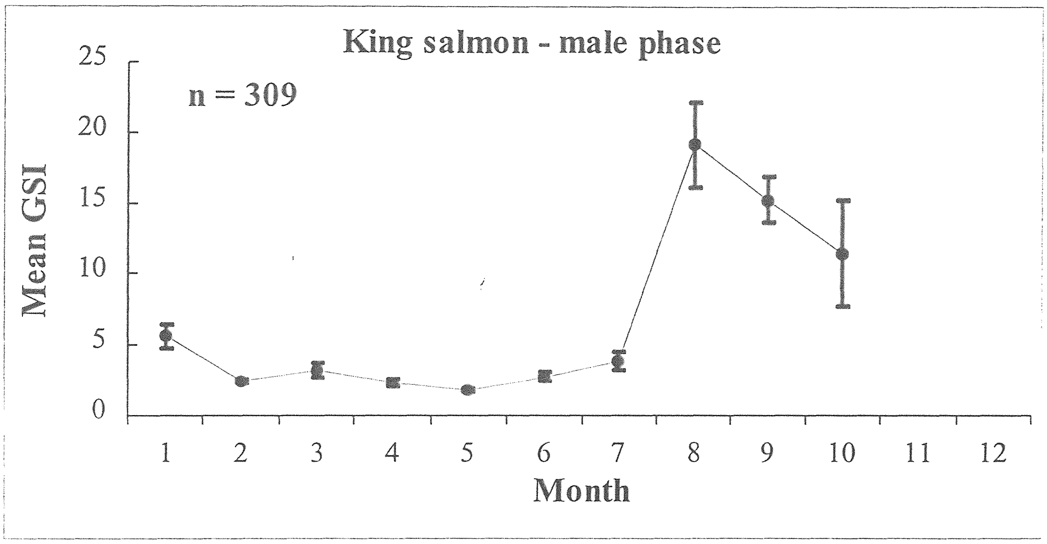

Figure 5.10 Gonadosomatic index for male phase king salmon.

GSI data for female king salmon (Figure 5.11) do not indicate such a clear seasonal pattern of sexual activity as demonstrated for the males, and the data subset are much less extensive through the year. The peak GSI values in late winter (August) appears consistent with the peak of gonad development in males. Once again, the availability of samples for reproductive assessment was very much dependent on commercial fishing activity - there is a virtual absence of female fish in samples from October to January.

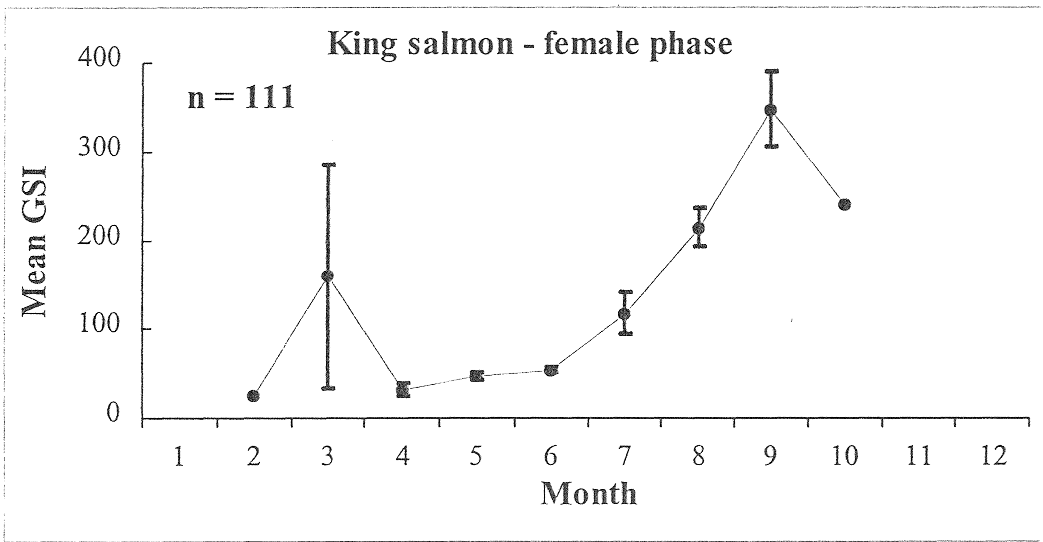

Figure 5.11 Gonadosomatic index for female phase king salmon.

Because of the limited data set available, no attempt has been made to present in this document even preliminary information on YPR analyses for Gulf king salmon.

5.4.5 Blue salmon

Preliminary histological examination of blue salmon gonads also suggested that the species is a protandrous hermaphrodite in Gulf of Carpentaria waters, with initial maturation as a male and subsequent change of sex to a female during the life cycle. The occurrence of hermaphroditism in this species is well documented in Queensland (Russell 1988; Stanger 1974) and in Asia (Kagwade 1970). Macroscopic assessment of gonad maturity status indicated that length at first maturity in the male phase occurs from about 24 cm LCF, during the second year of growth (Section 4, this study).

The observed length range of mature males and females of 24-44 and 33-88 cm LCF respectively (Table 5.1), is evidence that sex change is restricted to a much narrower length range in a much shorter lived species than king salmon. Maturity at age calculations showed that two year old females were present in the collected samples, which suggests that sex change commenced by the second year of life (unless direct maturation of females from sexually immature individuals occurs, contrary to the hermaphroditism status accepted for the species throughout its Indo-Pacific range). At the present preliminary state of data analysis, the best estimate of length at 50% maturity in the female phase (after Saila, *et al* 1988) is at 54.3 cm LCF (Figure 5.12), at about four years of age (Section 4, this study). The low proportion of fish, from this data set, especially in the larger size classes, observed in an advanced state of maturity may explain the poor representation of the data by this model.

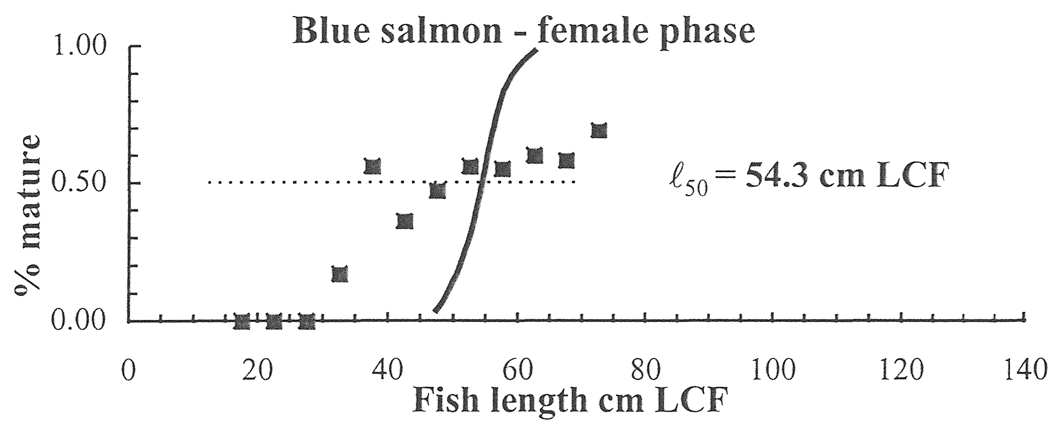

Figure 5.12 Logistic model estimation of the ℓ_{50} for female phase blue salmon.

The period of heightened reproductive activity for both male and female blue salmon as shown by GSI data (Figure 5.13 and Figure 5.14), suggests a more extended breeding season than in king salmon, even allowing for the low number of samples available during those summer months that coincide with the commercial fishery closure period. Gonad development starts in late autumn and early winter months, and reaches a peak in mid to late winter - July and August for males and females respectively. Reproductive activity continues into September and October, then falls away quickly by summer.

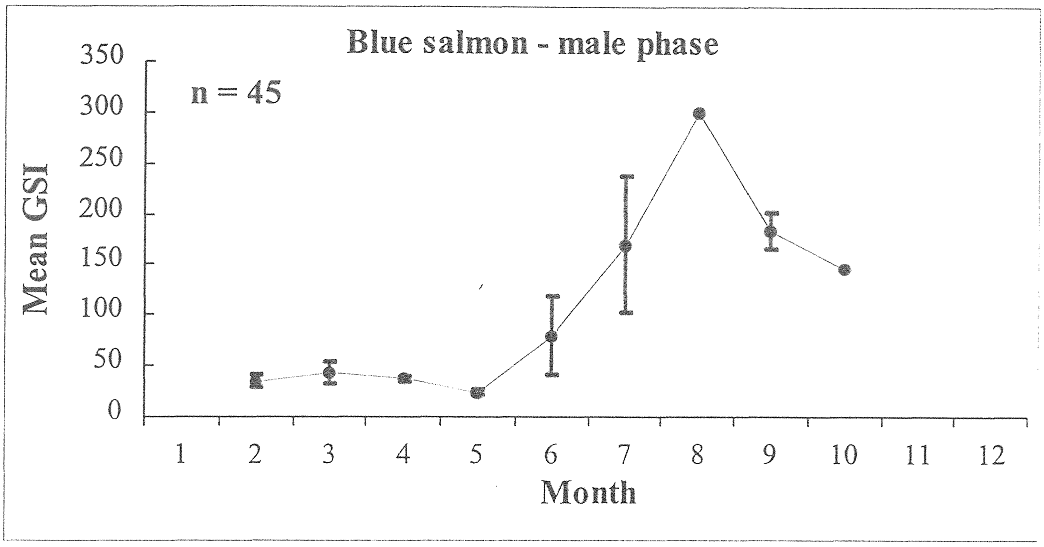

Figure 5.13 Gonadosomatic index for male phase blue salmon.

Preliminary YPR analyses of blue salmon catches in gillnets indicated that the full selection to any of the net mesh sizes used in the fishery did not occur until after the current 40cm TL minimum legal size for the species was reached. While present levels of fishing mortality could not be estimated effectively, there is no evidence based on the limited data available to suggest that present levels of gillnet fishing pose any threat to spawning stock biomass levels in blue salmon (Figure 5.15).

While the data set for the selection of blue salmon to recreational line fishing gear in Gulf waters (and elsewhere) is extremely limited, increasing the MLS from the relatively small 40 cm TL value may have benefits for the recreational fishery. Once again, survival rate after release of undersized fish is likely to be critical for calculations, but it is likely to exceed the release performance for fish taken in the gillnet fishery.

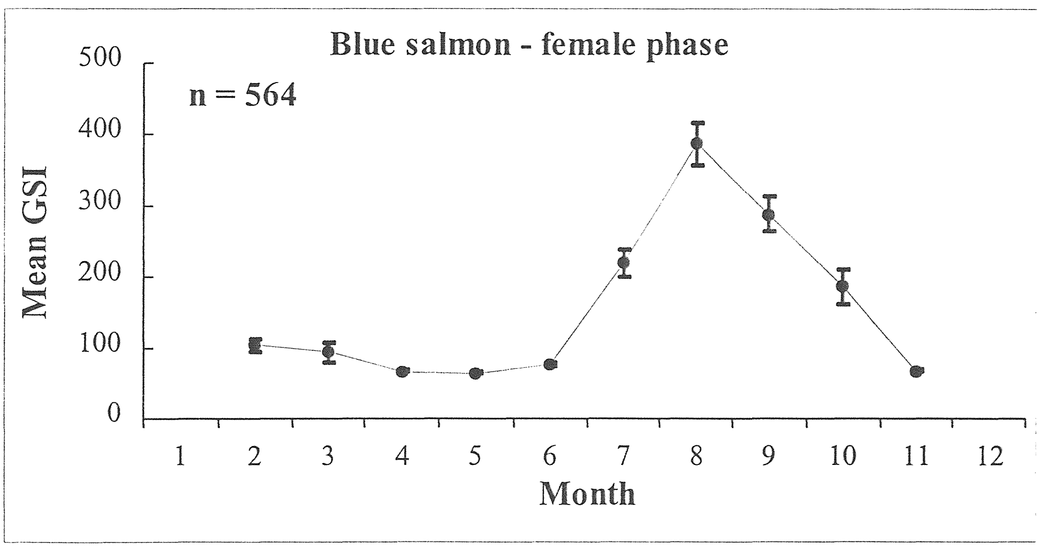

Figure 5.14 Gonadosomatic index for female phase blue salmon.

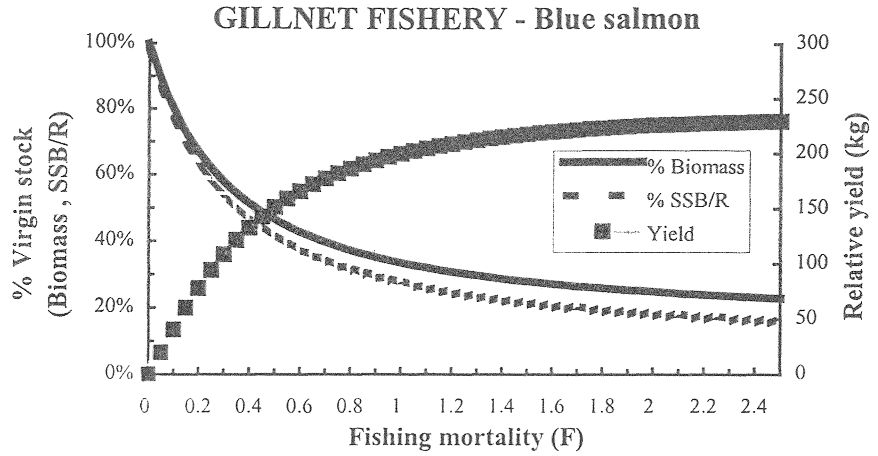

Figure 5.15 **YPR model (% biomass and SSB/R of virgin stocks and relative yield) for blue salmon from the gillnet fishery with the present minimum legal size of 40 cm TL.**

5.4.6 Black jewfish

Insufficient data were available to determine a period of peak reproductive activity for male or female black jewfish from GSI data, a circumstance that will alter when all collected material is examined. Size at first maturity details (Table 5.1) suggest that male black jewfish may mature at a smaller size than females. The observed length at first maturity of female black jewfish of 92 cm TL coincided with the length at 50% maturity estimate of 97.8 cm TL from the logistic model (Figure 5.16). These values in turn indicate an age at first maturity of 3-4 years for female black jewfish in Gulf waters (Section 4, this study).

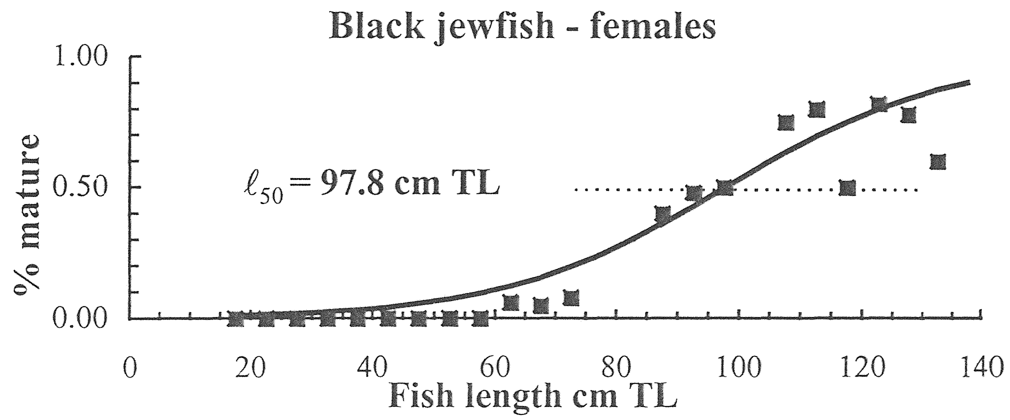

Figure 5.16 **Logistic model estimation of the ℓ_{50} for female black jewfish.**

Additional data to refine the estimate of length at first maturity established in this study will become available following analysis of the histological preparations from 153 male and 157 female black jewfish taken during the project (Table 5.1).

5.4.7 Jewelfish

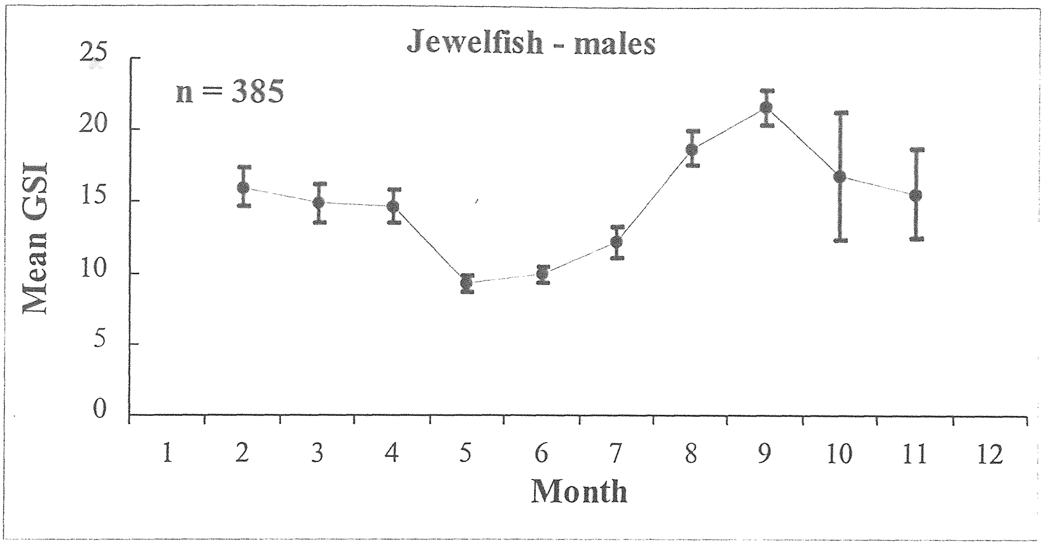

Figure 5.17 Gonadosomatic index for male jewelfish.

All estimates of reproductive parameters for jewelfish presented in this contribution must be regarded as uncertain because of the difficult taxonomic status of the species, particularly in the smaller size classes (Section 4, this study). Elimination of all doubtful samples using otolith morphologies (J Johnston, Queensland Museum, pers. comm) has reduced the collection of *Nibea squamosa* samples to 274 individuals (Table 5.1). Examination of these reveals that jewelfish males and females exhibit a very broad reproductive period. Lowest reproductive activity as demonstrated by reduced GSI levels occurs during late autumn and early winter (Figure 5.17 and Figure 5.18) for males and females respectively.

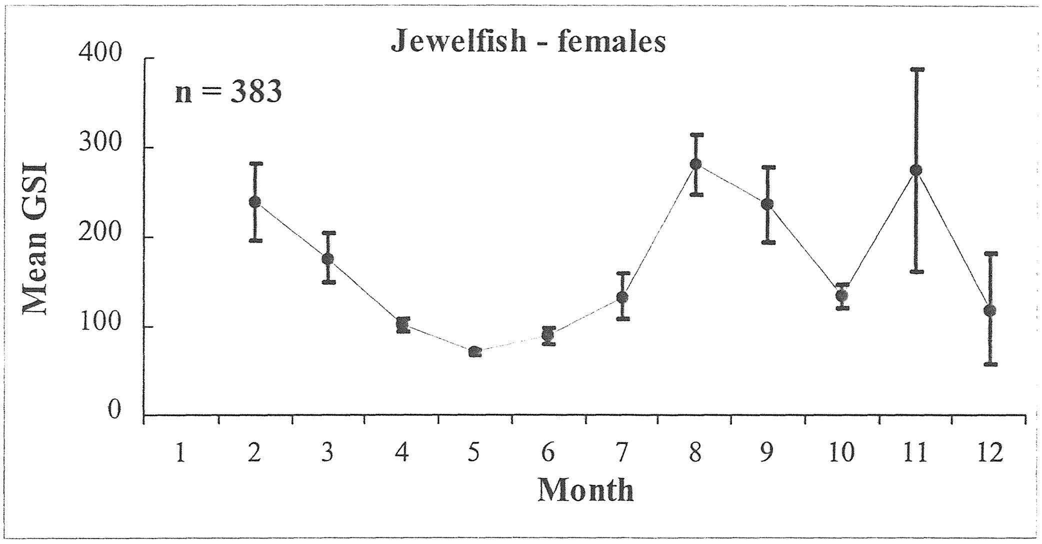

Figure 5.18 Gonadosomatic index for female jewelfish.

While the observed lengths at first maturity were 42 and 34 cm TL in male and female jewelfish (Table 5.1), an estimate for length at 50% maturity could only be calculated for males, at 45.6 cm TL (Figure 5.19). The low proportion of fish in the larger size classes in an advanced state of maturity influence the poor representation of the data by the logistic model. Both observed and calculated lengths at maturity and maturity at age data suggest an age at maturity in either the third or fourth year. A substantial number of histological samples remain to be examined, and this exercise should refine the preliminary estimate of length at maturity established above.

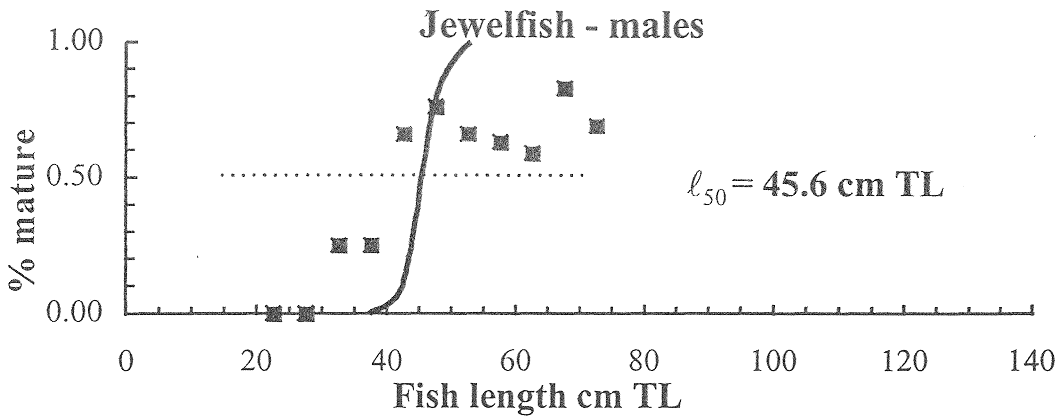

Figure 5.19 Logistic model estimation of the ℓ_{50} for male jewelfish.

5.5 DISCUSSION

This study has examined the reproductive biology of five finfish species associated with the Gulf of Carpentaria commercial gillnet and recreational line fisheries, namely, the golden grunter (*Pomadasys kaakan*), king salmon (*Polydactylus sheridani*), the blue salmon (*Eleutheronema tetradactylum*), the black jewfish (*Protonibea diacanthus*), and *Nibea squamosa*, a member of a group of sciaenid species commonly referred to as 'jewelfish'.

The erratic availability of material for the species of interest and the brief time-run of the project has meant that only preliminary estimates can be provided for the relevant reproductive parameters, based on detailed analysis of only a portion of the database. Nevertheless, baseline information is now available that can serve for future studies of Gulf fish populations.

The highly seasonal nature of the commercial gillnet fishery caused by the annual November through January gillnet closure period, and the recreational line fishery being largely confined to the cooler winter months, has made collection of monthly samples for reproductive analysis difficult. Achieving adequate samples for reproductive assessment was also influenced by the seasonal abundance of these species and their incidence of capture in commercial fishing operations targeted on barramundi.

5.5.1 Golden grunter

Bade (1989) observed a spring to summer reproductive period for *Pomadasys kaakan* on the east coast around Townsville, with a peak during September to November prior to the wet season. Russell (1988) found grunter on the central Queensland coast exhibited a prolonged summer spawning season between September and March. The spawning period for east coast fish appears to be a little later than that estimated for the Gulf stocks, although limited observations of reproductive activity in March suggest the possibility of a similarly extended season occurring in the Gulf.

The occurrence of mature gonads in young-of-year fish, or fish with lengths corresponding to this age group, observed in this study was also noted by Bade (1989). This author considered that the reproductive development in such fish was incomplete, and that spawning would not occur. Bade (1989) considered most golden grunter to be mature by the second year, a year earlier than the Gulf populations examined in our study.

The preliminary yield-per-recruit analyses suggest that the gillnet fishery has only a minor impact on the relative spawning biomass of grunter stocks in the major southern fishing grounds of the Gulf. The increase in minimum legal size from 30 to 40 cm TL in the 1997 fishing year appears to be an appropriate conservation measure for the recreational line fishery which has received considerable fishing effort over recent years (Anon 1996a).

5.5.2 King salmon

Griffin (1990) found evidence of protandric sex change for *Polydactylus sheridani* in Northern Territory waters. Males were observed to mature after 70 cm LCF and sex change occurred at an LCF of between 80 and 100 cm. Russell (1988) also reported hermaphroditism in central Queensland *P sheridani*, but found the size of first maturity (in male fish) was about 40 cm TL. Garrett (1992b) observed southern Gulf king salmon matured as males at 60-80 cm LCF, and females were first noted at 70-90 cm fork length. Essentially the same observations were made for Gulf king salmon in this study, except that mature males appeared in much smaller size classes.

Based on consideration of GSI data, our study established a late winter-spring breeding peak for Gulf king salmon. This finding appears at odds with those of Russell (1988), who established a late spring-summer (October-January) spawning season for east coast populations, and with that of Garrett (1992b) for southern Gulf fishing grounds. Barramundi in Gulf waters demonstrate an extended breeding season (Garrett 1987 and 1992b) with more northerly stocks spawning as early as September and October before water temperatures become unfavourable for egg fertilisation and development; more southerly Gulf barramundi spawn in November and December. A similar breeding strategy may be employed by Gulf king salmon. Support for this argument from genetic stock structure analysis is equivocal (Section 3, this study), unlike the strong evidence for population subdivision in Gulf barramundi (Keenan, 1994).

The present minimum legal size for the species in Queensland is 40 cm TL (or approximately 32 cm LCF). This measure serves to protect fish less than 2 years of age, which are almost entirely immature males. Russell (1988) also noted the preponderance of immature male fish in commercial net catches from the Queensland east coast. An increase in the minimum legal taking size of Gulf king salmon may well be warranted, but first the complete database must be analysed and appropriate yield-per-recruit analyses conducted.

5.5.3 Blue salmon

Blue salmon have a well-documented hermaphroditic life history throughout their Indo-Pacific range (Kagwade 1970; Russell 1988; Stanger 1974), and this finding can now be extended to Gulf of Carpentaria *Eleutheronema tetradactylum*. The present study confirmed precocious maturity as males at the end of the first year of growth, general maturity as males in the second year, and males being rare in three year old fish. Hermaphrodites and functional females were sampled at three years of age, although Stanger (1974) was unable to age fish from otoliths older than this. By four years of age, about half of all female blue salmon examined were reproductively active.

The species has a prolonged spawning period in Queensland east coast waters, from about July to April (Russell 1988; Stanger 1974). The breeding season for *E. tetradactylum* in Gulf waters appears to extend from early winter into summer, perhaps finishing before annual wet season flood rains degrade nearshore environmental conditions for spawning and larval development (as defined by Chao *et al* 1994).

The present levels of mortality in the Gulf blue salmon resource attributable to gillnet fishing operations could not be estimated effectively. However, yield-per-recruit analyses based on the available data suggested that the present level of gillnet fishing for this species in Gulf waters did not pose a threat to the resource. Nevertheless, the effect of concentrating fishing mortality primarily at the larger, female sex phase is uncertain, and should be investigated as a matter of urgency.

While an increase in minimum legal taking size would increase the estimated SSB/R level in the commercial net fishery, the extremely low likely survival rate of released fish (B Kehoe, Karumba QCFO pers. comm) suggests that this would never be a worthwhile option for the gillnet fishery. Calculations reveal that a survival rate of better than 95% would be required to achieve any obvious improvement in relative spawning stock biomass for this fishery.

5.5.4 Black jewfish and jewelfish

No comparative data are available for the reproductive biology of these species. No juvenile black jewfish with the characteristic colouration and markings attributed to this life cycle stage (Gloerfelt-Tarp and Kailola 1984) were present in collected specimens from Gulf fishing locations, and the location of spawning grounds and their environmental characteristics remain unknown. Even the largest (and oldest) specimens of *Protonibea diacanthus* examined in this study (ca 150 cm TL; the species is reputed to grow to at least 210 cm TL and 80 kg in Gulf waters; G Ward Karumba QCFO pers comm) appeared to be reproductively active. Seasonal aggregations of many hundreds of black jewfish have been reported at a number of remote northern Australian locations (eg Newman 1995) in recent years; these have been the focus of intense linefishing effort. Attempts to obtain material from these aggregations for examination proved unsuccessful, and their biological purpose is uncertain.

Nibea squamosa, a member of the sciaenid group commonly referred to as 'jewelfish', was described only recently (Sasaki 1992), and the information presented in this contribution (and in other Sections of this document) constitutes much of the known biology of the species. The ecological equivalent to *N. squamosa* on the eastern Queensland coast may well be the silver jewfish *Nibea soldado*. This small sciaenid is found mainly over sand and mud substrates along northern east coast foreshores and in lower estuaries (Russell 1988). As was established for Gulf *N. squamosa*, most silver jewfish are sexually mature at the size at which they enter the fishery, and spawning individuals are found in all months except late autumn and early winter (Russell 1988).

5.6 RECOMMENDATIONS FOR FURTHER INVESTIGATION

The results from this study must be regarded as very preliminary in nature, as a major proportion of sampled and processed material remains to be examined. Completion of the required assessments should be easily facilitated because all histological samples have been processed and only require microscopical examination. Additional examination of matching otolith samples must also be undertaken to refine estimates of age at maturity for all species.

6. IMPLICATIONS AND RECOMMENDATIONS

An on-going consultation process throughout the lifetime of the project has ensured that the implications of the research have already been recognised by industry and the management authorities. This has facilitated the consideration of project results by the QFMA's Tropical FinFish Management Advisory Committee in the development of new management arrangements for the Gulf of Carpentaria inshore fishery. A recommendation to increase the minimum legal size for golden grunter to a more biologically appropriate value has already been incorporated through legislation into the Gulf Fishery Management Plan (Anon 1996a). The measure is especially important for the recreational line fishery.

Confirmation that king salmon and blue salmon are both protandrous hermaphrodites in Gulf waters, with very different sizes at sexual maturity, should stimulate review of the appropriateness of their current minimum legal sizes. More detailed yield-per-recruit analyses for these species are required as a matter of urgency. The present MLS for king salmon serves to protect fish for only a part of their sexually immature phase of life. For blue salmon, the effect of concentrating fishing mortality almost exclusively on the female component of the population is uncertain, and should be investigated.

A maximum legal size may be introduced for a species if there is evidence of an insufficient ratio of male to female spawners in the population. Investigating possible influences of fishing-induced decreases in average adult fish size and altered population sex ratios in protandric species was outside the scope of this project. Nevertheless, future resource assessment programs should include monitoring of sex ratios of these species on heavily exploited Gulf fishing grounds.

Heavy fishing pressure can cause stock-recruitment problems in protandric species populations by removing the large fecund female fish which had contributed significantly to spawning output and eventual recruitment to the fishery. The dramatic decline of the Gulf king salmon fishery, and the rarity of large female fish in recent net catches, may be significant in this regard. Industry concerns about the impact of removal of large female barramundi were responsible for the introduction of the present maximum legal size for this species.

The study has demonstrated that peak reproductive activity for the five key species occurs during winter or spring months. The fishing closure period in summer, which was instituted to protect spawning barramundi stocks, does not afford the same protection for the Gulf species considered here. Peak spawning times may differ throughout a species' Queensland range, suggesting that seasonal closure specifications should reflect this variability for biological accuracy.

A feature of sciaenid life cycles around the world is the seasonal aggregation of adult fish for spawning. These concentrations can present especially vulnerable fishery targets, and their overexploitation can lead to severe depletion of local stocks. While the reproductive status of black jewfish aggregations has not yet been demonstrated, the potential impacts of intensive fishing pressure on these formations should be a concern for fishery managers. Establishing the biological basis for, and importance of, these aggregations should be a priority task.

The prudence of this action is reinforced by the preliminary findings of the genetics study. Available evidence suggests Gulf fish populations have localised restricted distributions, although the mechanisms responsible are not known. This level of stock differentiation, if substantiated by further investigations, has important implications for species management regimes, and suggests that Gulf-wide interventions may not be the most appropriate.

Finding that several different sciaenid species contributed to Gulf jewelfish landings was an unexpected result. This taxonomic complexity has implications for future harvest management of jewelfish. Not all the interventions applied to one species in the complex can be expected to suffice for the others. For biological accuracy, the needs of the component species should be considered.

Thanks to the co-operation of Gulf fishers with the new logbook, an enhanced level of information is now becoming available for monitoring fishery performance. While concerns remain about the insensitivity of several parameters being measured (eg fishing effort is recorded as 'fishing days' without consideration of the quantity of net being used), the logbook system now operating in the Gulf offers significant input to assessments of fishery status and about trends in resource condition. The introduction of an equivalent monitoring system on the east Queensland coast can be expected to provide similar benefits to industry and the management sector. When coupled with fishery-independent evaluation of fishery resources, the initiatives can provide real-time mechanisms for following the impact of interventions introduced through Fishery Management Plans, and for comparing observed results with predicted outcomes from fishery modelling exercises.

Recommendations

1. That the minimum legal size for golden grunter *Pomadasys kaakan* in Gulf of Carpentaria waters be increased from 30 cm TL to 40 cm TL. It should be noted that this measure has now been incorporated into Queensland fisheries legislation.

2. That work to establish a biologically appropriate minimum legal size for king salmon *Polydactylus sheridani* in Gulf waters be concluded as a matter of high priority. The present measure of 40 cm TL does not adequately protect sexually immature fish. The appropriate value for the new size measure should be ascertained after further consideration of all available data and the results of yield-per-recruit analyses.

3. That any future consideration of seasonal fishery closures for key fish species should take into account the likelihood of spawning asynchrony of populations in different regions of the Gulf. This approach has led to an extension of the closed season arrangements for barramundi, as part of the Gulf Fishery Management Plan.

4. That further investigations be carried out to determine the biological significance of seasonal aggregations of black jewfish *Protonibea diacanthus* in Gulf waters, and their fishery impacts on local populations.

5. That additional research be undertaken to complete the analysis of stock structure in key Gulf fish species. The resulting stock biogeography should provide information on patterns of dispersal of larval forms, and on the value of existing closed rivers as recruitment sources.

6. That the current Gulf Set Net Fishery logbook program be standardised for use in Gulf and Queensland east coast gillnet fisheries.

7. That selectivity curves be determined for gillnets of various mesh sizes used in the Gulf of Carpentaria set net fishery to establish their influence on biological parameters derived from fishery data. Tidal influences on net mesh performance needs to be established as part of this investigation.

8. That the potential yield (both biological and financial) from inshore resources be established for the Gulf Set Net Fishery, in order to define fisher incomes and to manage the fishery effort required to achieve them.

9. That long-term fishery-independent resource assessment and monitoring programs be developed and introduced for the tropical Queensland gillnet fisheries, to complement the commercial fishery logbook programs. Integrated resource assessment and monitoring initiatives in gillnet fisheries was a priority research need identified by the QFMA's Tropical FinFish MAC (Anon 1997). Appropriate sustainability indicators must be developed as part of the resource assessment, and this information included in the relevant Fishery Management Plans.

10. That detailed stock assessment of key Gulf inshore fish species be undertaken as a matter of urgency. Preliminary stock assessments for barramundi and threadfins will be facilitated by current efforts of the FRDC-funded Tropical Resources Assessment Program (95/049). This project is developing fishery models to test simulated exploitation under various management regimes, and will derive the analytical procedures needed for periodic intensive stock assessments of target species.

7. BENEFITS

The project has been successful in delivering a range of outcomes that were identified at its inception as being important to the fishing industry and to fishery managers.

Commercial, recreational and indigenous finfish fisheries along Queensland's tropical coastline depend on the continued viability of inshore fish resources. The research effort described in this report has contributed biological and fishery information required for the sustainable use of those resources, and to maintain prospects for the fishing industry over the long term.

Results from the project have been used by the Queensland Fisheries Management Authority in developing new Fishery Management Plans for the inshore fisheries in the Gulf and on the East Coast (Anon 1996a, 1996b). The inputs include the identification of biologically appropriate minimum legal sizes and gear use for the major target species, and the introduction of an improved commercial catch reporting system for Gulf fishery resource condition and trend evaluation (Williams 1997). Details revealed by the project for species stock structure have contributed to current Queensland Government policies that guide fish stock enhancement activities and aquaculture industry development in the State.

As well, the project has delivered direct benefits in understanding of the dynamics of target species populations in Queensland inshore net and line fisheries. FRDC funds a stock assessment project that is investigating tropical fish stocks in northern Queensland - the Tropical Resources Assessment Program (TRAP), FRDC Project 95/049. The fisheries-dependent and fisheries-independent information provided by the project to TRAP has ensured that this initiative has a more comprehensive information base to perform its stock assessments.

While the focus of the research investigations has been on the Gulf of Carpentaria fishery, the results have direct relevance to coastal gillnet fisheries operating in the Northern Territory and in Western Australia. Throughout northern Australia the target mix of species in the inshore fishery is similar. A sound biological information base for the threadfin salmon, grunter and jewfish species will allow Territory and WA fishery managers to assess their own Fishery Management Plans.

8. FURTHER DEVELOPMENT

Achieving responsible and sustainable use of fishery resources requires the integration of three key elements: detailed biological information and harvest statistics; an understanding of the dynamics of the resources in relation to fishing pressure and other impacts and; an ongoing evaluation of resource status and condition. The strategy for resource assessment in the tropical Queensland inshore fisheries has involved the progressive implementation of three key initiatives.

In the first phase, critical age growth and reproductive characteristics have been established for the target species. This information has now been obtained in FRDC Project 92/145 for the important Gulf threadfins, grunter and jewfishes. This project has also developed procedures for detailed monitoring of fishery performance in the Gulf inshore fishery. Short-term exercises such as these provide the benchmark information necessary for longer-term evaluation of resource condition and fishery monitoring.

The second phase has been to gather the tools that are necessary for examining the impacts of fishing on the dynamics of the fished resource. This is the function of the current Tropical Resources Assessment Program (TRAP) FRDC Project 95/049, which commenced in January 1996. Here, fishery models are being developed to test simulated exploitation under various management regimes, and to derive the analytical procedures for periodic intensive stock assessments of the key target species.

The third key element is to develop and put in place programs for biological and fishery monitoring of tropical inshore fish stocks in Queensland over the long-term. Routine ongoing monitoring is essential for the evaluation of changes in management policy now being proposed for the Gulf of Carpentaria and East Coast fisheries. Biological and fishery monitoring exercises that make effective use of the baselines established in the first and second phases of the Queensland resource assessment strategy can help ensure that new Fishery Management Plans meet their goals for sustainable resource use. Ideally, the continuous assessment of available fish stocks should include both fishery-dependent and fishery-independent data sets (Radovich 1975). Size/age-structured catch information can then be incorporated with harvest data for resource assessment over time, using fishery models developed in the TRAP project.

Now that the first and second phases of the resource assessment strategy are in hand, the implementation of the evaluation and monitoring initiative becomes the most critical. Its introduction should be pursed with vigour.

9. CONCLUSIONS

The project has attained its proposed objectives, and achieved clear outcomes for a sustainable inshore fishery in Queensland waters of the Gulf of Carpentaria.

1. Provision of biological baseline data and fishery assessment for Gulf threadfins, grunter and jewfishes, as inputs to the latest review of the Gulf Inshore Fishery Management Plan by the Queensland Fisheries Management Authority. New management arrangements proposed for the fishery incorporate minimum legal sizes for the target species based on project data, changes to the fishing gear used (especially mesh size) to diminish vulnerability of immature specimens to net capture, and alterations to the timing of fishing closures.

2. Development and successful introduction of monitoring systems necessary for long-term fishery assessment of the major catch species. The "research" catch and effort logbook trialed in 1994 had, in 1996, become the industry standard. The system enjoys high compliance among Gulf fishery participants and is expected to be introduced to the East Coast fisheries in the very near future. When coupled with fishery-independent evaluation of resources, a time-series of high quality data can be generated for detailed examination of resource dynamics, for periodic intensive stock assessment of target species, and for establishing the effectiveness of tropical inshore Fishery Management Plans.

3. Establishment of baseline details of resource status and fishery activity on the major fishing grounds. Such benchmarks are necessary for the detection and assessment of any changes that might occur over time. Biological (size-structured and age-structured catch data) and fishery (catch per unit effort) statistics are now available for the major inshore target finfish species in Gulf waters. However, measurement remains to be made of the range in variation over time for fishery-sensitive life history parameters including the age-structure of stocks, age/size of sex change (where this occurs), and the incidence of sexually immature specimens in catches.

4. Development of management options for the Gulf of Carpentaria multispecies inshore gillnet fishery, and the relevance of this information to similar fisheries on the east Queensland coast and elsewhere in tropical Australia. By putting in place industry-supported and -driven programs for fishery monitoring and resource analysis, this project has made a major contribution to informed review of the Gulf Fishery Management Plan and practices. Consultation with industry has been a cornerstone of the process that has developed management advice for the fishery.

5. Identification of further research priorities necessary for achieving sustainable use of Gulf inshore fishery resources. Support from FRDC has already enabled investigations to proceed on modelling the dynamics of the fished resources (Tropical Resources Assessment Program TRAP, Project 95/049). This initiative will permit forecasting of the likely outcomes of suggested management interventions, and will produce an initial assessment of tropical inshore stocks. Long-term fishery-independent resource assessment

and monitoring programs are required to complement fishery-based data sets. Appropriate sustainability indicators must be developed as part of this evaluation, and the information included in Fishery Management Plans.

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12. APPENDIX 1: INTELLECTUAL PROPERTY

No potential inventions or processes have been developed specifically as a result of this project.

13. APPENDIX 2: PROJECT STAFF

The following staff from the Queensland Department of Primary Industries Fisheries Group contributed to project activities during the lifetime of the project:

Northern Fisheries Centre, Cairns

Mr J M Bibby	Fisheries Technician
Mr G Cuff	Fisheries Technician
Mr R N Garrett	Principal Investigator
Mr P Leeson	Vessel Master
Mr G McPherson	Co-investigator
Mr G J Pomroy	Scientific Assistant
Mr A J Roelofs	Fisheries Technician
Mr L C Squire	Operations Officer

Southern Fisheries Centre, Deception Bay

Dr C P Keenan	Co-investigator
Ms R Street	Fisheries Technician

Resource Condition and Trend Unit, Brisbane

Mr L E Williams	Co-investigator

Queensland Boating & Fisheries Patrol, Karumba

Mr C Andrews	Patrol Officer
Mr T Bates	Patrol Officer
Mr P Cross	District Officer
Mr G Harsley	District Officer
Mr B Kingdom	Patrol Officer
Mr R Russell	District Officer