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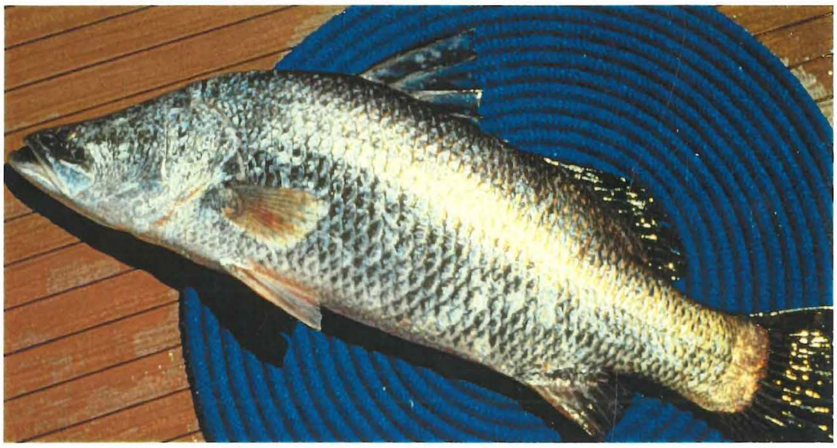
Assessment of the Barramundi Fishery in Queensland - 2002



Agency for Food and Fibre Sciences

FISHERIES AND AQUACULTURE

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Executive summary

The barramundi, *Lates calcarifer*, is an important target species of commercial, recreational and indigenous fishers across northern Australia. In Queensland stocks from the Gulf of Carpentaria and the east coast are managed separately. An assessment of both the Gulf and East Coast stocks are reported here.

Commercial catch and effort data has been collected since 1981 by different sets of logbooks. Reliable records for the East Coast have only been available since 1985. Compulsory commercial logbooks have been in use since 1988 (CFISH). Catch in the Gulf declined till the early 1990's and since then has increased to 1981 levels. Effort has declined over the time series to be about half that of 1981 and stable. Catch on the East Coast has been relatively stable over the time series with the highest catches being recorded for the last four years. Effort slowly decreased till the early 1990's and has been stable since then. Although total effort on the East Coast is almost half that of the Gulf, over twice as many boats report effort on the East Coast. CPUE has increased slowly over the time series in the Gulf and on the East Coast. CPUE in the Gulf is consistently higher than the East Coast by approximately 40%.

A biomass dynamic model developed by Dr David Die at a 1997 Cairns stock assessment workshop was fitted to CPUE data from the Gulf and East Coast barramundi fisheries. In both cases the model fitted the data reasonably well and both also indicated that barramundi stocks have been increasing steadily since the mid- 1980's. This apparent recovery is probably a result of effort restrictions and seasonal closures enforced from 1981, following a reported drop in stock numbers during the 1970's. Current stocks in the Gulf and on the East Coast appear to be healthy and current levels of fishing effort appear to be sustainable. A recent decline in estimated biomass of East Coast barramundi may be an artefact of spatial closures implemented in 1999. Cohort analysis on the Gulf barramundi also indicated a slowly increasing stock biomass over the time series.

Further monitoring of both fisheries are required, particularly on the East Coast given recent trends. Further use and development of the biomass dynamic model are encouraged to obtain better estimates of stock size. The development of risk assessment projections for each fishery is strongly recommended. Other recommendations for future work are made and the need to standardise commercial fishing effort and to obtain recent age and length data are identified as priorities.

Acknowledgments

We would like to acknowledge the contributions made that enabled the compilation of this report. Lew Williams, Jim Higgs and Clare Bullock (Queensland Fisheries Service) assisted in providing the CFISH catch and effort data and recreational catch data (RFISH and charter logbook). Clare Bullock, Sue Helmke and Darren Rose also assisted in providing QFS Long Term Monitoring data. Stirling Peverell provided fishery observer data from the Gulf of Carpentaria inshore net fishery. Dr David Die developed the biomass dynamic model used here. Malcolm Haddon and Clive Turnbull provided helpful comments during discussions on fitting data to the biomass dynamic model. Malcolm Haddon also kindly reviewed the report and the methods used in the analysis.

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1. Introduction

The distribution of barramundi, *Lates calcarifer*, extends throughout the Indo-West Pacific from the Arabian Sea and the Middle East, to the Malaysian Archipelago, Indonesia, Papua New Guinea, northern Australia, China and Taiwan (Grey, 1987). The distribution of barramundi extends east as far as Tahiti where it has been introduced for aquaculture and has reportedly escaped into the wild (Rod Garrett, Northern Fisheries Centre, pers. comm.). Within Australia, barramundi are found in coastal rivers and estuaries north of approximately 26 °S (Grey, 1987; Garrett, 1995). It is highly prized as both a table fish and a sportfish. Commercial, recreational and Indigenous fishers take the species, with many communities in remote areas of northern Australia benefiting from sport fishing tourism, as well as being the centres for commercial operations. In Queensland the management arrangements for the East Coast fishery and the Gulf of Carpentaria (GOC) fishery are different and so each fishery is treated separately here.

At a 1997 stock assessment workshop held in Cairns, two biomass dynamic models were developed for the Queensland barramundi fisheries. Only the GOC fishery data (1981 – 1996) was applied to these models due to the lack of contrast in the East Coast CPUE data. Both models suggested that biomass of barramundi was low at the beginning of the time series with a gradual re-building of the stocks at a rate of 1 – 2% per year (Gribble, 1998). Since then a new management plan for Queensland GOC Inshore Fishery was implemented in 1999. This plan called for a reduction in commercial fishing effort by over 30% followed by closures of some rivers in the fishery. This report provides the first assessment of the GOC fishery since the implementation of the 1999 management plan, along with a preliminary assessment of the East Coast fishery.

2. Biology and Ecology

Barramundi are generally found in freshwater, estuarine and coastal marine habitats, congregating during summer months in the estuaries and tidal flats at the mouths of rivers and creeks to spawn. Spawning tends to be associated with the full and new moon, generally on the incoming tide, and when temperatures are between 27 and 33 °C (MacKinnon *et al*, 1986; Kailola *et al*, 1993). Estuarine salinities of 28 to 32 ‰ are required for both successful fertilisation and embryonic development (Garrett, 1995). Early juveniles inhabit brackish lagoons and swamps and may migrate to freshwater environments as they grow and/or as the lagoons dry up or shrink (Russell and Garrett, 1983; Russell and Garrett, 1985). Being protandrous hermaphrodites, the barramundi starts out life as a male, then at a certain stage of its life, makes the change to female (Moore, 1979; Davis, 1982). In Queensland waters, males can mature between 45 to 75 cm total length (TL), then later change sex, becoming females between 55 and 95 cm TL or larger (Garrett, 1995). This has important implications for management, as the larger females need to be retained in the spawning biomass to ensure adequate egg production. Barramundi are a fairly long-lived species by tropical standards, living to over 25 years of age (Garrett, 1995) and recruit to the fishery after approximately three to five years (Davis, 1987; Garrett, 1995).

With the onset of the first substantial rains of summer, male barramundi of breeding size move from their upstream habitats to estuaries where spawning aggregations are formed with female fish (Davis, 1987). Therefore, movement of mature barramundi into the fishing and spawning grounds may be affected by the degree of flushing from the upstream habitats as poor rainfall and/or river run-off may not permit downstream migration. In years of high rainfall following several seasons of low rainfall or drought, an abundance of recruits may enter the fishery in coastal waters. Further, when rains come at the right time spawning success and subsequent recruitment to the population is enhanced. These fish will usually recruit to the fishery 3 – 5 years later (Ian Halliday, unpublished data). Sex change, the spawning aggregation behaviour and downstream migration aspects of the barramundi life history provide challenges for the successful management of this species.

3. Fishery

3.1 Management

In 1981 management strategies were implemented for both the GOC and East Coast barramundi fisheries following concerns that stocks were in decline due to increased fishing pressure through the 1970's. The strategies implemented included:

- a temporal closure during November, December and January, that banned the taking of barramundi and all river set netting operations during this period,
- no foreshore netting in the GOC and the East Coast south to Cape Flattery,
- restrictions on gill net mesh size and on total gill net length,
- reduction in commercial effort by limited licence regimes for both the GOC and East Coast fisheries, with entry based on historical and financial involvement as well as demonstration of professional standards of operation,
- compulsory monthly logbook entries of commercial catch and effort,
- introduction of an amateur bag limit,
- protection of nursery habitats,
- increase in legal minimum size.

Current management of the Queensland barramundi fisheries includes:

- East Coast management arrangements introduced in 1991.
- Gulf of Carpentaria Inshore Fishery Management Plan implemented in 1999 (N3 and N9 fisheries).
- Minimum legal size limit of 58cm TL for East Coast and 60cm TL for the Gulf of Carpentaria (GOC).
- Maximum legal size limit of 120 cm TL (introduced in ~1985).
- A closed season to protect spawning stock; Nov-Jan for the East Coast and Oct-Jan for the GOC (Garrett and Williams, 2002). The GOC closure is timed each year to lunar cycles.
- Recreational in possession limit of five barramundi per person.
- Spatial closures on the East Coast in zones designated as Dugong Protection Areas.
- Spatial closures in the Gulf (some for recreational fishing only; some for Indigenous fishing only) (Garrett and Williams, 2002).

3.2 Research and Monitoring

- QFS Long Term Monitoring Program in the Qld GOC and Qld East Coast.
- QFS compulsory commercial fishing logbooks (CFISH) with daily records.
- QFS bi-annual recreational fishing surveys (RFISH) since 1997.
- QFS N9 fishery observer program
- FRDC TRAP Phase II N3 fishery observer program (QDPI, AFFS)
- CRC Monitoring tasks (Coastal CRC: Fitzroy River; Reef CRC: World Heritage Area streams).

3.3 Commercial fishing

In the State of Queensland, the GOC and East Coast fisheries are managed as separate entities. The commercial fisheries for barramundi are primarily set net fisheries and fishing operations are generally individual family operations, with the apparent absence of any real influence of major seafood companies in the harvest. Product is sold throughout Australia mostly in frozen fillet form but also whole, with frozen fillet worth $10 - $11 per kg to the fisher (Williams, 2002). Since 1998 the annual GVP for the commercial fisheries has been between $5.1 and $6.7M.

During 2001 the total commercial catch for the Gulf of Carpentaria and the East Coast was 720t and 220t respectively. Since 1981 the GOC catch has been between 325t and 760t, and since 1989 the number of boats reporting catch each year has ranged from 81 - 98 boats. On the East Coast a much higher number of boats report catch of barramundi and since 1989 has ranged from 202 to 239 boats per year. East Coast catch of barramundi, however, is lower than the GOC catch and since 1985 has been between 122t and 275t per year. The vast majority of this catch (95%) is taken north of Bundaberg.

3.4 Recreational fishing

The recreational barramundi fishery in Queensland represents a multi-million dollar tourist industry, with many fishers travelling from other States. It includes a private sector and charter sector. Barramundi are caught using hook and line while the Indigenous fishery can use hook and line, nets, and traps (Garrett 1995). Historical information on catch and effort for the recreational fishery is very limited. Since 1997 bi-annual recreational catch data has been collected using telephone surveys and a voluntary diary system (RFISH) by QFS staff. Estimates of catch from the RFISH program for the East Coast were 130 – 168t in 1997 and 127 – 164t in 1999, and for the GOC 44 – 57t and 47 – 61t for 1997 and 1999 respectively (derived from RFISH estimates and Williams, 2002). Estimates from the Queensland charter boat logbook database are that barramundi catch from both the East Coast and GOC are relatively trivial averaging 1.7t and 0.4t respectively over the last four years.

4. Fishery assessment

Commercial catch and effort data since 1981 has been recorded using two different sets of logbooks. The early logbooks were used from 1981 - 1990 and the current database was introduced in 1988. Overlap occurred from 1988 to 1990 and any discrepancies between databases were reconciled by the QDPI Tropical Resource Assessment Program (TRAP) to provide a continuous time series for modelling exercises (Magro *et al*, 1996; Gribble, 1998). Reliable records from the East Coast were only available from 1985. Fishing effort is recorded in logbooks as numbers of boat days. An important assumption in using the number of boat days as a measure of effort is that individual boats are fishing with similar intensity in any given year. This assumption was validated by Magro *et al* (1996).

4.1 Historical Catch and Effort

4.1.1 Gulf of Carpentaria

There was a steady decline in catch in the GOC from 1981 to 1994 when catch was down by 45% of 1981 levels. Catch has increased fairly rapidly since 1994 and in 2001 was back to

1981 levels (Figure 1). The corresponding effort steadily declined from 1981 to the mid-nineties and has been fairly stable since. Throughout the time series CPUE has shown an increase, particularly since 1986 (Figure 1). These trends would suggest that the fishery is not currently under threat from overfishing at current effort levels.

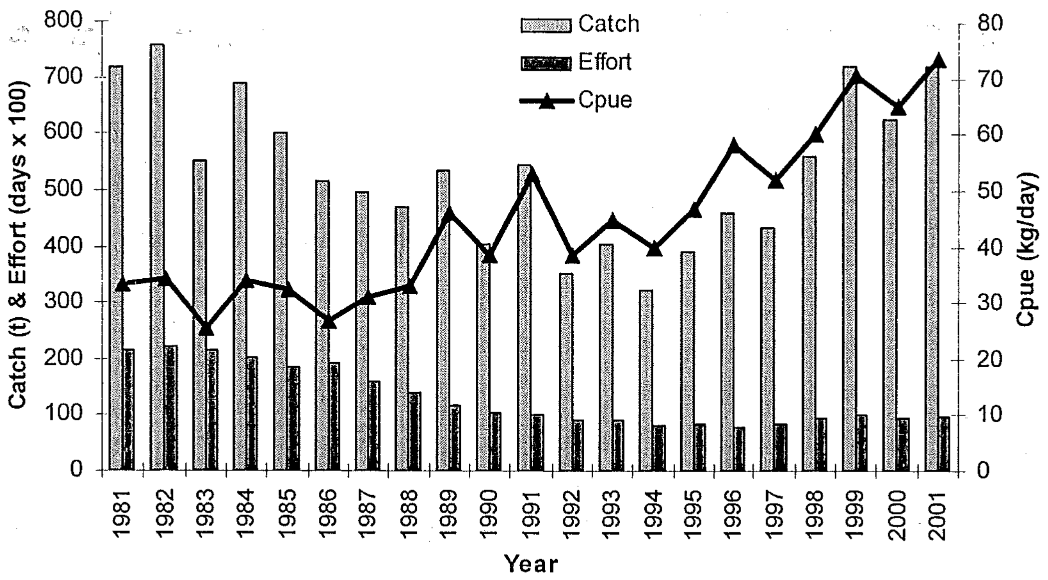

Figure 1. Catch (tonnes), effort (boat days) and CPUE for the Queensland Gulf of Carpentaria barramundi set net fishery from 1981 to 2001. (Source: QFS CFISH database).

4.1.2 East Coast

Catch of barramundi from the Queensland East Coast is presented for the period 1985 to 2001. Catch has been variable and the last three years have recorded the highest catches during the period of logbook records (Figure 2). Effort has also been variable but has declined over the time series to relatively stable levels over the last 5 years. Similar to the GOC, the CPUE trend has shown a steady increase over the time series (Figure 2), suggesting that current effort levels are not threatening the stock.

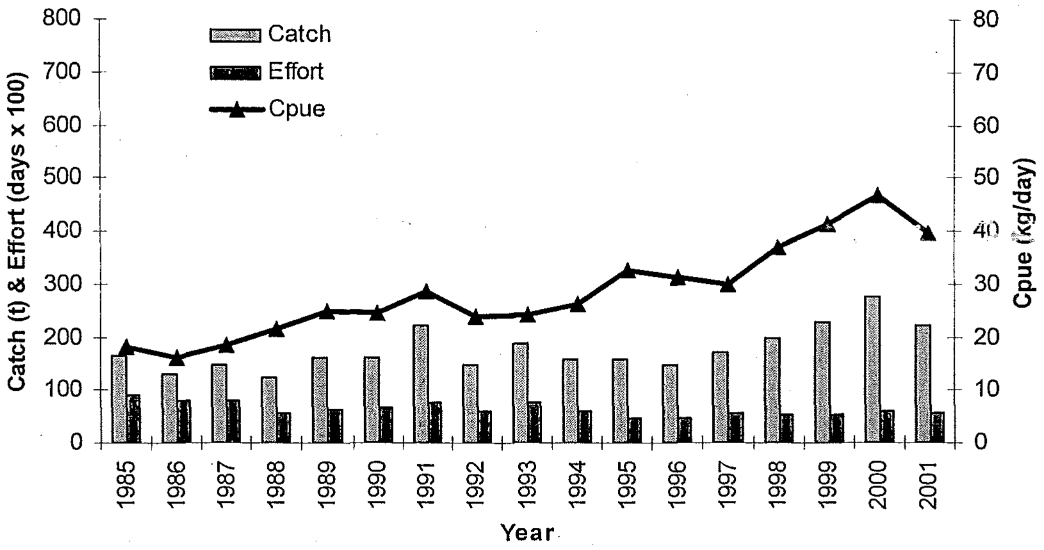

Figure 2. Catch (tonnes), effort (boat days) and CPUE for the Queensland East Coast set net barramundi fishery from 1985 to 2001. (Source: QFS CFISH database).

5. Stock assessment modelling

5.1 Biomass Dynamic model

Biomass dynamic models are used to describe the dynamics of a fished population in terms of biomass using the previous year's biomass, growth in biomass in that year, and catch (see Hilborn and Walters, 1992). These models use some measure of relative stock size (eg. CPUE) to model the population. We used a non-equilibrium biomass model developed by Dr David Die (see Gribble, 1998 for details) and fitted it to catch-per-unit-effort (CPUE) data. The model uses monthly data to account for seasonal differences and incorporates random recruitment seasonally. The model describes change in biomass as:

$$B_{y,t+1} = B_t + (r_y)p_t - C_t$$

where $p_t = 1/6$ for $9 \le t \le 12$ and $1 \le t \le 2$, and $p_t = 0$ elsewhere, B = biomass, C = catch, and r_y represents the random annual recruitment. The predicted CPUE was calculated by the model,

$$CPUE_{pred} = qB_t$$

where q is the catchability coefficient.

The parameters of the final model were q, the initial biomass (B_0), and the r_y for each year of the time series.

This model was first developed at a stock assessment workshop held in Cairns in 1997 (see Gribble, 1998) and was fitted to data from the Queensland GOC barramundi fishery for the years 1981 – 1996. We fitted the model again using the same data with the addition of data for the subsequent years, 1997 – 2001. The model was not used at the workshop with the East Coast barramundi data due to the lack of contrast in the CPUE, catch and effort over the time series available (1985 – 1996). After scanning the dataset with the 5 years of extra data, we felt that there was sufficient variability in CPUE to also apply the East Coast data to the biomass dynamic model.

5.1.1 Calculation of CPUE

We used daily catch and effort data obtained from the QFS CFISH commercial logbook database for the years 1988 – 2001. Data from earlier years were obtained through TRAP Phase I (see Gribble, 1998). We used geometric means of CPUE data as they are typically log-normally distributed (Haddon, 2001). We calculated geometric means of CPUE using the back-calculated value of the equation:

$$CPUEa = \frac{\sum_{i=1}^{n} \log \frac{C_i}{E_i}}{n}$$

where C_i is the unique observation of catch, E_i is the corresponding observation of effort (days fished), and n is the total number of observations for any given month. That is, the geometric mean of CPUE is given by:

$$eCPUEa = \exp(CPUEa)$$

Using this equation, estimates of CPUE for months during 1981 – 1996 correlated well with the estimates of CPUE used for the initial workshop analyses (see Gribble, 1998). Records of CPUE from the closed fishing season (November through January) were excluded from the model for both the GOC and the East coast data. Observations where effort was greater than 31 days in any given month were also excluded. This was consistent with the methods used at the Cairns workshop (see Gribble, 1998).

5.2 Cohort Analysis

Cohort analysis is a version of Virtual Population Analysis (VPA) and was developed by Pope (1972). Like VPA it uses commercial catch at age in numbers to follow fish cohorts throughout their lives. The model incorporates estimates of natural mortality and catch to back-calculate cohort size and ultimately provide estimates of fishing mortality (F) and population size by age class. We used Pope's cohort analysis on barramundi data to estimate trends in relative population size for comparison with estimates from the biomass dynamic model. We did this using an Excel spreadsheet developed by FAO (Lassen and Medley, 2001). Sufficient data was only available for the GOC to be used in the analysis.

Appropriate catch-at-age data was not available however a reasonable time-series of fishery-independent length frequency data was available from 1982 – 1994, 1997 (Hall *et al*, 1998) and 1998 – 2001 (QDPI, TRAP observer program). An estimate of 'relative age' was calculated using the von Bertalanffy equation and the parameters estimated by Davis and Kirkwood (1984). This is an indirect measurement of age and therefore assumes consistent growth patterns through the time series and equal selectivity across age classes. The latter, in particular, is unlikely to be true therefore the use of 'relative age' here should be treated with caution. Catch-at-age estimates for the analysis were derived using commercial catch records (CFISH), mean weight of the commercial catch (TRAP observer program) and yearly 'relative age class' proportions. Averaging across the previous three years for 1995, and the following three years for 1996 estimated age frequencies for the missing years (1995 & 1996).

5.3 Model outputs

5.3.1 Gulf of Carpentaria

5.3.1.1 Biomass Dynamic model

The model tracked the monthly decrease in CPUE fairly well for the first 6 years of the time series and tended to underestimate the decrease in monthly CPUE afterwards, although there was slight improvement in the final five years of the time series (Figure 3). The model suggested a very slowly declining population when fitted to the historic data (1981 – 1987) and a steadily increasing population from 1988 – 2001. Over the entire time series the resulting overall trend has been an increase in exploitable biomass at an average annual rate of 3.5% of the initial (1981) biomass (Figure 4).

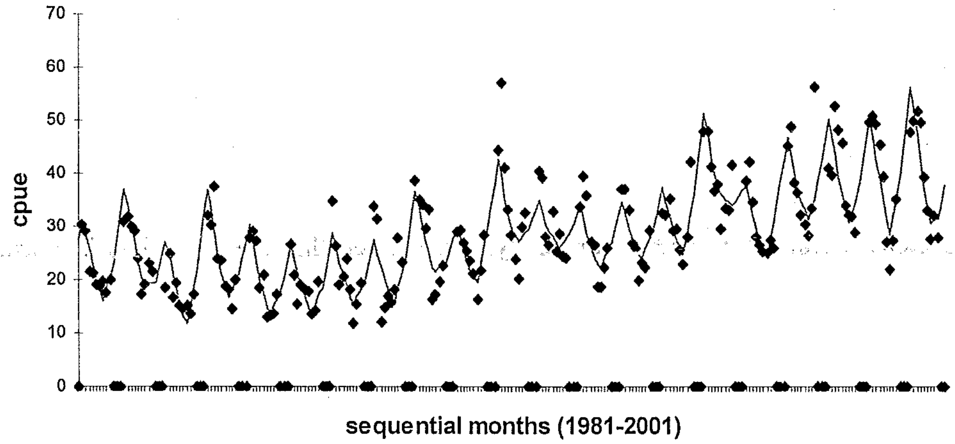

Figure 3. The model fitted to the observed monthly CPUE (kg/day) data for Gulf of Carpentaria barramundi over the time series 1981 – 2001. The line represents predicted CPUE and dots (♦) represent observed CPUE.

During the first 10 years of the time series the monthly exploitable biomass fluctuated between 300 and 1,000t (Figure 4). During the last ten years of the time series the model estimated that the stock fluctuated between 550 and 1,400t which reflects the rebuilding trend in the stock. The model estimated that the current (2002) exploitable biomass is approximately 1,100t (Figure 4) and suggested that the stock in 2002 is still increasing.

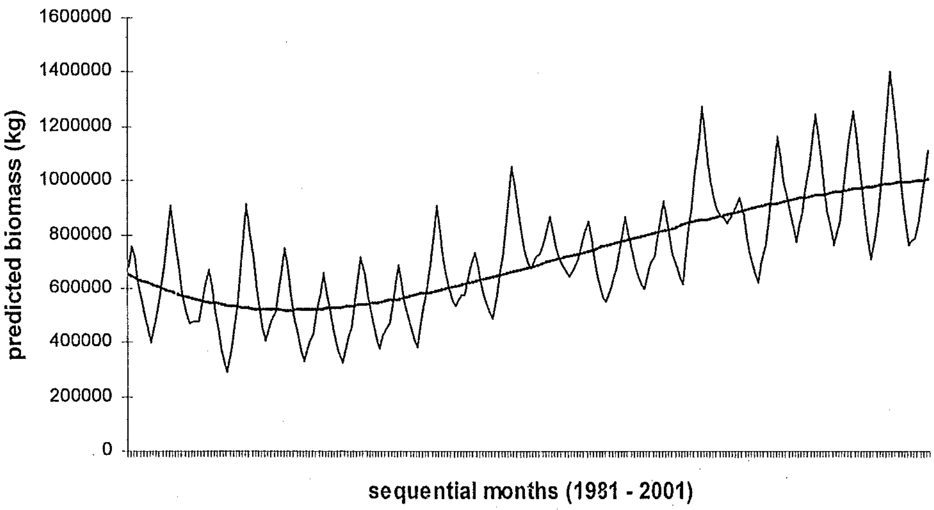

Figure 4. Exploitable biomass of Gulf of Carpentaria barramundi predicted by the model (thin line) showing monthly fluctuations over the time series 1981 – 2001. A polynomial curve is fitted to the predicted data to emphasise the overall trend (bold line).

5.3.1.2 Cohort analysis

It appeared that the cohort analysis did not estimate stock biomass very well early in the time series. However, it is important to note that the overall trend in the estimates of stock biomass from the cohort analysis was consistent with the predictions from the biomass dynamic model for the GOC barramundi. The cohort analysis estimated that the stock has increased at an average annual rate of 13% since 1986 (Figure 7).

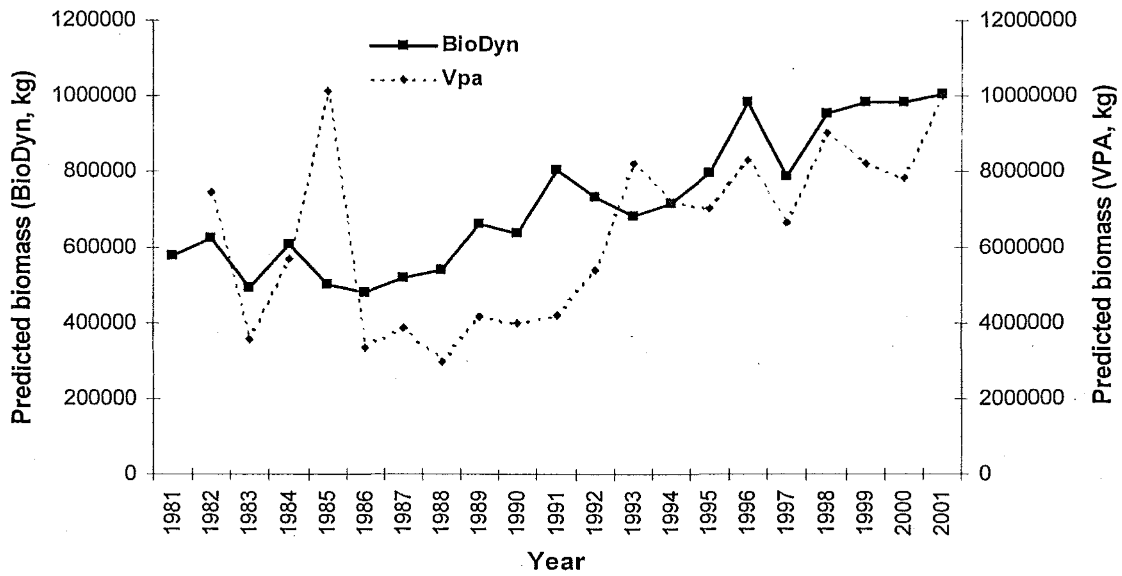

Figure 7. Comparison of the estimated biomass from the biomass dynamic model (solid line) and the cohort analysis (dotted line) of the GOC set net barramundi fishery from 1981 - 2001.

5.3.2 East Coast

The model tracked the observed monthly CPUE reasonably well, however it tended to underestimate the decrease in monthly CPUE in all years throughout the time series 1985 – 2001 (Figure 5).

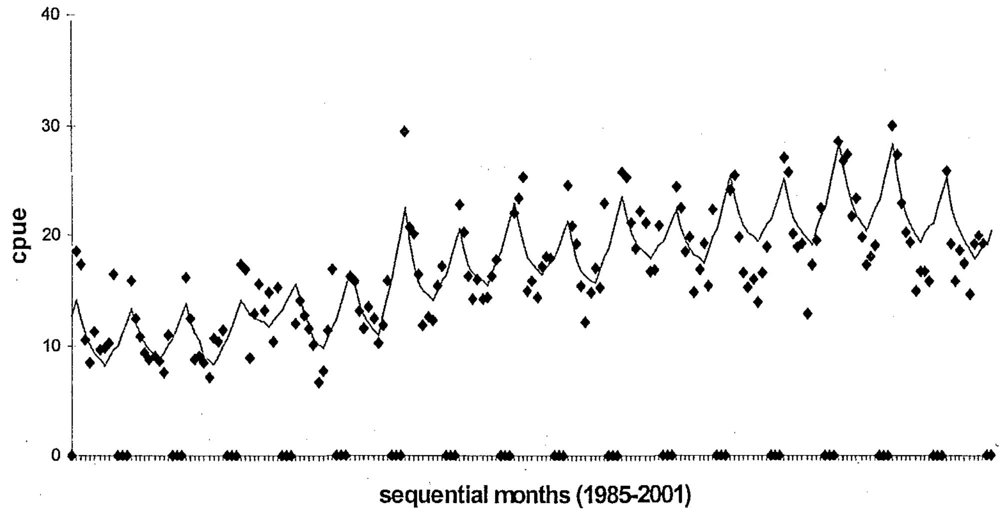

Figure 5. The model fitted to the observed monthly CPUE (kg/day) data for East Coast barramundi over the time series 1985 – 2001. The line represents predicted CPUE and dots (♦) represent observed CPUE.

The model suggested a steadily increasing population from 1985 – 1999 at an average annual rate of 8%. Between 1999 – 2001 the predicted average exploitable biomass decreased by 13% (Figure 6). During the time series the monthly exploitable biomass fluctuated between 200 and 600t. The model estimated that the current (2002) exploitable biomass is approximately 450t (Figure 6) and suggests that the stock is in slight decline from 1999 levels. It is possible that the apparent stock decline is due to reduced fishing efficiency observed following the implementation of revised management measures in 1999. These measures included the closure of some traditionally productive barramundi fishing areas with the introduction of Dugong Protection Areas and the northern re-zoning of the Great Barrier Reef Marine Park. For the apparent decline to be explained by the closures, the CPUE (and predicted underlying biomass) should stabilise over the next year or two. Catch and effort from the fishery should be monitored closely over the next few years to assess the stabilisation of CPUE. Monitoring will also reveal if the closures eventually cause an increase in production from edge effects of the closed areas effectively acting as fish sanctuaries.

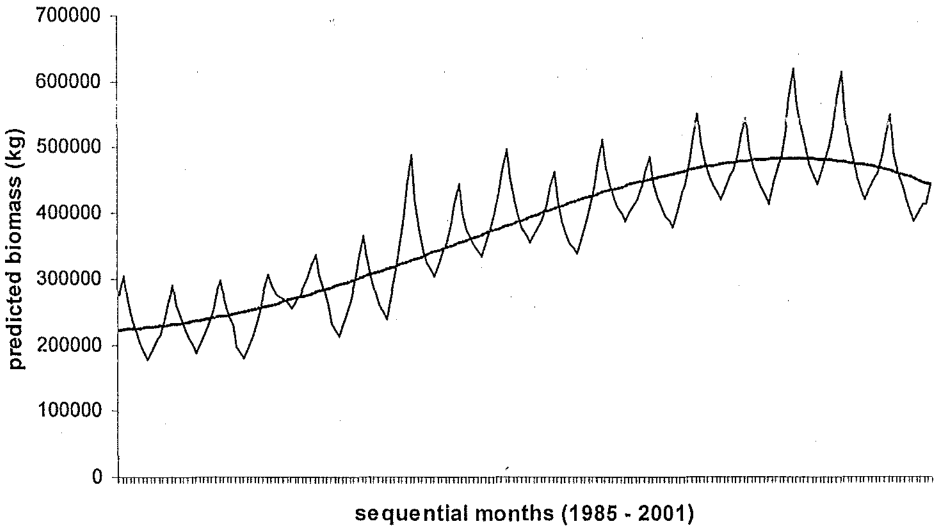

Figure 6. Exploitable biomass of East coast barramundi predicted by the model (thin line) showing monthly fluctuations over the time series 1985 – 2001. A polynomial curve is fitted to the predicted data to emphasise the overall trend (bold line).

5.4 Conclusions

This assessment suggests that barramundi stocks in the Queensland Gulf of Carpentaria and on the Queensland East Coast have been slowly increasing from 1981 and 1985 respectively, into the new millennium. This apparent recovery is probably a result of effort restrictions and seasonal closures enforced from 1981, following a reported drop in stock numbers during the 1970's. Current stocks in the GOC appear to be healthy and current levels of fishing effort appear to be sustainable. There are no obvious effects of the effort reductions and spatial closures implemented in 1999 through the GOC management plan. Any effects of this plan are more likely to be realised in the next few years with continued monitoring. East Coast barramundi stocks appear to follow the same trend as the GOC, however a recent decline in estimated biomass may be an artefact of spatial closures implemented in 1999. If so, then it is likely that current levels of fishing effort on the East Coast are also sustainable however the stock should be closely monitored given the recent trend.

The similarity in the trend in estimates of stock biomass over the time series from both the cohort analysis and the biomass dynamic model for the GOC fishery indicates the potential for the use of either model for future stock assessments of the Queensland barramundi fisheries. The use of biomass dynamic models is recommended as the preferred option however due to the availability of the appropriate data.

6. Future work

The assessment exercise reported in this document is a continuation of initial modelling work carried out at the 1997 Cairns workshop, whereby five years of GOC fishery data have been added to the time series. Catch and effort data from the East Coast inshore barramundi fishery have now also been fitted to the model. As data from future years become available they should also be incorporated into the model to ensure continued regular assessment of the Queensland barramundi fisheries. The current assessment did not incorporate recreational and indigenous catch. With the continuation of RFISH surveys and future estimates of indigenous catch, more certain estimates of total catch can be incorporated into future assessments. The East Coast stock in particular should be monitored in coming years given the recent apparent downturn in stock biomass estimates. A priority is to validate the commercial catch both in the GOC and on the east coast.

Future work should include further development of the biomass dynamic model by exploring extra parameters as well as developing risk assessment projections. It is also recommended that boot strapping be used to assess the variability and uncertainty in the model. Ideally, further development of the biomass dynamic model would be carried out in collaboration with Dr David Die.

A priority is to standardise commercial fishing effort across individual fishing operations. The CFISH database is detailed enough to allow standardisation using vessel ID numbers. Collection of catch and effort data from all sectors of the Queensland barramundi fisheries should also be continued. The acquisition of age and length samples taken annually from the fishery by the QFS Long Term Monitoring Program should be continued so that the annual catch of the species can be characterised. Fishery-independent age and length data should also be collected to allow estimation of growth parameters of the resource currently being exploited. It is particularly important that smaller, younger fish be represented in the dataset used for growth estimation.

Future work opportunities exist to carry out stock assessments on discrete genetic stocks of barramundi on the East Coast and in the GOC. Recent work identified several different genetic stocks in Queensland (see Keenan, 1994), and age and length information currently being collected by the QFS Long Term Monitoring Program corresponds with those genetic stocks which bear the highest levels of fishing effort. Such an approach appears relevant to recent developments in the GOC fishery, where market forces have resulted in very high demand for chilled fresh whole fish. This requires rapid transport of product from the fishing grounds and so local depletion may result from concentrated fishing near Gulf ports.

There is also an urgent need to continue the collection of estimates of recreational barramundi catch in Queensland, and also to obtain estimates of Indigenous catch. With better estimates of total barramundi harvest over time and from all fishery sectors, future assessments of Queensland barramundi resources can be carried out with greater certainty.

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