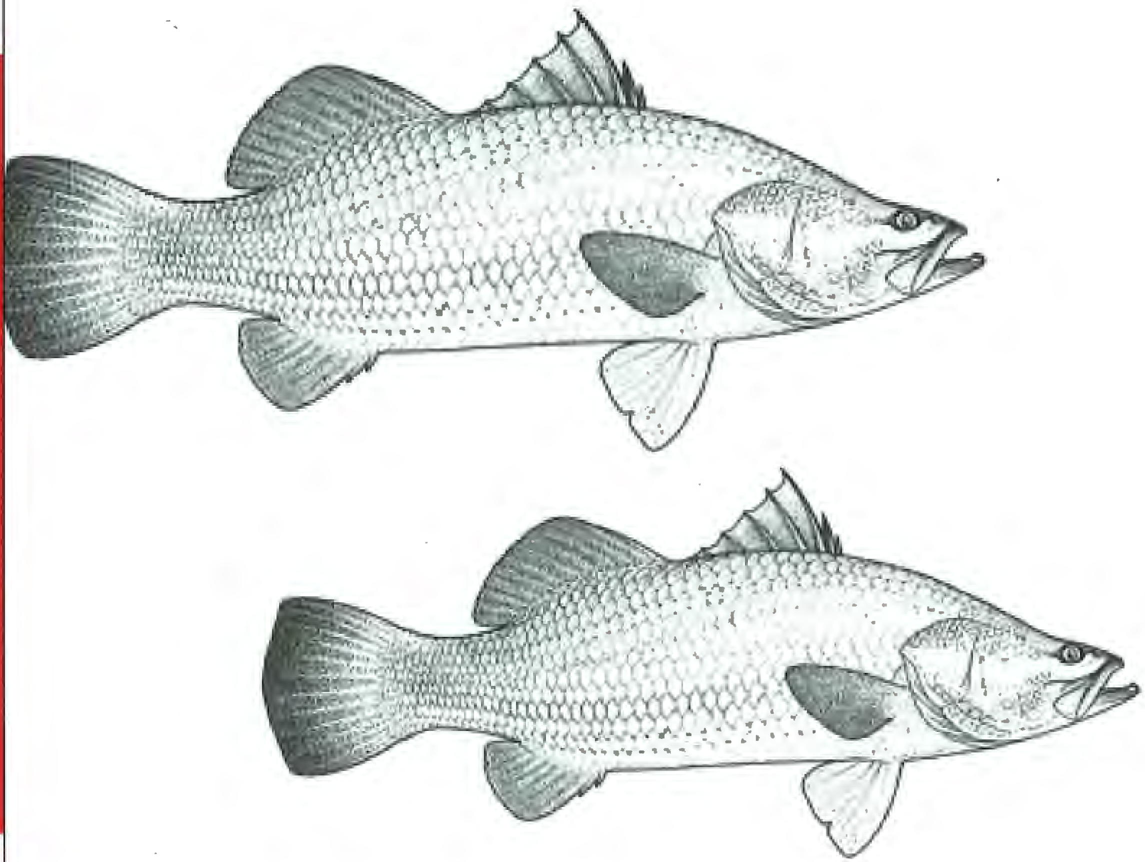
Queensland **the Smart State**

Assessment of the barramundi fishery in Queensland, 1989–2007



Alexander B. Campbell

Michael F. O'Neill

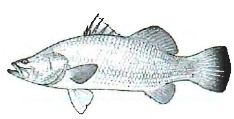
Rick Officer

Sustainable Fisheries

Animal Science

Queensland Government
Department of Primary Industries and Fisheries

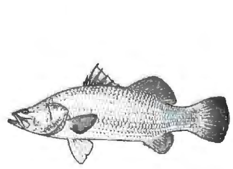
PR08–3730



Acknowledgements

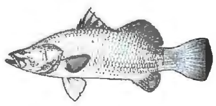
We would like to thank Ian Halliday for help with biologically plausible parameter estimates, and a number of interesting discussions about the barramundi fishery; Lew Williams for providing the commercial data, and especially for producing a modified data set at short notice; Len Olyott for providing the RFISH diary data; and Katherine Zahmel for providing the ESRI Shapefile that defines barramundi genetic regions. Darren Rose and Mai Tanimoto provided helpful comments on a draft of this document.

Contents



Acronyms

CEC Central east coast
CPUE Catch per unit effort
EC East coast
ECCY East coast Cape York
EG Eastern Gulf
GLM Generalised linear model
GoC Gulf of Carpentaria
LTMP Long-term monitoring program
MNEC Mid north-east coast
NWCY North-west Cape York
SEC South-east coast



Non-technical summary

The barramundi (*Lates calcarifer*) is an important target species for commercial, recreational and Indigenous fishers across northern Australia. In Queensland, barramundi stocks from the Gulf of Carpentaria (GoC) and the east coast (EC) are managed separately. Updated assessments of both the GoC and EC stocks are reported here.

The assessment used catch and effort information from both commercial (CFISH logbooks) and recreational (RFISH surveys) sources. The data were split into six different strata based on the genetic makeup of the stock, leading to six geographical regions with each having its own aggregated total commercial and recreational catch.

The analysis proceeded in two stages. The first stage was a standardisation of the catch rate per unit of effort (CPUE) to obtain an estimate of the relative changes in abundance over time. The second stage was fitting a biomass dynamic model to estimate absolute stock biomass and management parameters such as maximum sustainable yield.

The primary conclusion drawn from both the standardisation results and the dynamic modelling results is that the data are of insufficient quality to reliably estimate stock biomass or management parameters. This conclusion is based on a number of factors, including (but not limited to):

- large fluctuations in the standardised catch rate, which would be biologically implausible if taken as a reliable index of abundance
- an inability to find model parameters that lead to a good fit (unless certain parameters are taken past biologically plausible limits)
- large uncertainty in parameters estimated from the surplus production model.

Given this inherent unreliability in the data sources from which catch rate is estimated, stock biomass and maximum sustainable yield estimates must also be considered unreliable. It is therefore difficult to make specific conclusions about the status of the stock. With this caveat in mind, we can state the following tentative conclusions:

- Although absolute abundance is unknown, catch rate trends indicate the *direction* in which relative abundance is heading, and this appears to be clearly positive in four of the six geographic regions. (The CPUE in the east coast Cape York (ECCY) region and the total catch in the central east coast (CEC) region are fluctuating so much that we hesitate to reach even this mild conclusion.)
- If the surplus production model fits are to be believed, they indicate that absolute abundance is very low (in all regions) compared with unfished (virgin) biomass estimates (though, not surprisingly, the 'goodness of fit' for these models is relatively poor). It is important to ascertain how true these indications are—this emphasises the importance of obtaining better quality data (or understanding better the issues with the current data).

1 Introduction

Barramundi catches have the second highest gross value of product of EC Inshore Finfish Fishery species taken for domestic markets. Barramundi is a target species of Queensland commercial and recreational fishers. Gribble et al. (2005) analysed the EC fishery but difficulties with the data available and marked changes in the regional catch hindered a quantitative assessment of EC barramundi. Attempts to improve the assessment procedure (in collaboration with Dr Norm Hall) have also been hindered by uncertainties in available age composition data and inadequacies in selectivity data. A selectivity study (Hyland 2007) has just been completed, and a separate long-term monitoring program (LTMP) is now proposed to obtain better age composition data.

Despite these difficulties quantitative stock assessment for barramundi remains a requirement of the Department of Environment and Water Resources under the *Environment Protection and Biodiversity Conservation Act 1999.* This project has applied biomass dynamic stock assessment procedures to the three major catchments on the east coast and catchments in the EG with significant barramundi fisheries. It is expected that these assessments will provide a scientific basis for management of barramundi while impediments to a more certain assessment are resolved. However, given the primary findings—inherent unreliability of the data and resultant uncertainty about stock status—the importance and urgency of resolving of the aforementioned impediments is highlighted.

2 Materials and methods

2.1 Source data

The data for this assessment came from two sources: CFISH logbooks (which record commercial catch) and RFISH surveys (which estimate recreational catch).

2.1.1 CFISH logbook data (1989–2007)

The data were based on logbook catch and effort records over the 19-year period 1989–2007 from the Queensland EC and GoC fisheries. The data consisted of total monthly catch and associated number of vessels within each 30 minute x 30 minute latitudinal and longitudinal grid. Data also contained a field that indicated how many days were fished in that month. Lew Williams of the DPI&F Fisheries Business Group supplied catch data on 14 November 2007, based on queries applied to the CFISH logbook database. Data were available from January to October (inclusive) for 2007, and since the months of November and December typically account for less than 1% of the yearly catch (averaged over the years 1989–2006 November and December contributed only 0.18%), 2007 was included in the analysis.

2.1.2 RFISH survey data (1997, 1999, 2002 and 2005)

Queensland recreational fishing surveys conducted in 1997, 1999, 2002 and 2005 estimated the total barramundi catch of recreational anglers in Queensland. The data consisted of records of individual daily catch in numbers of fish retained. Associated with each catch record was a weighting factor that is intended to reflect this catch's contribution to the total amount of fishing by all anglers in the region. See the RFISH Technical Reports for more details on how this weighting factor was calculated (e.g. Higgs 1999). Also included in each record was a field for the nearest town to the fishing location. This information was used (see following section) to aggregate the catches into genetic stock regions. The DPI&F Fisheries Business Group staff supplied the data on 5 November 2007.

2.2 Data summarised by barramundi genetic stock region

The commercial and recreational data were aggregated into the barramundi genetic stock region from which they were most likely to have originated. The barramundi genetic stock boundaries (Shaklee 1993) used here to delineate the geographical regions are defined in

(DPI&F, 2005) and were provided as an Environmental Systems Research Institute Shapefile by DPI&F Fisheries Business Group staff on 7 November 2007.

In the case of the commercial data, each latitudinal–longitudinal grid was assigned to a unique genetic region due to it lying entirely within that region, the greatest amount of its area lying within the region relative to other regions, or the distance from its centroid to the closest point of that region being the shortest. For the recreational data, the nearest town field was used to assign catches to regions in an analogous manner.

Figure 1 is a map showing the spatial distribution and relative intensity of commercial catch (summed over all years). Figures 2 and 3 show the temporal pattern of commercial catch by genetic region. Figure 4 shows the recreational catch estimates (for the years 1997, 1999, 2002 and 2005) by genetic region.

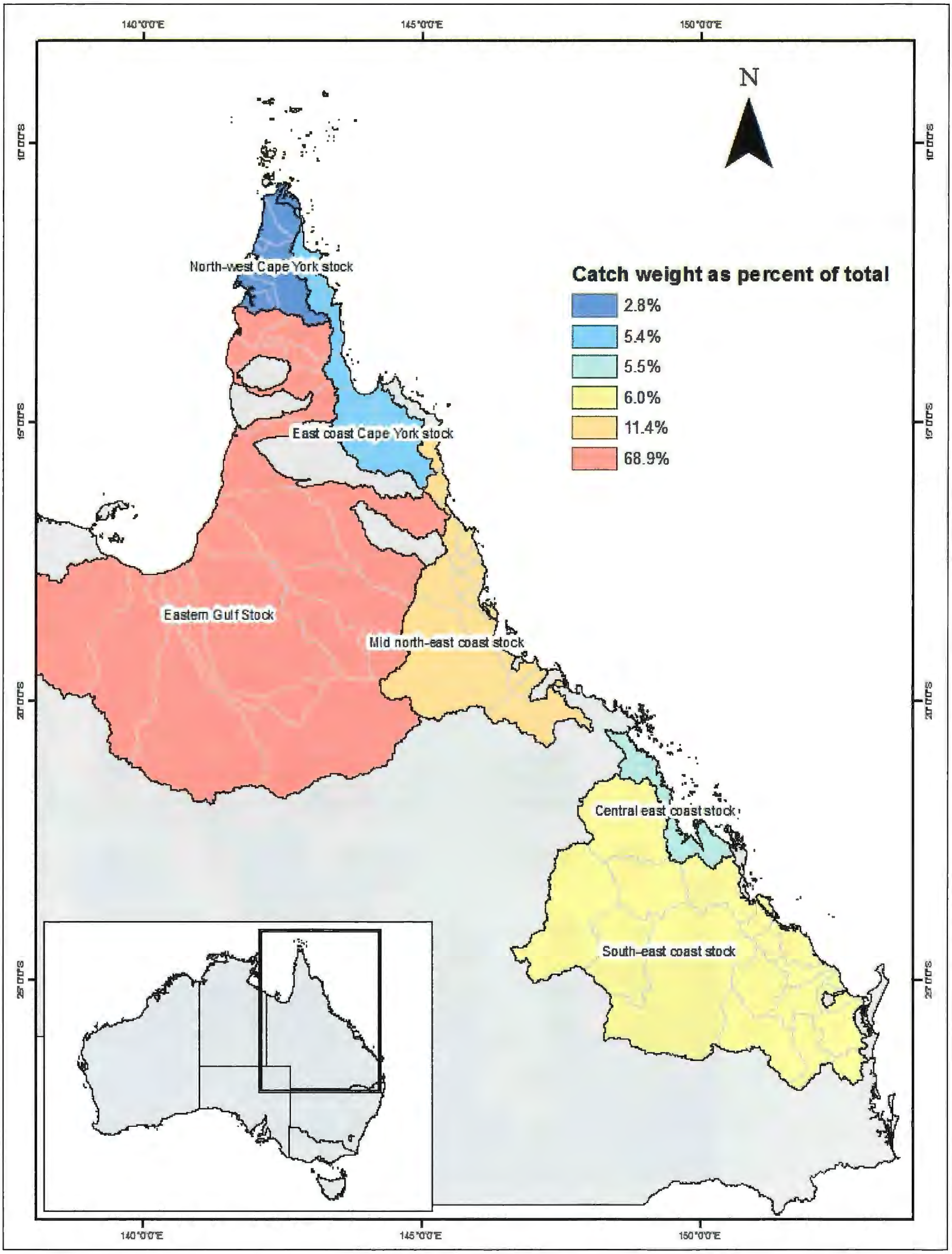


Figure 1. Geographical distribution of Barramundi catch from coastal and estuarine waters based on CFISH logbook data, 1989–2007. Barramundi genetic stock boundaries (Shaklee 1993) define the geographical strata.

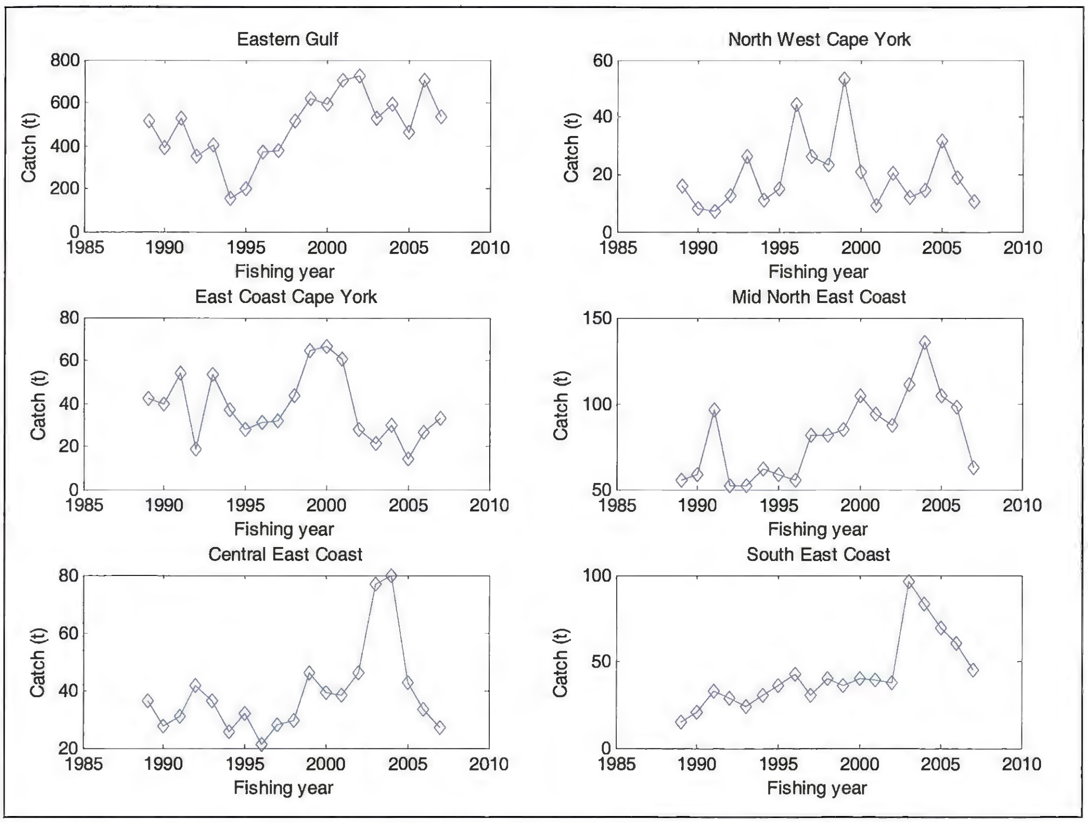


Figure 2. Total commercial catch (tonnes) 1989–2007, emphasising catch trends in each region.

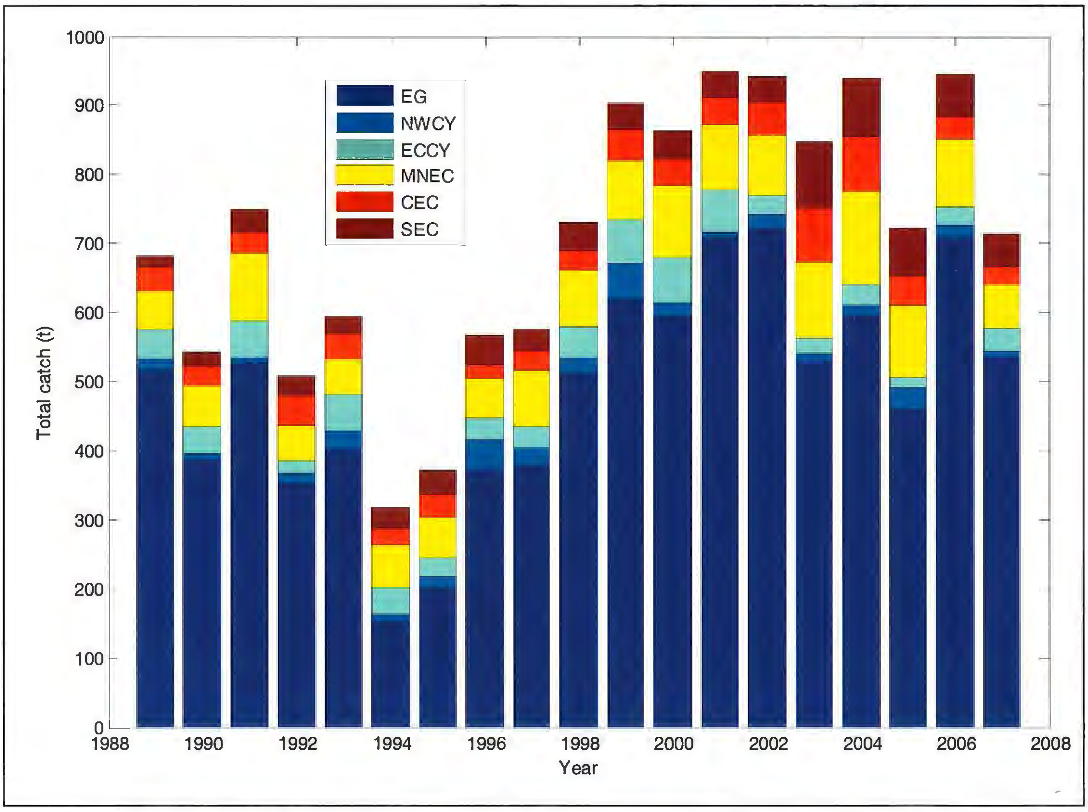
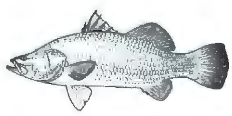


Figure 3. Total Queensland commercial catch (tonnes) 1989–2007, emphasising inter-regional variation.



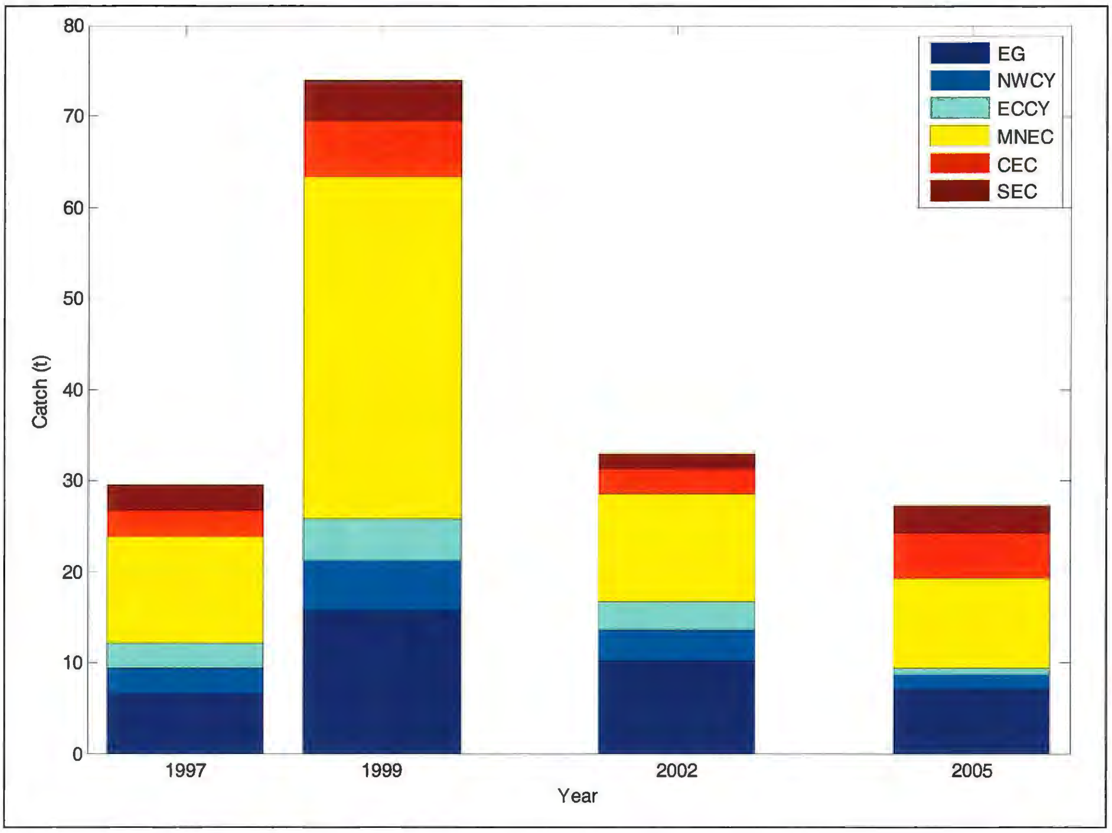


Figure 4. Total estimated recreational Queensland catch (tonnes) by genetic region.

2.3 Standardisation of catch rates

One of the two main inputs to a surplus production model is an index of abundance. Trends in catch over time may reflect changes in the proportion of the population caught, changes in abundance of the target species, or both, owing to catch being a function of fishing effort and abundance of the fished population (Quinn & Deriso 1999). Therefore, in order to obtain an index of abundance, the raw catch data must be standardised to remove, as much as possible, variation due to sources other than changes in abundance. In this report only the commercial (CFISH) catch was standardised, due to the unavailability of reliable recreational effort data.

A generalised linear model (GLM) was used to standardise barramundi catch rates using the commercial data by region for years 1989–2007 (Figures 2 and 3). The model assumed normally distributed errors and used an identity link function. The response variable was *logwt* (the log-transformed monthly barramundi catch). Explanatory variables were *fishyear*, *month*, *region*, *logdays* (log-transformed number of days fished in the month) and *logboats* (log-transformed number of boats fishing in the month). Main effects: *year*, *stock*, *month*, *logboats* and *logdays*. Interaction effects: *year.stock*, *stock.month*, *stock.logdays* and *stock.logboats*. (See Table 1 for the GENSTAT code.) Additionally, an interaction term between stock and grid was investigated, although this was found to not significantly raise the R^2 (coefficient of determination) value and a pragmatic decision was made to omit this term.

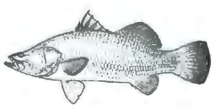


Table 1. GENSTAT GLM code.

```
MODEL [DISTRIBUTION=normal; LINK=identity; DISPERSION=*] logwt
```

```
FIT[PRINT=model,summary,estimates,accumulated;
selection=%variance,%ss,adjustedr2,\
r2,seobservations,dispersion,%meandeviance,%deviance,aic,sic;\
CONSTANT=estimate; FPROB=yes; TPROB=yes; FACT=2]\
year*stock+stock*month+stock*logboats+stock*logdays+stock.grid
```

2.4 Estimating a full recreational time series

The second of the two main inputs to a surplus production model was a time series of the total amount of catch in each year. As the recreational catch data only exists for four non-consecutive years (out of the total 18 years targeted for the assessment), some interpolation, extrapolation and assumptions were necessary. This was achieved through the following steps:

1. Using the index of abundance obtained from the commercial data, combined with the recreational catch data, a 'recreational effort' value is estimated in each of the four recreational data years (and in each region).
2. These values are then combined* to obtain an average recreational effort value for each region.
3. Recreational catch is then estimated in each year—except those for which catch data already exists (i.e. 1997, 1999, 2002 and 2005)—by multiplying the proxy effort value by the index of abundance in that year.

*In five of the six regions this combination was a straightforward mean value of the four effort values; however, in the MNEC region two separate effort values were estimated—one from the average of 1997 and 1999, and the second from the average of 2002 and 2005. The first average was used in step 3 for years 1989–2000, and the second for years 2001–2007.

The resultant estimated recreational time series is given in Figure 5.

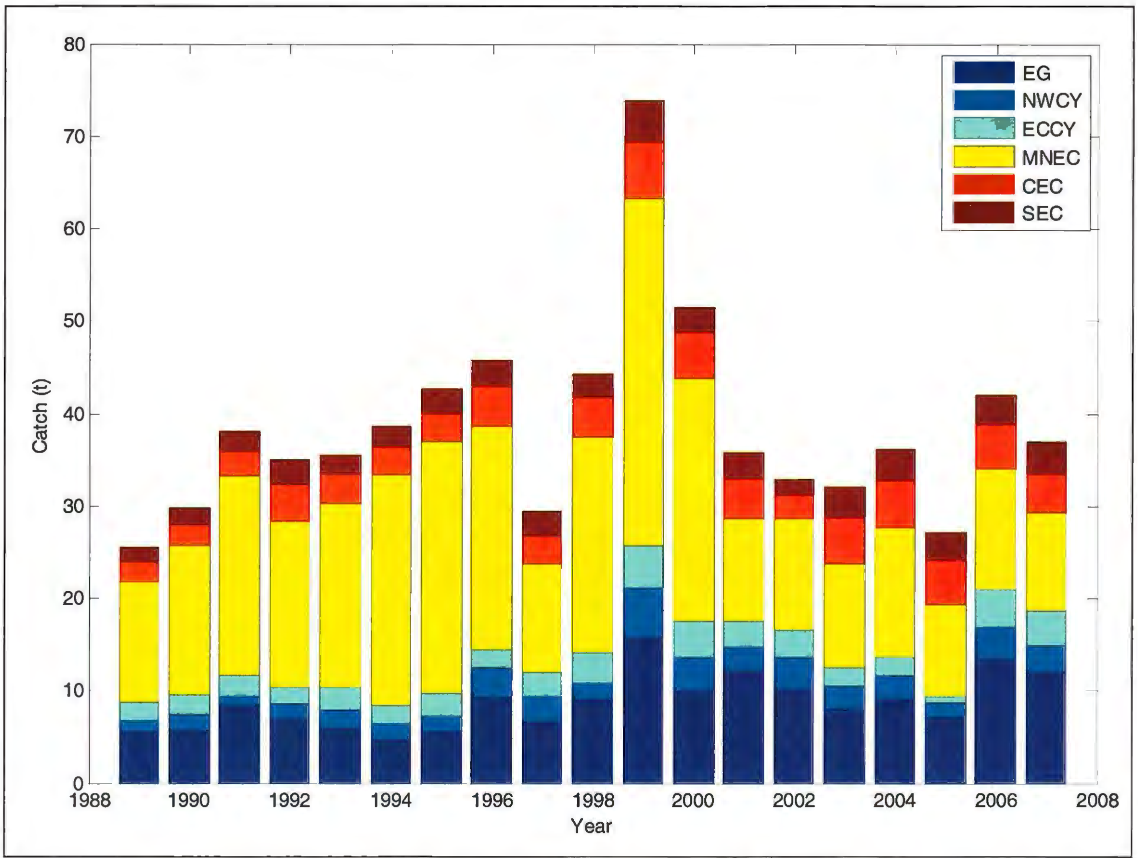


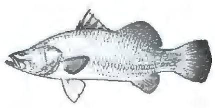
Figure 5. Estimated recreational catch time series (tonnes). Regions are colour-coded.

2.5 Surplus production modelling

Surplus production or biomass dynamics models are the simplest fisheries assessment models that evaluate the dynamics of a stock as these only consider changes in exploitable biomass (Schaefer 1954, 1957; Ricker 1975; Hilborn & Walters 1992). These models simplify all aspects of production (i.e. recruitment, growth and mortality) into a single function, where the stock is considered as undifferentiated biomass (Haddon 2001).

The 'surplus production' label refers to production from a stock above that which would be required to replace biomass losses due to natural mortality, and which, therefore, are (theoretically) available for catch. A typical management strategy therefore, would aim to maintain the stock at a size that would maximise the surplus production, and hence the potential catch or yield (Haddon 2001). Maximum sustainable Yield (MSY) and the associated effort or fishing mortality that generates MSY (E_{MSY}, F_{MSY}) given the respective biomass (B_{MSY}) are basic reference points estimated from surplus production models.

A major benefit (but also limitation) of these models is that they are far more simplistic than the age-structured models used in many assessments. Surplus production models are the least data intensive, only requiring a time series of catch and a relative abundance index (i.e. CPUE). Consequently, these models have been extensively used for data-poor fisheries, though it must always be kept in mind that these models are strongly based on some tentative assumptions. One of the major assumptions is that catch rates are linearly related to stock biomass, which may not be accurate for any species that is prone to hyperstability, or if there are other factors influencing total catch that are not able to be included in the standardisation process. As will be seen from the strong fluctuations in standardised catch rate in the next section, the claim that this catch rate is in fact an accurate representation of abundance is highly questionable. Any conclusions drawn from this analysis must therefore be treated with large degree of caution.



We used a non-equilibrium surplus production model (ASPIC Version 5) as defined in Prager (2004) to examine potential biomass trends of barramundi. The stock-production model incorporating covariates (ASPIC) fits a non-equilibrium logistic (Schaefer) production model to catch and effort data—in this case CPUE. (See Prager (1994) for theoretical details and a synthetic data example.)

The model was used to estimate four parameters:

1. B_1/K (the ratio of biomass at beginning of first year of time series to the biomass of the unfished equilibrium stock)
2. maximum sustainable yield (defined to be r*K/4, where r is the intrinsic rate of population growth)
3. K (unfished equilibrium stock size)
4. q (the catchability coefficient, defined as the proportion of total stock taken by one unit of fishing effort).

The combined totals of estimated commercial (Figures 2 and 3) and recreational (Figure 5) catch were used for the time series of catch. The standardised catch rates from the commercial data were used for the time series of abundance.

3 Results

3.1 Standardisation of catch rates

The GLM model defined in Table 1 was executed in GENSTAT and led to the following output:

- Adjusted R^2 statistic = 83.7 (83.7% of variance accounted for).
- Residual mean squares (dispersion parameter) = 0.5198.
- Standard error of observations estimated to be 0.721.
- All model terms significant in the accumulated analysis of variance (F distribution probability < 0.001)

This standardisation procedure led to the catch rates shown in Figure 6 (after bias-corrected back-transforming the log-predictions to mean value predictions). Figure 7 shows an analysis of the residuals from the model. The second and third plots in this figure appear to indicate a degree of heterogeneity in the variance (different amount of variance for different levels of response); however, figure 3 also shows that the vast majority (greater than 85%) of the data has homogenous variance. A square root transform (instead of a log) was applied to the response to try and reduce the heterogeneity; however, this did not have much effect and also caused the residuals to be less normally distributed. In the light of the concern over the reliability of the catch and effort data, this degree of heterogeneity was not considered to be an issue. Consequently, the error bars in Figure 6 should be treated as approximate.

Figure 6 shows that the EG region has the highest overall catch rate and that in general the overall trend in all regions is positive. However, the most noteworthy feature of this figure is the large year-to-year fluctuations; the ECCY region is particularly volatile. Although large fluctuations in total catch are possible for many reasons, the same is not true of standardised catch rates—if they really do represent a valid index of abundance then the only explanation is equivalent changes in stock biomass. Given biological knowledge of barramundi growth and natural mortality rates, these fluctuations are highly unlikely to represent actual biomass changes (Ian Halliday pers. comm.). This is a strong indicator that the catch and/or effort data are a poor representation of reality. One factor likely to have influenced the catch and effort data, but which was not taken into account by the standardisation procedure, is the impact of regulatory changes. This is discussed further in Section 4.

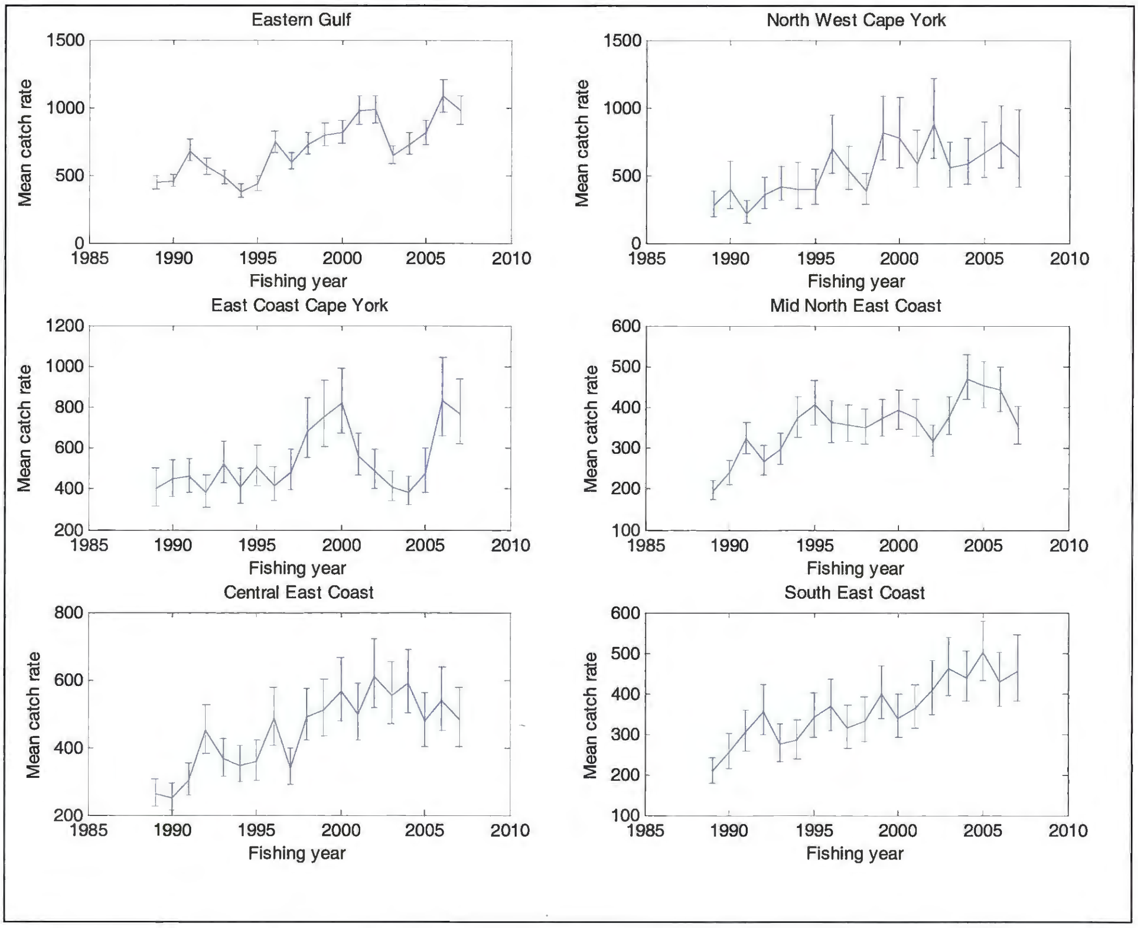


Figure 6. Standardised catch rates.

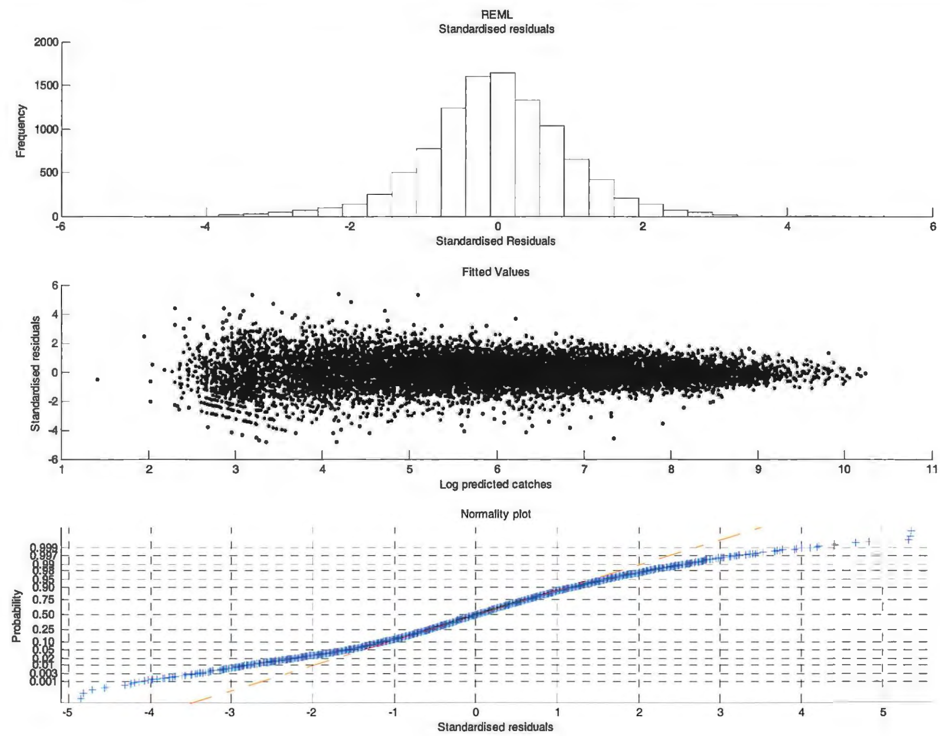


Figure 7. Residuals from the GLM.

3.2 Surplus production modelling

As discussed in Section 2.5, the model has four parameters over which it optimises—B_1/K (the ratio of biomass in the first year of the time series to the unfished equilibrium (virgin) biomass), MSY, K and q. In most cases B_1/K was fixed—that is, the model was instructed only to optimise over the remaining three parameters (MSY, K and q). This is because it was found that if this value was not fixed, the model would estimate implausibly low values for B_1/K and/or implausible values for other parameters (Ian Halliday pers. comm.). B_1/K was fixed at particular values in an experimental fashion by stepping up from zero in increments of 0.1 to find values that led to satisfactory estimates for the other parameters (the latter were decided upon through consultation with Dr. Ian Halliday).

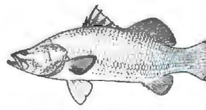
The following results consist of point estimates, relative bias (estimated via 500 bootstrap runs of the model), and bias-corrected confidence limits for these four parameters (although in most cases only three are estimated as discussed above). Given these parameters, the model then defines a time series of estimated biomass, which combined with the parameter estimates, is used to plot a graph of relative biomass through time (B_t/B_{MSY}) and relative fishing mortality through time (F_t/F_{MSY}).

Goodness of fit plots (observed CPUE vs predicted CPUE) are provided in the Appendix.

3.2.1 EG

Table 2. B_1/K fixed at 0.2.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.2 (fixed)	0%	0.2	0.2
MSY (tonnes)	883.7	-6.44%	765.5	1522
K (tonnes)	20500	-17.45%	12220	47490
q	0.00011	69.00%	0.000043	0.0001798



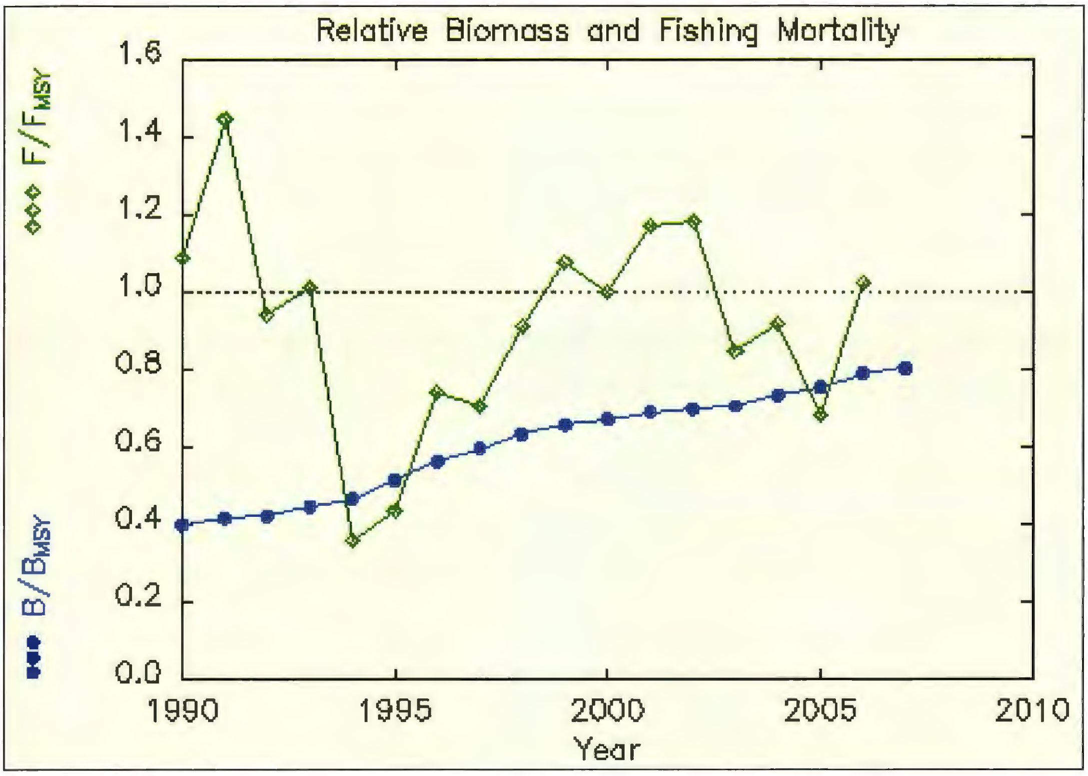


Figure 8. Relative biomass and fishing mortality with B_1/K fixed at 0.2—Table 2.

3.2.2 NWCY

The data from this region was unable to be fit for any reasonable (biologically plausible) parameter values.

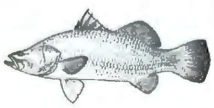
3.2.3 ECCY

Table 3. B_1/K floating—estimated to be 0.0412.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.04119	217.39%	0.01275	0.06312
MSY (tonnes)	273.5	-17.62%	174.1	820.4
K (tonnes)	2213	-17.75%	1467	8706
q	0.00552	4.37%	0.00356	0.00680

Table 4. B_1/K fixed at 0.2.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.2 (fixed)	0%	0.2	0.2
MSY (tonnes)	67.23	0.18%	66.98	67.52
K (tonnes)	475.8	3.78%	359.2	695.6
q	0.005114	4.37%	0.003482	0.006990



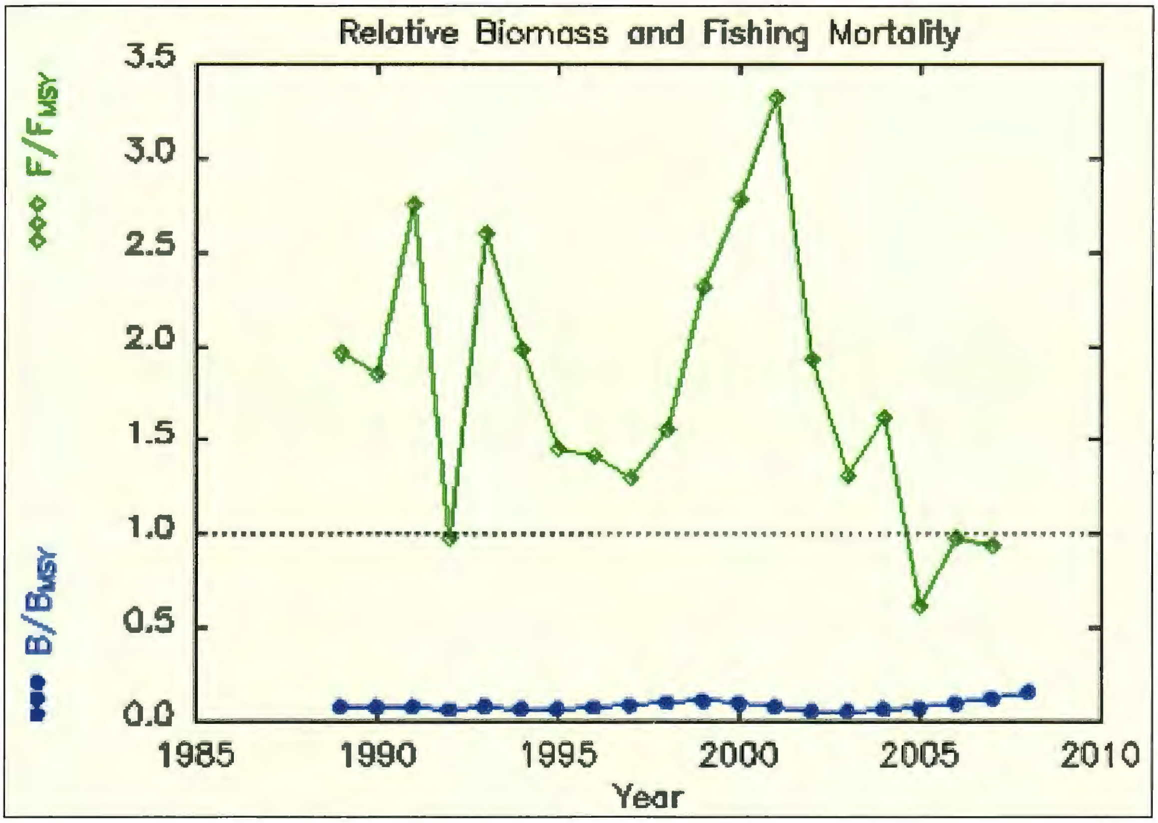


Figure 9. Relative biomass and fishing mortality with all parameters estimated (none fixed)—Table 3.

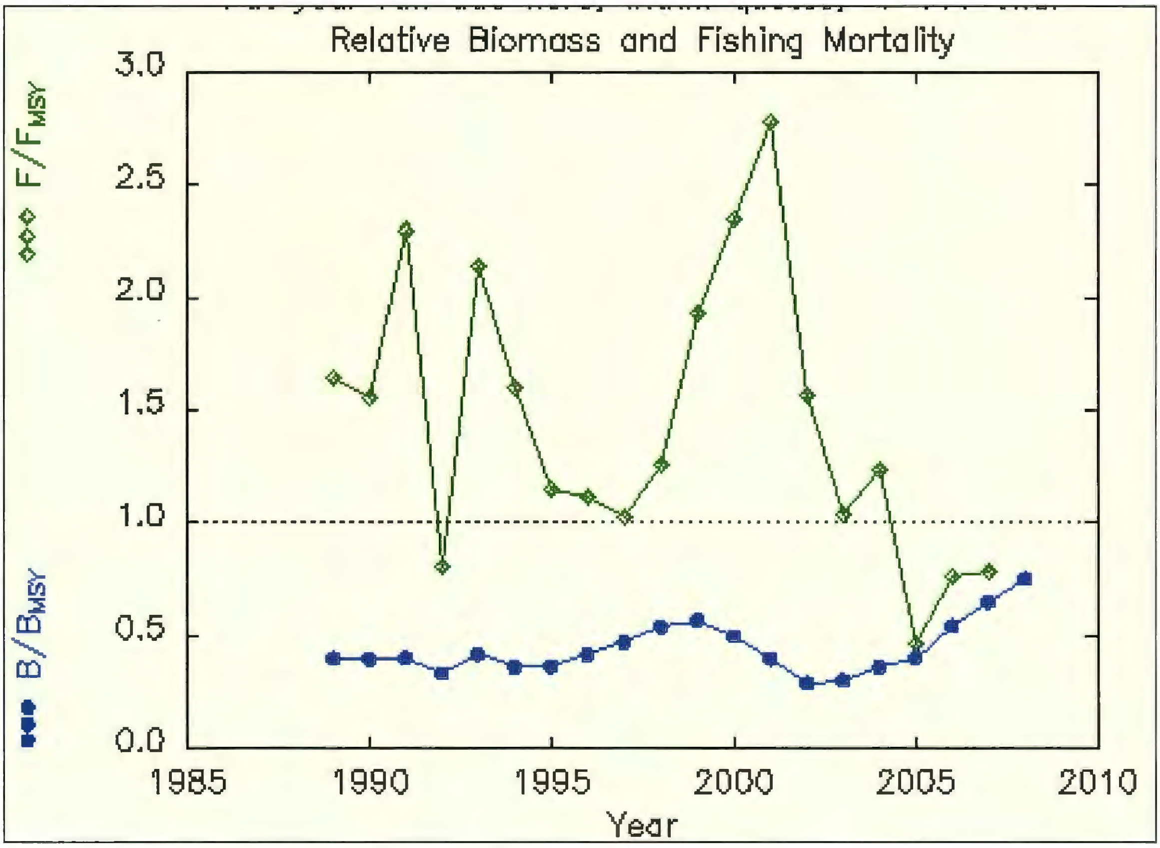
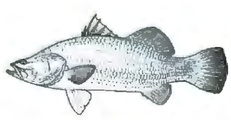


Figure 10. Relative biomass and fishing mortality with B_1/K fixed at 0.2—Table 4.



3.2.4 MNEC

Table 5. B_1/K fixed at 0.2.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.2 (fixed)	0%	0.2	0.2
MSY (tonnes)	177.8	-0.39%	156.8	352.5
K (tonnes)	5634	3.60%	2875	28760
q	0.000252	79.91%	0.000049	0.000495

Table 6. B_1/K fixed at 0.3.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.3 (fixed)	0%	0.3	0.3
MSY (tonnes)	140.9	8.96%	124.9	327.9
K (tonnes)	3503	40.22%	1938	22370
q	0.000264	34.76%	0.0000415	0.000472

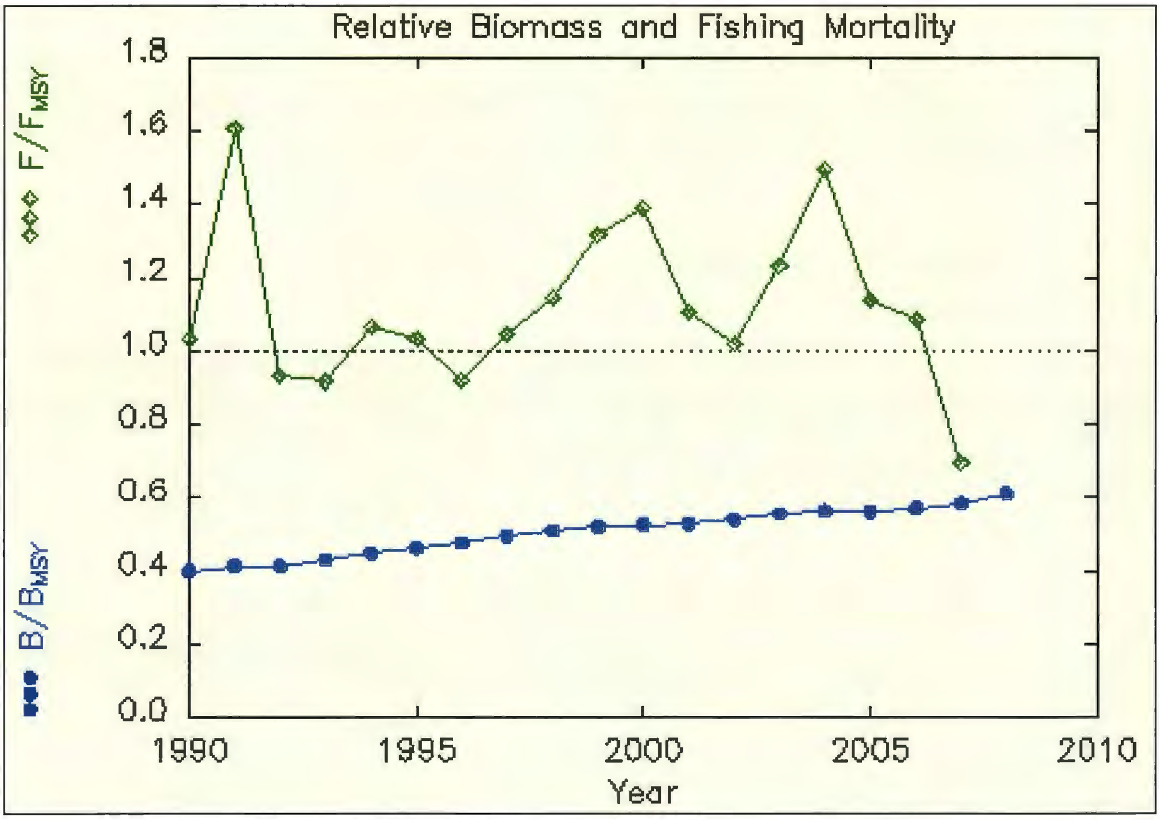
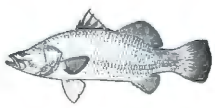


Figure 11. Relative biomass and fishing mortality with B_1/K fixed at 0.2—Table 5.



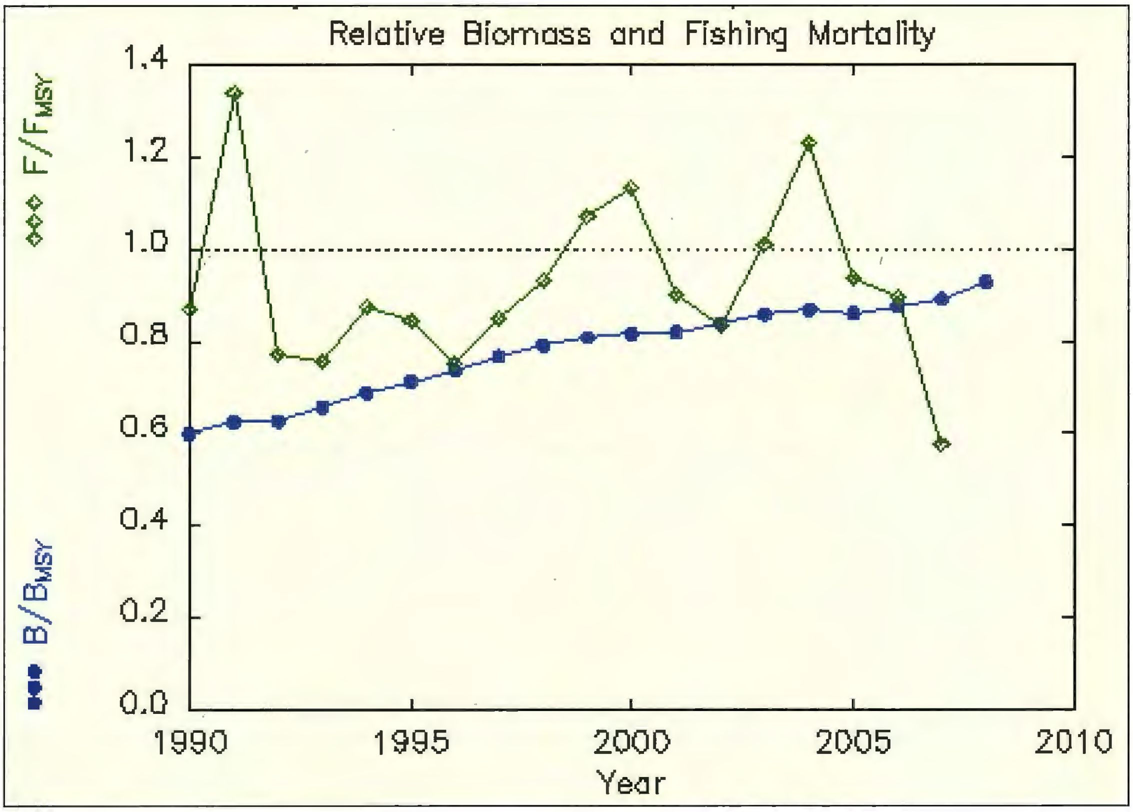


Figure 12. Relative biomass and fishing mortality with B_1/K fixed at 0.3—Table 6.

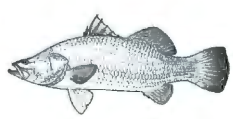
3.2.5 CEC and SEC (combined)

Table 7. B_1/K fixed at 0.2.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.2 (fixed)	0%	0.2	0.2
MSY (tonnes)	148.4	6.87%	128.8	213.5
K (tonnes)	3471	22.74%	2123	8305
q	0.000364	5.33%	0.000160	0.000577

Table 8. B_1/K fixed at 0.3.

	Point estimate	Estimated relative bias	Bias-corrected confidence limits	
			80% lower	80% upper
B_1/K	0.3 (fixed)	0%	0.3	0.3
MSY (tonnes)	158.8	10.67%	128.8	236.8
K (tonnes)	3784	22.53%	2249	7867
q	0.000216	3.79%	0.000110	0.000355



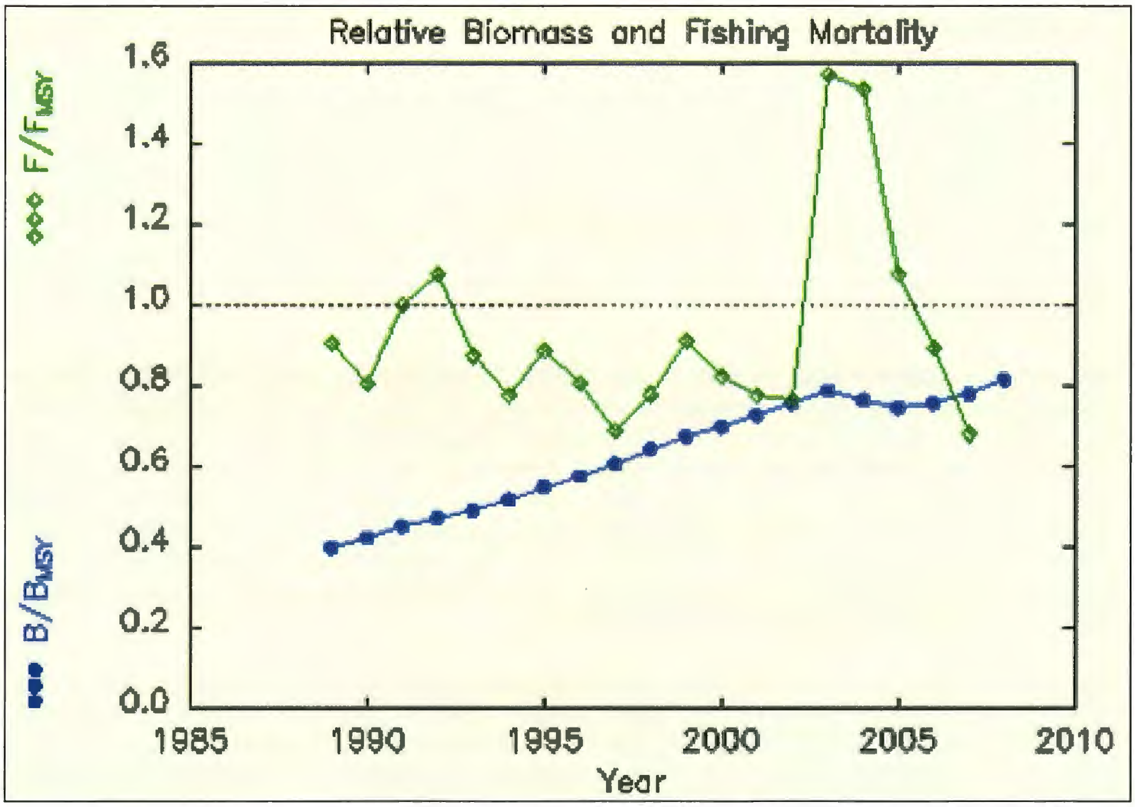


Figure 13. Relative biomass and fishing mortality with B_1/K fixed at 0.2—Table 7.

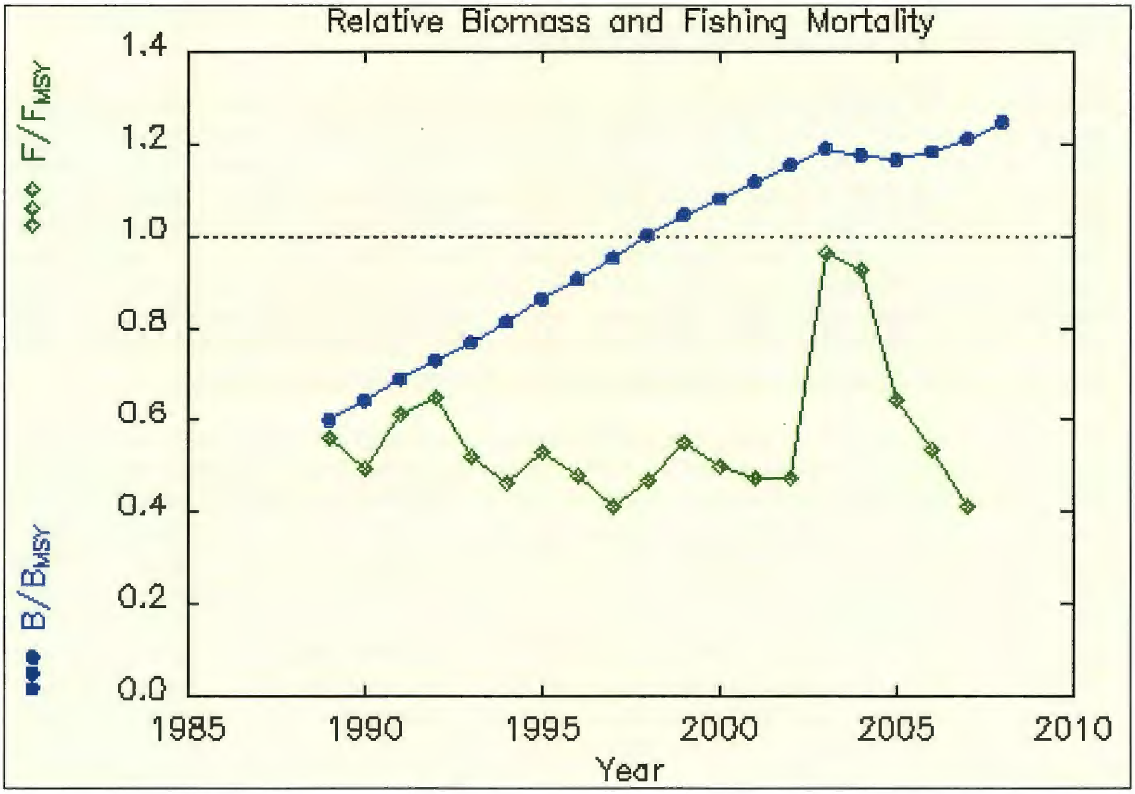
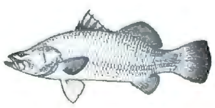


Figure 14. Relative biomass and fishing mortality with B_1/K fixed at 0.3—Table 8.



4 Discussion

Although the overall trend is one of rising CPUE for all regions, the surplus production models were difficult to fit unless the assumption was made that overall biomass is very low compared to unfished equilibrium (virgin) biomass. The only surplus production model run that was able to estimate all four of the parameters was in the ECCY region, where B_1/K was estimated to be 0.04 (Figure 9). This means that, according to the model fit, in 1989 the stock was down to 4% of its virgin biomass, and at only 8% of B_{MSY} (biomass giving maximum sustainable yield). If true, this would be an extremely unsatisfactory situation from an economical viewpoint, and (the increasing CPUE trend notwithstanding) disastrous from a biological perspective.

According to these model fits, either the fishery is dangerously overfished or the data are systematically an unfaithful representation of reality. However, the MSY and K arising from the ECCY fit—at 273.5 tonnes and 2213 tonnes respectively—are above the highest ever historical catch, and above what biological knowledge of the fishery would suggest (Ian Halliday pers. comm.). When combined with other concerns about the data already mentioned—the ECCY region catch rates are particularly in doubt—we prefer the latter conclusion (the data are unfaithful). This is *not* to say that the fishery is not overfished, just that we cannot ascertain its status from the current data sources and within the constraints imposed by the resources allocated to this project.

Another piece of evidence that points towards some systematic irregularity in the data (rather than dangerous overfishing) is the overall positive trend in CPUE. Although it is technically possible that CPUE will trend upwards over an 18-year period (or thereabouts) in a fishery at less than 1% of virgin biomass—and the surplus production model clearly is not incompatible with such a situation (as the results illustrate)—such a situation seems practically unlikely.

Aside from the difficulties encountered in fitting a surplus production model, the main reason for scepticism regarding data quality is the strong fluctuations in catch rates—in some cases indicating a more than twofold increase or decrease in abundance over the space of only a couple of years. As mentioned in Section 3.1, it is highly likely that regulatory changes have had an impact on the fidelity of the catch and effort data.

For example, Princess Charlotte Bay, the primary fishing area in the ECCY region, has been subject to a number of regulatory changes over the period of greatest catch rate fluctuation. These include (but are not limited to): Queensland Fisheries Regulations 1995; Dugong Protection Areas (1997); Great Barrier Reef Representative Areas Program (2004). The latter requires fishers to have a permit to fish in the Normanby River and banned fishing in the Bizant River, two rivers which flow into the bay (Darren Rose pers. comm.). Subsequent complementary arrangements would have been put in place by the Environmental Protection Agency and DPI&F (Mark Lightowler pers. comm.). Over this period the catch rate trend shows a high of 800 (units are kilograms per 'boat month', but are not important here) in 2000 to a low of less than 400 in 2004, and then back up to over 800 again in 2006.

It is not obvious how to attribute the particular catch rate patterns observed to the complex history of regulatory changes (such an enterprise would be an effort-intensive, but ultimately very worthwhile exercise). However, there are two phenomena that we can be confident are involved. Firstly, regulatory changes that tie future access conditions to a fisher's history of catch can result in over-reporting of catch in the period between the point when the fisher becomes aware of this change and the point at which it is actually implemented. Because effort is not necessarily over-reported in the same manner, catch rates will usually be skewed upwards. Secondly, remote regions (such as Princess Charlotte Bay) can respond in a more volatile fashion to regulatory changes because fishers might decide it is no longer worth the effort of travelling to the location, even if the regulatory change is minimal. In other words, the response to regulatory changes in remote regions can be highly non-continuous ('knife-edged').

Beyond regulatory change impacts, systematic changes in other un-modelled externalities (such as fuel prices and the price fishers are paid for their catch) will also have had a negative impact on the reliability of standardised catch rate as an index of abundance.

Turning to the issue of what can be done to rectify the data quality situation, it is clear that having some age composition information would be of great benefit. This would allow the use of more powerful age-based models. In particular it would allow the use of the sex, habitat and age-structured stock assessment model (SHASSAM)—a model developed by Hall et al. (2006) for Australian barramundi fisheries. Another detailed model is being developed to quantify the effect of river flow on barramundi growth rates and biology in the SEC region (E-water Barramundi project). Although some age composition data has been collected in a number of regions for some time, a LTMP is proposed to increase the comprehensiveness of this information source (DPI&F LTMP pers. comm.).

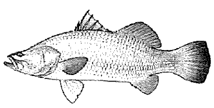
Another important component in understanding the barramundi fishery better is selectivity information—quantifying the tendency for particular sizes (and consequently ages and gender) of fish to be removed. Hyland (2007) has just completed a study on this issue that should be of great value for future assessments.

A previous report on the barramundi fishery in Queensland, (Welch et al. 2002) came to the conclusion that current (then up to 2002) effort levels were not a threat to the fishery. Given that much of the extreme fluctuation in catch rates has been in the years since that report was published, there are three main possible interpretations:

1. The data has been more inconsistent since 2002, and it is this later data that has caused difficulties in fitting the surplus production models, and hence the Welch et al. (2002) statement (effort levels in 2002 were not dangerous) may be valid.
2. The data has been unreliable for the whole of the time series, in which case the Welch et al. statement must be treated with some scepticism.
3. The data are more-or-less a faithful representation of reality, in which case the fishery is dangerously overfished. Given that CPUE has not been severely decreasing since 2002, the Welch et al. (2002) statement must then be considered inaccurate.

To reiterate, our preferred conclusion is for the data being unreliable (i.e. not interpretation three), and it is quite possible that some combination of interpretation one and two is most accurate.

In conclusion, the importance of readdressing the state of the barramundi fishery in Queensland—once better age and selectivity data becomes available, and the fidelity of the catch and effort data can be verified—cannot be over-emphasised.



References

Department of Primary Industries and Fisheries 2005, *Fisheries long term monitoring program Sampling protocol – barramundi: (2000–2005) section 1*, Department of Primary Industries and Fisheries, Queensland, Information series QI05117, Brisbane, Australia.

Gribble, N, Welch, D, Garrett, R, Higgs, J & Whybird, O 2005, *Draft 1981–2004 assessment of the barramundi fishery in Queensland*.

Hall, NG, de Lestang, P, Buckworth, RC, Hearnden, MN, Gribble, NA, Newman, SJ, Garrett, RN, Halliday, IA, Officer, RA, Wise, BS, Walters CJ & Griffin, RK 2006, *Development of a sex, habitat, and age-structured stock assessment model for Australian barramundi fisheries*, National Barramundi Assessment Working Group, 27 February – 3 March 2006, Western Australian Fisheries and Marine Research Laboratories, Hillary's Boat Harbour, Perth, Australia.

Haddon, M 2001, *Modelling and quantitative methods in fisheries*, Chapman & Hall, Boca Raton.

Higgs, J 1999, *Recreational catch estimates for Queensland residents*, RFISH Technical report no. 3, Department of Primary Industries, Queensland.

Hilborn, R & Walters, CJ 1992, *Quantitative fisheries stock assessment: choice, dynamics and uncertainty*, Chapman & Hall, London.

Hyland, SJ 2007, *Mesh selectivity for barramundi*, DPI&F Project report, DPI&F Northern Fisheries Centre, Cairns.

Myers, RA, Bowen, KG & Barrowman, NJ 1999, 'Maximum reproductive rate of fish at low population sizes', *Canadian Journal of Fisheries and Aquatic Science*, no. 56, pp. 2404–19.

Prager, MH 1994, 'A suite of extensions to a nonequilibrium surplus-production model', *Fishery Bulletin*, no. 92, pp. 374–89.

Prager, MH 2004, *User's manual for aspic: a stock-production model incorporating covariates (ver. 5) and auxiliary programs*, National Marine Fisheries Service, Beaufort Laboratory document BL–2004001.

Quinn, TJ & Deriso RB 1999, *Quantitative fish dynamics*, Oxford University Press, New York.

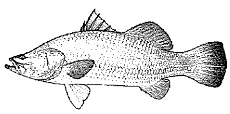
Ricker, WE 1975, *Computation and interpretation of biological statistics of fish populations*, Fisheries Research Board of Canada, Bulletin no. 191.

Schaefer, MB 1954, 'Some aspects of the dynamics of populations important to the management of the commercial marine fisheries', *Bulletin of the Inter-American Tropical Tuna Commission*, no. 1, pp. 25–6.

Schaefer, MB 1957, 'A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean', *Bulletin of the Inter-American Tropical Tuna Commission*, no. 2, 247–68.

Shaklee, JB, Salini, J & Garrett, RN 1993, 'Electrophoretic characterization of multiple genetic stocks of barramundi perch in Queensland, Australia', *Transactions of the American Fisheries Society*, no. 122, pp. 685–701.

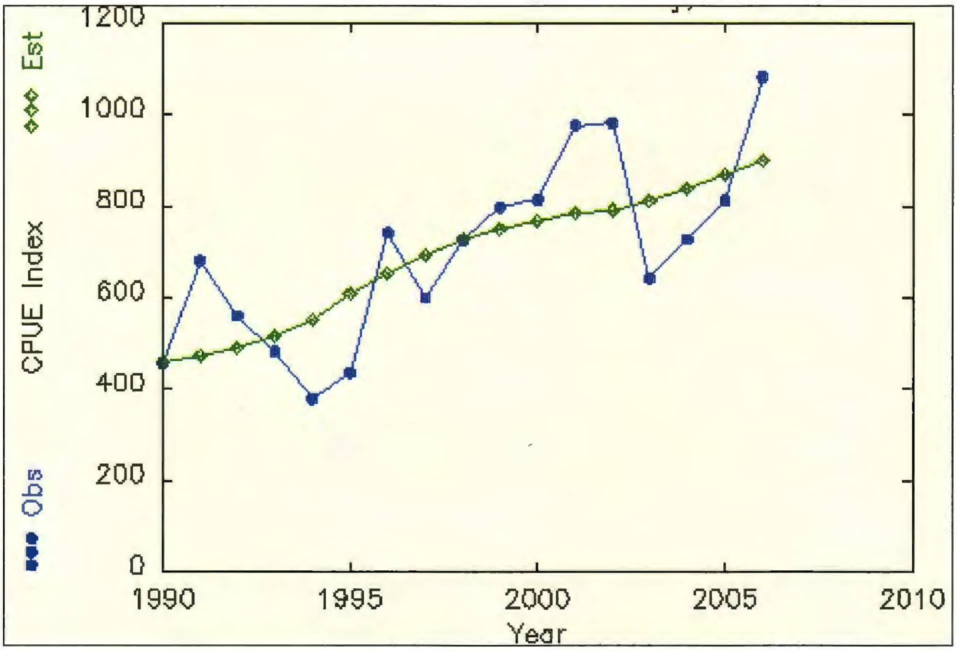
Welch, D, Gribble, N & Garrett, R 2002, *Assessment of the barramundi fishery in Queensland – 2002*, Department of Primary Industries and Fisheries, Queensland, QI02116.



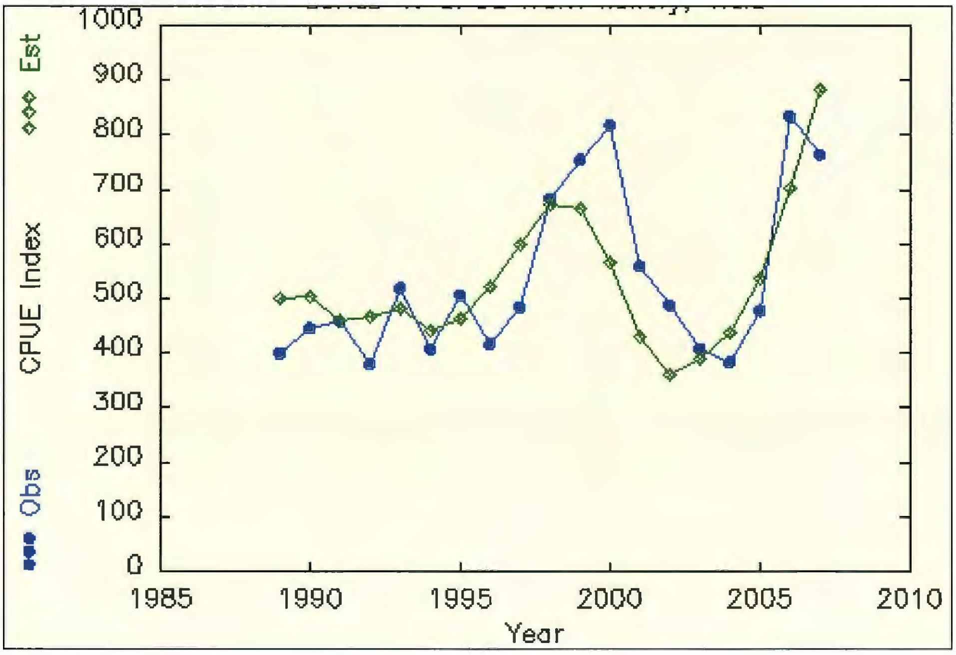
Appendix – Goodness of fit plots

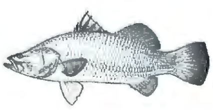
The following plots show the goodness of fit for the surplus production models.

EG – B_1/K fixed at 0.2

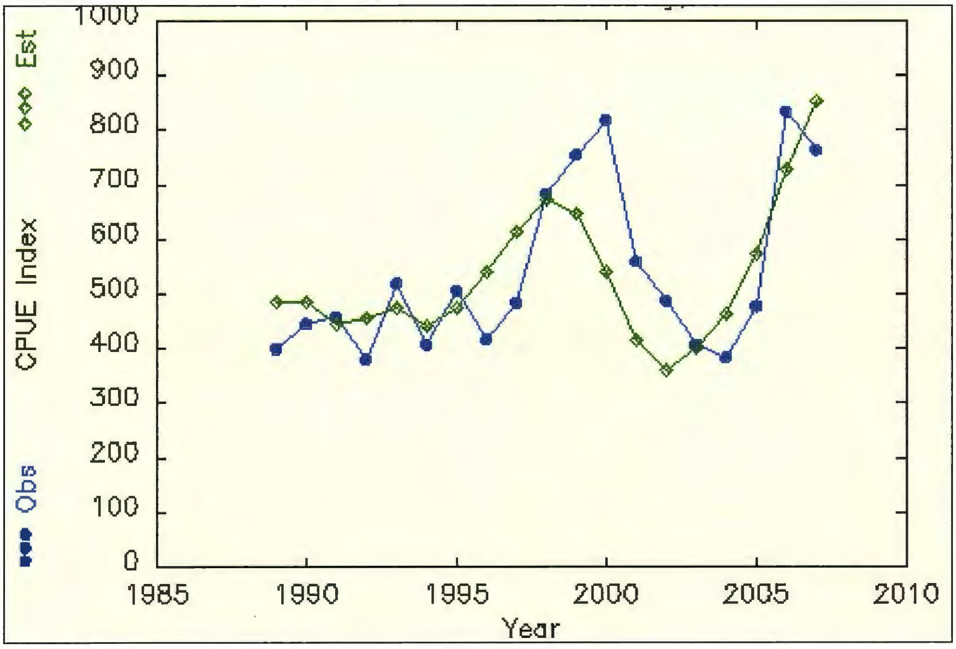


ECCY – B_1/K floating (estimated to be 0.04)

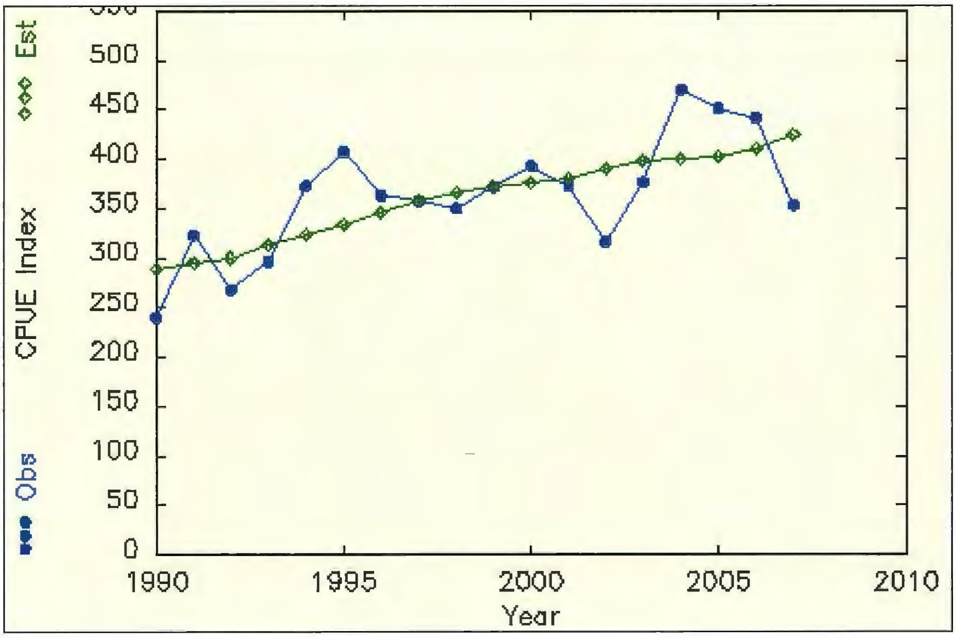


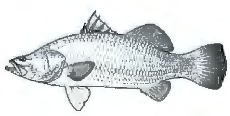


ECCY – B_1/K fixed at 0.2

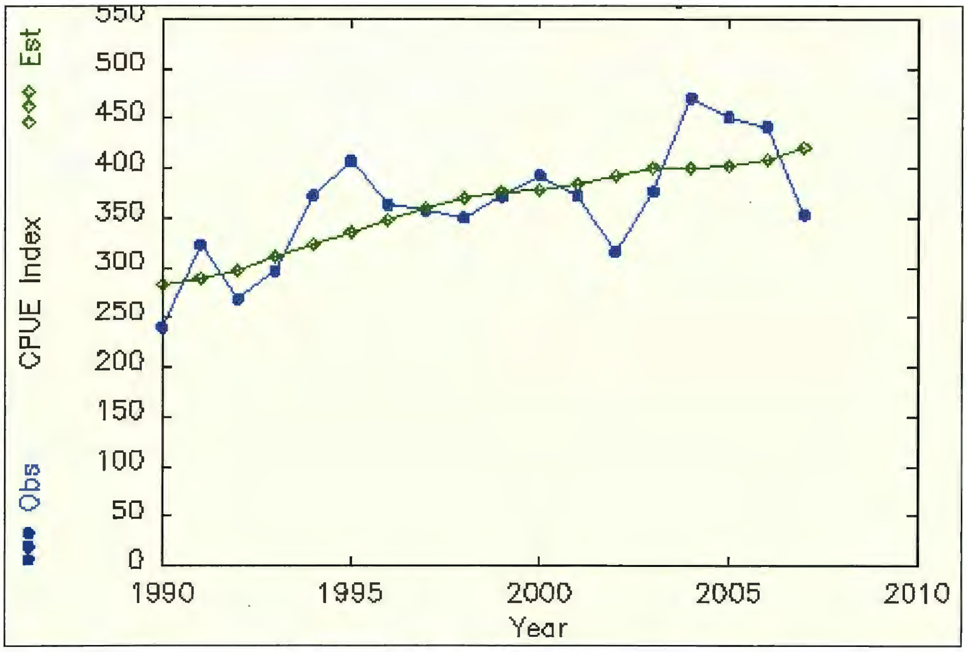


MNEC – B_1/K fixed at 0.2





MNEC – B_1/K fixed at 0.3



CEC and SEC – B_1/K fixed at 0.2