MODELLING THE NORTHERN TERRITORY BARRAMUNDI FISHERY - 1978-1992

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Abstract

Catch and effort data for the Northern Territory commercial barramundi fishery have been collected since 1972. In 1978 and 1979 surplus production models suggested that the stock was being overexploited. That analysis formed the basis of a major review of management. The illustrative power of the Schaefer curve was probably a significant factor in implementing major reductions in the commercial fishery.

In 1987 Fox's Generalised Exploited Population Simulator (GXPOPS) was used with inputs of biological parameters. This model enabled assessment of various management strategies. Further reductions in the commercial and recreational sectors of the fishery in the heavily exploited Mary River were recommended.

More recently emphasis has shifted from optimising yield as management has largely focussed on reallocation of the resource.

Recent research has identified significant effects of rainfall on recruitment, and current efforts are aimed at developing realistic biomass dynamic models which can simulate these effects.

Introduction

The barramundi (*Lates calcarifer)* is a large centropomid perch which is widely distributed throughout the Indo-West Pacific. The species has a complex biology being both catadromous and protandrous (Davis 1982; Moore 1982; Moore and Reynolds 1982; Griffin 1987). It occupies diverse habitats including freshwater and estuarine sections of rivers and coastal waters. Larger, mature barramundi are found in estuarine and coastal waters while immature fish are found mainly (but not exclusively) in upper fresh water reaches of rivers (Griffin 1987).

In the Northern Territory, barramundi is an important commercial fishery target and is also a sought after game fish. The species is fished commercially with gill nets in inshore waters and in some river mouths (NT Barramundi Fishery Management Plan). The gill nets used range from 152 mm (6 inch) to 203 mm (8 inch) mesh and the majority of the catch consists of fish of 3 to 7 years of age.

Commercial exploitation has been undertaken since the 1950s but did not reach significant proportions until the 1970s. Reliable commercial catch and effort data have been collected since 1972. Some information on recreational fishery catches is available for the period 1978-1992 but only for limited areas (Griffin 1982; 1988; 1993).

Since 1979 the fishery has been intensively managed, mainly by input controls on the commercial sector. This paper describes the history and management of the fishery with emphasis on the population models used to describe or illustrate the status of the stocks.

History of the Barramundi Fishery

Prior to 1970, fishery management in the Northern Territory could be described as generally *ad hoc* in nature and there were no research programmes in place. There was basically only one category of commercial licence which entitled a licensee to take and sell virtually any fish. All licensees were required to submit a monthly return detailing catch, effort and areas fished. From 1972 that database was subject to closer scrutiny and checking and is believed to be reasonably reliable from that time. Prior to the development of the Northern Prawn Fishery, barramundi was the primary target of most commercial fishermen in the NT. There was a rapid expansion of effort targeting barramundi in the 1970s with catch also rising dramatically (Table 1). The highest annual harvest, just over 1000 tonnes, was taken in 1977. The peak of effort occurred two years later in 1979. Following what is unfortunately the usual trend in developing fisheries by 1977 the catch per unit effort (CPUE) had declined to around of 50% of that achieved in the early development of the fishery. As a consequence many of the large number of operators who had entered the fishery and had substantial capital investment encountered financial difficulties. Concern was expressed that the barramundi resource was being overexploited. A major review of the fishery was conducted during 1978 and 1979 (Grey and Griffin 1979). Following that review effort limitations were placed on the commercial fishery.

At the same time a major biological research project was commenced as a joint effort between CSIRO, NT and Queensland.

Further commercial effort reductions were implemented in the 1980s mainly by reduction of the number of licences. This was achieved by a government/industry funded licence buy-back scheme. The number of licences was reduced from 108 in 1979 to 28 in 1991. As effort has been reduced the downward trend in CPUE has been reversed but the catch rate has not yet returned to the levels of the early 1970s.

Initial management of the fishery focussed on the commercial sector, with the impact of the recreational sector assumed to be relatively unimportant. Commercial management was aimed at maximising the sustainable yield.

In the late 1970s as the population of the NT grew rapidly it became clear that the impact of recreational fishing for barramundi was not insignificant particularly in readily accessible areas close to population centres where the recreational catch was estimated to be as much as 30% of the total harvest (Griffin 1982; 1988). As a consequence there were output limitations placed on the anglers in the form of bag limits.

From the mid-1980s the economic and social value of recreational fishing in the NT was acknowledged and as a consequence the focus of management shifted from maximising the commercial yield to optimising the benefits of the recreational sector. In many cases this took the form of reallocation of the resource to the recreational sector as popular recreational fishing river systems were closed to commercial fishing. From 1988 a recreational minimum size was implemented and the possession limit in the heavily exploited Mary River was reduced to 2 fish.

In recent years the fishery has remained fairly stable in terms of commercial yield (400-600 t per annum) and the process of resource allocation is largely complete. The economic performance of the commercial fishery is much improved with licences valued at $100,000-$150,000.

Stock Assessment Models Used or Investigated

Surplus Production Models

The simple Schaefer surplus production model (Schaefer 1954) was used to assess the status of the fishery in the course of the 1978/79 review (Grey and Griffin 1979). Only six years of data were available but a reasonable fit was obtained which graphically illustrated that the fishery was indeed overexploited (Figure 1). Maximum sustainable yield (MSY) was estimated to be around 1000 t at an effort level of about 70,000 hmd (hundred metre net days). As years of data were added the MSY estimate was reduced. The plot of catch versus effort showed a typical spiral back pattern (Figure 2). In the early 1980s Fox's modification of the surplus production model (Fox 1970) was fitted, giving basically similar results. It was recognised early on that the surplus production model was flawed, clearly violating several of the assumptions required, primarily that of equilibrium and single unit stock. The model was applied to individual river systems. In discussions with fishers the fact that the current effort level was far to the right of the optimum peak of the curve was a useful illustrator of the situation. At that time there were insufficient data available for any other kind of model.

Yield Per Recruit Type Models

From 1978 the amount of knowledge of barramundi biology available increased rapidly as a result of extensive studies in Australia and Papua New Guinea (Davis 1982; Moore 1982; Moore and Reynolds 1982; Reynolds and Moore 1982; Davis and Kirkwood 1984; Davis 1986; Griffin 1987). Acquisition of this knowledge allowed for more sophisticated and realistic assessment of barramundi stocks.

Yield per recruit models of the barramundi population were extensively explored by Dr John Glaister during a period of collaborative work with Professor W. Fox and associates at the University of Miami. This collaborative work led to a visit to Australia by Professor Fox during which Fox's Generalised Exploited Population Simulator, GXPOPS (Fox 1973) was used to assess the status of the barramundi population and to simulate the likely impact of a range of management alternatives. This model was initially derived for a protandrous pandalid shrimp and consequently was readily applicable to barramundi. Input of data on growth, mortality, fecundity and recruitment at "conservative", "average" and "liberal" ranges was subject to a simulated exploitation regime over a 15 year period. The principal output was the spawning biomass remaining, with 20% of the virgin level being considered a critical level below which the population should not fall. Modelling of a "typical" barramundi fishery using best estimates available as input parameters suggested that the remaining spawning biomass was well below a "safe" level. This demonstration of modelling, presented to a gathering of fishers, was instrumental in achieving agreement for a number of further restrictions on both the commercial and recreational sectors in 1988-89.

Walters and Hilborn Modelling

In the course of several training workshops conducted by Dr Ray Hilborn and Dr Carl Walters in Australia in the 1980s the barramundi fishery data provided a useful example for several of the models presented. The first of these was the DEPLETE model (Hilborn and Walters 1992). This model is basically an extension of the Leslie and Delury type depletion estimators for closed populations with systems for accounting for growth and recruitment. Data required are basically a time series of catch and effort data and information on growth and size at recruitment. A good fit has been obtained using data for the Daly River and for the Mary River. When the data were first fitted using this model there were only 14 years available and the trend of CPUE was downward. Addition of the later years of data with a rising trend in CPUE still results in good fits and reasonable parameter estimates. When a fit has been obtained the model allows for simulation of possible future scenarios with a graphical output. Only minimal testing of this model and validation of parameter estimates has been conducted. A preliminary model was used to simulate behaviour of the Mary River population under various levels of exploitation.

The next step in modelling of barramundi under the influence of Walters and Hilborn was using the Schnute/Deriso delay difference models (Deriso 1980; Schnute 1985; 1987; Hilborn and Walters 1992). This was achieved using the GENEST program package (Walters 1987). Again good fits to the data for Daly River were obtained with apparently reasonable parameter estimates. As with the DEPLETE model some apparently good fits were obtained with parameters which are quite unrealistic, sometimes ridiculously so. Obviously models of this type will need to be thoroughly tested and evaluated before they can be confidently used for stock assessment or simulation. Such testing and development is currently being undertaken. Developments of the delay-difference model along lines suggested by Norm Hall of WA Fisheries are being investigated.

Biological and Fishery Peculiarities and Problems with Modelling

It has been shown (Russell and Garrett 1983; Davis 1985; Griffin 1987) that temporary supralittoral swamp habitat is critical to survival of very early juvenile barramundi. Recent research in the NT (Griffin, unpublished data) has shown that recruitment of barramundi is extremely variable and appears to be strongly influenced by the amount of early wet season rainfall. Any models developed for barramundi will therefore only be realistic if recruitment components are able to account for this variability. Any model which assumes constant recruitment or a simple relationship between stock and recruitment could be very misleading.

The fact that the fishery has significant commercial and recreational sectors using different gears and with changing relativities between the two has been a major difficulty with modelling of the fishery. Useful time series data are only available for the commercial sector.

There have been changes in the fishery over the past 20 years (changes in areas available, changes in fishing strategies, changes in operator efficiency) which may have had an influence on the relationship between CPUE and actual stock abundance. These factors must be considered.

The fact that the species is protandrous has been a problem in applying some models which rely on an even sex ratio and renders the biological/philosophical basis of some common management measures inappropriate.

Genetic studies of barramundi (Shaklee and Salini 1985; Salini and Shaklee 1988) have shown that there are several genetically distinct stocks of barramundi in northern Australia. In the NT there appears to be a separate stock associated with each major river system. This information indicates that any barramundi population models should be applied to individual river systems rather than to the general population.

Summary and Conclusion

The Northern Territory barramundi fishery is now tightly managed with a profitable commercial sector and a recreational sector which enjoys a high level of fishing quality. Stock assessment modelling of this biologically and operationally complex fishery has been largely based on the time series of catch and effort data dating from 1972. The initial surplus production model in 1978 indicated that the stock was overexploited and was used to set and adjust levels of sustainable catch and effort for the commercial fishery. As more and more biological and ecological knowledge has become available more complex modelling strategies have been employed. Because of the complexities none has yet been used to set firm management objectives. A major problem with all models has been the lack of stability in the fishery and the high degree of variability of recruitment which is independent of the fishery. Further development of delay-difference models with an emphasis on realistic modelling of recruitment variability is recommended.

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Table 1 . Catch, effort, catch per unit effort (CPUE) and number of licensed operators in the Northern Territory barramundi fishery, 1972-1992.

Effort is recorded in hundred metre net days (hmd). Effort for 1976 is not available.

Year	Catch (tonnes)	Effort (hmd x 1000)	CPUE (kg/hmd)	No. Operators
1972	382	17	22.1	
1973	431	21	20.5	
1974	656	23	28.8	
1975	432	16	27.5	
1976	974			
1977	1054	72	14.6	
1978	820	96	8.6	
1979	745	101	7.4	108
1980	532	71	7.4	107
1981	764	67	11.4	99
1982	856	95	9.0	81
1983	607	86	7.1	71
1984	632	71	8.9	49
1985	593	66	9.0	47
1986	534	45	11.9	41
1987	505	41	12.2	40
1988	508	35	14.6	36
1989	594	31	19.0	31
1990	456	31	14.7	29
1991	435	30	14.5	28
1992	389	31	12.6	28

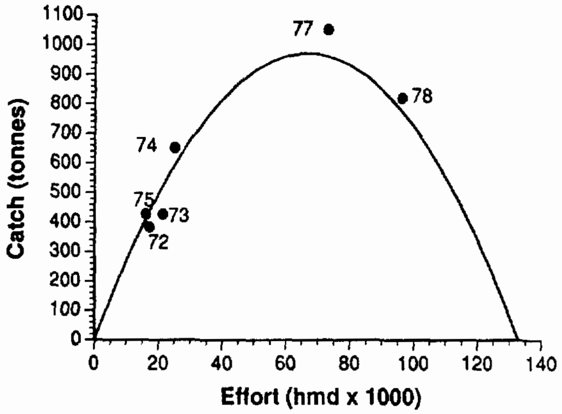

Figure 1. Schaefer surplus production model based on catch and effort data for the Northern Territory barramundi fishery from 1972-1978 (effort for 1976 not avaliable).

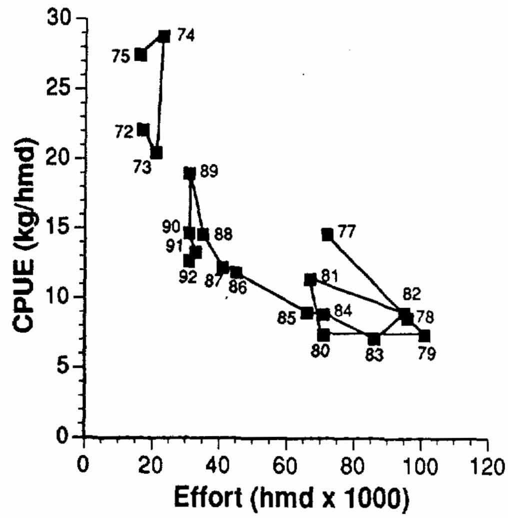

Figure 2. Relationship between catch per unit effort (CPUE) in kilograms per hundred metre net day (hmd) and effort in hundred metre net days, 1972-1992.