Australian Government
Australian Centre for International Agricultural Research

Final report

project	**Economic performance and management of the Gulf of Papua prawn fishery**
project number	ASEM/2002/050
date published	June 2009
prepared by	Associate Professor Tom Kompas Australian National University, Crawford School of Economics and Government
co-authors/ contributors/ collaborators	Ronald Kuk National Fisheries Authority, Papua New Guinea
approved by	Dr Caroline Lemerle
final report number	FR2009-19
ISBN	978 1 921531 99 6
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

This publication is published by ACIAR ABN 34 864 955 427. Care is taken to ensure the accuracy of the information contained in this publication. However ACIAR cannot accept responsibility for the accuracy or completeness of the information or opinions contained in the publication. You should make your own enquiries before making decisions concerning your interests.

© Commonwealth of Australia 2009 - This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the Commonwealth. Requests and inquiries concerning reproduction and rights should be addressed to the Commonwealth Copyright Administration, Attorney-General's Department, Robert Garran Offices, National Circuit, Barton ACT 2600 or posted at http://www.ag.gov.au/cca.

Contents

1 Executive summary 4

2 Objectives 6

3 Impacts 7

3.1 Community impacts – now and in 5 years 7

3.2 Communication and dissemination activities 7

3.3 Training and capacity building 7

3.4 Analytical method 8

4 Specific results and discussion 12

5 Relationship to other activities 15

6 Future project plans to build on project outputs / outcomes 16

1 Executive summary

The management of limited access fisheries is a difficult challenge. In most cases the harvesting capacity of the fishing fleet exceeds the biological capacity of the resource to regenerate, threatening the viability of the natural resource itself. As a result some type of control with the aim of reducing catch or harvesting capacity is necessary. Ideally, management of the fishery should both enhance economic performance and guarantee the biological and economic sustainability of fish stocks for generations to come. The key target for the economic management of the fishery is Maximum Economic Yield (MEY), or a catch or effort level that maximizes the discounted value of total revenue minus the total costs of fishing. Economic efficiency also requires that vessel and fleet capacity minimizes the cost of harvest at this MEY catch rate.

The National Fisheries Authority (NFA) has the task of managing all fisheries in Papua New Guinea, including the Gulf of Papua Prawn Fishery (GPPF). The GPPF currently catches between 400 and 650 tonnes of banana prawns and 160 tonnes of Black tiger prawns each year, worth roughly K 15M. There are 15 vessels in the fishery, with average landings that range between 25 and 70 tonnes. Formal assessment of the economic and biological status of the fishery has been hampered by poor quality logbook and financial data and a lack of an adequate time series of catches and catch rates in order to undertake a stock assessment or construct a bioeconomic model. Recent rises in fuel prices and catch rates have threatened the economic viability of the fishery.

This project worked in tandem with a biological stock assessment project (FIS/2002/056) to compile extensive paper logbook records in order to estimate the biological and economic yield of the resource. The main component of the economic research has to combine the stock assessment analysis with a stochastic bioeconomic model to determine optimal catch and profit levels at MEY for the fishery. The stock assessment generated a standard surplus-production model, and a survey of fishing vessels provided the required information on the price of prawns by species and grade and the cost of fishing. Extensive data was complied on both variable and fixed costs from fishing, including capital components, crew and skipper costs, repairs and maintenance and fuel. The bioeconomic model found that the recent catches of about 450 tonnes were biologically but not economically sustainable (especially with current fleet size), and that the fishery should target a catch of 580 tonnes of banana prawns per year to maximise profits. Given these catch rates, the project also found that the number of fishing licences should be reduced to roughly10, improving the returns each operator and matching fleet capacity to the amount of annual catch. Economic data collection and analysis revealed that a substantial portion of variable costs accrued to repairs and maintenance. Much of the GPPF fleet is composed of vessels in excess of 20 years, purchased from operators in the Northern Prawn Fishery (NPF) of Australia. Current vessel capital and catch rates were not sufficient to allow for adequate upgrade and repairs of vessels. The MEY target of 580 tonnes and a fleet of 10 boats will generate sufficient revenues at current prices to address this problem, and allow for cost recovery management of the fishery.

The measure of MEY changes periodically, given changes in the price of fish and the cost of fishing. This project equipped and trained economists at NFA to conduct suitable bioeconomic analyses to determine dynamic MEY levels in the future, so that the target value of catch can be adjusted with proper economic management of the fishery. Current management directives indicate that MEY will be recalculated annually. This process is facilitated by the ongoing collection of economic data as a planned part of licence requirements to fish in the GPPF. One of the consequences of the extensive data collection during the project has been to improve the level of interaction and trust between the fishing companies and the NFA. The combined projects recommended that these improved relations be made ongoing by appointing an industry liaison officer to facilitate collection of vessel logbooks and company landings, along with financial and economic

data. The liaison officer will also provide data summaries to each company that will enable them to better track the status of the prawn resource.

As part of the overall management of the fishery, a key recommendation of this project is to allow an extension of fishing licences from the current one-year renewable to a five-year renewable system. This would provide operators with more security (and a potential for accessing loans based on this right), and further secure effective property rights to fish. It was also recommended that these licences be tradeable so that the right to fish can be effectively transferred from high to low marginal cost fishers. This transfer enhances efficiency in the fishery and lowers the overall cost of fishing.

A final component of the project was to assess the potential for an independent fishery inshore of the 3nm closure by small vessels operated by the local community. VMS and logbook data showed that about a third of the total prawn catch in the GPPF was coming from within the 3nm closure zone, despite trawling in this zone being prohibited. This illegal accessing of the inshore waters has been a

source of great tension between the fishing industry and traditional resource owners in the Gulf of Papua. The biology project found that this illegal fishing into the 3nm zone did not appear to substantially impact the sustainability of the prawn resource. However, from an economic perspective, catch rates within the 3nm zone were over 30% higher than on the adjacent fishing grounds, and thus, for the most part, the economic viability of the fishery depends on operators in the industrial fishery being able to access the inshore waters with higher prawn densities. With this in mind, the project recommended that fishing operators be allowed to access the zone up to 2 nm from the coast during the second half of the year (or from July to November). The project also recommended that individual operators enter into an access agreement with the traditional resource owners before they can fish within the 3nm limit. This resource sharing will enable some of the economic benefits gained by the industrial fishery to be returned to the community and thus reduce the tension between both parties.

2 Objectives

- To document the financial, biological and economic characteristics of the Gulf of Papua prawn fishery.
- To conduct a bioeconomic analysis to assess the economic performance of the fishery and to determine the optimal level of effort and catch to maximize sustainable fishery returns and promote efficiency, thus improving the well-being of the people of PNG through the proper management of its natural resources.
- To quantify and assess various management regimes for the control of the fishery, including devices for an efficient cost recovery management program.
- To assess the impact of a possible small boat (inshore) fishery on the fishery as a whole.
- To build research capacity for continued economic research and management of fisheries in PNG.

3 Impacts

3.1 Community impacts – now and in 5 years

Pursing an MEY economic target helps assure economic profitability for the GPPF fishery. The NFA is now committed to this target. To do so, they have established two essential changes in infrastructure: (1) biological and logbook data is now systematically collected, and concerns over data collection and processing have been corrected; (2) economic data is now collected and processed annually, or whenever changes in the MEY target are needed. Combined, the NFA now has the capacity to manage the GPPF based on both sound economic and biological targets. There should be considerable gains in profitability of the fishery and a clear potential for cost-recovery management as a result.

Industry has long been frustrated by the tenuous right to fish provided by annual leases. Extending fishing permits to 5 year leases and allowing tradability of these rights establishes and effective property right to fish in the GPPF. The project has also fostered increased interaction between fishing companies and the NFA, and thus encouraging greater involvement of the fishers in the management of their fishery. The companies are optimistic that changes to NFA management following this project's recommendations will improve their financial viability substantially.

Finally, the NFA will introduce provisions for fishing companies to enter voluntary access agreements with traditional owners of the resource to enable the company to fish within the more productive 3nm exclusion zone. This should enable the resource owners to receive compensation for the harvesting of their resources without necessarily incurring a large expenditure in vessel purchase and direct fishing activity.

3.2 Communication and dissemination activities

The project undertook regular communication events. Three quarterly industry meetings were held to report on project progress each year, with additional annual meetings with industry to document and determine the economic status of the fishery. Stakeholder consultation was accomplished through direct meetings with industry and industry representatives, primarily in conjunction with the process of economic data collection. Provincial government and community stakeholder consultation was conducted annually through trips around the Gulf of Papua, visiting provincial staff in Kerema and villages adjacent to the fishing grounds. During these trips, public meetings were also held to talk about local concerns and provide information from the project to each group. As well, the senior provincial fisheries officer participated in all project meetings, gathered the results of the project and provided with summaries to each provincial government.

The following scientific publications are planned to be completed from the project:

- T. Kompas and R. Kuk, "Maximum economic yield in the Gulf of Papua prawn fishery," submitted to Marine Resource Economics.
- T. Kompas and R. Kuk, "The challenges of managing a fishery resource in a developing country context: the right target and the right instruments," submitted to The Pacific Economic Bulletin.

3.3 Training and capacity building

There have been no formal external training activities since the last annual report. Each year during this project extensive training in bioeconomic modelling was provided to NFA staff.

3.4 Analytical method

In terms of management objectives and fisheries policy, the major achievement of this project was to construct a bioeconomic model of the GPPF, establishing an MEY target. Concentrating on sustainable yields alone, MEY and economic efficiency occurs when the sustainable catch or effort level for the fishery as a whole creates the largest difference between total revenues and the total costs of fishing. For profits to be maximized it must also be the case that the fishery applies a level of boat capital and other resources in combinations that minimize the costs of harvest at the MEY catch level. The fishery, in other words, cannot be over-capitalized and vessels must use the right combinations of such inputs as gear, engine power, fuel, hull size, and crew to minimize the cost of a given harvest.

There are several things to note about MEY at the outset. First, for most practical discount rates and costs, MEY will imply that the equilibrium stock of fish is larger than that associated with Maximum Sustainable Yield (MSY). In this sense the economic objective of MEY is more 'conservationist' than MSY and should in principle help protect the fishery from unforseen or negative stochastic environmental shocks that may diminish the fish population. Second, the catch and effort levels associated with MEY will vary, as will profits, with a change in the price of fish or the cost of fishing. This is as it should be. If the price of fish increases it pays to exploit the fishery more intensively, albeit at yields still less than MSY. If the cost of fishing rises, it is preferable to have larger stocks of fish and thus less effort and catch. Finally, as long as the cost of fishing increases with days fished, as it generally will, MEY as a target will always be preferred to MSY and of course to any catch or effort level that corresponds to stocks that are smaller than those associated with MSY. The reason is simple. Regardless of what happens to prices and costs, targeting catch and effort at MEY will always ensure that profits are maximized. Profits may be relatively low when the price of fish is low and the cost of fishing is high, but profits will still be maximized. With a biological target of MSY alone, however, it is quite possible that profits will be very small or even zero. The fishery would thus be sustainable at MSY but not commercial, much less efficient.

The following figure (Figure 1) captures the 'static' representation of MEY, measured in terms of effort and dollars earned.

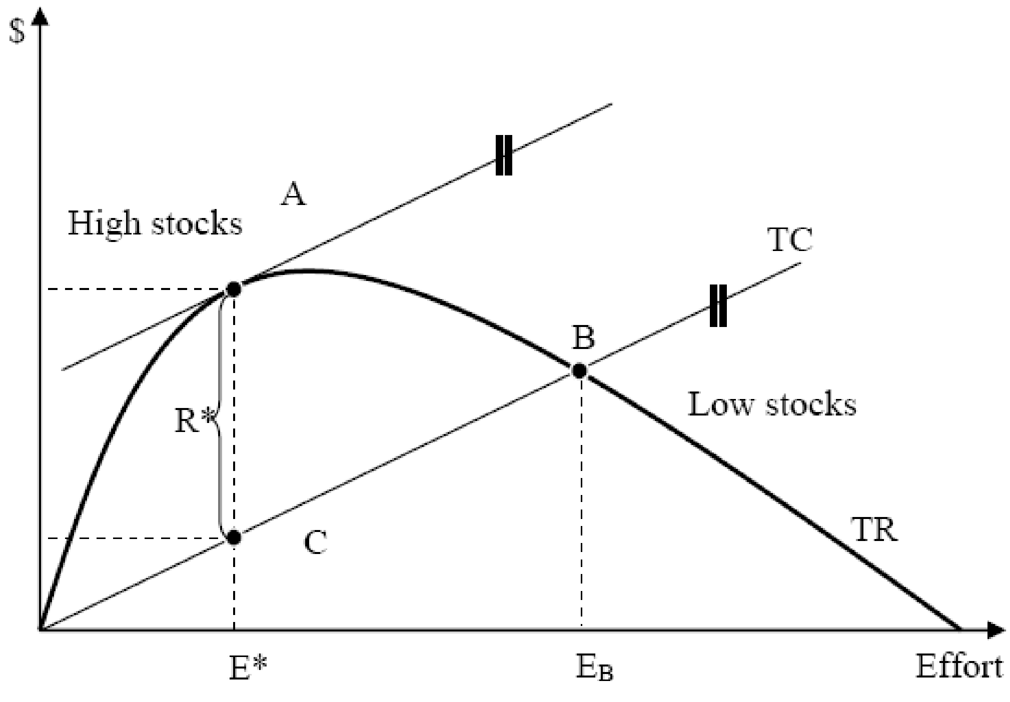

Figure 1: Illustrating MEY

(Futher detail is contained in R. Q. Grafton, J. Kirkley, T. Kompas and D. Squires, Economics for Fisheries Management, London: Asgate, 2006.) The solid 'inverted' U-shaped line represents the stock-recruitment relationship in tems of effort and yield. At high effort levels, stocks of prawns are low. At low effort levels, stocks are large. This relatinship is determined in conjunction with the bilogical component of the GPPF project, based on survey data for catch and effort. When multiplied by the price of fish this relationship is also a measure of total revenue (TR) for the fishery as a whole. As effort in the fishery increases, TR rises, reaches a maximum (at an effort level corresponding to MSY), and then falls as the fishery is fully exploited. For the purposes of illustration, the total cost (TC) of fishing is assumed to increase in a linear fashion with effort. (In the GPPF this is not the case, as costs generally rise at and increasing rate as stocks deplete.) MEY is thus achieved at an effort level (E*) that maximizes the difference between the total revenues and the costs of fishing, given by the distance A to C or the value R*. In this representation MEY thus occurs at an effort level that implies that stocks are larger than stocks at MSY.

There are three important qualifications to the discussion above, and the accompanying graph. First, the diagram illustrating MEY, as it stands, presupposes a zero rate of discount, that the cost of fishing depends on stock size in a simple linear fashion, as mentioned, and that fishing costs rise proportionately with effort. Consider the discount rate first. The discount rate is the interest rate at which future income or catches are valued today. A case can be made for a zero discount rate in common property resources, but it is accepted practice to assume some positive interest rate to account for the fact that a harvest some time in the distant future is worth less than a harvest today. If so, it implies a modified version of MEY is appropriate, in that a positive discount rate moves optimal effort and catch closer to MSY. In other words, if current catch is valued more highly than future harvest it pays to work the fishery harder today, with smaller equilibrium stocks of fish. It is even possible that if the discount rate is high enough, that MEY will correspond to stocks that are smaller than that associated with MSY. It will generally depend on how strong is the stock effect in either the harvest or cost function. In general terms, it is not hard to show that if the discount rate becomes infinitely large, MEY will correspond to a CPE, and at a zero discount rate MEY will be exactly as portrayed in the diagrams above (Clark 1990). A positive discount rate will place MEY somewhere in between these two extremes. In practice, for most fisheries that are productive — with reasonably large intrinsic rates of biological growth — and with discount rates that reflect normal rates of return (say 5 per cent or less), it will almost always be the case that this modified MEY will occur to the left of MSY as in the diagram, or at stock sizes that are larger than those associated with MSY. For practical fisheries and discount rates, MEY will thus normally be more 'conservationist' than MSY, or a comparable biological target. In principle this should help protect the fishery from unforseen or negative stochastic environmental shocks that may diminish the fish population.

Second, this point is strengthened if relevant cost considerations are also taken into account. The implication of a cost of fishing that increases with stock depletion, at an increasing rate — what economists refer to as convex cost functions in terms of stock; ones that would probably characterize most fishing activity — is to move optimal catch and effort further to the left of MSY. If it is more costly to fish as stock decreases, and if this cost increases at an increasing rate, it pays to have even larger stock sizes than that depicted at MEY in the above diagrams. This will partly offset (and in some cases even more than offset) the effect of the discount rate.

Finally, the analysis and discussion above assumed that the population biology and all of the relevant economic functions and parameters were clear, as if drawn from a deterministic setting, or one with no uncertainty about the state of nature or the economics of the fishery. This of course will never be the case. One source of uncertainty is a lack of complete biological data and the nature of the stock-recruitment relationship (the stock-recruitment relationship in the figure) itself. In some cases natural variability in stocks may make it all but impossible to even estimate a yield curve, and thus the relationship between total revenue and effort. (Natural variability implies that the TR curve shifts up and down in a hard to predict fashion.) The calculation of MEY requires that a stock-recruitment relationship be specified and if there is uncertainty in that relationship, the measure of the standard deviation must also be known or estimated. Another source of uncertainty is the price of fish and the precise cost of fishing. These must be forecasted and forecast errors are common.

Turning to the GPPF in particular, constructing the appropriate bioeconomic model to determine MEY requires and underlying biology, or stock-recruitmment relationship, and the relevant measure of economic costs and revenues from fishing. In conjuction with the biological component of this project it was determined that the best representation of the GPPF in terms of its stock-recruitment relatinship is that of a 'surplus-production model'. Surplus-production models map the relationship between the growth or net additions to the stock of fish, as a function of existing stock size. The key parameters are the intrinsic rate of growth r and 'maximum carrying capacity'. In a continuous-time model of population growth, without fishing behaviour included, a surplus-production model is given by

$$\frac{dB}{dt} = rB_t(1 - B_t / B_0) \qquad (1)$$

where B_t is the biomass of the stock and B_0 is virgin biomass, or stock at time zero, defined as maximum carrying capacity. In discrete time, the relevant relationship is

$$B_{t+1} = \left[B_t + r\,B_t(1 - \frac{B_t}{B_0}) \right] - h_t \qquad (2)$$

where h_t is harvest. Harvest is generally assumed to be a function of the biomass and fishing effort at time any time t

The relevant economic model is built 'on top of' the surplus-production relationship given by equation (2). For the case of the GPPF the following model was constructed, calibrated and tested. Annual total revenue of the fishery is defined as the multiple of annual fish harvest and the annual (average) price of fish, so that

$$TR_t = p_h h_t \qquad (3)$$

where p_h is the price of fish drawn from an inverse demand curve. For the GPPF, price is determined by

$$p_h = p_0 (H_0 / h_t)^{1/\varepsilon} \qquad (4)$$

where ε is the elasticity of demand for catch and p0 is the unit price of the catch when the volume of the catch is H_0. Annual total cost is assumed to be the sum of labour, material, capital and other costs. Labour costs generally include a share of total fish revenue and packaging and gear maintenance expenditures directly correspond to total fish revenue. Capital costs and other costs (of which fuel is a major component) are assumed to depend on fishing effort so that total costs can be expressed as

$$TC_t = \alpha + c_L h_t p_h + c_M h_t p_h + c_K E_t + c_O E_t \qquad (5)$$

for c_L and c_M the share cost of labour and materials per each Australian dollar of output, and where c_K and c_O is the average capital and other costs per unit of effort. The average capital cost of a unit of effort (c_K) is estimated by dividing total capital costs by total effort. Average other costs (c_O) per unit of effort are estimated by dividing total other costs by total fishing effort. The value of α represents a fixed cost component.

Annual fishery profit is defined by subtracting annual total cost from annual total revenue, so that profit is given by

$$\Pi_t = p_h h_t - (\alpha + c_L h_t p_h + c_M h_t p_h + c_K E_t + c_O E_t)\,. \qquad (6)$$

The MEY objective in the GPPF to maximise expected profits over time. For output controls the problem is to maximize

$$\max_{h_t} \sum_{i=1}^{T} \hat{\Pi}_t = \sum_{i=1}^{T} \left(\frac{1}{(1+\delta)^t} \right) (p_h h_t - (c_L h_t p_h + c_M h_t p_h + c_K E_t + c_O E_t) \qquad (7)$$

through a choice of harvest (h_t) and where $\hat{\Pi}_t$ is the net present value of profit at year t, subject to the stock-recruitment relationship given by equation (2) and an initial biomass. Measures of uncertainty where included, based on the variance in the stock-recruitment relationship and measures of economic variables. Estimated values for the harvest function were generated through econometric estimation, with coefficients for effort of 0.47 (and a standard error of 0.032) and for biomass of 0.42 (and standard error or 0.08). All biological and economic parameter values were estimated and reported in a series of workshops in PNG, based on complied data sets and estimations.

4 Specific results and discussion

Solving equation (7) subject to (1) and an initial stock requires solving a dynamic programming problem over a given horizon. For the GPPF project the procedure was coded in Maple, allowing fisheries economists at NFA in PNG to revise MEY forecasts (when prices and costs change), and to potentially extend this analysis to other fisheries. Calculating MEY in this way is new and innovative, having only been applied before to the Northern Prawn fishery in Australia, and just recently to tuna stocks in the Western and Central Pacific and the stock of orange roughy in Australia's South East fishery (see R. Q. Grafton, T. Kompas and R. Hilborn, "The economics of overexploitation revisited," Science (7/12/2007)). Obtaining results from the bioeconomic model required hand-in-hand cooperation with the biology component of this project (FIS/2002/056), especially in terms of the construction of a joint and comprehensive biology-economics data set. The biomass series is illustrated in the following diagram (Figure 2) for the GPPF, from 1970 to 2003. This was constructed from a catch and effort series and fitted to a 'logistic' stock-recruitment relationship, described by equation (1) above. The catch series for the GPPF is illustrated by Figure 3. Figure 4 represents the estimated surplus-production model determined for the fishery, depicted as an equilibrium relationship at each time t. The intrinsic rate of growth r was calculated to be 1.611. Solving the bioeconomic models required price and costs data. Prices per kg in USD for banana prawns are $7.17, for tiger prawns $8.62 and endeavours $3.42. Variable cost data was collected from industry, and included the cost of labour, fuel, repairs and maintenance and gear.

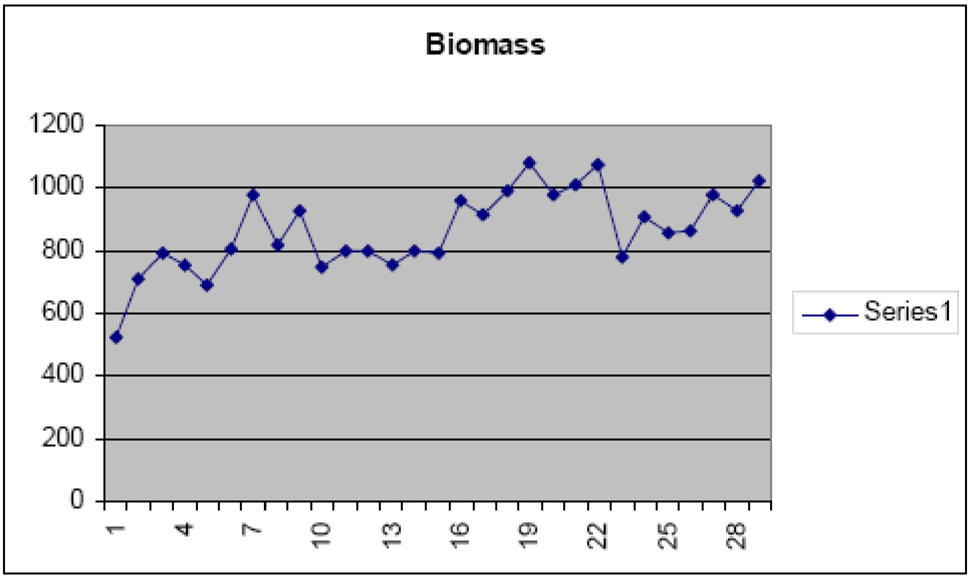

Figure 2: The Stock series for the GPPF

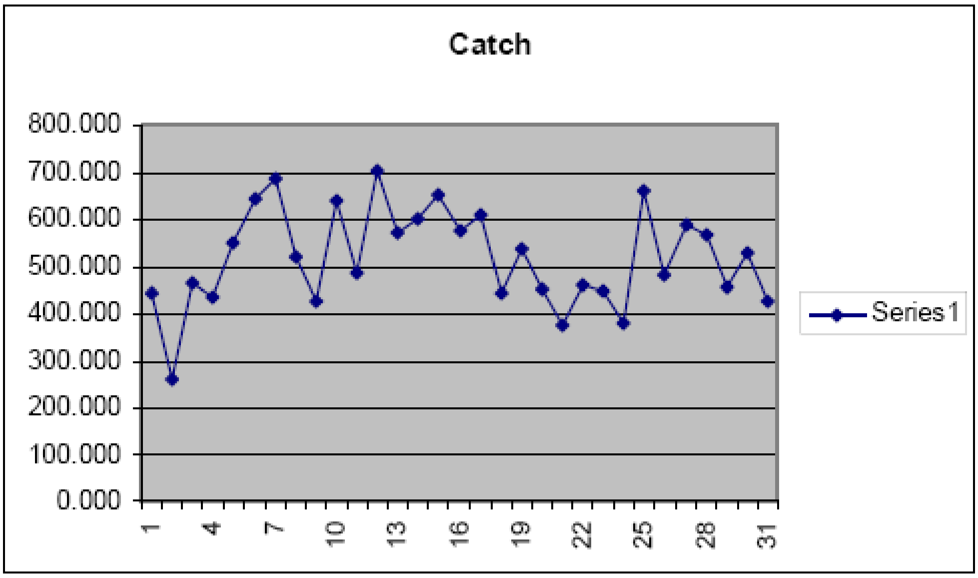

Figure 3: the Catch series for the GPPF

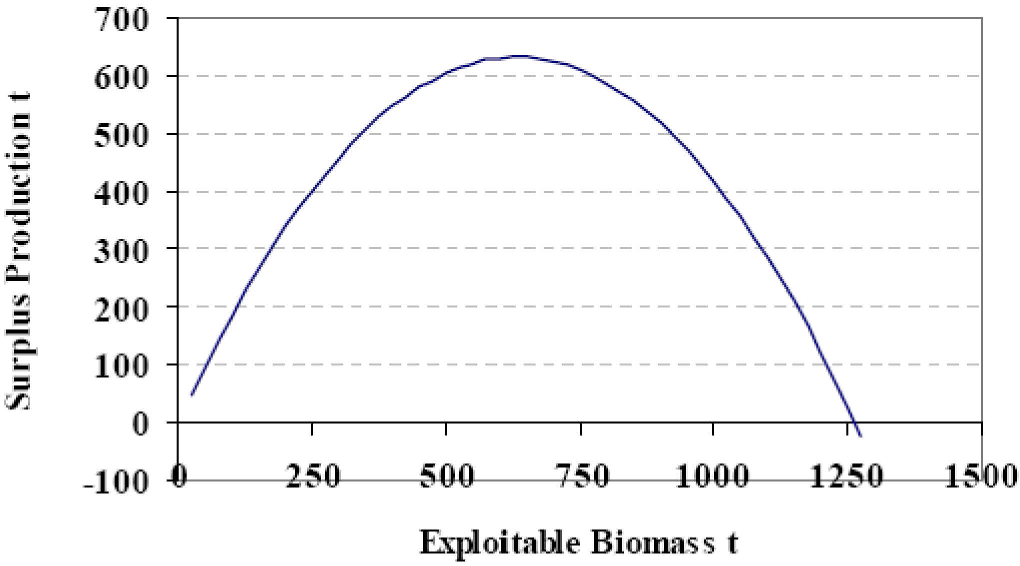

Figure 4: The Stock-recruitment relationship for the GPPF

The bioeconomic model given by equation (7) found that the fishery should target a catch of 580 tonnes of banana prawns per year to maximise profits. The mean value of MEY was thus determined to be 580 tonnes of banana prawns per year. The ratio of stock at MEY to MSY is 1.23. Stock at MEY is 800 and harvest at MSY is 638 tonnes. Given the MEY catch rate, the project also found that the number of fishing licences should be reduced to roughly 10, improving the returns each operator and matching fleet capacity to the amount of annual catch. MEY targets require not only the right catch, but the right amount of boat capital, so that the costs of harvest can be minimized at that catch level.

A final component of the project was to assess the potential for an independent fishery inshore of the 3nm closure by small vessels operated by the local community. As mentioned, VMS and logbook data showed that about a third of the total prawn catch in the GPPF was coming from within the 3nm closure zone, despite trawling in this zone being prohibited. The biology project found that this illegal fishing into the 3nm zone did not appear to substantially impact the sustainability of the prawn resource. However, from an economic perspective, catch rates within the 3nm zone were over 30% higher than on the adjacent fishing grounds, and thus, for the most part, the economic viability of the fishery depends on operators in the industrial fishery being able to access the inshore waters with higher prawn densities. With this in mind, the project recommended that fishing operators be allowed to access the zone up to 2 nm from the coast during the second half of the year (or from July to November). The project also recommended that individual operators enter into an access agreement with the traditional resource owners before they can fish within the 3nm limit. This resource sharing will enable some of the economic benefits gained by the industrial fishery to be returned to the community and thus reduce the tension between both parties.

5 Relationship to other activities

The MEY estimates obtained in this project clearly complement the MEY estimates done by Project Leader in the NPF in Australia. Insights gained in this ACIAR project are of substantial benefit to work done on banana prawns in the NPF.

6 Future project plans to build on project outputs / outcomes

Fisheries management that uses the right target and the right instrument ensures not only sustainability but economic profitability of the fishery. Given stock effects, MEY usually occurs at stock levels that are larger than stock at maximum sustainable yield, providing a “win-win” for both conservationists and the fishing industry, as highlighted in R. Q. Grafton, T. Kompas and R. Hilborn, “The economics of overexploitation revisited,” Science (7/12/2007). It would be useful to extend this MEY bioeconomic modelling to other fisheries of interest to ACAIR, especially the Western and Central Pacific tuna fisheries where the gains in profitability are substantial. The bioeconomic modelling done in the GPPF and this ACIAR project establishes a good model for this sort of work in the future.